Government of Tamil Nadu
State Planning Commission

REPORT

2025

Urban Growth and Thermal Stress: A Decadal Assessment of Built-Up Area and Climate Interactions in Tamil Nadu

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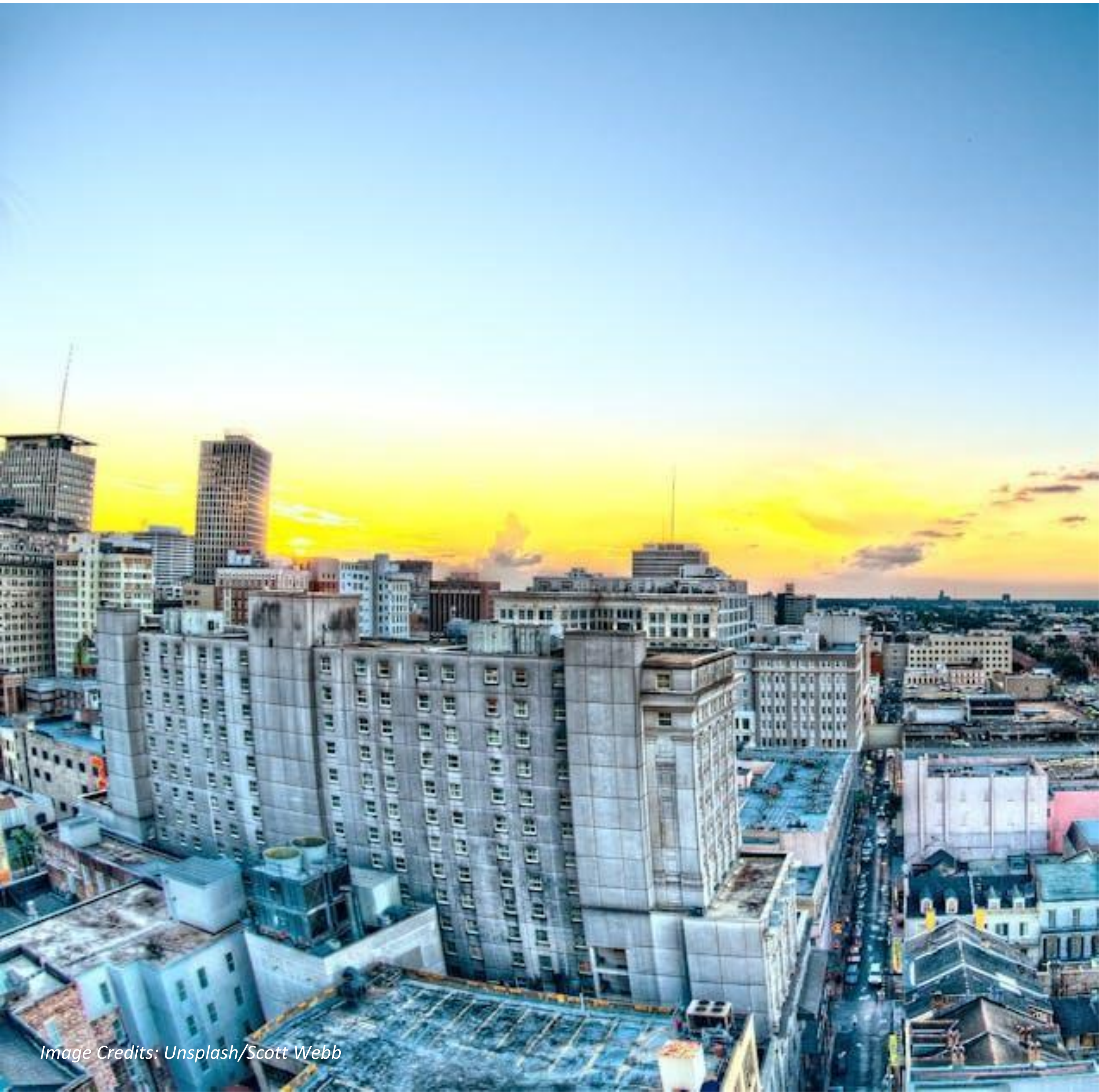

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FOREWORD

Dr. J. Jeyaranjan

Executive Vice Chairman

State Planning Commission

Tamil Nadu is witnessing rapid urbanisation and economic growth, but this progress comes with significant climate challenges. Rising temperatures, erratic monsoons, and increasing urban heat stress are already impacting public health, agriculture, and water resources. Over the past two decades, deforestation, loss of wetlands, and unregulated urban expansion have contributed to rising land surface temperatures, intensifying the urban heat island effect. The need for strategic climate action has never been more critical.

The Government of Tamil Nadu has been at the forefront of taking climate resilience efforts. The Tamil Nadu Climate Change Mission**,** along with the State Action Plan on Climate Change (SAPCC 2.0)**,** aims to integrate climate adaptation into governance and development. The Tamil Nadu Heat Mitigation Strategy outlines key measures such as expanding green cover, conserving wetlands, improving urban planning, and promoting climate-sensitive infrastructure. These initiatives, supported by scientific research, will help mitigate rising temperatures and enhance resilience across districts.

This study, *Urban Growth and Thermal Stress: A Decadal Assessment of Built-Up Area and Climate Interactions in Tamil Nadu* provides critical insights into how urban expansion and land use changes affect local climate conditions at the block level. By using high-resolution spatial data, the study identifies the most heat-vulnerable blocks and districts and offers evidence-based recommendations for targeted interventions. Such research is essential for ensuring that policies are backed by data and that development remains sustainable.

Moving forward, the integration of climate data into land use planning, enforcement of urban regulations, and increased investments in green and blue infrastructure must be prioritized. Tamil Nadu's vision for a climate-resilient future depends on collaborative efforts between policymakers, researchers, and communities. This report serves as a vital step toward that goal, guiding informed decision-making for a sustainable and climate-secure Tamil Nadu.

EXECUTIVE SUMMARY

Climate change stands as one of the most pressing global challenges, threatening future generations through its profound impacts on health, food systems, ecosystems, and economic stability. In Tamil Nadu, the accelerating rise in temperature, both at the surface and atmospheric levels, is already manifesting in changing weather patterns, urban discomfort, and agricultural stress. This study builds on the Tamil Nadu Heat Mitigation Strategy (2024) and presents a high-resolution, block-level analysis of heat exposure across the state, using spatial, climatic, and land use datasets to inform evidence-based climate resilience planning.

Over the past three decades, the study examines how Land Use and Land Cover (LULC) changes, particularly urbanisation, forest degradation, and conversion of agricultural lands, have contributed to local climate variation. According to the 2023 Status of Forests Report by the Tamil Nadu State Land Use Research Board (TNSLURB), over 3,025 sq. km. of forest cover have been lost in the state in just two decades, contributing directly to surface temperature increases. Rapid urban expansion and deforestation have not only altered surface albedo but also exacerbated the Urban Heat Island effect. This is further intensified by increased Land Surface Temperatures (LST), which affect local evapotranspiration cycles and may contribute to larger-scale climate anomalies such as El Niño and La Niña.

Future climate projections under the RCP 4.5 and 8.5 scenarios indicate an increase in annual Maximum Air Temperatures in Tamil Nadu ranging between 0.9°C and 2.7°C by 2050, with direct implications for crop viability, ecological integrity, and human thermal comfort. This study provides both a temporal and spatial understanding of heat exposure, distinguishing between Blocks that have experienced a significant rise in temperature over time (decadal change) and those that currently experience extreme heat stress (present exposure), even without drastic past changes. The study uses data from multiple sources, including MODIS LST, ERA5 air temperature, building footprint changes from GHSL, and elevation data from SRTM DEM. Using QGIS and spatial overlay analysis, both day and night-time temperatures were mapped, normalised, and compared against state averages. The Universal Thermal Comfort Index (UTCI) was also computed to assess physiological heat stress, offering an integrated view of health factors.

The results reveal that 94 Blocks across the state have experienced the most significant changes in heat over the past four decades. Another 64 Blocks, although not showing a long-term rise, are currently experiencing state above-average temperatures, leading to extreme discomfort and ecosystem stress. Notably, 25 Blocks, including those in districts like Chennai, Karur, and Ramanathapuram, fall into both categories, indicating a combination of long-term trends and present-day exposure. These regions are thereby identified as the most vulnerable to high temperatures in Tamil Nadu. Coastal districts are disproportionately affected, and new hotspots have emerged in peri-urban zones and hilly terrains such as Kodaikanal, Sulur, and Theni.

Urbanisation emerges as a dominant driver. The correlation between building footprint expansion and temperature rise is evident Blocks such as Chennai (74% built-up in 2015), St. Thomas Malai (43%), and peri-urban areas in Coimbatore, Tiruppur, and Villupuram show a direct link between surface development and heat accumulation. In some districts, average temperatures have risen by up to 2°C more than the state average in just two decades, affecting 11 districts with significant changes. This spatial sensitivity framework is not only a continuation of the Tamil Nadu Heat Mitigation Strategy but also contributes to the State Climate Change Mission, SAPCC 2.0, and key Sustainable Development Goals, particularly SDGs 11, 13, and 15. The findings highlight the importance of integrating heat stress indicators into land use planning, smart city programmes, and block-level development schemes. The analysis also reinforces the need for nature-based solutions, stricter urban planning regulations, wetland and forest conservation, and a renewed focus on climate-informed infrastructure development.

The study proposes a strategy grounded in spatial emphasis, institutional convergence, and transparent monitoring systems. It recommends integrating thermal indicators into local planning, investing in Nature-based Solutions (NbS) such as green and blue infrastructure development, enforcing climate-sensitive building regulations, and prioritizing high-risk blocks for immediate intervention. Tamil Nadu’s vision for a climate-resilient and net-zero future must include block-level action plans that reflect both climate data and local land dynamics. By offering a robust evidence base, this study enables district and block-level officials to act with precision in tackling heat-related challenges. The integration of climate science, land use data, and policy frameworks creates an actionable pathway for Tamil Nadu to strengthen its resilience to rising heat ensuring long-term sustainability and protection for its people, ecosystems, and economy.

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Glossary of Key terms

Term	Explanation
Air Temperature	The temperature of the air measured at approximately 2 meters above ground level. Used as a baseline metric in climatology to assess ambient atmospheric conditions.
Land Surface Temperature (LST)	The temperature of the Earth's surface derived from satellite thermal imagery. Reflects how different land cover types absorb and emit heat.
Night-time LST	LST measured during nighttime hours, typically more stable and less influenced by solar radiation, offering insights into heat retention and urban heat islands.
Universal Thermal Comfort Index (UTCI)	A composite index that accounts for air temperature, humidity, wind, and solar radiation to assess human thermal comfort under outdoor conditions.
Wet Bulb Globe Temperature (WBGT)	A heat stress index combining temperature, humidity, wind speed, and solar radiation. Used to assess safe limits for outdoor physical activity.
Heat Index	An index that estimates how hot it feels based on air temperature and relative humidity, often referred to as the "feels-like" temperature.
Urban Heat Island (UHI)	The phenomenon where urban or built-up areas experience higher temperatures than surrounding rural areas due to human activity and land cover changes.
Thermal Comfort	A condition in which people feel neither too hot nor too cold, influenced by air temperature, humidity, radiation, wind, and clothing.
Baseline Analysis Period	A defined timeframe used as a historical reference for comparative analysis. In this study, 1981–1990 and 2000–2005 are used as baseline periods for trend analysis.
Recent Analysis Period	The latest temporal window used for evaluating current conditions. In this study, 2011–2020 and 2018–2023 are considered as recent periods for comparison.
Decadal Change in Heat Intensity	A measure of how much the thermal conditions in an area have shifted over time, based on trend analysis of air temperature and LST.
Current Heat Intensity	An assessment of present-day heat exposure levels in comparison to state-wide averages, based on LST and air temperature data from 2018–2023.
Weighted Overlay Analysis	A GIS-based spatial analysis method that combines multiple indicators with assigned weights to produce a composite vulnerability index.
MODIS (MOD11A1 V6.1)	A NASA satellite product that provides daily global Land Surface Temperature and Emissivity data at 1 km resolution.
ERA5	A high-resolution global reanalysis dataset developed by the European Centre for Medium-Range Weather Forecasts (ECMWF), offering hourly atmospheric variables.
SRTM DEM	Shuttle Radar Topography Mission – Digital Elevation Model; used to identify elevation and topographic features for terrain-based vulnerability mapping.

Green Cover	The area of land covered by vegetation, including trees, shrubs, and grasslands, which plays a critical role in moderating surface temperatures.
Peri-Urban Areas	Transitional zones between urban and rural areas that are often subject to unplanned expansion and heat stress due to rapid land use change.
Heat Stress	A condition where the body cannot maintain its normal temperature due to external thermal load, leading to health risks.
Blue-Green Infrastructure (BGI)	An approach that integrates natural water management (blue) and vegetation-based systems (green) to improve urban resilience and reduce heat.
Tree Outside Forest (TOF)	Trees that grow outside formally recognized forest areas, such as those in agricultural lands, parks, or urban spaces.
Tamil Nadu Climate Change Mission	A state-level policy framework aimed at enhancing climate resilience through sectoral adaptation, emission reductions, and environmental sustainability.
SAPCC (State Action Plan on Climate Change)	A state-specific roadmap aligned with India’s National Action Plan on Climate Change, updated in Tamil Nadu’s SAPCC 2.0.

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Urban Growth and Thermal Stress: A Decadal Assessment of Built-Up Area and Climate Interactions in Tamil Nadu

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Introduction

Global warming poses an urgent and critical threat to Earth. In 2024, the global average air temperature increased by 1.5°C compared to the pre-industrial level (1850-1900), making it the warmest year on record, as confirmed by the World Meteorological Organization (WMO). Study done by N.S. Diffenbaugh et al., 2023 predicted that the world's average temperature would increase by 2°C by 2050, even under a low-emission scenario. However, the 2024 temperature records indicate that this 2°C threshold could be reached before 2050 at the current rate of greenhouse gas (GHG) emissions. This scenario would render the Paris Agreement unattainable, which aims to limit global warming to below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5°C. A recent report published by Copernicus (ESA) stated that the average air temperature increased by 1.5°C and highlighted the concerning levels of GHG concentrations. According to their report, atmospheric concentrations of carbon dioxide and methane reached record levels in 2024, at 422.1 ppm and 1897 ppb, respectively. Methane has a significantly higher heat-trapping capacity, more than 27.9 times that of carbon dioxide. The extreme heat increase is leading to various consequences, including seasonal variations, an increase in natural disasters, the emergence of pandemic diseases, sea-level rise, desertification, and economic crises. Addressing the rising temperature and taking action to reduce it are crucial. Global warming since the pre-industrial era has been primarily driven by industrial developments and urbanization.

India is an emerging country, and as a result, the extent of the metropolitan area is constantly expanding, and the pattern of land use and land cover is rapidly transforming. Tamil Nadu is one of the states with the fastest rate of urbanization, with a 48.8% urban population, according to the 2011 Census (National Institute of Urban Affairs), has been estimated to increase roughly more than 52% by 2025. The requirement for infrastructure to meet the rapidly expanding urban population's needs for residence, schooling, sanitation, and employment through industrial developments is the factor that promotes built area expansion in the urban regions. Although these developments advance the nation's economy, they also contribute to environmental degradation (Mohamed Shamsudeen et al., 2022). Unplanned urbanization has affected the natural resources, such as ponds, lakes, and wetlands. Once this category of land parcels is converted into built infrastructures, these lands get exposed to anthropogenic catastrophes like urban flooding during extreme rainfall events (SK Roy et al., 2020).

Furthermore, land use and land cover changes over the past thirty years are evident through the rapid changes over the land use classes. These land use conversions occur with little regard for environmental concerns, leading to increased land surface temperatures, air, water, and noise pollution, as well as a rise in frequency of droughts and flooding. Groundwater depletion decreased urban green cover, and the conversion of agricultural land to non- agricultural uses are among other consequences (Shahfahad et al., 2021).

Over the past decades, Tamil Nadu has experienced a significant increase in Land Surface Temperature both during day-time and night-time. Mohamed et al. (2022) study shows an increase in urban areas which leads to the urban heat island effect. The mean of Minimum, maximum, and annual air temperature has risen (Ramesh et al., 2021). Anushya et al. (2019) Soil-Adjusted Vegetation Index value has indicated a decline in surface permeability, while LST values have shown an overall increase, especially in urban Built-up Areas, with the highest upsurge observed in major cities of Tamil Nadu in the past two decades. These findings underscore the escalating impact of urbanization and ecosystem degradation on LST variations in Tamil Nadu over the past four decades.

Tamil Nadu has experienced significant urbanization over the past four decades, leading to land use and land cover changes, particularly in urban cities like Chennai, Coimbatore, Tirupur, etc. The study done by Mohamed et al. (2022) proves the substantial increase in urban areas with a 75% expansion detected in mainly suburban and major cities in the past two decades (2000 to 2020). The urban growth model predicted the expansion of the Chennai Metropolitan Area (CMA) based on historical datasets, emphasizing the need for careful planning to address congested urban growth and dispersed urbanization in different regions of the city (Subramanian et al., 2002). These changes reflect the ongoing urbanization trends, and the challenges associated with transforming cities into metropolitan areas while ensuring sustainability and efficiency.

Climate change is one of the most severe concerns worldwide. Although Climate Change is a global phenomenon, the Earth's surface does not experience a uniform increase in temperature. Analyzing Regional-Level Climate Change is crucial. These results will provide invaluable outputs that are highly important for policymakers and the government to initiate Local Climate Change-based solutions. This will also help strengthen government efforts by providing information about environmentally vulnerable regions, enabling them to make informed precautionary decisions. 'Heat' is one of the most pressing and complex dimensions of climate change, especially in urban and densely populated regions. As cities grow and temperatures rise, measuring and understanding heat exposure requires more than just tracking daily weather reports. The way heat is quantified has critical implications for urban planning, climate adaptation, and public health, particularly in regions like Tamil Nadu, where diverse geographies and land use patterns shape local thermal conditions.

Tamil Nadu, the southernmost state in India, has a tropical climate. Despite being flanked by the sea and the Western Ghats, most of the state is extremely vulnerable to heat stress. **It regularly faces soaring temperatures of more than 40°C for a significant part of the year.** Studies indicate that the temperatures and heat stress are likely to increase drastically in the coming years. Between 2011 and 2021, Tamil Nadu has, on average, witnessed more than eight heat wave (HW) days a year, as reported by India's Ministry of Earth Sciences (MoES, 2022). The state faces an increased number of heat stress days, notably from March to August, with a rising trend in heat waves observed from 1961 to 2021 (MoES, 2022). In 2023, 12 heat wave-related deaths were reported in Tamil Nadu upto to the end of June (Sansad, 2023).

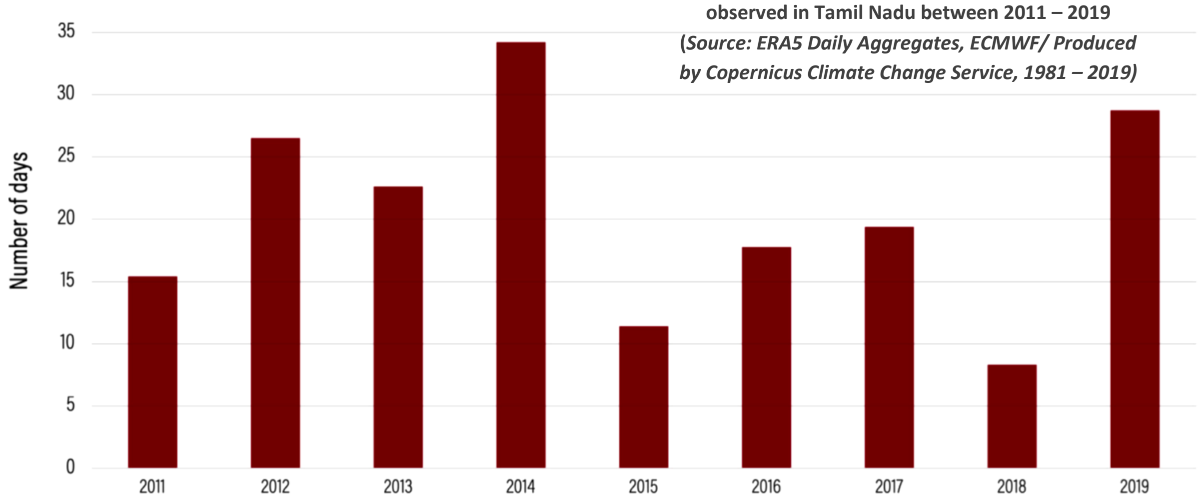
Generally, health-related numbers are hugely under-reported or unreported, as health impacts are often not attributed to heat stress or exposure. Morbidity due to physical and mental stress from prolonged exposure to extreme heat is also not adequately captured. Further, heat has differential impacts affecting the most vulnerable, who lack the access or ability to report heat-related health distress; it also impacts systems and living organisms.

The phenomenon of Urban Heat Island (UHI) can be spatially understood with the help of Land Surface Temperature (LST) variations. LST is the radiative skin temperature of the land surface that has interrelation with the air temperature, both contributing as factors to thermal comfort. The searing effects of UHI are most prominent while observing nighttime LST trends. Surface temperature variation at night is caused by differences in land cover, built form and density, building materials, vegetation, and soil moisture levels. An analysis referred in the Tamil Nadu Heat Mitigation Strategy states, Data for recent years' (2019 - 2023) summer months – March to May, show an average nighttime LST of 24°C (refer to Figure 9) across the state, with 26°C across major built areas including major cities, indicating urban heat island effects.

About 27% of the state's population resides in areas with higher nighttime land surface temperature than the state-wide average nighttime LST over built. The map (refer to Figure 9) illustrates the trends in the average nighttime LST from 2019 to 2023, compared to 2001 - 2005, as the built areas expanded. The linkages between vegetation loss and increasing expanse of relatively higher nighttime LST can be easily seen across all four major cities of Tamil Nadu, namely, Chennai (refer to Figure 10), Tiruchirappalli, Coimbatore, and Madurai. Refer to Annexure A2, Figure 30 - 35 for more details on built expansion, vegetation changes and LST.

This study aims to analyze the extent to which land use change especially the change in the Built area in the state of Tamil Nadu has affected the local climate. It focuses on changes in the temperature of Tamil Nadu over the years, comparing these changes with built area changes. It is also well-established that LULC influences Climate Change at both global and local levels, however the scale of influence is more at the local level. Therefore, this study attempts to compare built area change at the regional level to understand how climatic variations have occurred over the years in these regions.

Figure 1: Average number of annual heat wave days observed in Tamil Nadu between 2011 – 2019
(*Source: ERA5 Daily Aggregates, ECMWF/ Produced by Copernicus Climate Change Service, 1981 – 2019)*



Objective

This study seeks to investigate the long-term and present-day impacts of built-up area expansion on local climate dynamics across Tamil Nadu, with a specific focus on heat exposure at the **Block level**. The key objectives are:

1. **To analyse the spatial and temporal correlation between built area growth and local temperature variations**, including both Land Surface Temperature (LST) and air temperature, across Tamil Nadu's 389 Blocks.
2. **To develop a scientifically grounded district-wise categorisation** based on the proportion of heat-exposed Blocks, enabling targeted interventions and policy prioritisation under the state's climate adaptation and urban planning strategies.

To fulfil these objectives, the study undertakes the following analytical components:

- **Decadal Change in Heat Intensity**:
  This component identifies Blocks that have undergone significant warming trends over the past decades (based on ERA5 and MODIS datasets), even if their present-day temperatures remain below the state average. This helps capture areas undergoing gradual but impactful thermal shifts.
- **Current Heat Intensity**:
  This analysis highlights Blocks where the average temperature in recent years (2018–2023) exceeds the current state average, regardless of long-term trends. This ensures that currently heat-stressed areas, potentially overlooked in decadal comparisons, are also recognised and prioritised.

Together, these two assessments provide a **comprehensive heat vulnerability profile** for each Block, capturing both **historical change** and **current exposure**, thereby informing a more nuanced and actionable strategy for climate resilience planning across Tamil Nadu.

Study Area

Tamil Nadu, the southernmost state of India, spans approximately 130,000 km², making it the 10th largest state in the country by area. It is bounded by the Bay of Bengal to the east, Andhra Pradesh and Karnataka to the north, Kerala and the Western Ghats to the west, and the Indian Ocean to the south. This strategic geographical positioning gives the state a diverse ecological and climatic profile, influenced by coastal, forested, hilly, and agricultural ecosystems.

Climatically, Tamil Nadu experiences a sub-humid to semi-arid environment, with mean temperatures ranging between 18°C and 45°C annually. Rainfall is primarily governed by two monsoons: The Northeast monsoon (October–December) contributing 48%, and the Southwest monsoon (June–September) contributing 35% of the state's average annual rainfall of 898 mm (TNGCC, 2022). However, temperature distributions vary spatially, with interior districts such as Tiruchirappalli, Tiruvannamalai, Erode, and Vellore experiencing notably higher ambient temperatures than coastal and hilly regions. As one of India's economic powerhouses, Tamil Nadu contributes nearly 9% to the national GDP, with a Gross State Domestic Product (GSDP) of USD 266 billion (2020–21). The state's industrialisation and rapid urbanisation, while central to its growth, also increase its climate vulnerability, particularly to heat stress, water scarcity, and environmental degradation. Approximately 48% of Tamil Nadu's population resides in urban areas, and a significant proportion of this population, around 35%, lives in slums with inadequate thermal resilience.

From a climate risk perspective, Tamil Nadu faces compounding challenges: recurring droughts, erratic rainfall, cyclones, floods, sea-level rise, and increasingly, heat waves. The India Meteorological Department (IMD) recorded 591 disastrous heatwave days across Tamil Nadu's districts between 1969 and 2021, where at least one heat-related fatality was reported per day. However, these numbers are likely underreported due to gaps in heat-related mortality data attribution, reinforcing the status of heat as a "silent disaster."

Studies show a growing thermal threat: according to Anna University's Centre for Climate Change and Disaster Management, thermal discomfort days are projected to rise from an average of 107 days per year (1985–2014) to 150 days per year by 2050. Concurrently, Tamil Nadu's Status of Forest Report (2023) notes a loss of 3,025 km² of forest cover over the past two decades, reflecting rapid land use change, primarily driven by built area expansion and agricultural encroachment.

Additionally, 11% of the forested area in Tamil Nadu is classified as highly susceptible to forest fires, exacerbated by rising temperatures and declining soil moisture (FSI, 2019). With 38 administrative districts, 389 development Blocks, 17 major river basins, and a population density of 555 persons/km², Tamil Nadu's natural and built environments are deeply interlinked, making it highly sensitive to thermal shifts at micro and meso scales.

The current study contextualises Tamil Nadu's heat vulnerability by drawing attention to these multi-scalar climate risks, examining how built-up area growth and ecosystem decline are driving regional warming. The state's ecological diversity, ranging from the Eastern and Western Ghats to rich marine ecosystems and arid plains, makes localized climate analysis crucial. With a forest area of 26,419 km², including 23,188 km² of reserved forests, and a network of wildlife sanctuaries and national parks, Tamil Nadu holds significant ecological assets that must be integrated into climate planning frameworks. Temperatures are only expected to soar further.

A study by Anna University's Centre for Climate Change and Disaster Management confirms that thermal discomfort is projected to increase from an average of 107 days per year (observed between 1985 and 2014) to 150 days per year by 2050 (Times of India, 2024). Losses in terms of finances, lives, productivity, and ecological resources, are likely to be dire for vulnerable and marginalised groups.

Tamil Nadu's Thermal Profile: Need for Heat Action

- ***Diverse physiography:*** *coastal belts, plains, and hill regions with varying climatic responses.*
- *A rising trend in* ***heat wave days and thermal discomfort****, as confirmed by multiple studies.*
- ***Urban and peri-urban heat intensification****, linked to rapid growth in built-up areas and forest loss.*
- ***Socio-economic vulnerabilities****: with large urban slum populations and high exposure to natural disasters.*
- ***Environmental degradation****: including forest fragmentation, water stress, and biodiversity loss.*

Tamil Nadu's approach to heat resilience must be geographically nuanced, data-driven, and aligned with the state's broader climate policies*, including the* ***Tamil Nadu State Action Plan on Climate Change (SAPCC 2.0)*** *and the* ***Heat Mitigation Strategy 2024****. This study provides a spatially disaggregated heat profile to inform targeted and equitable interventions at the* ***Block and district levels****.*

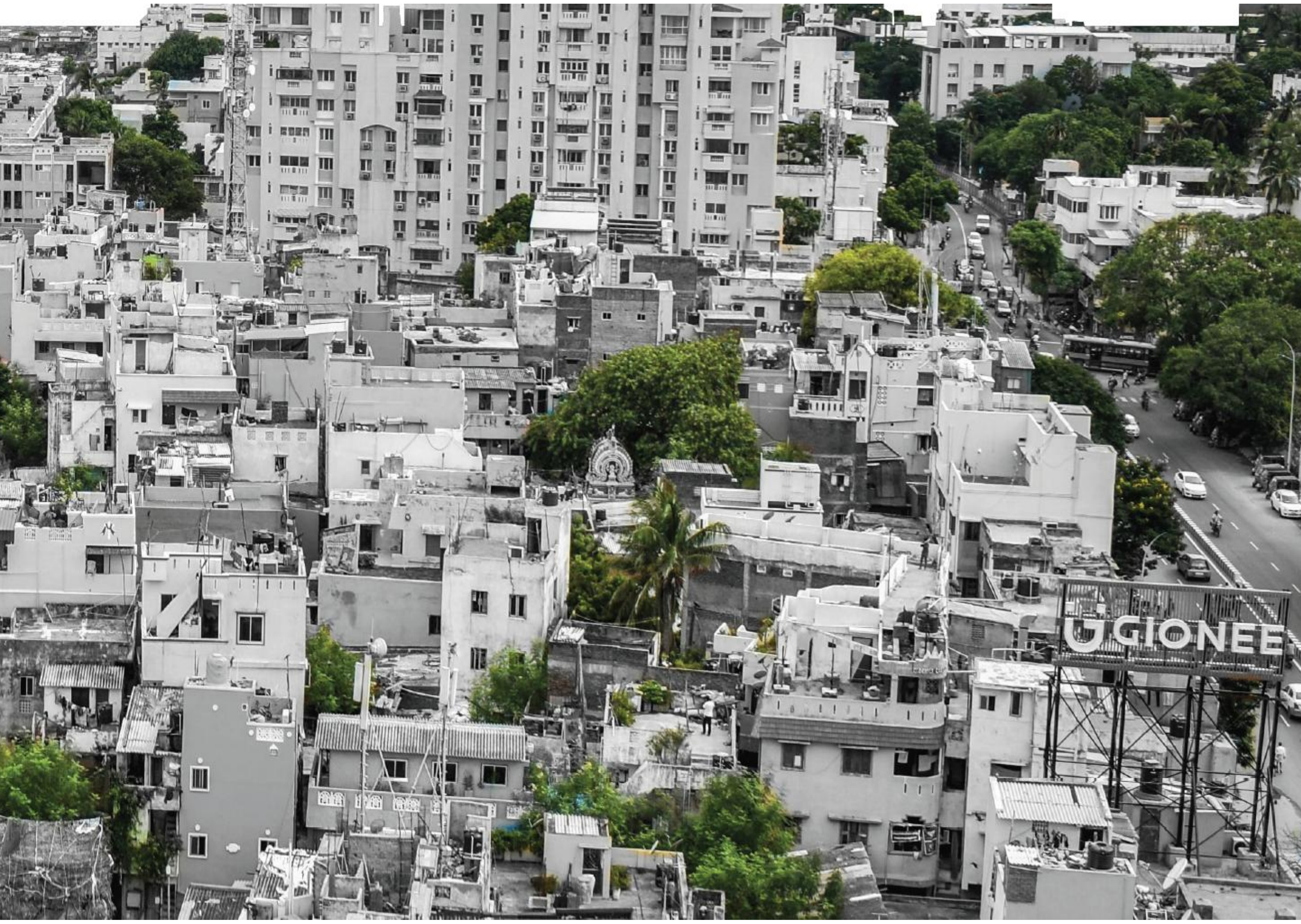


Figure 2: Study Area

Data utilized

To address the heat Stress in Tamil Nadu, the following data has been utilized:

1. Building footprint data was derived from the **Copernicus Global Human Settlement Layers** (Copernicus GHSL) dataset, provided by the European Space Agency, covering the years 1985 to 2015, with a spatial resolution of 30 meters.

2. **Land Surface Temperature data** for both day-time and night-time has been derived from MOD11A1 V6.1. dataset of MODIS (Moderate Resolution Imaging Spectroradiometer), NASA. This product provides daily Land Surface Temperature and emissivity at a grid range of 1200 x 1200 kilometers. The data spans from 2000 to 2023, with a spatial resolution of 1 km.

3. **Maximum Air Temperature and Air Temperature** in Summer and Winter months were obtained from **ERA5**, ESA (European Space Agency). ERA5 DAILY provides aggregated values for each day for seven ERA5 climate reanalysis parameters. Specifically, 2m Air temperature data was obtained for the period from 1981 to 2023, focusing on the summer and winter months in Tamil Nadu. The resolution of this data was 27 km.

4. **SRTM (Shuttle Radar Topography Mission) DEM data - NASA**, with a Spatial resolution of 30m.

5. To ensure accuracy, the most recent district, and block boundaries of Tamil Nadu were used in this study. Over the past four decades, Tamil Nadu has experienced numerous changes in its district and block boundaries. To mitigate potential boundary discrepancies, current delineations were adopted. According to these boundaries, Tamil Nadu comprises of 38 districts and 388 Blocks. Given that Chennai was treated as a block, the total number of Blocks considered in this study are 389.

Note: This study utilized QGIS, an open-source GIS platform, the Google Earth Engine cloud platform, Google Earth Pro, and Microsoft Workspace for analysis, visualization, and documentation.

For this study, the Indian Meteorological Department (IMD) data was not utilized due to limitations in its land record distributions. Since the study period began in 1980, the available data from IMD consisted of only 17 stations of LST data, which was insufficient to cover all over the region of Tamil Nadu. Furthermore, the IMD's 1-degree gridded data had low spatial resolution. Due to these limitations, higher-resolution ERA5 data and MODIS data were utilized for this study.

METHODOLOGY

METHODOLOGY

Traditional metrics like **air temperature** offer a general sense of background climatic conditions, they fail to capture the multidimensional ways in which individuals and ecosystems experience heat. Air temperature, typically measured two meters above the ground, is easy to model and widely reported. However, it does not reflect surface heating or account for humidity, radiation, and wind speed, all of which contribute significantly to how heat is perceived and how it affects health.

In contrast, **Land Surface Temperature (LST)**, derived from satellite data, provides high-resolution spatial coverage of how different materials, such as rooftops, asphalt, or vegetated land absorb and emit heat. LST is particularly useful in detecting surface-level temperature anomalies and urban heat island effects, as it reveals how land use and land cover (LULC) changes impact local thermal dynamics. However, while it is invaluable for comparative analysis across regions, it does not represent how humans physiologically feel heat.

To bridge this gap, scientists increasingly rely on **thermal comfort indices**, such as the **Universal Thermal Comfort Index (UTCI)** and **Wet Bulb Globe Temperature (WBGT)**, which integrate multiple environmental variables, solar radiation, humidity, wind, and air temperature to estimate human heat exposure more accurately. These indices are especially useful for planning public safety measures, optimizing urban design, and assessing exposure risks at the microclimate scale.

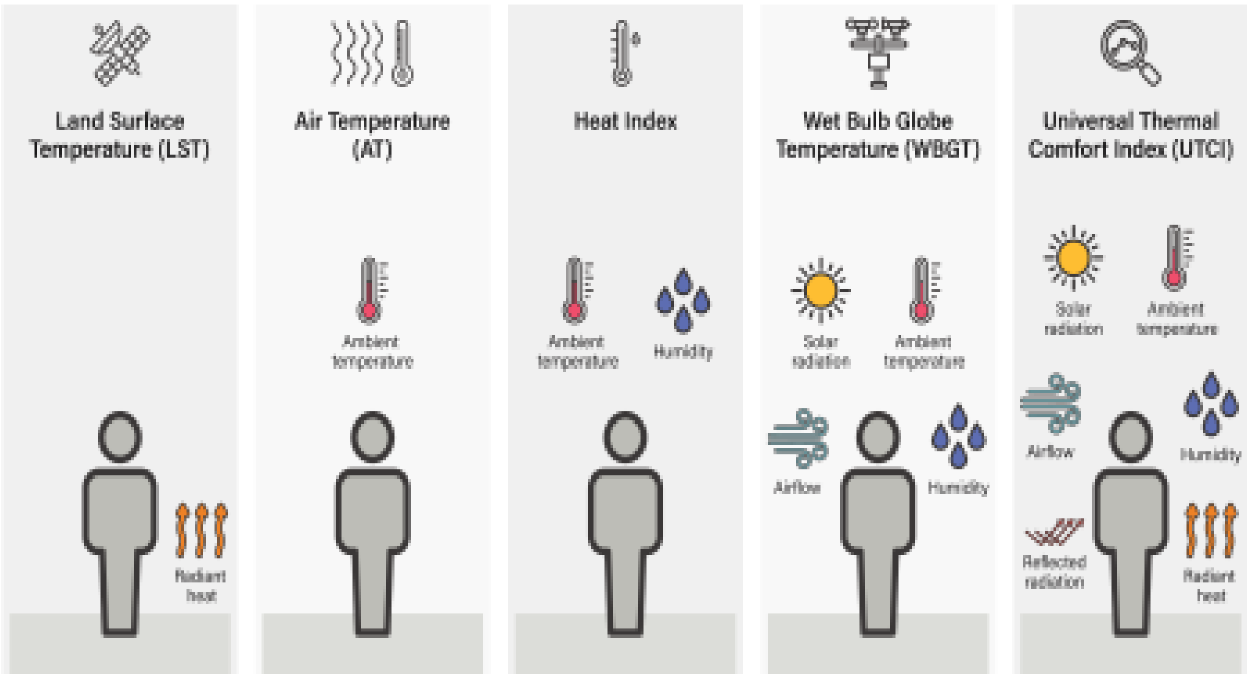


Figure 3: Different terms used for temperature

Understanding which heat metric to apply for which objective is critical. For example:

- Air temperature is ideal for tracking long-term climate trends and evaluating regional cooling strategies.
- LST highlights heat absorption and re-radiation across surfaces,

helping assess the impact of land cover and urban materials.

- Thermal comfort indices inform localized human experiences of heat and help determine the effectiveness of shading, ventilation, and cooling interventions.

In this study, a combination of ERA5-based air temperature and MODIS-based night-time land surface temperature has been used to evaluate both long-term thermal trends and current heat exposure patterns at the block level. These parameters were selected for their complementary strengths: air temperature captures atmospheric conditions over decades, while night-time LST reflects how built surfaces and urban morphology retain heat overnight.

Given the record-breaking global temperatures of 2024 and projections of a 3°C rise by the end of the century without significant emission reductions, the importance of high-resolution, location-specific heat assessments is paramount. Urban characteristics, such as dense construction, limited vegetation, and impervious surfaces, can contribute an additional 1°C or more of warming beyond ambient climate trends, disproportionately affecting the 4+ billion people who now live in cities.

This study builds upon Tamil Nadu's State Heat Mitigation Strategy, which already outlines a sectoral framework for addressing rising temperatures, particularly through interventions in the built environment, urban planning, and landscape restoration. By leveraging advanced heat metrics and satellite data, this study provides a scientific basis for prioritising vulnerable blocks and designing adaptive, climate-resilient interventions that reflect both the intensity and human experience of heat.

Land Surface Temperature data of MOD11A1 V6.1, and ERA5 Air Temperature data were directly derived and downloaded from the Google Earth Engine Platform. The values of LST have been aggregated, and the mean average LST of the study period has been calculated within the Google Earth Engine platform.
The average LST for both daytime and nighttime during the past and present study periods has been derived as a single layer from the GEE platform. Similarly, the air temperature data for the summer and winter months has been aggregated, and the mean value has been calculated. The annual Maximum Air Temperature has been extracted from the GEE catalog, and the average annual Maximum Air Temperature has been calculated.

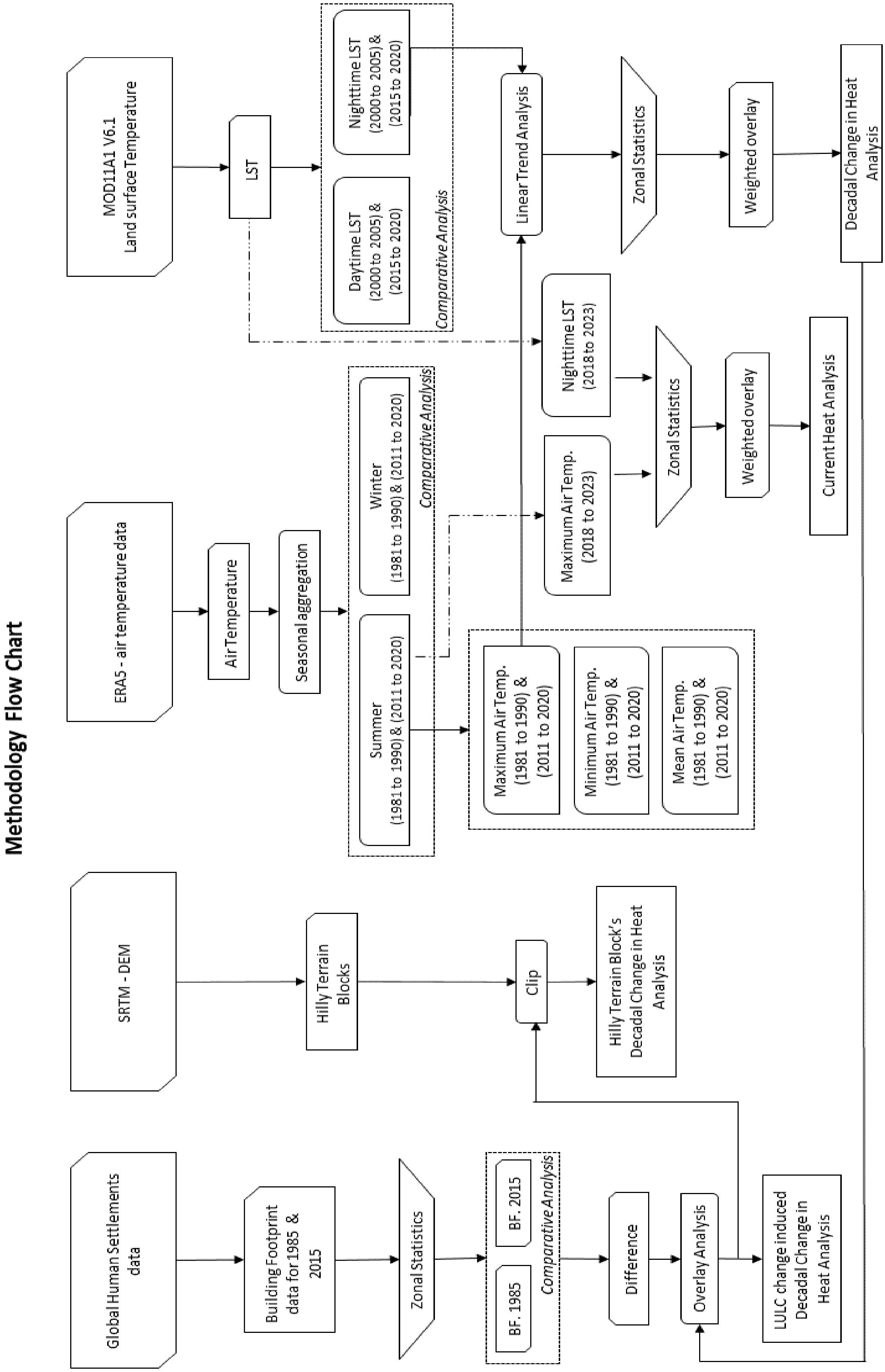


Figure 4 - Methodology

For the Universal Thermal Comfort Index (UTCI) analysis, data on air temperature (measured 2 meters above the surface), relative humidity, wind speed (measured 10 meters above the surface), and radiation (e.g., downward shortwave radiation) were used, considering the desired time period and spatial resolution. For this study, UTCI data was calculated using these parameters. Building footprint data was obtained from the Global Building Settlements.

The primary focus of this study is to assess heat exposure at the block level. Therefore, all the above-mentioned indicators were calculated at the block level in Tamil Nadu using Zonal Statistics analysis. A weighted overlay was then performed using Night-time Land Surface Temperature (LST) and Maximum Air Temperature. All values were reclassified based on the positive and negative values of each indicator's linear trends, after which weightages of 60% and 40% were assigned to the indicators, respectively. A Change in Heat Exposure Map has been generated based on the results of the weighted overlay. Likewise, to reveal the current heat exposure of Tamil Nadu, the Night time LST and Maximum Air Temperature, taken from 2018 to 2023, identified the current heat-exposed Blocks that were not captured in the change in exposure analysis. The Change in Heat Exposure Map has been further analyzed based on changes in building footprints, determining how heat has increased in urban, suburban, peri-urban, and hilly terrain Blocks due to urbanization.

S.No	Indicator	Information derived from Assessments
1	**LULC change - Building footprint**	Global Human Settlement Layer data with a 30m resolution has been used for three-decade intervals to understand rapid urbanization. For the comparative analysis, building footprint data from Tamil Nadu for the year 1985 has been used as the past year's data, while the 2015 data serves as the recent data. To determine the increase in building footprints, the arithmetic difference between the two years' data is calculated by providing both datasets as inputs.
2	**Air Temperature**	ERA5 provides 2m above-surface air temperature data on an hourly basis with a spatial coverage of 27.5 sq. km. The maximum, minimum, and mean air temperatures for Tamil Nadu are derived from the average values of baseline and recent decades. The average values from 1981 to 1990 serve as the baseline for the past years, while the average values from 2011 to 2020 serve as the baseline for recent years. These baseline values are also used to analyse seasonal variations: for the summer season, data from March, April, and May are used, and for the winter season, data from January and February are used. All parameters are depicted in figures 7 to 11, and variations over the decades have been analysed.

3	**Land Surface Temperature**	MOD11A1 V6.1 data with a 1km spatial resolution has been utilized for this analysis. The bands named LST_Day_1km and LST_Night_1km are used to identify the day and night variations in Land Surface Temperature (LST). Two baseline periods have been used for comparison: the aggregation of values from 2000 to 2005 serves as the past baseline, and values from 2018 to 2023 serve as the recent baseline. The same baseline values are applied for both day and night-time comparisons. The differences in daytime and night-time temperatures are illustrated.
4	**UTCI**	The Universal Thermal Comfort Index (UTCI) helps to understand the thermal comfort or stress levels experienced by humans. This indicator identifies regions facing extreme heat stress. The baseline years are the same as those used for air temperature, and Figure 12 shows the comparison of these baseline values.
5	**Hilly Terrain** Blocks	SRTM – Digital Elevation Model data has been aggregated to the block level, with Blocks having an average elevation of more than 330 meters classified as hilly terrain Blocks. Out of 389 Blocks, 90 were classified as terrain Blocks based on the threshold value obtained from the analysis. The results were compared with Change in Heat Exposure Map to understand how these terrain Blocks are performing in terms of heat.
6	**Reclassification**	For this study, two main indicators were chosen from the above listed indicators to identify heat exposure and they were Maximum Air Temperature and Night-time Land Surface temperature. Maximum Air Temperature (of summer months of Tamil Nadu) is used to represent variations in air temperature, while NLST (Night-time Land Surface Temperature of summer months of Tamil Nadu) is employed to assess the increase in LST over the years. A linear trend has been identified for both air temperature and NLST indicators. Based on the threshold value, the data have been reclassified into the following categories: significant change, minimal change, and low change.
7	**Block level aggregation**	The resultant reclassified images were also aggregated to the block level. These parameters were aggregated using Zonal statistical analysis in QGIS. For the temperature, the majority of temperature recorded in the block has been taken as block values. The sum of the pixels of the Blocks of the building footprint data is taken as a block value.
8	**Weighted overlay**	Weightages were assigned to NLST and air temperature data, with 60% and 40% respectively. NLST received the highest weight due to its high precision and accuracy, owing to its finer spatial resolution. Air temperature received 40% weight because of its coarser resolution. The resultant map displays four different classes: High Change, Change, Moderate Change, and Less Change. Based on this result, the areas experiencing significant changes were grouped at the block level to identify the districts most impacted by heat stress.

Table 1 - Research flow

RESULTS AND DISCUSSION

BUILDING FOOTPRINTS CHANGE ANALYSIS

1. Building Footprints Change Analysis

The Global Human Settlement Layer (GHSL) dataset serves as a critical tool for assessing the spatial dynamics of urbanization. For Tamil Nadu, it provides building footprint data at a 30-meter spatial resolution, enabling precise identification of urban growth patterns over time. This high-resolution data facilitates block-level analysis of how urban expansion influences land use, ecosystem services, and climate resilience across the state.

Over the past three decades, rapid urbanization has emerged as a dominant force driving land cover change, particularly in peri-urban and ecologically sensitive regions. The unchecked sprawl of urban areas, often at the expense of agricultural land, open spaces, and forested terrain, has increased exposure to heat stress and degraded the natural heat-regulating capacity of landscapes.

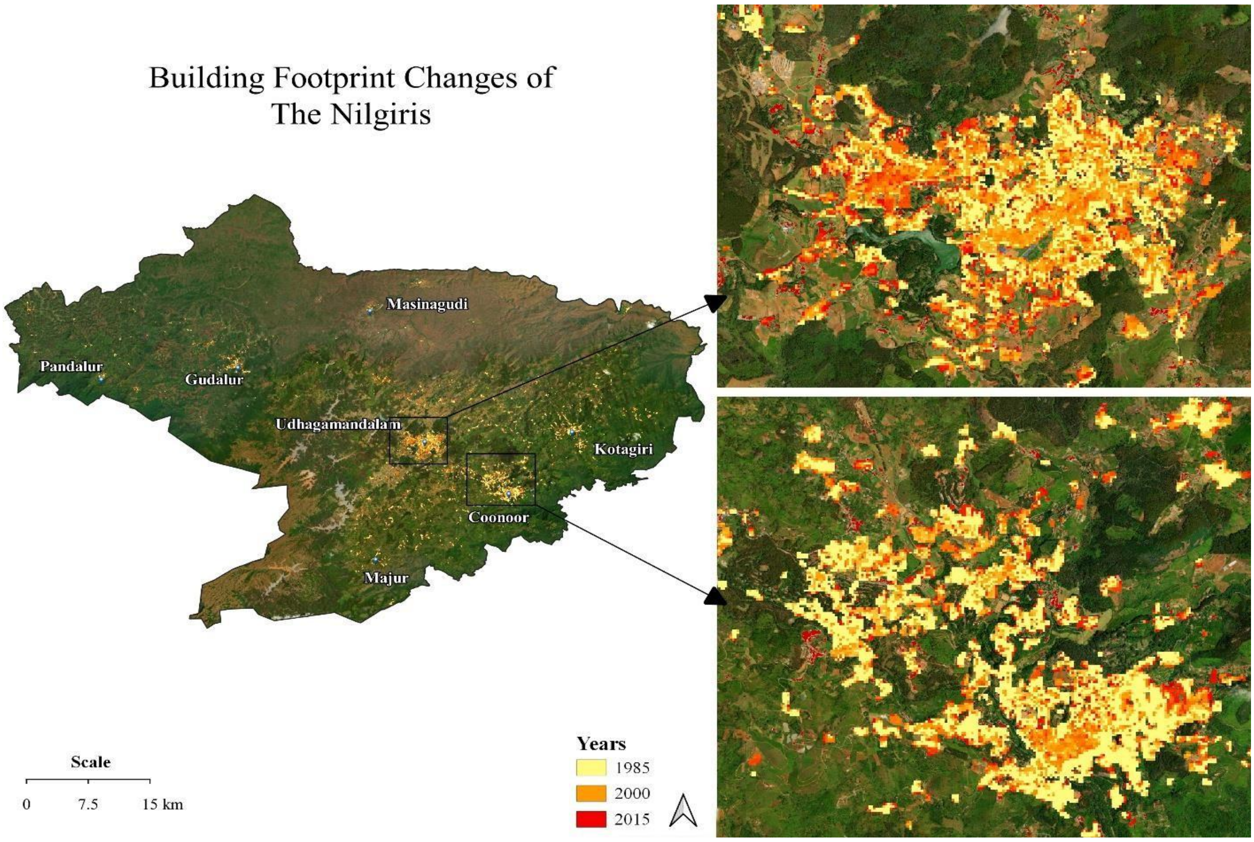


Figure 5 - Built up expansion of the Nilgiris from 1985 to 2015

One illustrative example is shown in Figure 5, which visualizes the spatial expansion of built-up areas in The Nilgiris district between 1985 and 2015. The Nilgiris, a critical highland ecosystem, has seen significant land cover transformation due to the spread of settlements into fragile hill slopes and forest fringes. This transformation is not only altering local hydrology and biodiversity but has also coincided with notable increases in land surface and air temperature across the district. As highlighted in recent climate studies and WRI research, the built environment is a hidden driver of urban heat in Indian cities, and Tamil Nadu is no exception.

Hard, impervious surfaces such as concrete and asphalt, trap solar radiation and re-radiate heat throughout the night, resulting in elevated night-time Land Surface Temperatures (LST) and intensifying the Urban Heat Island (UHI) effect. This is further exacerbated in hilly terrains, where deforestation and slope destabilization amplify climate vulnerabilities.

Using the GHSL dataset, building footprint values were derived at the block level for the years 1985 and 2015. These values were then used to generate two thematic maps:

- Figure 6 displays the total built-up area in square kilometers for each block in Tamil Nadu.
- Figure 8 represents the percentage of built-up area relative to each block’s total geographical area, allowing for normalized spatial comparisons.

These visualizations offer valuable insights into which blocks have undergone significant urban transformation, helping planners and policymakers identify areas at heightened risk of heat exposure, ecological degradation, and climate vulnerability. The findings clearly indicate that urban growth in Tamil Nadu is not just a demographic or economic phenomenon, but a key driver of regional climate shifts.

By integrating urban morphology data with temperature trends, this study underscores the critical need for climate-informed land use planning in Tamil Nadu, particularly in peri-urban zones and hill ecosystems, where the consequences of unregulated growth are already manifesting in the form of elevated heat stress, biodiversity loss, and reduced climate resilience.

The spatial patterns observed in the Global Human Settlement data reveal that urban expansion has not been uniform across Tamil Nadu. While metropolitan areas such as Chennai, Coimbatore, and Madurai have exhibited concentrated growth, several Tier-II cities and peri-urban blocks have experienced sprawling expansion. This decentralized and unplanned urban growth exerts increasing pressure on land resources, often encroaching upon agricultural and ecologically sensitive zones. In the case of hilly districts like the Nilgiris, Kodaikanal, and parts of the Western Ghats, the expansion of built-up areas is particularly alarming as it compromises the natural land cover that plays a vital role in local climate regulation and water retention. The subsequent sections analyse the relation of built area and heat stress in detail.

Urban growth not only transforms land use patterns but also alters the region's thermal profile. Built surfaces like concrete and asphalt absorb and re-emit more heat than natural landscapes, resulting in elevated Land Surface Temperatures (LST). This intensifies the Urban Heat Island (UHI) effect, especially in areas with low vegetation cover and dense construction. Studies have shown that building typologies, orientation, and materials contribute to excess heat retention in cities. As Tamil Nadu continues to urbanize rapidly, especially in ecologically vulnerable and topographically sensitive zones, integrating climate-conscious urban planning becomes imperative. The evidence from this study underscores the need to prioritize green infrastructure, regulate built density, and strengthen regional land use governance frameworks to mitigate long-term heat stress.

1.1. Change in Built-up Area at Block Level

Urban expansion is a critical indicator of land use change and a major contributor to climate risks, particularly in fast-developing regions. Analyzing the spatial distribution and growth of Built-up Areas at the block level (389 Blocks) over this 30-year period provides valuable insights into urbanization trends, regional development pressures, and environmental impacts. This section examines the extent of Built-up Areas across these Blocks using data from 1985 and 2015, highlighting key zones of transformation and urban hotspots. In 1985, the Built-up Areas of Chennai and S.S. Kulam (a block in Coimbatore district) were 86 and 62 square kilometers, respectively. The building footprints in Thoothukudi, Thiruparankundram (Madurai), Salem, Thiruverumbur (Tiruchirappalli), and Tiruppur ranged between 30 and 35 square kilometers. Other notable Blocks such as Palayamkottai (Tirunelveli), Agastheeswaram (Kanniyakumari), Erode, St. Thomas Malai (Chengalpattu), Periyanayakanpalayam (Coimbatore), and Mandapam (Ramanathapuram) recorded building footprints of 27.1, 24.3, 21.8, 20.5, 17.06, and 17.04 square kilometers, respectively.

Nearly 30 Blocks had a Built-up Area between 10 and 16 square kilometers, while 109 Blocks recorded areas between 5 and 10 square kilometers. A significant portion, 237 Blocks, had less than 5 square kilometers of Built-up Area. Figure 6 visualizes the Built-up Areas across Tamil Nadu in 1985 and 2015, highlighting spatial expansion over time and identifying regions experiencing rapid urban growth.

Area class (in sq.km.)	No of Blocks under each category in 1985	Percentage (%) of Block under each area class in 1985	No of Blocks under each category in 2015	Percentage (%) of Block under each area class in 2025
140 to 115	0	0	3	1
115 to 90	0	0	0	0
90 to 65	1	0	3	1
65 to 40	1	0	11	3
40 to 15	15	4	65	17
15 to 10	26	7	83	21
10 to 5	109	28	135	35
5 – 0	237	61	89	23

Table 2 - Blocks were categorized based on their Built-up Area

By 2015, the landscape had changed dramatically. For example, S.S. Kulam's (a block in Coimbatore) Built-up Area had expanded to 137 square kilometers, more than double its 1985 footprint, surpassing even Chennai; St. Thomas Malai (Chengalpattu) grew to 126 square kilometers, marking a fivefold increase; Chennai's built- up area reached 131 square kilometers, reflecting a 50% rise since 1985. Tiruppur, Thiruverumbur (Tiruchirappalli), and Villivakkam (Tiruvallur) expanded its Built-up Areas to 84, 76, and 70 square kilometers, respectively.

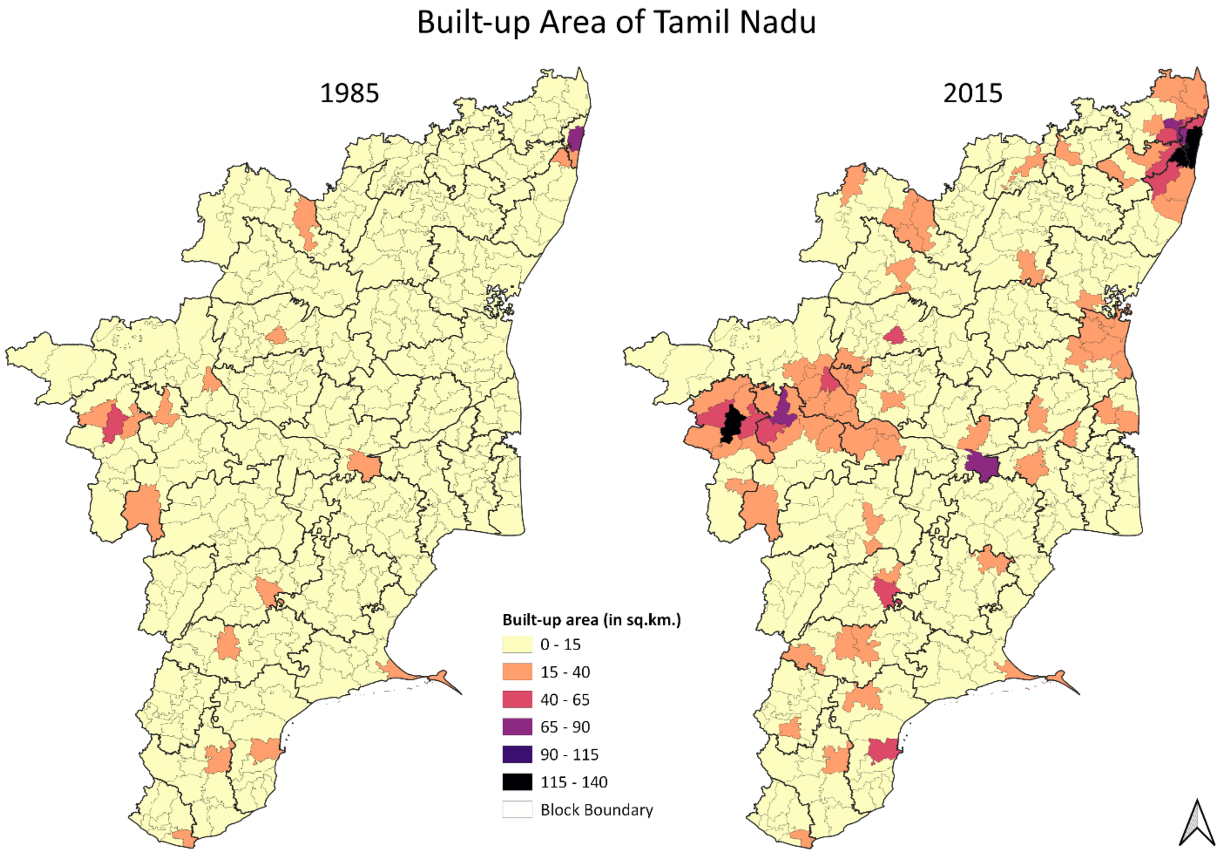


Figure 6 - Building Footprint at Block level

Other Blocks, including Salem, Puzhal (Tiruvallur), Periyanayakanpalayam (Coimbatore), Sulur (Coimbatore), Kattankolathur (Chengalpattu), Erode, Thiruparankundram (Madurai), Thoothukudi, Kundrathur (Kancheepuram), Palladam (Tiruppur), and Poonamallee (Tiruvallur), showed increases ranging between 41 and 58 square kilometers. The corresponding absolute increases for these Blocks were 27, 39, 35, 36, 46, 29, 13, 10, 41, 28, and 37 square kilometers.

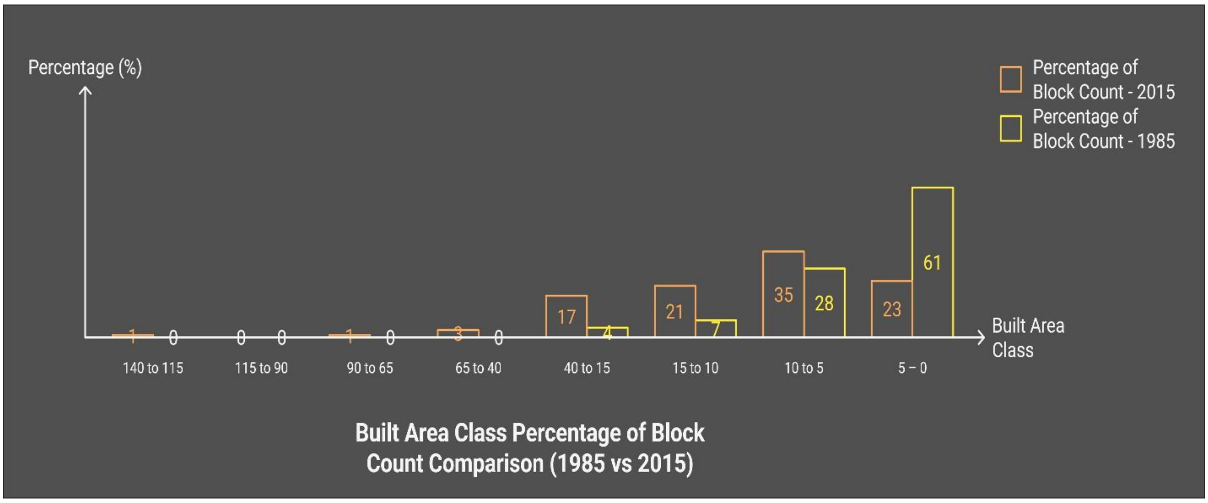


Figure 7 - Built Area Class Percentage of Block - Count Comparison (1985 vs 2015)

Further, 65 Blocks demonstrated Built-up Area increase by 15 to 40 square kilometer range, while 85 Blocks showed growth between 10 and 15 square kilometers. By 2015, 135 Blocks fell within the 5 to 10 square kilometers category, and only 89 Blocks remained with Built-up Areas under 5 square kilometers, a sharp decline from the 237 Blocks in that category in 1985.

These patterns, detailed in Table 2 & Figures 6, and 7, reflect the significant spatial expansion of urban areas across the state. In 1985, only Chennai had a Built-up Area in the 65 to 90 square kilometer range, with no Blocks exceeding this threshold. By 2015, six Blocks had crossed into this range, including three that reached the 115 to 140 square kilometer category, underscoring the pace of urbanisation over three decades.

The spatial patterns of urbanisation over the three-decade period highlight clear clusters of rapid development, especially around industrial and economic hubs. For instance, Blocks such as Sriperumbudur and Oragadam near Chennai, and the Tiruppur-Coimbatore corridor, show consistent expansion in building footprints, suggesting a direct correlation between infrastructure-led growth and urban sprawl. These growth corridors are particularly significant as they coincide with key transport infrastructure like highways and industrial parks, drawing in both residential settlements and commercial construction.

Furthermore, the spatial expansion of built-up land beyond traditional urban cores has led to the emergence of new peri-urban regions. These areas often lack the regulatory frameworks and environmental safeguards seen in established cities, leading to unplanned growth. Such unregulated expansion has implications not only for land use efficiency but also for heat exposure, as natural vegetation and agricultural buffers are replaced with impervious surfaces. This makes it critical to consider these emerging urban forms in future land-use planning and climate mitigation frameworks. These trends highlight the rapid urban transformation that had occurred at the block level across Tamil Nadu, with implications for infrastructure planning, environmental management, and climate resilience.

1.2. Percentage of Built-up Area in Each Block Relative to its Total Geographical Area

The percentage of Built-up Area relative to the Total Geographical Area (TGA) of a block serves as a critical indicator for assessing the spatial intensity of urbanisation and its corresponding impact on land use dynamics. This metric not only reflects the degree of land transformation but also helps identify Blocks experiencing developmental pressures, especially in the context of climate risk, ecological degradation, and resource scarcity.

Using data from 1985 and 2015, Figure 8 visualises the Built-up Area percentage for each block in Tamil Nadu, derived by calculating the ratio between the Built-up Area and the block's TGA. This analysis provides a clearer understanding of urban density, aiding in the identification of Blocks that have transitioned from predominantly rural to semi-urban or fully urban landscapes over the three decades.

In 1985, the spatial distribution of development was highly skewed towards low-density occupation. As shown in Table 3, approximately 93% of the Blocks (362 out of 389) had less than 5% of their area classified as built-up, indicating minimal urban influence and a dominance of agricultural, forested, or natural landscapes. Only 1% of the blocks (19 Blocks) had a Built-up Area ranging between 5% and 10%, and a negligible number (less than 1%) fell into higher categories. This pattern suggests a landscape characterized by dispersed rural settlements with limited infrastructure development or spatial footprint.

By 2015, however, a notable shift was observed. Although the majority of Blocks (74%) remained within the <5% Built-up Area category, this represents a 19% reduction compared to 1985, signaling the encroachment of built-up land into previously classified in other land-use areas. The proportion of Blocks with 5 to 10% Built-up Area increased sharply from 5% to 18%, indicating a marked rise in medium-density development. Additionally, the emergence of higher urban density categories, such as 10 to 15% (4%), 15 to 20% (2%), and 20 to 40% (2%), suggests the evolution of new urban cores and suburban growth zones, particularly around major cities and transport corridors.

One of the most significant findings from the analysis is the transformation of Chennai and its surrounding regions. Chennai's Built-up Area increased from 48% of its TGA in 1985 to 74% in 2015, marking a 26% rise over three decades and indicating near-saturation in urban land use. However, what is even more striking is the urban trajectory of St. Thomas Malai block in Chengalpattu district, which recorded a 44% increase in Built-up Area, surpassing even Chennai in relative growth. This reflects a broader pattern of peri-urban expansion, where urban sprawl extends rapidly into neighbouring per-urban or rural Blocks due to population pressure, housing demand, and industrial development.

Other Blocks exhibiting substantial relative increases include Villivakkam (Tiruvallur) with a 32% rise, Puzhal (27%), Poonamallee (24%), S.S. Kulam in Coimbatore (23%), Salem (18%), Erode (17%), and Tiruppur (17%). These Blocks are either part of expanding metropolitan regions or industrial belts, suggesting that economic activity is a major key driver of spatial transformation. On the other hand, Agastheeswaram block in Kanniyakumari, despite its population density, showed only a 3% increase, potentially due to geographic constraints, conservation policies, or land use regulation. Conversely, Kundrathur (Kanchipuram), which had almost negligible development in 1985, saw a 16% increase, highlighting the emergence of new urbanising zones from a low baseline.

Area with respect to TGA (in %)	No of Blocks with respective category - 1985	Percentage (%) of Block count with total no of blocks - 1985	No of Blocks with respective category -2015	Percentage (%) of Block count with total no of blocks - 2015
74 to 60	0	0	1	0
60 to 50	0	0	1	0
50 to 40	1	0	1	0
40 to 30	0	0	3	1
30 to 20	1	0	3	1
20 to 15	1	0	6	2
15 to 10	5	1	17	4
10 to 5	19	5	71	18
5 – 0	362	93	286	74

Table 3 - Blocks categorized based on percentage of build-up area to the Total Geographical Area

The shift in land use patterns, as indicated by these changes, has several environmental implications. Increased Built-up Areas are associated with reduced vegetation cover, higher impervious surface ratios, and elevated Land Surface Temperatures (LST), contributing to the Urban Heat Island (UHI) effect. This in turn can alter local microclimates, increase energy demand, and reduce urban livability. Moreover, the replacement of permeable land with constructed surfaces affects groundwater recharge, surface runoff, and increases the risk of flash floods, particularly in monsoon-prone regions like Tamil Nadu.

The data also suggest the beginning of urban consolidation and densification in certain Blocks, where growth is no longer just horizontal but increasingly vertical, especially in metropolitan and industrial corridors. The emergence of Blocks with more than 15% of their land area built-up by 2015 indicates a shift towards urban centre formation, commercial clustering, or special economic zones.

Overall, the transition from predominantly low-density to medium- and high-density development between 1985 and 2015 underscores the urgency for integrating spatial planning with sustainable urban development strategies. Identifying these patterns enables policymakers to anticipate future urban growth, design infrastructure accordingly, and implement zoning regulations that minimise ecological impact while supporting climate resilience.

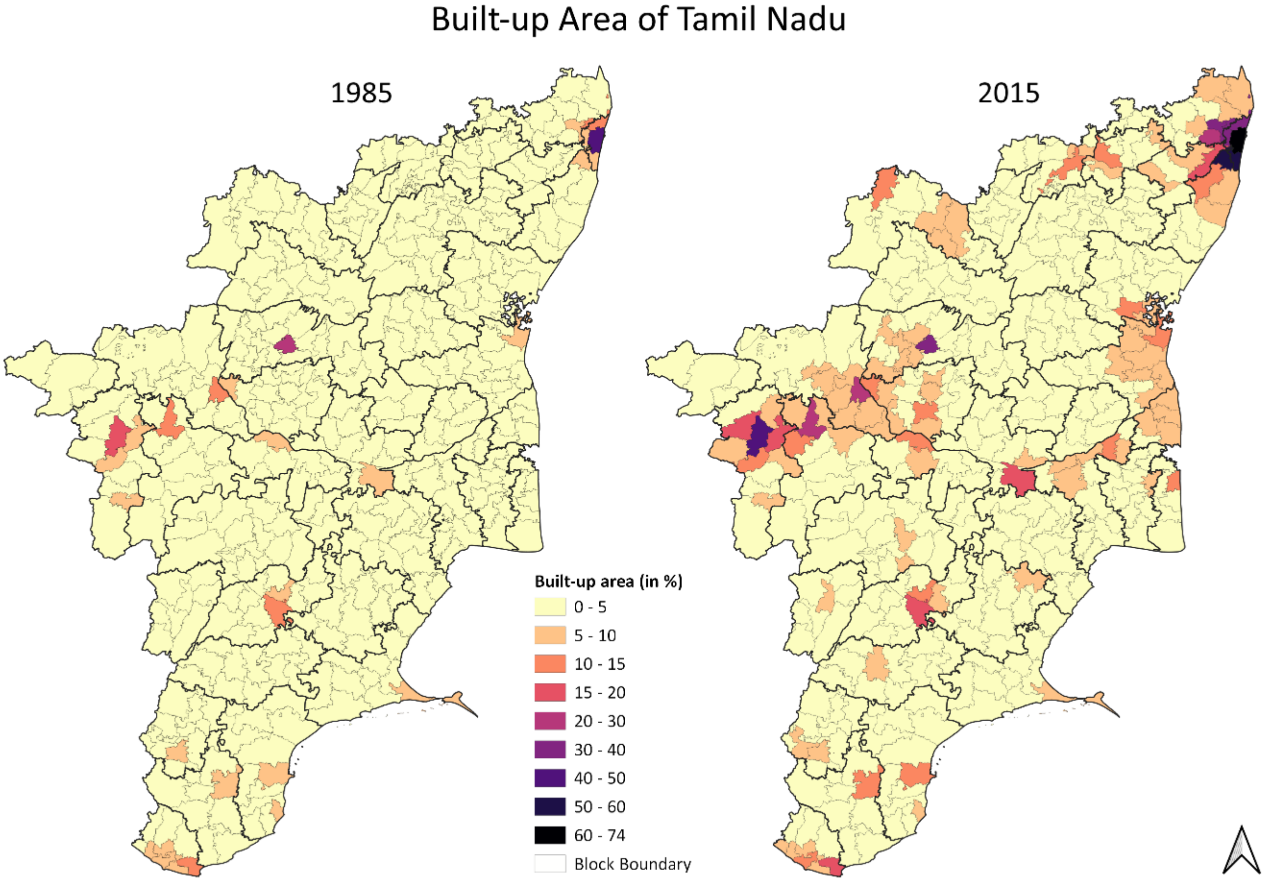


Figure 8 - Building Footprint in Percentage

The analysis of Built-up Area as a percentage of total geographical area (TGA) reveals deeper insights into spatial intensity, beyond just physical expansion. A high percentage of built-up land indicates reduced ecological buffers, such as wetlands, agricultural zones, or forest patches. This spatial intensity is particularly concerning in districts like Tiruvallur, Chengalpattu, and Coimbatore, where multiple blocks exhibit over 15% built-up ratios. In such contexts, the environmental cost of urban growth becomes more visible, as green cover shrinks and heat retention increases.

Additionally, the rising urban density in these blocks affects not only the physical landscape but also exacerbates social vulnerabilities. Higher density often correlates with increased population exposure, limited access to cooling infrastructure, and greater sensitivity to heatwaves. This raises questions about the adequacy of existing urban policies in managing urban expansion in a climate-sensitive manner. Moving forward, the percentage-based analysis provides a critical baseline for prioritizing climate-adaptive zoning policies, land-use restrictions, and investment in green infrastructure to balance development with ecological resilience.

The escalating proportion of built-up areas within Tamil Nadu's blocks has profound implications for the state's climate and environmental sustainability. Urbanization, characterized by the expansion of impervious surfaces such as concrete and asphalt, significantly contributes to the Urban Heat Island (UHI) effect. This phenomenon results in higher ambient temperatures in urban areas compared to their rural counterparts, exacerbating heat stress among residents and increasing energy demands for cooling. A study across ten Indian cities revealed that peripheral regions experienced an 85% increase in built-up areas, compared to a 35% increase in core areas, highlighting the rapid urban sprawl and its potential climatic consequences.

Furthermore, the densification of built-up areas influences local wind patterns and air quality. Tall buildings in densely packed regions can obstruct airflow, reducing wind speeds and trapping pollutants at ground level. This stagnation not only elevates temperatures but also increases exposure to air pollutants such as ozone, sulfur oxides, nitrogen oxides, and particulate matter, posing significant health risks to urban populations.

Addressing these challenges necessitates the integration of climate-responsive strategies into urban planning. Implementing green infrastructure, such as urban forests and green roofs, can mitigate the UHI effect by enhancing evapotranspiration and providing shade. Additionally, adopting building designs that promote natural ventilation and incorporating reflective materials can reduce heat accumulation. By prioritizing sustainable urban development practices, Tamil Nadu can alleviate the adverse climatic impacts associated with increased built-up areas and foster resilient, livable cities.

TEMPERATURE ASSESSMENT

Image Credits: Unsplash / Raajit Sharma

2. Temperature Assessment

Land Surface Temperature (LST) is a critical parameter for understanding the thermal characteristics of a region, particularly in the context of land use change and urbanisation. LST is highly influenced by surface properties such as vegetation cover, soil moisture, Built-up Area, and the extent of bare land. Variations in these surface features determine how heat is absorbed, stored, and emitted, which in turn shapes local and regional temperature profiles.

As highlighted by Duan et al., 2021, LST plays a vital role in the energy exchange processes between the Earth’s surface and the atmosphere. The nature of a surface, whether vegetated, urban, or barren, directly impacts its thermal response. Surfaces with high vegetation cover typically have lower surface temperatures due to evapotranspiration, whereas impervious surfaces such as roads and buildings tend to absorb and retain more heat, contributing to elevated LST values.

Temperature release properties, therefore, refer to a surface's inherent ability to absorb, store, and subsequently emit heat energy. These characteristics are fundamental in understanding spatial variations in LST. For instance, urban areas with dense built-up infrastructure exhibit higher thermal retention, leading to the Urban Heat Island (UHI) effect, where city centres remain significantly warmer than their surrounding rural areas. In contrast, vegetated or moist surfaces release heat more efficiently, contributing to localized cooling effects.

Recent studies, including evidence from Tamil Nadu, indicate a strong correlation between increased Built-up Area and LST rise, particularly in peri-urban zones where rapid land conversion occurs with minimal regulatory oversight. Night-time LST data has proven especially useful in capturing thermal retention trends, as it reflects the cumulative heat stored by surfaces during the day. This aspect is particularly important for assessing human thermal discomfort and nocturnal heat stress, which have direct implications on health, sleep quality, and public safety in urban environments.

Moreover, spatial mapping of LST enables planners to pinpoint heat-vulnerable hotspots at a granular level, aiding in the prioritization of heat mitigation interventions. In the context of Tamil Nadu, blocks with declining vegetation and increasing impervious surfaces have exhibited a consistent upward trend in LST. Integrating this thermal data with land use planning can guide targeted interventions such as afforestation, waterbody restoration, and low-impact urban design. As cities expand, maintaining a balance between development and ecological integrity becomes essential for sustainable climate adaptation.

2.1. Land Surface Temperature - Day and Night

This analysis focuses on the spatial and temporal variations in Land Surface Temperature (LST) during both day-time and night-time across Tamil Nadu, specifically during the summer months of March, April, and May, when surface temperatures typically peak. The study uses mean LST values for two time periods: the baseline analysis period (2000–2005) and recent analysis period (2018–2023). Both day-time and night-time LST trends are examined to capture diurnal temperature behavior and assess long-term thermal changes.

Daytime Land Surface Temperature (LST) reflects the immediate thermal response of land surfaces to incoming solar radiation. Urban materials such as asphalt, concrete, and rooftops absorb and retain more heat compared to vegetated or moist surfaces, leading to elevated surface temperatures during the day. Figure 9 illustrates the spatial distribution of daytime LST during the baseline analysis period (2000-2005) and recent analysis period (2018-2023), showing clear increases in temperature across many regions of Tamil Nadu. This trend closely aligns with the expansion of Built-up Areas and the reduction of vegetative cover, particularly in urban and peri-urban zones.

In contrast, night-time LST provides insights into how efficiently surfaces release absorbed heat back into the atmosphere after sunset. This parameter is especially important in the context of the Urban Heat Island (UHI) effect, as impervious urban surfaces tend to cool down more slowly than rural or vegetated areas, resulting in sustained higher temperatures during the night.

As shown in Figure 10, night-time LST has risen significantly in many parts of Tamil Nadu, reinforcing the impact of urban expansion and land cover transformation on thermal retention and climate vulnerability.

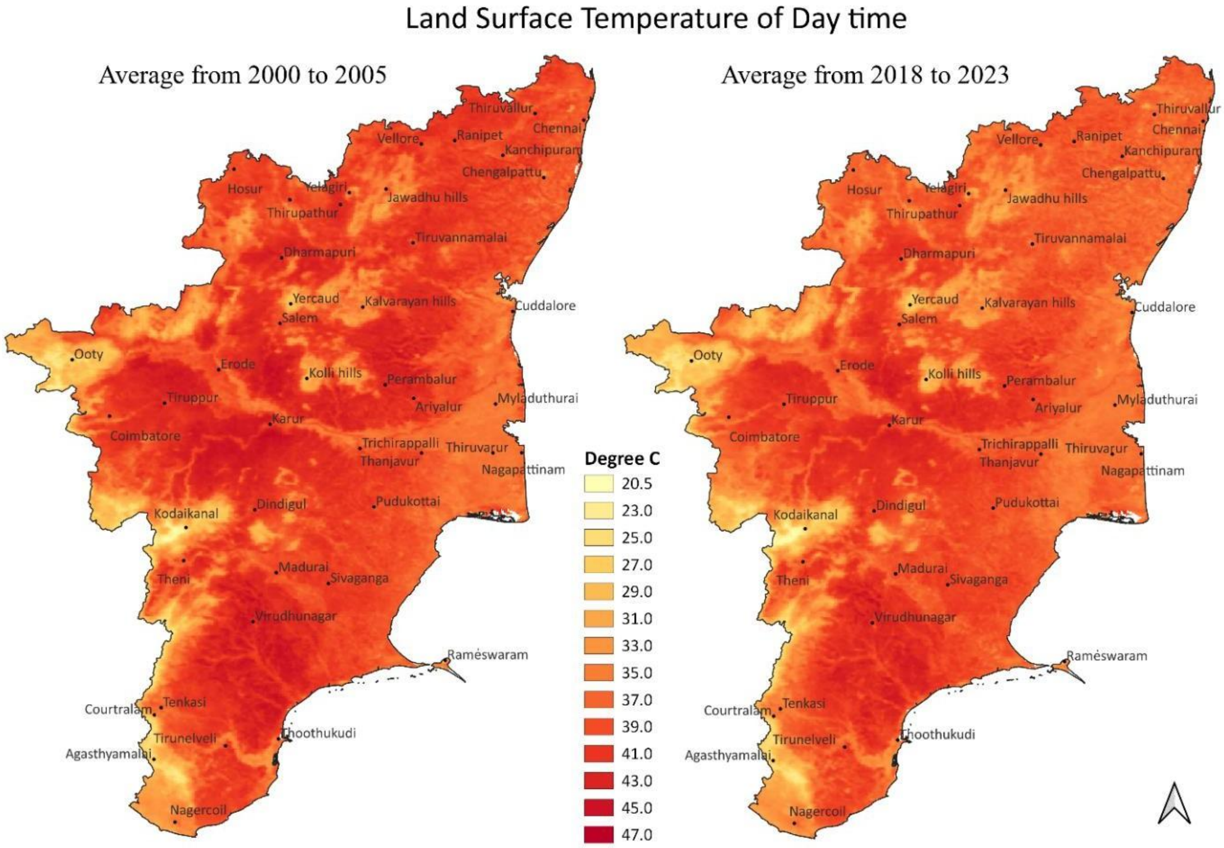


Figure 9 – Average LST during day

Notably, urban centres such as Chennai, Salem, Erode, Coimbatore, Tiruppur, Karur, Tiruchirappalli, and Madurai exhibit pronounced increases in night-time LST. These regions have experienced rapid urban expansion over the past two decades, accompanied by the loss of vegetation and open land. As a result, heat retention during the night has intensified, contributing to thermal discomfort, higher energy demand for cooling, and increased health risks during heatwaves.

Quantitatively, the analysis reveals that night-time LST has increased by approximately 4°C in dense urban, suburban, and peri-urban zones between 2000-2005 and 2018-2023 periods. On a broader scale, Tamil Nadu has witnessed a general night-time LST rise of about 2°C, indicating a pervasive warming trend linked to land use and land cover (LULC) changes.

As noted in the Heat Mitigation Strategy (2024) report and the Study on Urban Heat Island Hotspot Analysis and Mitigation Strategies for Tamil Nadu, conducted by the State Planning Commission (SPC), there is an urgent need for climate-sensitive urban planning, increased green cover, and heat-resilient infrastructure design to mitigate the long-term consequences of rising Land Surface Temperature (LST) in Tamil Nadu.

These findings highlight the growing impact of urbanization on thermal dynamics across the state. Elevated night-time temperatures not only exacerbate heat stress but also reduce the capacity of ecosystems and infrastructure to recover from daytime heat loads.

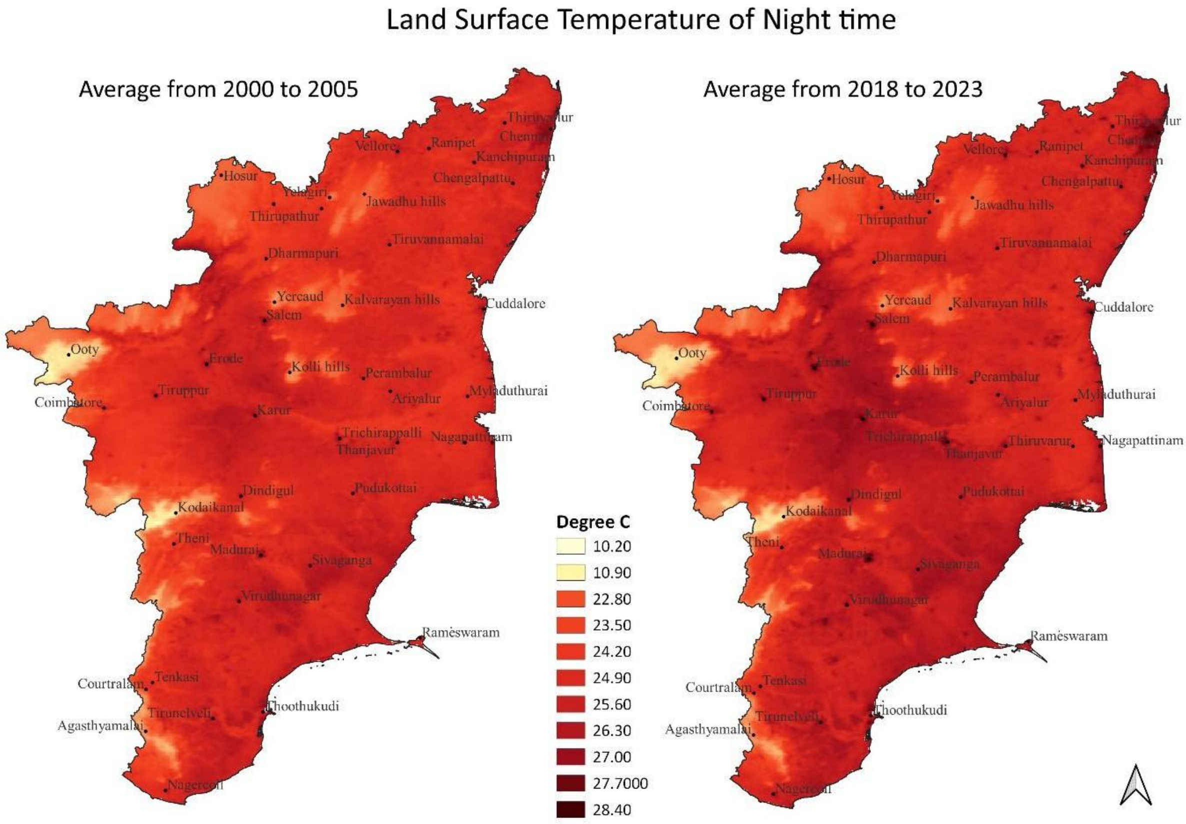


Figure 10 – Average LST at night

The spatial analysis further indicates that night-time LST increases are not limited to major metropolitan regions alone. Several rapidly urbanising tier-II and tier-III towns, such as Dindigul, Thoothukudi, Vellore, Sivagangai, and Kanchipuram, have also recorded significant LST anomalies, especially during the night-time. This trend reflects the widespread nature of unregulated urban expansion and highlights the thermal consequences of replacing green or open spaces with impervious infrastructure across smaller urban centres. These findings suggest the emergence of new urban heat island hotspots that may be overlooked in broader climate risk assessments if only daytime data or city-level metrics are considered.

Moreover, LST variations correlate strongly with the typology of land use. Industrial clusters and transport corridors show elevated LST values, particularly at night, due to the presence of large paved areas, warehouses, and limited vegetation. In contrast, blocks with higher forest cover, water bodies, or agricultural land, such as parts of The Nilgiris, Theni, and Tiruvannamalai, exhibit lower LST values and better night-time cooling potential. This spatial divergence in heat retention underscores the critical role of land cover in moderating local climate. It also presents an opportunity for targeted interventions such as preserving peri-urban agricultural zones, regulating industrial siting, and enhancing tree canopy coverage in high-LST regions to improve night-time thermal comfort.

2.2. Annual Air Temperature

Air temperature is a core climatic variable with direct implications for ecological balance, agricultural productivity, human health, and infrastructure resilience. In the context of climate change studies, long-term assessments of air temperature trends are essential for identifying warming patterns, understanding the frequency of extreme events, and designing appropriate adaptation strategies.

For this analysis, the date from ERA5 was utilised, the fifth generation of global atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA5 provides high-quality, high-resolution hourly climate data at a global scale, combining advanced numerical weather prediction models with observational data from satellites, weather stations, and other sources through data assimilation techniques.

Specifically, ERA5 offers 2-meter air temperature data, which is a standard measurement height for near-surface temperature used in climate and weather studies. This study extracts hourly temperature data for three key metrics:

- Maximum Air Temperature: The highest recorded temperature at 2 meters above ground level in a given day.
- Minimum Air Temperature: The lowest recorded temperature at the same height.
- Mean Air Temperature: The average of all hourly temperature values over a 24-hour period.

To assess long-term temperature changes across Tamil Nadu, the study aggregates four decades of hourly ERA5 air temperature data, focusing on two comparative decadal periods:

- Baseline Decade: 1981–1990
- Recent Decade: 2011–2020

These decadal averages provide a robust basis for identifying persistent warming trends and regional anomalies. Figures 11, 12, and 13 illustrate the spatial distribution of maximum, minimum, and mean air temperatures, respectively, for the two study periods.

However, it is important to note that the spatial resolution of ERA5 data (approximately 27.5 km² per grid cell) limits the detection of highly localized thermal variations. For example, fine-scale phenomena such as the Urban Heat Island (UHI) effect, temperature gradients in complex terrains like the Western Ghats, or coastal temperature fluctuations may not be fully captured due to the coarse granularity. Consequently, while ERA5 is ideal for identifying regional and state-level trends, it may underrepresent microclimatic variations that are critical at the district or sub-district scale.

Despite these limitations, ERA5 remains a highly reliable dataset for assessing large-scale temperature patterns and changes over time. In the following subsections, decadal trends in maximum, minimum, and mean air temperatures across Tamil Nadu are examined to understand how different regions are responding to ongoing climatic shifts, with a focus on the implications for heat exposure, ecological health, and regional climate resilience.

2.2.1. Maximum Air Temperature

Maximum air temperature is a key climatic variable that reflects the intensity of daytime heating. It is particularly relevant in the context of Climate Change, as sustained increases in maximum temperatures can lead to frequent and prolonged heatwaves, increased evapotranspiration, heat stress, and reduced agricultural productivity. In this study, the Maximum Air Temperature was computed using decadal averages of hourly ERA5 2-meter air temperature data, allowing for a robust comparison between two periods: 1981–1990 (baseline decade) and 2011–2020 (recent decade).

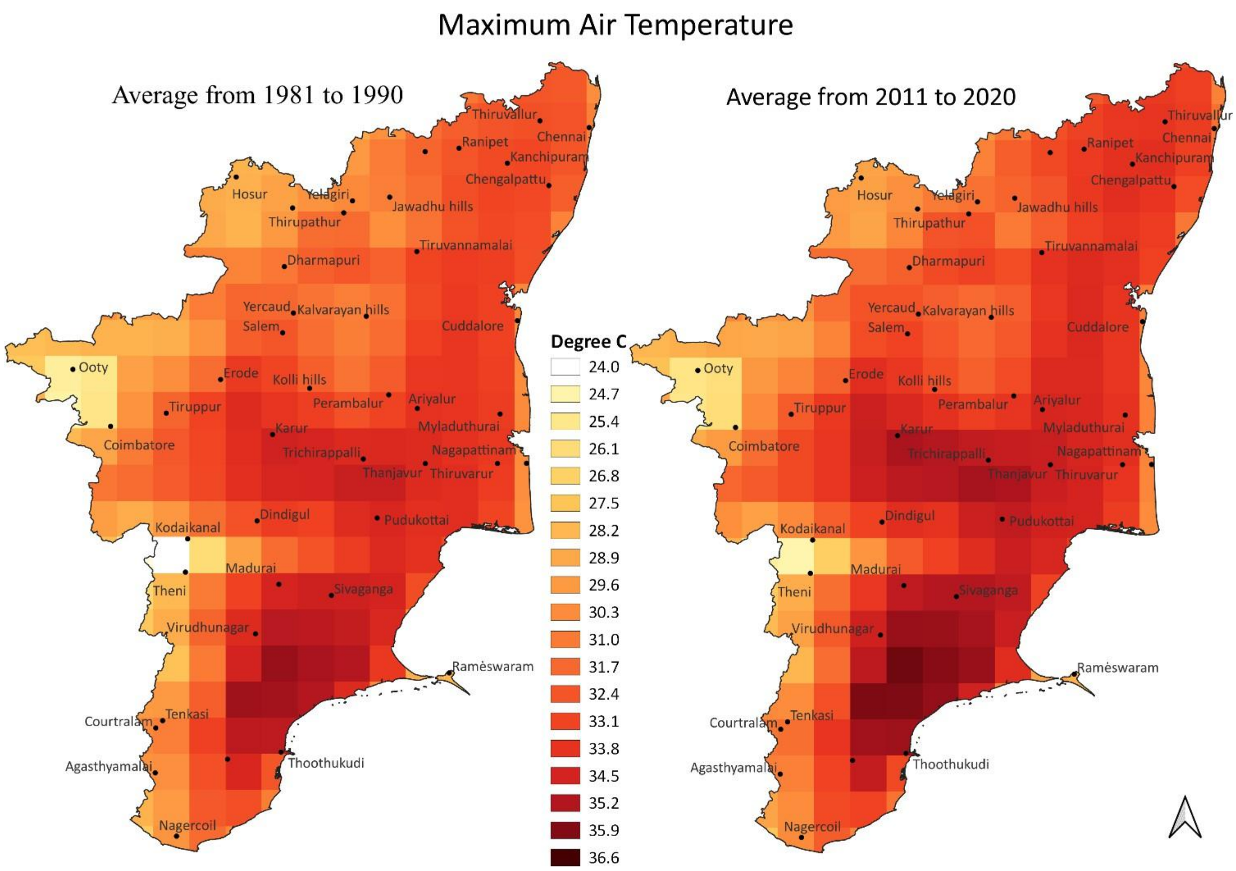


Figure 11 - Maximum Air Temperature

Figure 11 presents the spatial distribution of the decadal mean of Maximum Air Temperature across Tamil Nadu. The present decade shows a notable increase in maximum temperature, particularly in the northeastern districts, where an increase of up to 1.2°C is observed compared to the past. Districts such as Chennai, Chengalpattu, Thiruvallur, and Cuddalore are among the most affected, likely due to high population density, urban expansion, and intensification of built-up areas. These factors contribute to the Urban Heat Island (UHI) effect, which enhances heat accumulation during the day.

Although the ERA5 dataset's spatial resolution (~27.5 km² per pixel) may smooth out micro-level variations, the temperature rise remains evident even in hill stations such as Kodaikanal, indicating that elevated terrains are not immune to warming. This has serious ecological implications, as even modest temperature increases in high-altitude ecosystems can disturb endemic flora and fauna and shift climatic zones uphill.

Additionally, several inland districts such as Virudhunagar, Sivagangai, Madurai, Tiruchirappalli, Karur, Thiruvannamalai, Vellore, Krishnagiri, and Dharmapuri have shown a clear upward trend in maximum temperatures. These regions are characterized by mixed land use—agriculture, small- scale industries, and expanding peri-urban settlements—and have increasingly witnessed deforestation and land degradation, contributing to localized warming.

Coastal districts, including Tirunelveli, Thoothukudi, Ramanathapuram, and Pudukottai have also experienced warming in the present decade. The proximity to warming Sea Surface Temperatures (SSTs), urbanization of coastal zones, and loss of natural coastal buffers such as mangroves may contribute to this trend. Rising Maximum Air Temperature in these areas can exacerbate heat-related health risks, stress on freshwater availability, and increase vulnerability to cyclonic heat surges.

2.2.2. Minimum Air Temperature

Minimum air temperature represents the lowest temperature recorded at 2 meters above ground level within a 24-hour period. This metric is critical in evaluating nighttime cooling, the Urban Heat Island (UHI) effect, and thermal stress recovery. Rising minimum temperatures over time are an indicator of reduced nocturnal cooling, which has implications for both human health and ecological stability. In this study, the minimum air temperature data was derived from hourly ERA5 reanalysis, averaged across the same decadal periods used for maximum temperature analysis: 1981–1990 (baseline) and 2011–2020 (recent).

Figure 12 displays the spatial variation in decadal average minimum air temperatures across Tamil Nadu for both study periods. The data reveals clear warming trends across the state, including in traditionally cooler zones. Hilly regions such as Ooty and Kodaikanal, which have historically recorded the lowest annual air temperatures, now show noticeable increases in their decadal averages. This rise is likely attributed to increasing land surface temperatures, reduced forest cover, and changes in atmospheric circulation patterns over high-altitude regions.

In the baseline decade (1981–1990), the minimum air temperature across Tamil Nadu ranged from 15.8°C to 35.6°C. In the recent decade (2011–2020), this range shifted upwards, with the lowest recorded minimum temperature increasing to 17.0°C, and the highest rising to 36.2°C. This suggests a consistent warming trend during nighttime, reinforcing the evidence of reduced terrestrial heat dissipation, particularly in urbanised or deforested areas.

Several districts in southern and western Tamil Nadu have shown a significant rise in minimum temperatures. Districts such as Tenkasi, Theni, Madurai, and Coimbatore have experienced increases approaching 1.4°C, while even the lowest regional increases were about 0.3°C, highlighting a widespread warming effect.

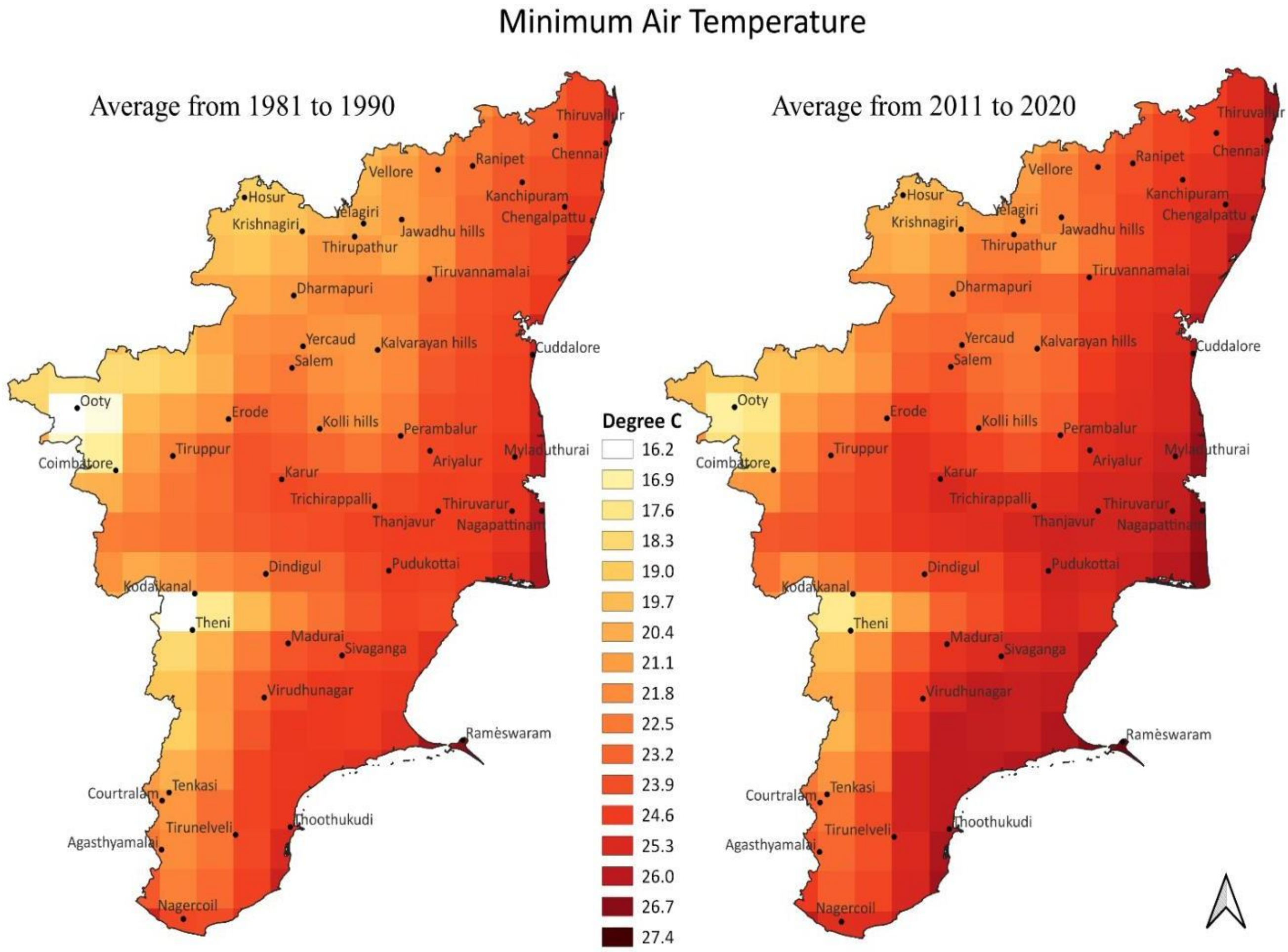


Figure 12 - Minimum Air Temperature

The warming trend is especially pronounced in districts along the Western Ghats, including Tenkasi, Theni, Coimbatore, Erode, and Dharmapuri. These ecologically sensitive regions are experiencing the compound effects of land use changes, such as deforestation and increasing Built-up Areas, which have altered natural cooling dynamics.

Beyond the hilly regions, several inland districts also demonstrate increased minimum air temperatures, including Madurai, Tiruchirappalli, Karur, Salem, Dindigul, Sivagangai, Pudukottai, Tiruppur, Virudhunagar, and Thiruvannamalai. These areas often combine agricultural landscapes with growing urban settlements, where warming can lead to increased crop stress, changes in pest behavior, and altered hydrological cycles.

Moreover, the coastal districts of Tamil Nadu show some of the highest minimum air temperature values in the present decade. These include Chennai, Chengalpattu, Cuddalore, Villupuram, Mayiladuthurai, Nagapattinam, Thiruvarur, Thanjavur, Ramanathapuram, and Thoothukudi. The proximity to warming Sea Surface Temperatures (SSTs) and increased urbanization along the coast likely contribute to the observed thermal rise. Coastal regions are also prone to thermal entrapment due to high humidity levels, which amplifies the discomfort during warm nights and can have serious implications for vulnerable populations.

2.2.3. Mean Air Temperature

Mean air temperature is a key climatic indicator derived from the average of daily maximum and minimum temperatures. It represents the general thermal conditions experienced in a region and is often used to detect long-term warming trends. Changes in mean temperature have direct implications for agricultural productivity, human health, biodiversity, water demand, and energy use.

Figure 13 illustrates the spatial distribution of decadal mean air temperature across Tamil Nadu for both study periods. The analysis shows a consistent and widespread increase in mean air temperature across all physiographic zones of the state, with significant changes in both highland and lowland regions.

In the Western Ghats region, the historically cooler hill stations of Ooty and Kodaikanal have experienced mean temperature increases of 0.7°C and 0.9°C, respectively. These changes are ecologically significant, as even small thermal shifts in high-altitude ecosystems can disrupt endemic species, alter phenological patterns, and shift climate-sensitive vegetation zones of uphill.

Across the northern and northeastern districts—including Thiruvallur, Ranipet, Vellore, Kanchipuram, Thiruvannamalai, Krishnagiri, and Dharmapuri—mean temperature increases of approximately 1°C or more have been observed. These districts are undergoing rapid urbanisation, industrial development, and deforestation, which contribute to surface heating and reduced cooling at night. The shift in mean temperature here reflects the compounded effects of land use change and regional climate variability.

Central Tamil Nadu, comprising districts such as Salem, Karur, Tiruchirappalli, Dindigul, and Madurai, also shows a strong warming signal. These regions lie within agriculturally productive zones and river basins, where rising mean temperatures can adversely affect crop yield, water availability, and evapotranspiration rates, potentially altering local agro-climatic zones.

In the southwestern belt, including Tiruppur, Theni, Coimbatore, and Tenkasi, the increase in mean air temperature further supports the trend observed in maximum and minimum temperature analyses. These areas are a mix of peri-urban industrial corridors and hilly agricultural landscapes, where warming can increase energy demand (particularly for cooling), reduce work productivity, and exacerbate water stress.

Southern districts like Tirunelveli and Kanniyakumari, traditionally buffered by coastal moderation, are now showing signs of thermal intensification. Additionally, Virudhunagar, Sivagangai, Ramanathapuram, and Pudukottai recorded the highest mean air temperatures during the recent decade. These districts, situated in semi-arid and dry sub-humid zones, are particularly vulnerable due to low vegetation cover, frequent droughts, and limited water resources.

Crucially, all fourteen coastal districts of Tamil Nadu demonstrate an increase in mean air temperature over the study period. Coastal areas, including Chennai, Chengalpattu, Cuddalore, Villupuram, Mayiladuthurai, Nagapattinam, Thanjavur, Thiruvarur, Ramanathapuram, and Thoothukudi, face compound climate risks: rising mean air temperature, warming sea surface temperatures (SSTs), and increasing coastal humidity. These factors intensify thermal discomfort, amplify the Urban Heat Island effect, and elevate the risk of vector-borne diseases and heat-related illnesses.

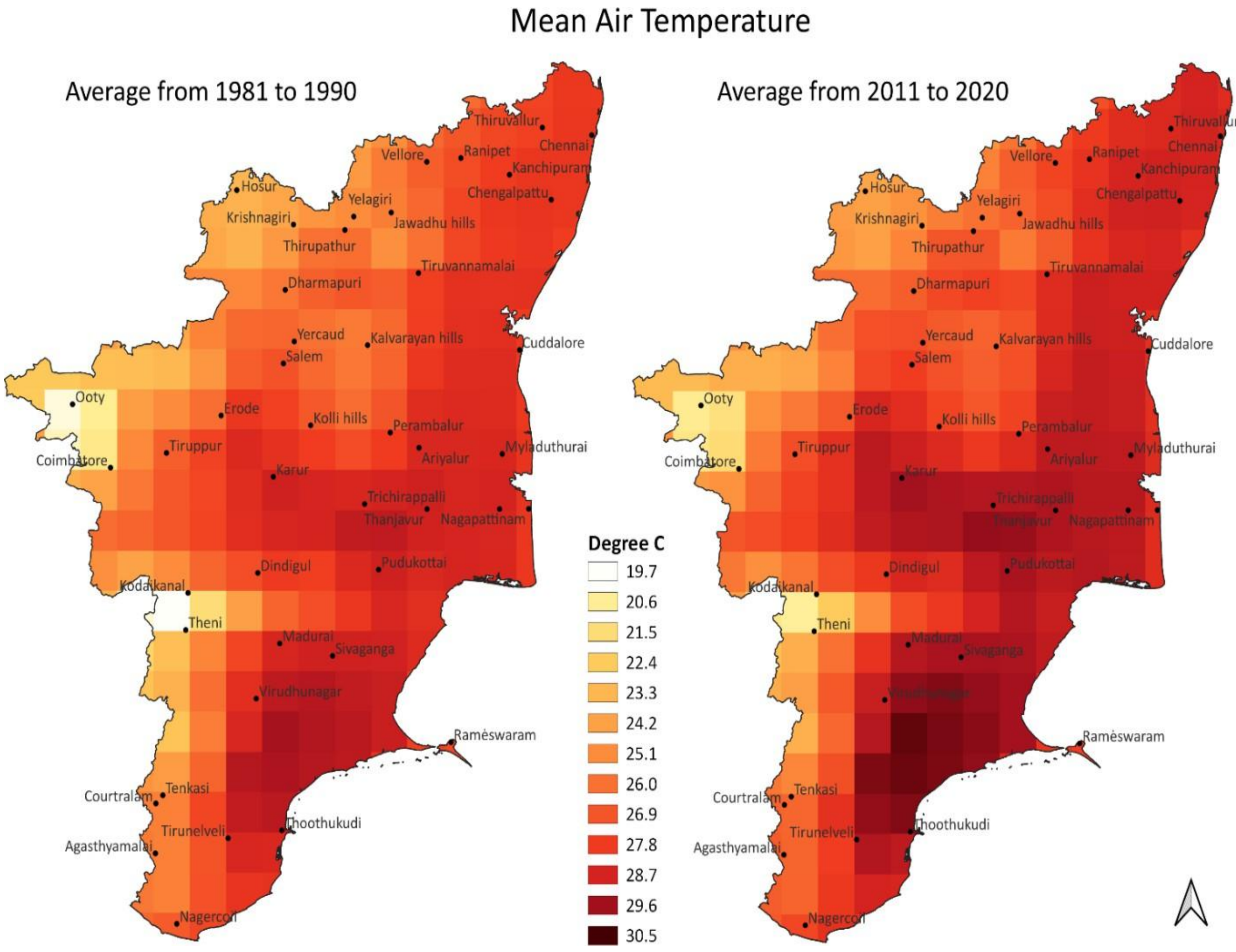


Figure 13 – Mean Air Temperature

2.3. Seasonal Air Temperature

Seasonal Air Temperature Analysis is crucial for understanding period-specific climate sensitivity and the implications for heat exposure, seasonal climatic variations, and thermal comfort. This section focuses on seasonal temperature shifts in Tamil Nadu using decadal averages of ERA5 air temperature data for summer (March–May) and winter (December–February) months across two timeframes: 1981–1990 and 2011–2020.

The summer analysis, based on 2-meter Maximum Air Temperature, reveals a spatial redistribution of thermal intensity. Several districts that previously remained within moderate summer temperature thresholds have now transitioned into higher heat zones, particularly in interior and transition belts. The change is especially notable in districts at the urban rural interface, where land use conversion has intensified in the past two decades. These shifts are significant as they indicate emerging heat hotspots in zones that were not previously addressed for heat adaptation planning.

In the winter season, assessed through 2-meter minimum air temperature, the warming is less about extreme temperatures and more about the loss of cold variability. Regions that once had distinctively cooler winters are showing increasingly uniform night-time temperatures, suggesting a reduction in seasonal contrast. This could influence the timing of phenological events, from flowering cycles to pest emergence, and affect the thermal comfort balance of the region's traditionally temperate zones.

Furthermore, the narrowing temperature gradient between summer and winter suggests a trend toward a prolonged warm season in Tamil Nadu. This has potential cascading effects on groundwater recharge, evaporation rates, and energy demand curves, especially in districts undergoing rapid demographic or economic transitions. This analysis on the seasonal data not only reveals warming but also points to shifts in seasonal climate behavior, which are just as critical to climate adaptation as annual trends.

2.3.1. Summer Season

Seasonal temperature variations play a critical role in shaping regional climate impacts, particularly during the summer months when thermal extremes are most pronounced. In Tamil Nadu, the pre-monsoon summer period (March to May) is characterized by peak temperatures, leading to intensified heat stress impacts. Analyzing changes in summer air temperature over time helps to identify emerging heat-prone zones and assess the shifting intensity of seasonal warming. This section compares the decadal average Maximum Air Temperature s for summer between 1981–1990 and 2011–2020, highlighting spatial patterns of temperature rise across the state.

Figure 14 presents the spatial distribution of average Maximum Air Temperature during the summer months (March to May) for the two study periods: 1981–1990 and 2011–2020. This comparison enables the identification of temporal and spatial shifts in thermal intensity during the hottest part of the year.

The analysis reveals that the northern and northeastern districts of Tamil Nadu have experienced an average increase of approximately 0.8°C in summer Maximum Air Temperature over the last three decades. This warming is not uniformly distributed and appears more pronounced in urbanizing districts and those undergoing rapid land use transformation, particularly in peri-urban zones.

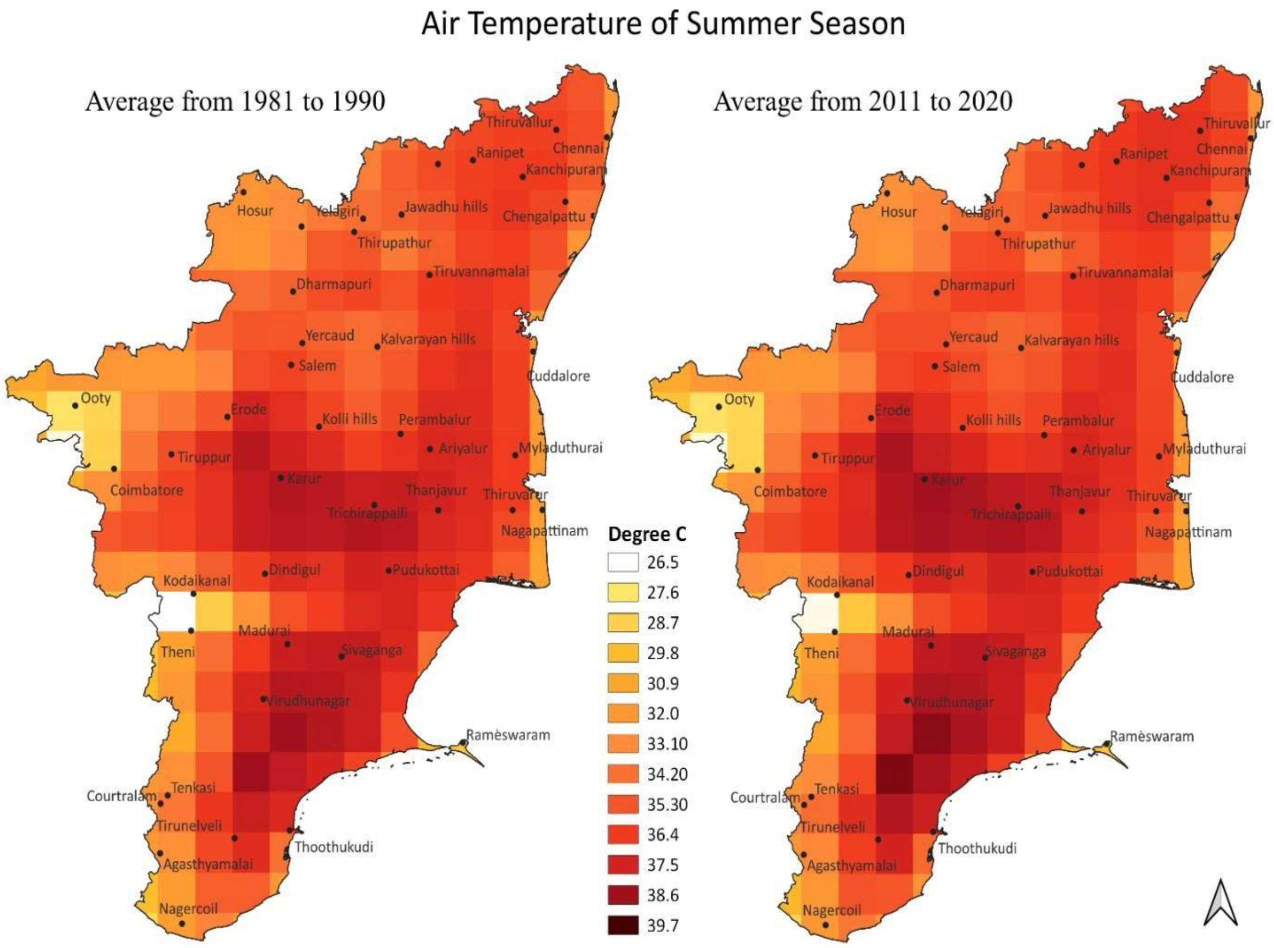


Figure 14 - Summer Air Temperature

The Western Ghats, including regions such as The Nilgiris and Kodaikanal, along with adjacent highland belts, also show noticeable warming. While these regions historically maintained relatively stable thermal regimes due to elevation and vegetation cover, the observed temperature rise suggests a shift in high-altitude thermal sensitivity, potentially linked to changes in forest cover, soil moisture loss, and increasing anthropogenic pressure.

Furthermore, central and southeastern Tamil Nadu, which includes Tiruchirappalli, Karur, Dindigul, and Pudukkottai, also demonstrates elevated summer temperatures in the recent decade. These regions are agriculturally intensive and are now facing increased evapotranspiration stress, which could influence irrigation demand and cropping patterns during the peak summer season.

Particularly concerning is the marked rise in summer temperatures observed in the southern coastal and inland districts, including Thoothukudi, Virudhunagar, and Ramanathapuram. These districts, traditionally semi-arid and drought-prone, are now experiencing additional thermal pressure, which may exacerbate existing water scarcity issues and livelihood vulnerabilities, especially in agriculture and fisheries sectors.

2.3.2. Winter Season

Winter temperatures in Tamil Nadu, although generally mild, play an important role in regulating agricultural cycles, biodiversity, and seasonal comfort. Monitoring long-term changes in winter temperatures can reveal critical shifts in cold season dynamics, which are often overshadowed by summer-focused climate assessments. This section examines variations in minimum air temperature during the winter months (December to February), comparing decadal averages between 1981–1990 and 2011–2020, using ERA5 reanalysis data.

Figure 15 depicts the spatial change in winter minimum air temperatures across the state. The analysis reveals a state-wide warming trend, with the average minimum air temperature during winter increasing by approximately 0.5°C in the recent decade compared to the past. However, several regions exhibit above-average warming, with some zones recording increases of up to 1.6°C.

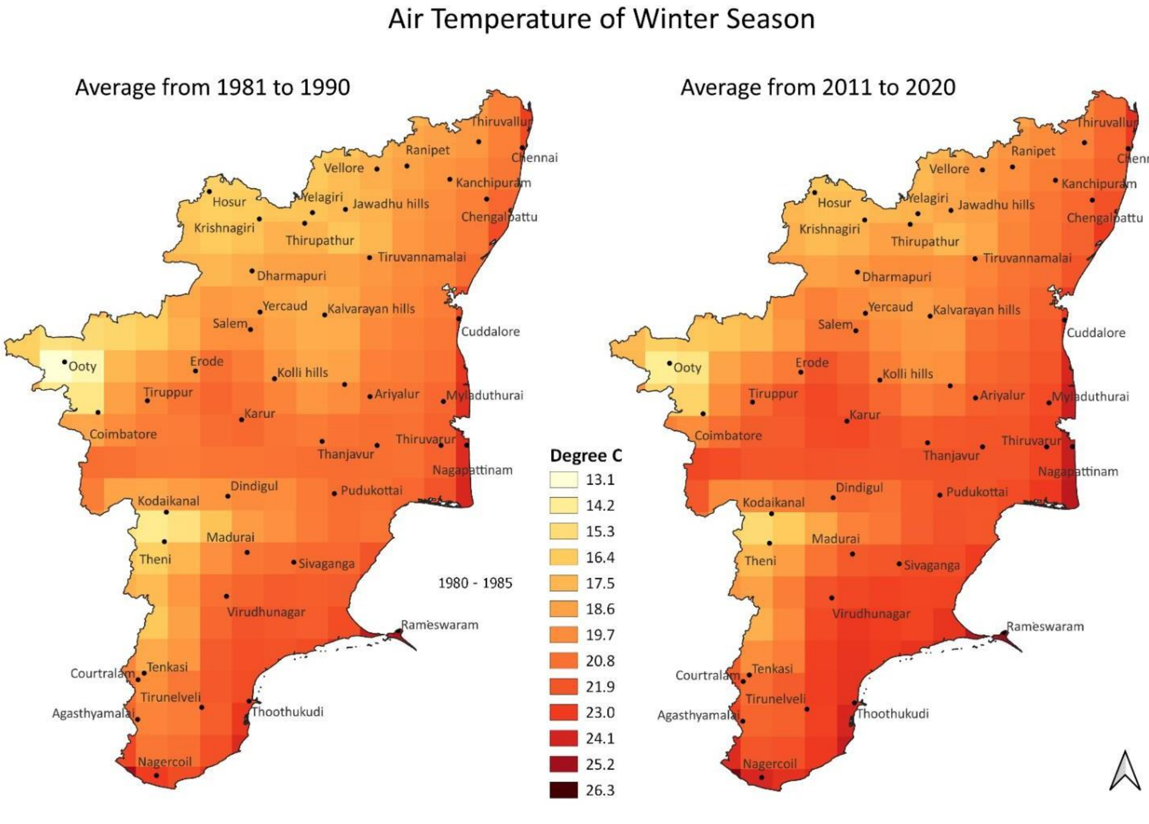


Figure 15 - Winter Air Temperature

Notably, the Western Ghats terrain, including high-altitude districts such as The Nilgiris, Theni, and parts of Coimbatore, has shown a significant increase in winter season temperatures. These areas, historically known for cooler climates and lower winter night temperatures, are now experiencing warmer winters, which can disrupt mountain ecosystem dynamics, affect plant phenology, and reduce chilling hours necessary for certain crops. Beyond the hilly regions, coastal districts such as Chennai, Cuddalore, Nagapattinam, and Thoothukudi, and central districts like Tiruchirappalli, Karur, and Dindigul also exhibit substantial warming. These areas are increasingly affected by land cover change, urbanisation, and sea surface temperature anomalies, which contribute to warmer winter nights and reduce diurnal temperature ranges.

The mean winter season temperature has increased from 25.4°C in the baseline decade to 26.3°C in the recent decade, confirming a warming trend not only at seasonal peaks but also during typically cooler periods. Rapidly urbanising districts such as Coimbatore, Tiruppur, Erode, and Karur show marked increases, likely due to expanding Built-up Areas and the decline of green cover. Interestingly, even the lowest recorded winter temperatures in the ERA5 dataset reflect a significant upward shift, indicating that cold extremes are becoming less frequent or less intense. This has implications for pest cycles, crop resilience, and public health, especially in rural areas that depend on winter-specific cropping patterns.

Image Credits: Unsplash/Sudo

3. Universal Thermal Comfort Index (UTCI)

The Universal Thermal Comfort Index (UTCI) is a comprehensive bioclimatic indicator used to assess human thermal comfort under varying environmental conditions. Unlike temperature-based metrics alone, the UTCI incorporates multiple atmospheric and surface parameters, including air temperature, humidity, wind speed, solar radiation, and rainfall, to estimate the physiological impact of thermal conditions on the human body. It is particularly useful for identifying heat stress zones, aiding in climate adaptation planning and public health preparedness.

Figure 16 presents the spatial distribution of UTCI across Tamil Nadu during the summer months (March to May) for the present study decade. The analysis reveals a significant increase in UTCI values across large parts of the state, indicating a heightened level of thermal stress in recent years.

According to the European Climate Adaptation Platform (Climate-ADAPT), the UTCI values are categorised as follows:

- +46°C: Extreme heat stress
- +38°C to +46°C: Very Strong heat stress
- +32°C to +38°C: Strong heat stress
- +26°C to +32°C: Moderate heat stress
- +9°C to +26°C: No thermal stress

Based on this classification, ***the current analysis shows that most regions in Tamil Nadu fall under the "Strong heat stress" categories, with some zones approaching the "Very Strong heat stress".*** This is a notable shift from previous decades when larger areas fell within the "moderate" stress zone. The data clearly indicates an intensification of heat- related discomfort, particularly during the pre-monsoon summer season.

Urban, suburban, and rapidly urbanising regions have shown the most significant increase in UTCI values. These include major city regions and urban corridors such as:

- Chennai, Chengalpattu, Thiruvallur, Kanchipuram (Greater Chennai Region)
- Madurai, Erode, Karur, Tiruppur, Coimbatore (Industrial belts)
- Tiruchirappalli, Thiruvannamalai, Pudukottai, and Sivagangai (Central and Southern Districts)

These areas are experiencing a combination of factors such as high population density, land surface modification, reduced vegetative cover, and increased anthropogenic heat release, all of which contribute to higher UTCI levels. In particular, coastal districts have demonstrated a notable rise in UTCI, influenced not only by rising air temperatures but also by high humidity levels, which significantly reduce the body's ability to cool through perspiration.

The rise in UTCI indicates an increased frequency and intensity of thermal discomfort and heat-related health risks, especially in vulnerable populations such as outdoor workers, the elderly, and children. It also underscores the urgent need for:

- Urban climate-sensitive planning, such as increasing green cover and reflective surfaces,
- Improved heatwave warning systems and public awareness campaigns,
- Integration of UTCI data in local development and public health policies.

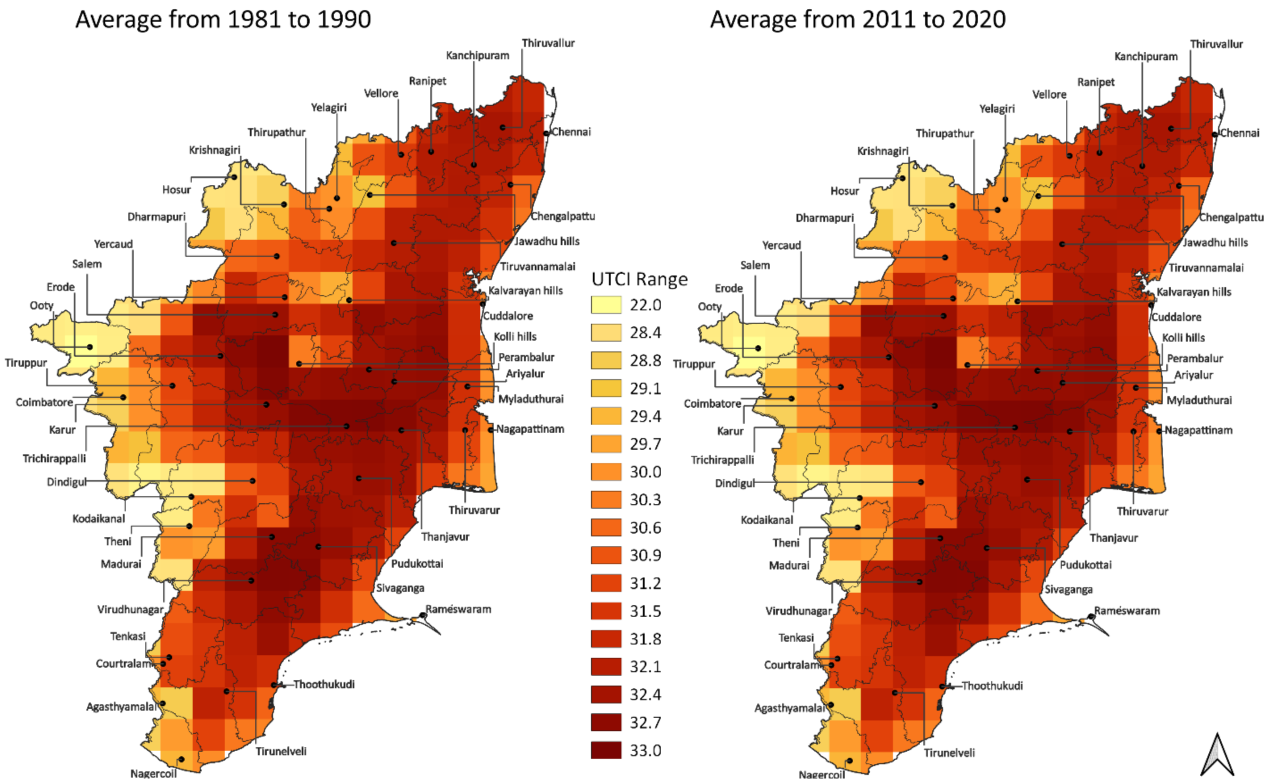


Figure 16 – UTCI of summer months in TN

4. Assessing the Block-Level Heat Stress

To spatially quantify heat stress at a finer administrative scale, this study performed a block-level aggregation of all heat-related datasets. Tamil Nadu's Blocks served as the analytical units for integrating various temperature indicators into a unified Block-Level Heat Stress framework.

As the datasets vary in type and resolution, they were first normalized to a common scale, enabling consistent comparison across Blocks. Each raster layer, representing thermal indicators, was processed using zonal statistics in QGIS, where the mean value of each heat variable was extracted for every block based on its spatial extent.

The normalized outputs were then used in a multi-criteria weighted overlay analysis, allowing the synthesis of diverse temperature metrics into a composite heat stress index. This index highlights spatial disparities in heat exposure across Blocks and serves as the basis for identifying critical zones that warrant immediate attention for climate adaptation measures.

4.1. Land Surface Temperature

Land Surface Temperature (LST) data used in this study has been sourced from the MODIS MOD11A1 V6.1 dataset, which provides daily thermal readings at a 1 km spatial resolution. Figures 9 and 10 illustrate the distribution of LST across Tamil Nadu. Among the available thermal parameters, night-time LST was selected for analysis due to its greater reliability in capturing surface heat retention. Unlike daytime LST, which is significantly influenced by direct solar radiation and may not reflect actual surface heat storage, night-time LST is more closely aligned with the effects of urban heat islands (UHIs), land cover type, vegetation density, and soil moisture content. These attributes make night-time LST a valuable indicator for thermal stress assessment, drought monitoring, and urban climate mapping.

For the purpose of this study, night-time LST data was aggregated to the block level using zonal statistics in GIS and normalized to enable integration into a multi-criteria Block-Level Heat Stress framework. The two temporal windows selected were: 2000–2005 (Baseline Analysis period) and 2018–2023 (Recent Analysis period), aligning with the timeframes used in earlier analyses. This enabled a comparative evaluation of thermal shifts over the last two decades.

As shown in Figure 17, the present study period reveals a significant increase in block-level night-time LST values across Tamil Nadu. Chennai recorded the highest value of 27.6°C, a level not matched by any other block in the state. In the earlier period, only six Blocks fell into the 26–27°C night-time LST category: Chennai, St. Thomas Malai (Chengalpattu), Kalaiyarkovil (Sivagangai), Puzhal (Thiruvallur), Namakkal, and K. Paramathi (Karur). However, in the present study period, the number of Blocks in this category has dramatically increased to 80, indicating a widespread escalation of night-time thermal stress.

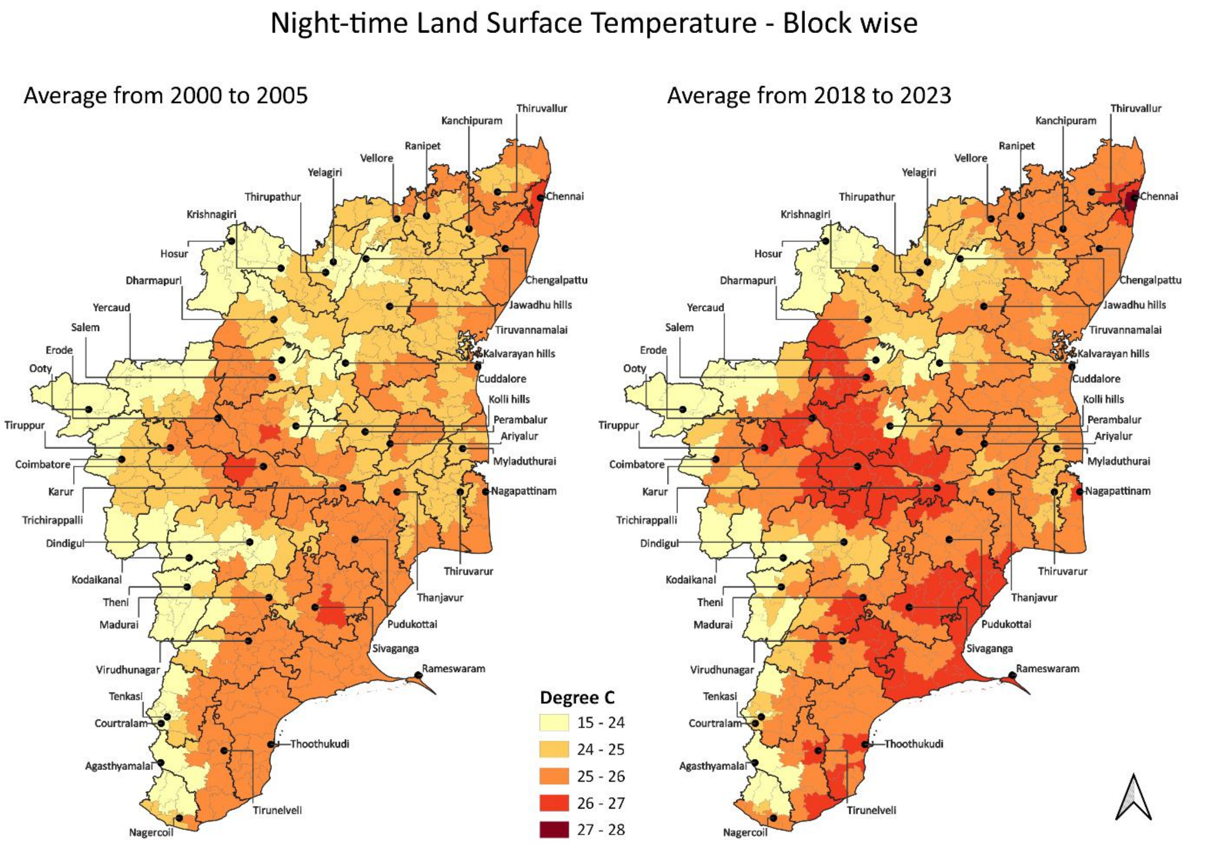


Figure 17 – Block level Land Surface Temperature – Night-time

These 80 Blocks are spatially distributed across multiple districts. Karur district alone accounts for seven Blocks within this range, followed by eleven Blocks in Namakkal, nine in Salem, and seven each in Tiruchirappalli, Sivagangai, and Ramanathapuram. Additionally, Erode, Tiruppur, Pudukottai, and Virudhunagar each have four Blocks, while Madurai, Thoothukudi, and Thiruvallur each have three Blocks. Chengalpattu, Tirunelveli, and Dindigul have two Blocks each, and Thanjavur, Nagapattinam, and Krishnagiri each have one block in this high-temperature category. This shift points to a broader regional transition into higher thermal stress zones, not limited to urban centers alone.

A notable decline is observed in Blocks within lower temperature categories. For instance, the number of Blocks with night-time LST between 15–24°C decreased from 60 (past) to 34 (present). Similarly, Blocks in the 24–25°C category dropped from 151 to 76. In contrast, the 25–26°C category expanded from 171 to 198 Blocks, suggesting a clear upward migration of surface temperatures into hotter categories.

Thermal changes are not restricted to lowland and urban areas. High-terrain regions such as Ooty, Kodaikanal, Yercaud, and Kolli Hills also recorded rising LST values. In The Nilgiris, the block average night-time LST increased by 0.5°C, while the Kodaikanal block of Dindigul district rose by 0.7°C. Significant increases were also observed in Udumalpet (Tiruppur) and Anaimalai (Coimbatore) with rises of 0.9°C and 0.8°C, respectively. In Dharmapuri and Krishnagiri, Palacode and Hosur experienced increases of 0.7°C and 0.8°C, respectively. Similarly, in Theni district, the Cumbum, Chinnamanur, and Mayiladumparai Blocks saw increases of 0.8°C.

The highest recorded increases in block average night-time LST were found in S.S. Kulam (Coimbatore) and Palani (Dindigul), both registering a 1.3°C rise over the past two decades. These results are significant as they underscore that even high-altitude and ecologically sensitive regions are not immune to rising thermal exposure.

4.2. Air Temperature

To complement LST analysis, this study integrates 2-meter air temperature data from ERA5, normalized and aggregated at the block level. Using GIS-based zonal statistics, mean air temperature values were extracted for all 389 Blocks, enabling spatial comparison across Tamil Nadu.

Figure 18 presents the distribution of Maximum Air Temperatures for the 2011–2020 period, revealing a clear upward trend when compared to the 1981–1990 baseline. Coastal districts emerge as particularly vulnerable to heat intensification, driven by a combination of environmental and anthropogenic factors.

4.2.1. Maximum Air Temperature

The increase in Maximum Air Temperature is particularly evident in Tamil Nadu's coastal districts, where multiple environmental and anthropogenic factors converge. Districts such as Thiruvallur, Chennai, Chengalpattu, Cuddalore, Villupuram, Mayiladuthurai, Nagapattinam, Thiruvarur, Thanjavur, Pudukottai, Ramanathapuram, Thoothukudi, Tirunelveli, and Kanniyakumari are especially prone to high daytime temperatures, driven by a combination of land use change, reduced vegetation cover, and proximity to warming sea surfaces.

The decadal comparison shows a substantial upward shift in the number of Blocks falling into higher temperature brackets. In the recent decade (2011–2020), 12 Blocks recorded a mean Maximum Air Temperature in the 26–27°C category. A category that had no representation in the baseline decade. Furthermore, the number of Blocks in the 25–26°C range increased sharply from 16 (in the past) to 130 in the current period. This indicates a significant broadening of areas experiencing elevated daily maximum temperatures, which has direct implications for human comfort, agricultural stress, and energy demand.

Conversely, the number of Blocks in cooler categories has declined. The 24–25°C category saw a reduction from 111 Blocks to 85, while the 23–24°C range dropped from 87 to 66 Blocks. Similarly, Blocks in the 22–23°C category decreased from 63 to 48. These shifts reflect a clear migration of block temperatures into warmer categories, suggesting the increasing dominance of heat-prone conditions across the state.

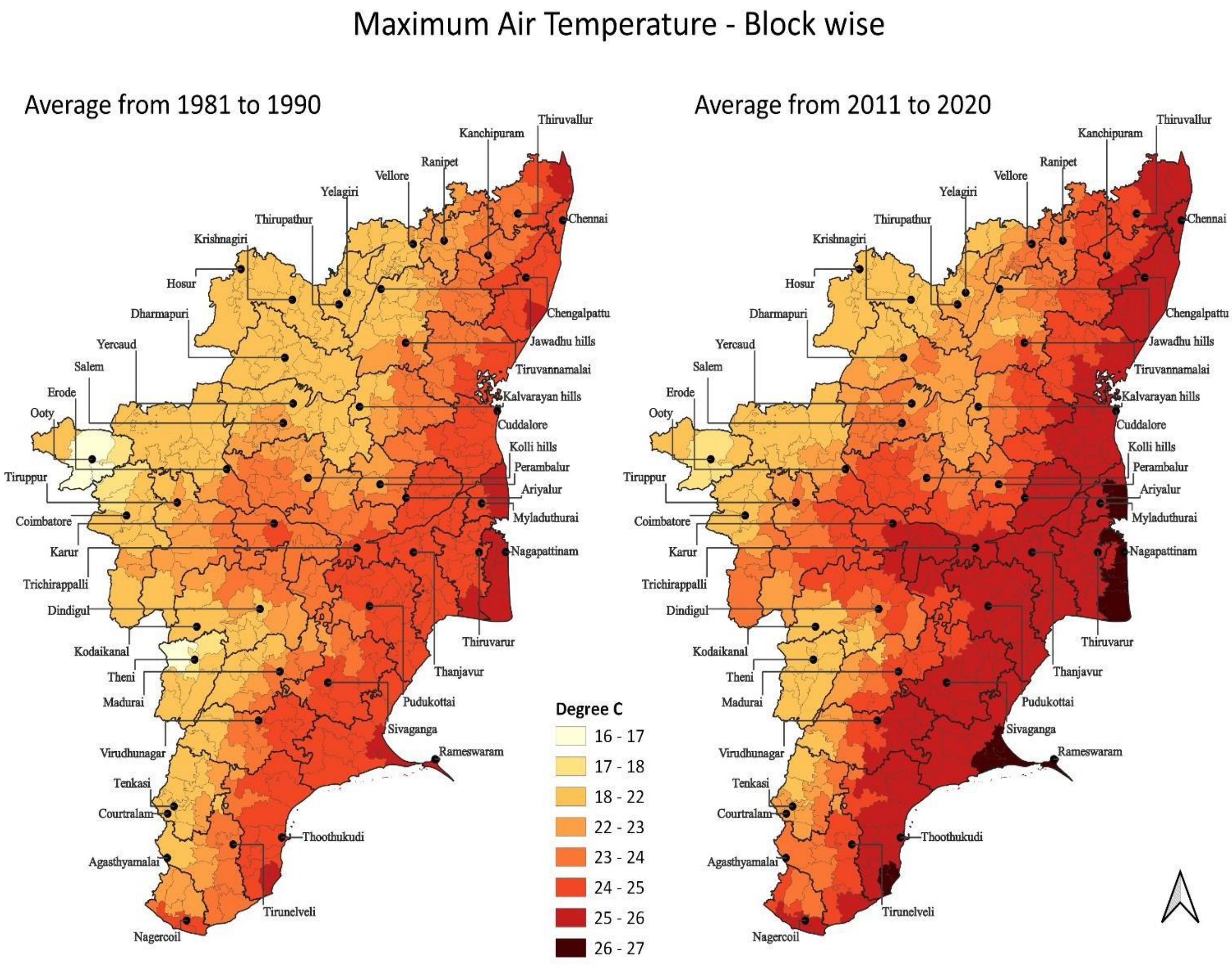


Figure 18 – Block level Maximum Air Temperature

This trend is even more pronounced in lower temperature bands. The number of Blocks with a mean Maximum Air Temperature between 18–22°C dropped significantly from 104 in the past decade to just 46 in the recent decade. Additionally, only two Blocks currently fall in the 17–18°C range, down from five previously. Notably, three Blocks, Udagamandalam and Coonoor (The Nilgiris) and Bodinayakkanur (Theni), which had mean temperatures between 16–17°C in the baseline decade, no longer fall within this range in the present study. These changes highlight the steady contraction of cooler zones and the expansion of heat-exposed areas, including in traditionally temperate regions.

From a heat stress perspective, Maximum Air Temperature is a more critical indicator than minimum or mean temperatures. It represents the peak thermal exposure experienced by populations and ecosystems on a daily basis and is more closely linked to heat stress events, crop damage, and public health emergencies. For this reason, Maximum Air Temperature has been selected as the representative variable for air temperature in the weighted overlay analysis. Focusing on these high-heat zones is crucial for informing climate-resilient policy interventions, particularly in urban and peri-urban Blocks experiencing rapidly increasing heat.

5. Mapping the Decadal Change in Heat Stress at Block Level

Mapping the change in heat stress is essential for understanding how thermal stress has evolved over time at the block level and for identifying regions where the intensity of heat exposure is increasing most rapidly. This analysis enables the targeted Blocks for climate adaptation, urban planning, and heat mitigation strategies.

To quantify change in heat stress, two primary indicators were selected, Air Temperature and Night-time Land Surface Temperature (LST), as they offer complementary insights into the thermal characteristics of both the atmosphere and Earth's surface. These indicators were processed over extended time periods to capture long-term trends: ERA5 air temperature data from 1981 to 1990 and 2011 to 2020, MODIS night-time LST data from 2000 to 2005 and 2018 to 2023.

For each indicator, linear trend values were computed to assess the rate and direction of temperature change across time. These trend values were then spatially aggregated to the block level using GIS techniques, enabling a standardized comparison across Tamil Nadu’s 389 administrative Blocks.

The calculated trends were reclassified into three categories based on their deviation from the neutral (no-change) point: Significant Change (above neutral), Minimal Change (near neutral) and Low Change (below neutral). This classification allowed for a simplified representation of how much each block’s temperature profile has shifted over the study period.

To integrate both indicators into a single risk metric, weights were assigned to air temperature and LST based on their statistical correlation with overall temperature increase. These weighted indicators were then used in a composite overlay analysis, producing the final map of change in heat stress across Tamil Nadu, as shown in Figure 19.

Based on the overlay results, Blocks were categorized into four levels of **Heat Intensive Change:**

- Low Change Intensity
- Moderate Change Intensity
- High Change Intensity
- Very High Change Intensity

The final map reveals that 94 Blocks fall into the Very High Change category, indicating substantial increases in temperature over the study period. Notably, entire districts such as Chennai, Kanniyakumari, and Ramanathapuram have all of their Blocks classified as very high-change intensity zones. Additionally, several other districts contain a large number of Blocks that fall under the first and second highest heat exposed categories, highlighting broader regional trends in temperature escalation.

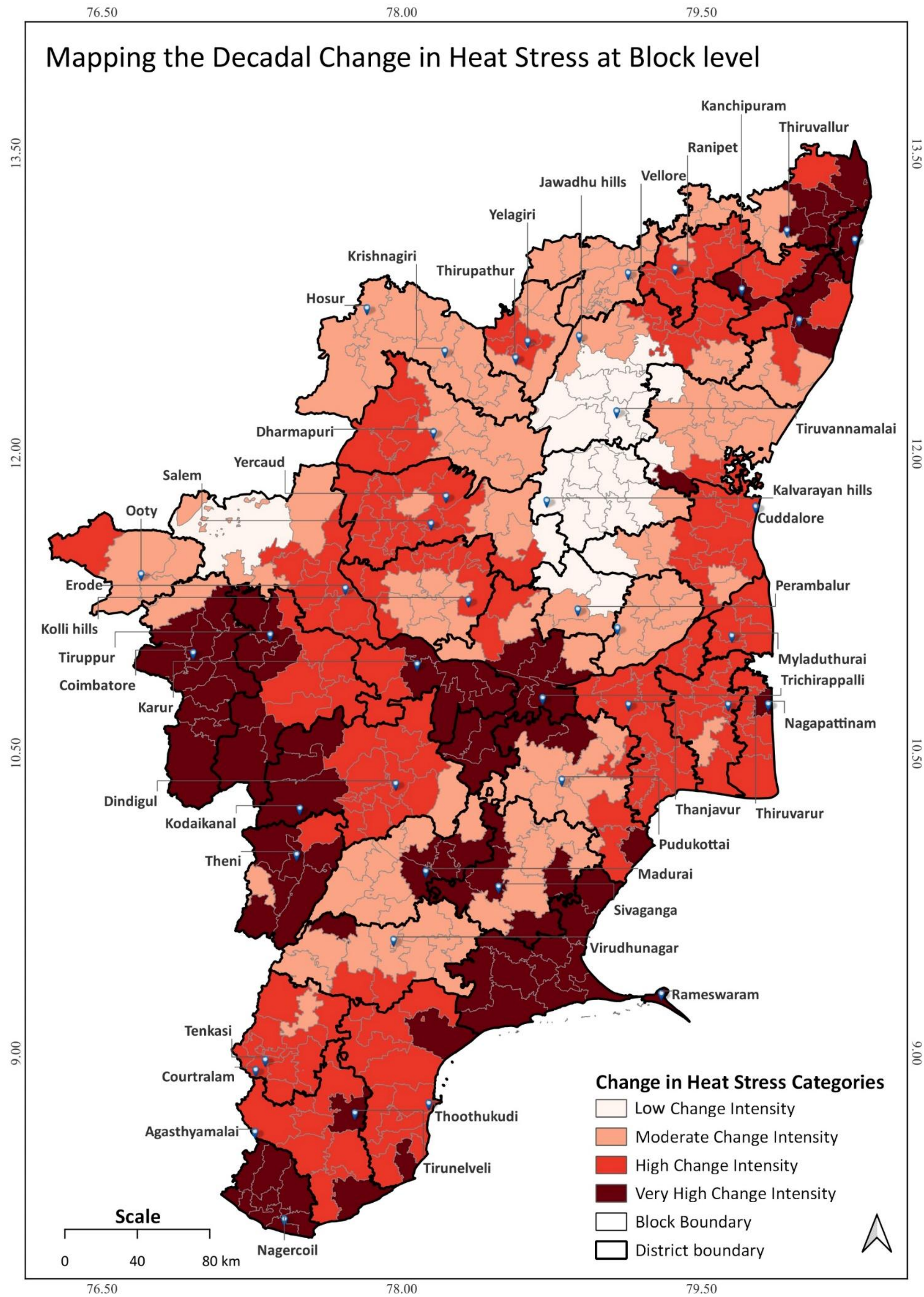


Figure 19 –Decadal change in heat stress (Block level)

5.1. Mapping of Districts Based on Change in Heat Intensity

A decadal analysis of heat stress level change provides a critical perspective on how thermal stress has evolved across districts in Tamil Nadu. Based on the weighted overlay analysis combining long-term trends in air temperature and night-time Land Surface Temperature (LST), a total of 94 out of 389 Blocks have been classified under the 'Very High Change in Heat Intensity' category. The list of categorised Blocks is provided in Annexure 1.

Blocks with 'Very High Change in Heat Intensity' are distributed across 19 districts, highlighting that significant warming is no longer confined to a few isolated locations but is now a state-wide phenomenon. Addressed the districts with a higher concentration of such Blocks is essential for formulating targeted mitigation policies and adaptive planning strategies.

To determine District Level Heat Stress, the proportion of Blocks falling under the "Very High Change in Heat intensity" and "High change in Heat intensity" categories were calculated relative to the total number of Blocks in each district. This method provides a quantifiable basis for identifying districts where thermal stress has intensified over recent decades. The resulting percentage serves as a proxy for assessing the spatial extent and concentration of temperature rise or heat stress within districts. However, it is important to note that this classification is based solely on changes in heat- related indicators, specifically air temperature and night-time land surface temperature. While these are critical components of heat intensity, they do not capture the full complexity of district-level climate sensitivity. Other ecological and environmental factors, including terrain characteristics, land cover types, the presence of sensitive ecosystems, and water resource availability, also significantly influence a region's overall heat intensity and adaptive capacity.

Since such factors were beyond the scope of the current analysis, this categorization should be interpreted as a preliminary framework for understanding spatial trends in thermal change. It is not intended to serve as a definitive guide for policy-level decisions. Instead, it highlights districts that may warrant further, more comprehensive assessments incorporating multi-dimensional Heat Stress parameters. The results of this heat stress classification are presented in Table 4 and visualized in Figure 20, providing a useful reference for identifying potential hotspots of concern that merit deeper investigation.

5.1.1. Extremely Heat-Stressed Districts (95 to 100% Heat Intensified class)

Eleven districts show 100% of their Blocks classified under the "Very High Change" and "High Change" categories in the Change in Heat Stress Analysis (section 5). These include: Chennai, Kanniyakumari, Karur, Tiruppur, Tirunelveli, Thoothukudi, Ramanathapuram, Kanchipuram, Thanjavur, Nagapattinam, and Mayiladuthurai. Each block in these districts has undergone a substantial rise in surface and air temperatures over the past decades. These districts are thus classified as crucial zones for heat adaptation interventions.

5.1.2. Severe Heat-Stressed Districts (80–95% Heat Intensified class)

Districts such as Dindigul, Coimbatore, Tenkasi, Theni, Tiruvarur, and Ranipet fall under this category, with 80–95% of their Blocks experiencing a measurable increase in heat stress. These areas are experiencing consistent warming trends and must be closely monitored and integrated into state-level heat action plans.

5.1.3. **Highly Heat-Stressed Districts** (50–79% Heat Intensified class)

Districts including Tiruchirappalli, Salem, Cuddalore, Erode, Tiruvallur, Namakkal, Chengalpattu, and Tirupathur fall within this range. These districts have a moderate number of high-change Blocks and are recommended for regionally focused interventions, especially in urban and semi-urban clusters showing rapid land cover change.

5.1.4. **Moderately Heat-Stressed Districts** (26–49% Heat Intensified class)

A smaller share of Blocks in Pudukkottai, Sivagangai, Dharmapuri, Thiruvannamalai, Madurai, and Virudhunagar show change in heat stress. Although these districts are in a lower less affected, their heat intensified and high risk Blocks still required localized mitigation actions such as urban greening, improved ventilation corridors, and heat awareness programs.

5.1.5. **Low Heat-Stressed Districts** (Below 25% class)

The Nilgiris and Villupuram have only 25% and 23% of their Blocks, respectively, falling under vulnerable categories. While these districts are classified under the very low concern tier for heat risk in terms of temperature change, the existing vulnerable Blocks within them should not be overlooked. In particular, The Nilgiris, being an ecologically sensitive high-altitude region, is especially susceptible to even minor thermal shifts. A one-degree Celsius increase in such a district could be more ecologically damaging than a two-degree rise in a lowland district with greater adaptive infrastructure. Changes in temperature in these fragile ecosystems could lead to loss of endemic biodiversity, altered hydrological cycles, and disruption of agro-climatic stability.

Similarly, districts such as Ariyalur, Perambalur, Kallakurichi, Krishnagiri, and Vellore though currently showing no Blocks in the "Very High Change in Heat intensity" or " High Change in heat intensity" categories, should not be excluded from future planning considerations. These areas may not have experienced any rise in temperature between 1980 to 2020, but ongoing land use changes, developmental pressures, or shifts in regional climate dynamics could alter their heat stress status over time. However, these 5 districts have recorded temperature above the state average which has been explained in section 6. Therefore, regular monitoring and climate sensitivity assessments in these districts remain essential for proactive risk management.

This district-level classification framework provides a data-informed foundation for directing climate action, while recognizing the need for contextual ecological and socio-economic considerations. It enables decision-makers to allocate resources strategically, focusing immediate interventions in districts with high exposure to rising temperatures, especially those undergoing rapid urban expansion, deforestation, or with limited adaptive capacity. At the same time, it underscores the importance of early preparedness and resilience-building in districts not currently exhibiting sharp temperature increases but which may become vulnerable in the near future.

S.No	Districts	No. of Blocks under Very High Change in Heat Intensity category	No. of blocks under High Change in heat Intensity category	Total No of Blocks per district	Percentage of districts vulnerable in terms of Change in Heat
1	Chennai	1	0	1	100
2	Kanniyakumari	9	0	9	100
3	Karur	6	2	8	100
4	Tiruppur	7	6	13	100
5	Ramanathapuram	11	0	11	100
6	Tirunelveli	2	7	9	100
7	Tuticorin	2	10	12	100
8	Kanchipuram	2	3	5	100
9	Nagapattinam	1	5	6	100
10	Mayilladuthurai	0	5	5	100
11	Thanjavur	0	14	14	100
12	Dindigul	3	10	14	93
13	Coimbatore	11	0	12	92
14	Tenkasi	0	9	10	90
15	Tiruvarur	0	9	10	90
16	Theni	6	1	8	88
17	Ranipet	0	6	7	86
18	Tiruchirappalli	9	2	14	79
19	Salem	0	15	20	75
20	Cuddalore	0	9	14	64
21	Erode	0	9	14	64
22	Tiruvallur	7	1	14	57
23	Namakkal	0	8	15	53
24	Chengalpattu	3	1	8	50
25	Tirupathur	0	3	6	50
26	Pudukkottai	3	3	13	46
27	Sivagangai	5	0	12	42
28	Dharmapuri	0	4	10	40
29	Thiruvannamalai	0	6	18	33
30	Madurai	4	0	13	31
31	Virudhunagar	1	2	11	27
32	The Nilgiris	0	1	4	25
33	Villupuram	1	2	13	23

Table 4 – Vulnerability of Districts to Heat stress

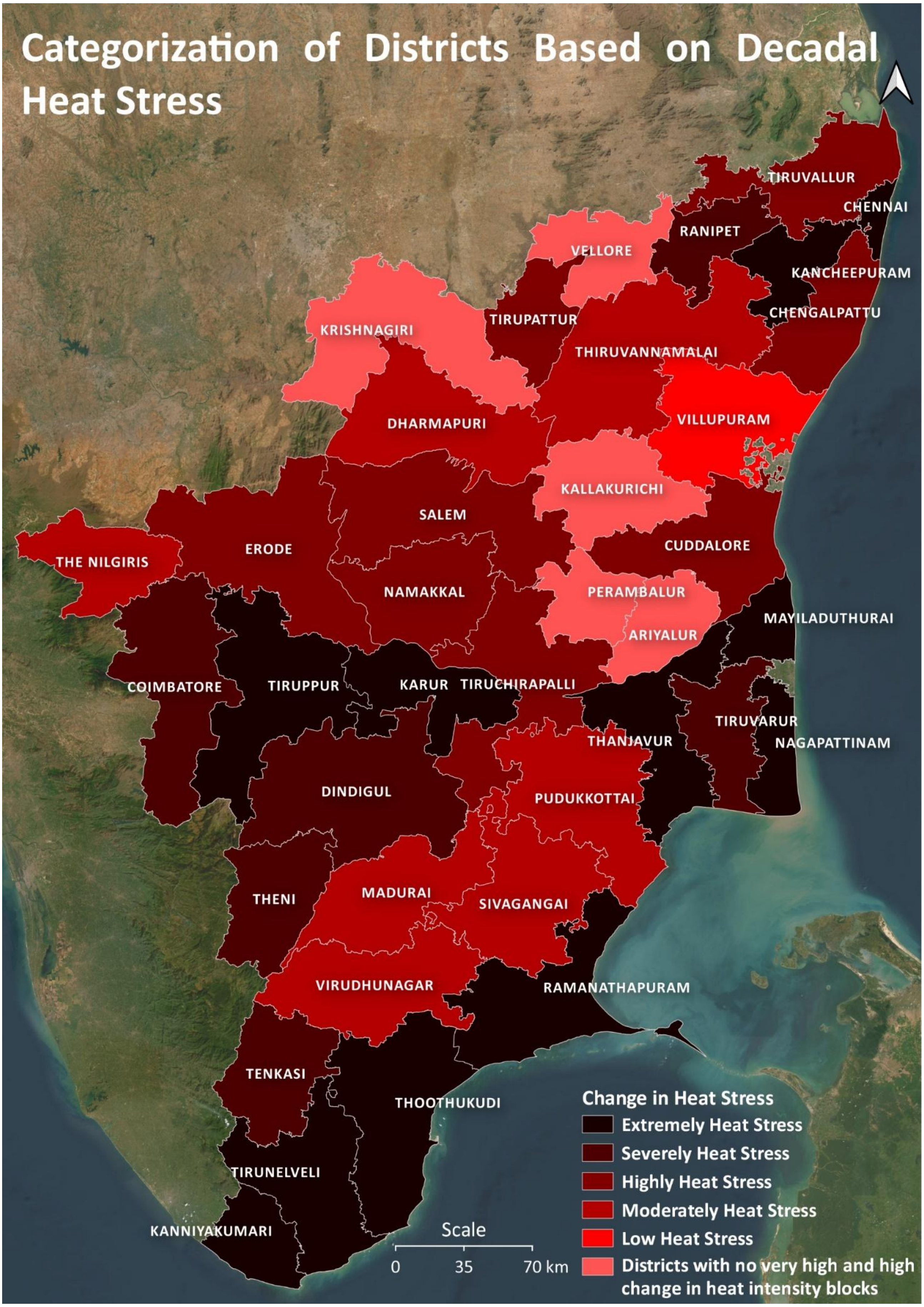


Figure 20 – Categorization of Districts based on decadal Heat stress

6. Mapping Current Heat Exposure at Block Level

While the previous section discusses about heat stress assessment at block level based on decadal data, this section is about current heat exposure mapping that provides a real-time snapshot of thermal stress across Tamil Nadu using recent data (2028 to 2023), helping to identify Blocks currently experiencing above-average temperatures, even if they did not exhibit significant changes in historical trend analyses. This complementary approach ensures that areas with persistently high temperatures are not overlooked simply because their rate of change over time is moderate.

The current heat exposure level analysis used data from 2018 to 2023, incorporating two key thermal indicators: Night-time Land Surface Temperature (NLST) derived from MODIS based thermal imagery, and Maximum Air Temperature sourced from ERA5 2-meter data.

As shown in Figure 21 and Figure 22, both datasets were reclassified using the state average as a reference baseline. Blocks with temperature values exceeding the state average were considered more vulnerable. The NLST and air temperature layers were integrated using a weighted overlay analysis, assigning 60% weight to NLST and 40% to air temperature. This weightage overlay emphasises surface temperature, which is more sensitive to land cover and urban heat dynamics. To avoid confusion, the study uses separate category labels for decadal trend-based change in heat (e.g., Low to Very High Change Intensity) (section 5) and current heat exposure (e.g., Less to Critically Heat-Intensified). This reflects the distinct objectives and datasets used in each analysis. The resultant map (Figure 23) categorizes all Blocks into four heat intensity classes:

- Critical Heat-Intensity
- High Heat-Intensity
- Moderate Heat-Intensity
- Less Heat-Intensity

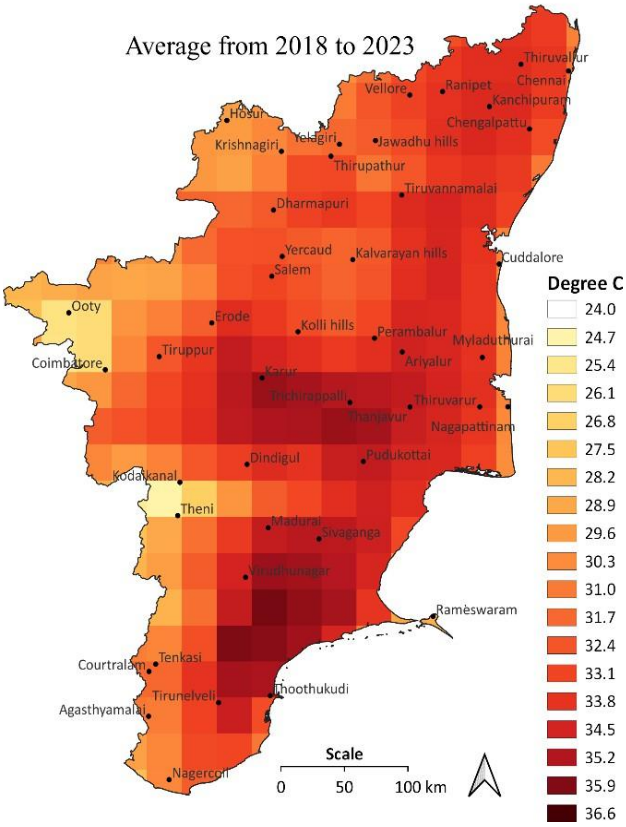
The analysis reveals that 64 Blocks fall into the Critical heat intensity category. These Blocks are spread across Karur, Namakkal, Tiruchirappalli, Pudukottai, Sivagangai, Ramanathapuram, Virudhunagar, and Madurai districts. These districts, located primarily in the interior and southern regions of Tamil Nadu, exhibit consistently high surface and air temperatures, warranting immediate attention in heat mitigation strategies.

Furthermore, 161 Blocks, representing more than one-third of the total, are classified as High heat intensity blocks. These are distributed across a wide geographic range including Tenkasi, Tirunelveli, Thoothukudi, Thanjavur, Tiruppur, Erode, Salem, Ariyalur, Cuddalore, Mayiladuthurai, Ranipet, Kanchipuram, Chengalpattu, and Chennai. The inclusion of both coastal and inland districts in this category reflects the broad exposure to thermal stress experienced across different landscapes.

An interesting insight from this analysis is that Blocks such as Udagamandalam (The Nilgiris), Kodaikanal (Dindigul), Talavadi (Erode), Hosur (Krishnagiri), and Minjur (Tiruvallur) are categorized as blocks with Less heat intensity in the current heat analysis due to their lower-than-average surface and air temperatures, largely influenced by their elevation, vegetation cover, and climate- modulating geography. However, Kodaikanal and Minjur were classified under Very High Change in heat intensity and remaining 3 Blocks are under moderate change in heat intensity in the decadal trend analysis. This contrast highlights the importance of combining both current and long-term change perspectives to avoid underestimating the risks of ecologically sensitive or rapidly warming regions, even if they currently have lower temperatures.

A combined assessment of both current and long-term changes is essential to avoid underestimating heat stress in ecologically sensitive or rapidly warming regions, even if their present temperatures are relatively lower. By integrating present-day temperature data with state averages, this approach identifies thermal hotspots that may not be prominent in change detection but remain critical from a heat stress and public health perspective. Coupled with the decadal analysis, it offers a comprehensive understanding of where interventions are most urgently needed, enabling the required immediate actions such as heat action plans, urban cooling infrastructure, and agricultural advisories.

Maximum Air Temperature



Night time - Land Surface Temperature

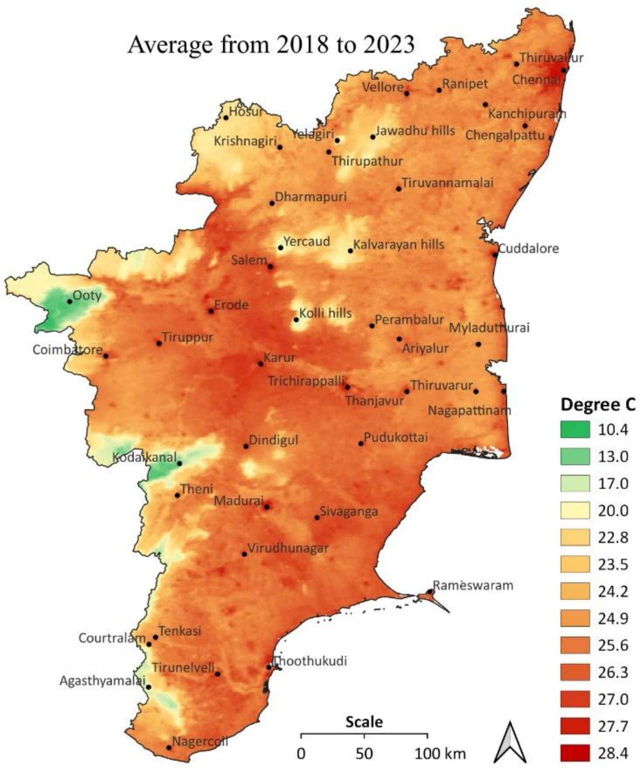


Figure 21: Average Maximum Air Temperature from 2018 to 2023; Figure 22: Average Night-time Land Surface Temperature from 2018 to 2023

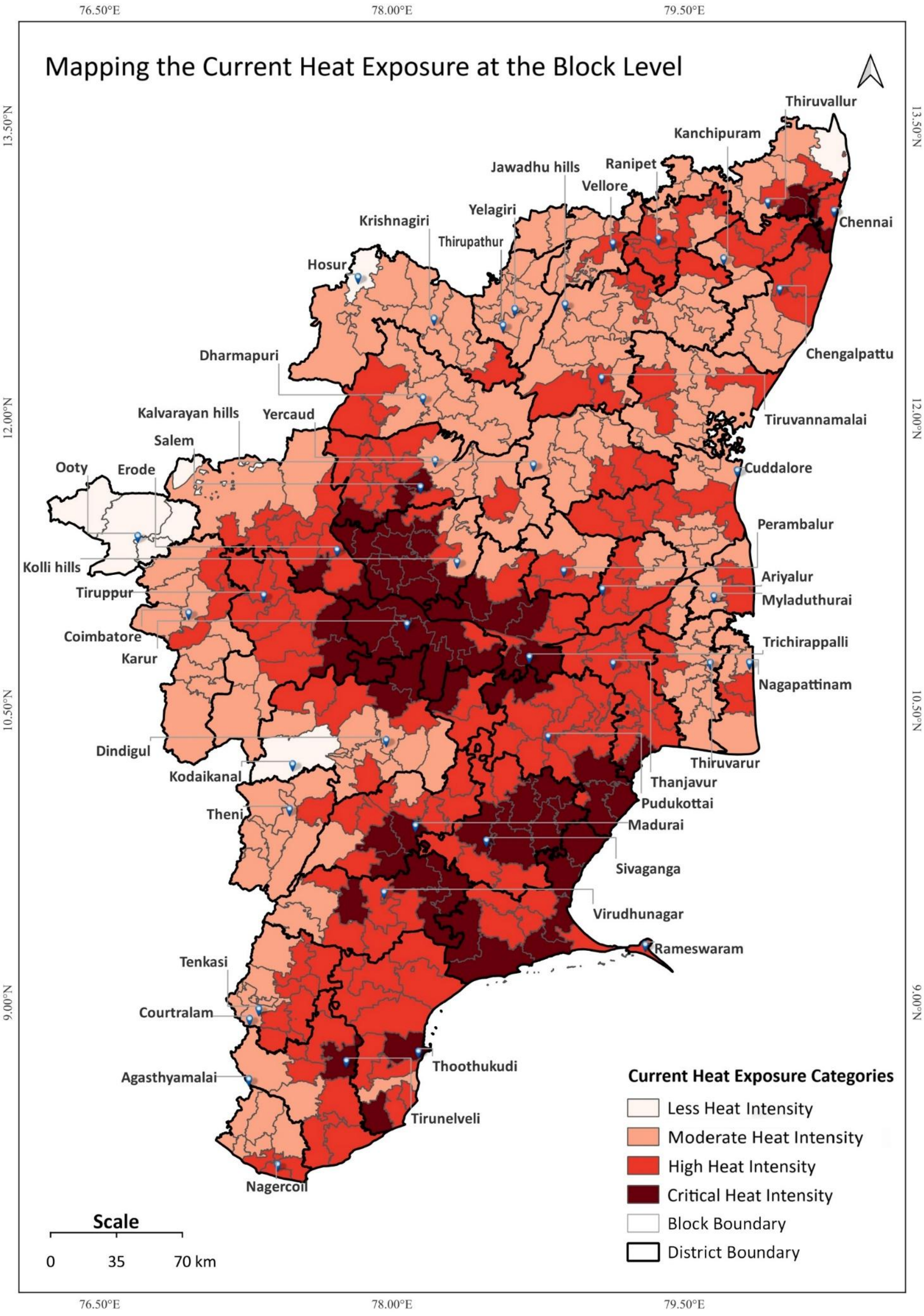


Figure 23: Current heat exposure at block level

6.1. Mapping of Districts Based on Current Heat Intensity

Assessing the current heat Intensity of districts is critical for understanding present-day exposure to thermal stress, irrespective of historical temperature trends. While the decadal change analysis identifies long-term warming patterns, mapping current Heat Intensity helps highlight districts that are already experiencing above-average heat conditions and where immediate interventions may be required.

This analysis is based on the proportion of Blocks in each district that fall under the "Critically Heat Intensified" and "Highly Heat Intensified" categories as defined by the current heat Intensity index (Figure 21). Heat Intensity classification was derived using weighted overlay analysis of Night-time Land Surface Temperature (NLST) and Maximum Air Temperature data from 2018 to 2023. The values were normalized and classified relative to the state-level mean.

To facilitate spatial Analysis impacts, Tamil Nadu's 38 districts were categorized into five Heat Intensity classes based on the percentage of Blocks exhibiting high current heat Intensity. The classification system is as follows:

- Extremely Heat-Intensified: ≥ 95% of Blocks classified as highly heat-affected
- Significantly Heat-Intensified: 80% – 94% of Blocks classified as highly heat-affected
- Moderately Heat-Intensified: 50% – 79% of Blocks classified as heat-affected
- Marginally Heat-Intensified: 25% – 49% of Blocks classified as heat-affected
- Less Heat-Intensified: < 25% of Blocks classified as heat-affected

The results are presented in Table 5 and visualized in Figure 24.

6.1.1. Extremely Heat-Intensified: ≥ 95%

Five districts, Chennai, Karur, Pudukkottai, Ramanathapuram, and Sivagangai—showed 100% of their Blocks falling under the vulnerable categories. These districts are currently facing intense thermal conditions, likely driven by a combination of urban expansion, land cover change, and loss of vegetative buffers. Immediate heat mitigation measures, including urban greening, heat action plans, and land-use controls, are essential in these zones.

6.1.2. Significantly Heat-Intensified: 80% – 94%

Districts such as Tiruchirappalli (93%), Thoothukudi (92%) Namakkal (87%), Thanjavur (86%), Madurai (85%), Ranipet (83%), and Virudhunagar (82%) fall under this category. These regions are characterized by persistent exposure to high surface and air temperatures and may face compounding risks due to socioeconomic pressures and reduced ecological resilience.

6.1.3. Moderately Heat-Intensified: 50% – 79%

Districts such as Erode (79%), Tirunelveli (78%), Tiruppur (77%), Salem (70%), Ariyalur (67%), Tenkasi (60%), and Kanchipuram (60%) have more than half of their Blocks currently vulnerable to heat. Chengalpattu (50%), and Perambalur (50%) districts have half of their total blocks under heat stress. While not as uniformly exposed as the higher categories, these districts are at risk of escalating thermal stress if unaddressed, particularly in rapidly urbanizing or agricultural regions.

6.1.4. Marginally Heat-Intensified: 26% – 49%

Districts including, Cuddalore (43%), Dindigul (43%), Mayiladuthurai (40%), Tiruvallur (36%), Kallakurichi, Kanniyakumari, and Nagapattinam (each 33%) and Tiruvannamalai (28%), fall under this tier. These areas have a moderate concentration of vulnerable Blocks and may benefit from targeted interventions in local hotspots, especially in semi-urban and peri-urban environments.

6.1.5. Less Heat-Intensified: ≤ 25%

Districts such as Coimbatore (25%), Villupuram (23%), Dharmapuri (20%), Tiruvarur (20%), Vellore (14%), Theni (13%), and Krishnagiri (10%) are classified under the lowest current heat intensity category. These districts currently show fewer Blocks with elevated temperatures, often due to terrain features, vegetation cover, or less intensive land use. However, several Blocks in these districts still exhibited notable long-term temperature increases in the decadal change analysis, indicating that future heat risk may emerge if warming trends persist.

Out of 38 districts, 36 have at least one block falling under the critical or high heat intensity category (figure 23). Only Tirupattur, and The Nilgiris have no Blocks categorized as currently high heat affected. However, The Nilgiris and Tirupattur have shown measurable warming in the long-term trend analysis. This emphasizes the need for continuous monitoring and inclusion of such districts in early warning and adaptation planning, even if present exposure is low.

The findings of this classification offer a district-scale understanding of heat exposure and serve as a foundation for:

- Developing district-specific climate resilience strategies
- Facilitating infrastructure and public health interventions
- Guiding land-use planning and urban development policies

This spatial intensity mapping is essential for evidence-based governance in the context of rising regional temperatures and their impacts on human health, ecosystems, and economic activities.

S.No.	Districts	Blocks categorized as Critical Heat-Intensity (per district)	Blocks categorized as High Heat-Intensity (per district)	Total no of Blocks per District	Percentage of vulnerability to current heat intensity
1	Chennai	0	1	1	100
2	Karur	7	1	8	100
3	Pudukkottai	4	9	13	100
4	Ramanathapuram	6	5	11	100
5	Sivagangai	6	6	12	100
6	Tiruchirappalli	6	7	14	93
7	Tuticorin	2	9	12	92
8	Namakkal	11	2	15	87
9	Thanjavur	1	11	14	86
10	Madurai	3	8	13	85
11	Ranipet	0	5	6	83
12	Virudhunagar	4	5	11	82
13	Erode	2	9	14	79
14	Tirunelveli	1	6	9	78
15	Tiruppur	2	8	13	77
16	Salem	3	11	20	70
17	Ariyalur	0	4	6	67
18	Kanchipuram	0	3	5	60
19	Tenkasi	0	6	10	60
20	Chengalpattu	1	3	8	50
21	Perambalur	0	2	4	50
22	Cuddalore	0	6	14	43
23	Dindigul	2	4	14	43
24	Mayiladuthurai	0	2	5	40
25	Tiruvallur	4	1	14	36
26	Kallakuruchi	0	3	9	33
27	Kanniyakumari	0	3	9	33
28	Nagapattinam	0	2	6	33
29	Tiruvannamalai	0	5	18	28
30	Coimbatore	0	3	12	25
31	Villupuram	0	3	13	23
32	Dharmapuri	0	2	10	20
33	Tiruvarur	0	2	10	20
34	Vellore	0	1	7	14
35	Theni	0	1	8	13
36	Krishnagiri	0	1	10	10

Table 5 – Percentage of vulnerability of Districts to current heat intensity

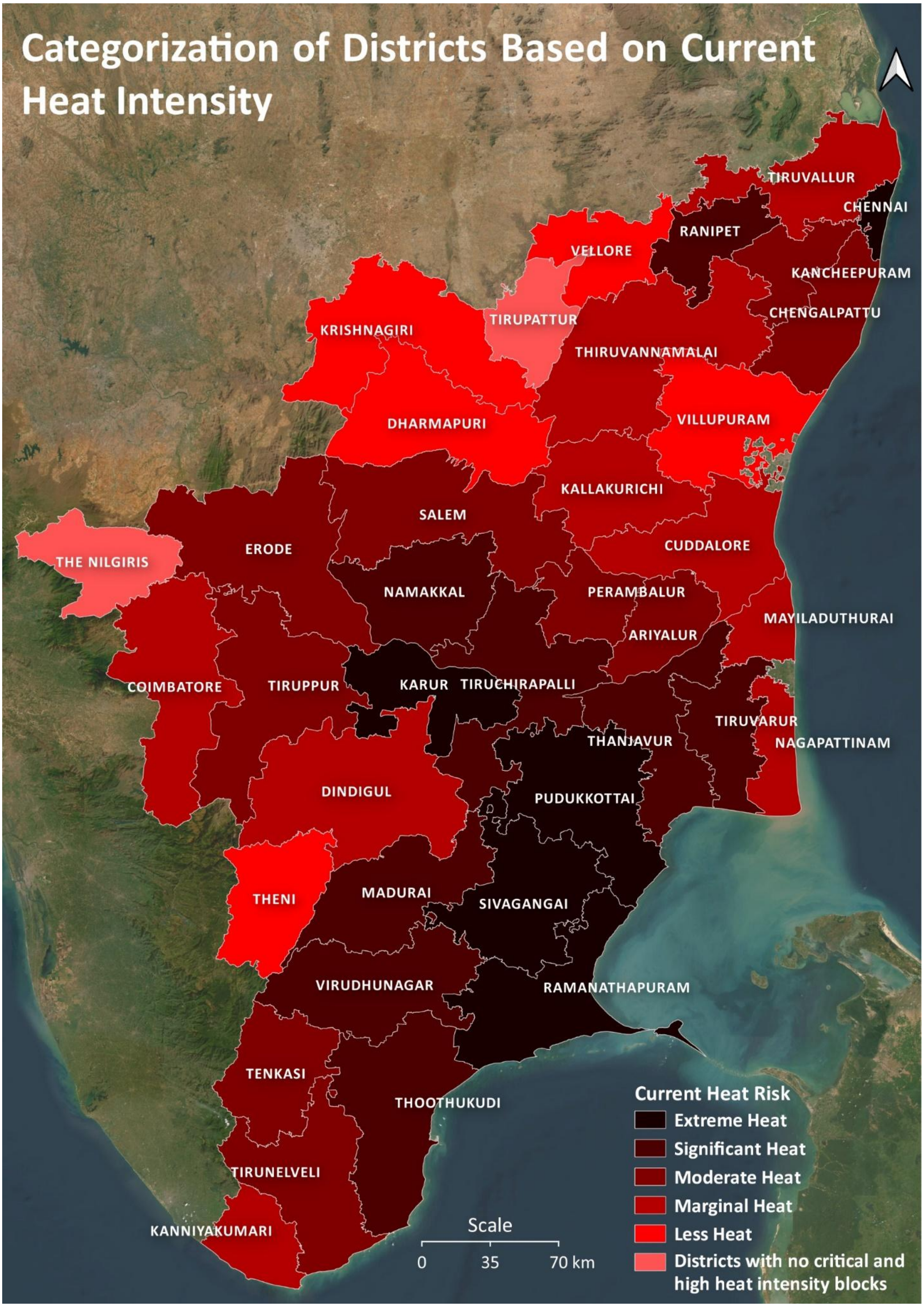


Figure 24 – Categorization of districts based on current heat intensity

7. Comparison of Decadal Change in Heat and Current Heat Exposure Analysis

To comprehensively understand the spatial and temporal dynamics of heat stress across Tamil Nadu, this study integrates two analytical approaches: decadal change in heat and current heat exposure analysis. Each method provides unique insights, one focusing on long-term temperature trends, and the other on present-day thermal exposure.

The decadal change in heat analysis evaluates temperature shifts over time by analyzing trends in air temperature (1981 – 2020) and night-time Land Surface Temperature (2000 – 2023). This approach is effective in detecting regions that have undergone significant warming over the decades. However, blocks that have consistently experienced high temperatures but without significant decadal variation may be overlooked in this analysis. To capture such areas, the current heat exposure analysis was conducted, identifying Blocks that exceed the state average in surface and air temperatures during the recent period (2018 – 2023), regardless of long-term trends.

A comparative evaluation of both analyses reveals that 25 Blocks are common in the high heat intensified category of both datasets (Table 6). These Blocks are of particular concern as they represent areas where temperatures have both increased significantly over time and are currently above the state average, indicating persistent and intensifying thermal stress. Districts such as Chennai, Karur, Tiruchirappalli, and Ramanathapuram emerge as critical hotspots, with multiple Blocks appearing in both analyses.

For example, Blocks like Villivakkam (Chennai), St. Thomas Malai (Chengalpattu), Thiruparankundram (Madurai), and Palayamkottai (Tirunelveli) exhibit both elevated historical warming and extreme heat levels in the recent period too. These Blocks record temperatures more than 2.5°C above the state average, pointing to intensified urban heat island effects, rapid land use changes, and ecological degradation. Factors contributing to heat stress in these regions include urbanization, industrialization, deforestation, and greenhouse gas emissions.

Additionally, the current heat exposure analysis identified 39 new Blocks as highly heat-vulnerable that were not flagged in the decadal change analysis. These include:

- Eleven Blocks in Namakkal
- Four Blocks each in Sivagangai and Virudhunagar
- Three Blocks in Dharmapuri
- Two Blocks each in Pudukkottai, Thoothukudi, Madurai, Tiruchirappalli, Dindigul, Karur, Erode, and Tiruppur
- One block in Thanjavur

These Blocks currently experience severe heat stress, even though their temperature change over time has been minimal. This highlights the value of present-day assessments in capturing latent heat exposure not evident through trend analysis alone.

Conversely, 69 Blocks that showed High Change in Heat over time were only categorized as “Highly Heat-Intensified”, and not “Critically Heat-Intensified”, in the current heat analysis. This indicates that while these areas have experienced notable warming, their present-day temperature levels are not yet as extreme as other regions. Such Blocks may be called as emerging risk zones and warrant early adaptation strategies to prevent future heat disasters.

The integration of both analyses is essential. Blocks exhibiting high exposure in both dimensions, historically and current dimensions require immediate and intensive heat mitigation measures such as urban cooling strategies, heat action plans, infrastructure retrofitting, and climate-resilient interventions. Similarly, Blocks showing **early signs of warming** or experiencing high current heat without significant historical trends should be closely monitored to prevent future crises. This comparative approach provides a layered understanding of Heat Stress, enabling planners and policymakers to identify critical zones of concern, balance immediate and long-term risks, and formulate targeted climate adaptation responses.

Blocks that are Extremely Heat-Stressed in Both Assessments
(Decadal assessment and Current Heat Exposure Analysis)

S.No.	District Name	Block Name
1	Chennai	Villivakkam
2	Chengalpattu	St. Thomas Malai
3	Karur	Kadavur
4	Karur	Karur
5	Karur	Krishnarayapuram
6	Karur	Thanthoni
7	Karur	Thogamalai
8	Madurai	Thirupparankundram
9	Pudukkottai	Manamelkudi
10	Pudukkottai	Viralimalai
11	Ramanathapuram	Kadaladi
12	Ramanathapuram	Kamuthi
13	Ramanathapuram	R.S. Mangalam
14	Ramanathapuram	Ramanathapuram
15	Ramanathapuram	Thiruppullani
16	Ramanathapuram	Thiruvadanai
17	Sivagangai	Devakottai
18	Sivagangai	Sivagangai

19	Tiruchirappalli	Manachanallur
20	Tiruchirappalli	Manikandam
21	Tiruchirappalli	Musiri
22	Tiruchirappalli	Thiruverambur
23	Tiruchirappalli	Vaiyampatty
24	Tirunelveli	Palayamkottai
25	Tiruvallur	Poonamallee

Table 6 - Blocks that are Extremely Heat-Stressed in Both Assessments

This dual-assessment framework offers a more robust methodology for identifying high-risk areas. By capturing both historical temperature increases and present-day heat stress, the study enables better prioritization for heat mitigation investments. For instance, while the decadal change analysis highlights the cumulative impact of long-term climate and land use trends, the current exposure mapping captures the urgency of recent thermal extremes. Together, they allow decision-makers to distinguish between long-term climatically vulnerable zones and newly emerging heat hotspots.

An interesting observation from this comparison is that many of the blocks appearing in both critical categories are associated with intensive urban development or proximity to industrial belts. For example, Thiruverumbur (Tiruchirappalli), an industrial corridor with limited green space, shows persistently high night-time LST values and increasing maximum air temperatures. Likewise, Poonamallee (Tiruvallur) and St. Thomas Malai (Chengalpattu), located on the urban fringe of Chennai, reflect the vulnerability of peri-urban regions that are often left out of conventional urban climate action planning. These areas, due to rapid land use changes, may lack the infrastructure or green buffers needed to mitigate heat built up, making them priority targets for immediate adaptation.

Additionally, the analysis reveals important spatial patterns in the geography of heat vulnerability. Districts like Ramanathapuram and Karur demonstrate a cluster effect, with multiple blocks exhibiting concurrent historical warming and current thermal stress. This pattern suggests that district-level action plans cannot adopt a one-size-fits-all approach; instead, intra-district variations must be considered. In contrast, isolated blocks like Villivakkam (Chennai) or Palayamkottai (Tirunelveli) underscore the need for micro-level interventions even within otherwise moderately affected districts.

The identification of “emerging risk zones” offers a strategic opportunity for pre-emptive action. These are blocks that have shown long-term warming trends but have not yet crossed critical thresholds in present-day temperature levels. Early interventions in these zones, such as increasing vegetation cover, promoting cool roof technologies, and regulating land use, can prevent future heat crises. Incorporating this anticipatory approach into the state’s broader heat mitigation strategy will support sustainable urban development and long-term resilience.

Finally, this comparative analysis underscores the value of spatial disaggregation in climate studies. While state-level or district-level averages may obscure local anomalies, block-level assessment reveals hidden vulnerabilities. This granularity is crucial in a state like Tamil Nadu, which spans diverse geographies, from coastal plains to hilly terrains. The study thus advocates for block-level heat action planning integrated with the Tamil Nadu State Action Plan on Climate Change (TNSAPCC 2.0), enabling the state to move from reactive disaster response to proactive climate resilience building. As temperatures continue to rise, these data-driven insights can guide equitable and location-specific interventions, ensuring that vulnerable communities are not left behind.

URBANIZATION AND TEMPERATURE RISE

8. Urbanization and Temperature Rise

The role of urbanization in amplifying temperature rise has become increasingly evident, particularly in rapidly developing regions such as Tamil Nadu. Urban expansion is typically accompanied by changes in land surface characteristics, such as the replacement of natural vegetation and water bodies with impervious materials like concrete, asphalt, and built-up infrastructure. These materials have high heat storage capacity and low albedo, leading to increased heat absorption during the day and slow heat release at night, resulting in the well-known Urban Heat Island (UHI) effect. In parallel, deforestation, inappropriate land use changes, and unregulated land cover transitions further exacerbate the situation by reducing evapotranspiration, altering surface moisture dynamics, and fragmenting natural climate-regulating systems.

To empirically assess the relationship between urbanization and temperature increase, this study compares the change in Built-up Area with temperature rise over multiple decades. Two scatterplots were generated to visualize this relationship: the first examines the correlation between built-up expansion (1985 – 2015) and Maximum Air Temperature increase (1981 – 1990 to 2011 – 2020), and the second compares built-up expansion with night-time Land Surface Temperature (NLST) rise (2000 – 2005 to 2018 – 2023). These analyses help quantify the impact of urban development on local and regional thermal environments.

The scatterplot in Figure 25 (Image A) demonstrates a strong positive correlation between the change in Built-up Area and increase in Maximum Air Temperature across Tamil Nadu Blocks. As the x-axis shows Built-up Area expansion between 1985 and 2015, and the y-axis indicates the change in Maximum Air Temperature from 1981 – 1990 to 2011 – 2020, the trend line reveals a clear upward trajectory. Blocks that experienced higher levels of urban growth also showed a corresponding increase in air temperature, in some cases up to 1.4°C over two decades.

This relationship suggests that land cover modification due to urbanization is a significant contributor to atmospheric warming. The increase in temperature is not uniform but concentrated in Blocks with high urban expansion, highlighting the localized nature of urban heat effects. Additionally, the pattern reinforces the role of built environments in modifying local climate, particularly by altering the energy balance and reducing vegetative cooling. The findings support broader climate literature which links urban sprawl to enhanced surface heating, reduced thermal comfort, and increased heat stress to heat-related health impacts.

The second scatterplot (Image B in Figure 25) presents the correlation between Built-up Area change and NLST increase, revealing a similarly strong positive association. As night-time surface temperatures are less influenced by solar radiation and more by surface heat retention and urban morphology, this analysis provides a clearer picture of urban heat storage and retention effects. The plot indicates that many Blocks experienced up to 1.5°C rise in night-time LST, particularly in areas with high urban expansion.

The implications of this finding are significant: night-time temperatures play a critical role in human health and comfort, particularly in vulnerable populations such as the elderly and urban poor. The inability of urban areas to cool down at night leads to chronic heat stress, higher energy demands for cooling, and greater exposure to heat-related illnesses. The correlation in this plot underscores the urgent need to integrate green infrastructure, reflective materials, and sustainable land-use practices into urban planning to mitigate thermal impacts.

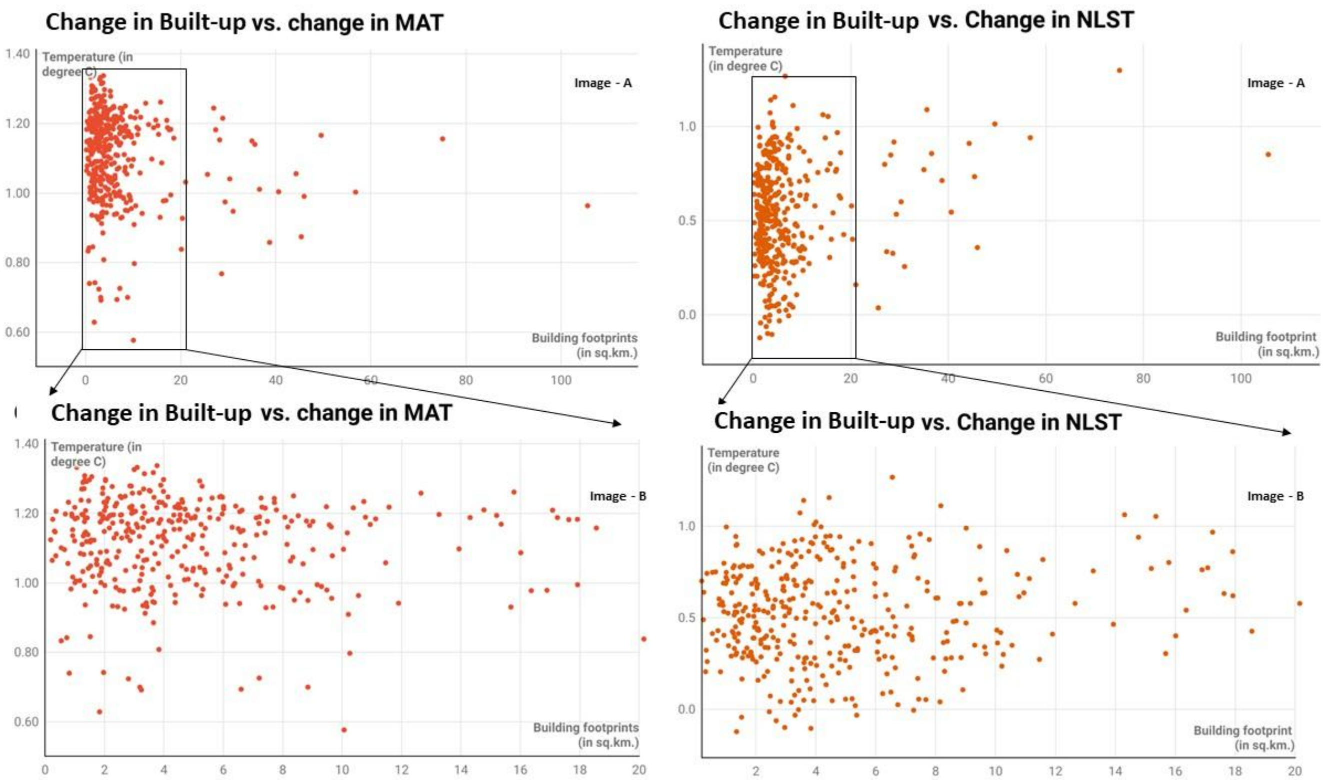


Figure 25 – Scatterplot

Image A - Scatterplot of Building Footprint vs. Maximum Air Temperature (MAT) Image B - Building Footprint vs. night-time Land Surface Temperature (NLST)

While the scatterplot analysis establishes a statistically significant relationship between Built-up Area expansion and rising temperatures, spatial comparisons provide further contextual understanding of how urban morphology, elevation, vegetation, and water availability influence local thermal conditions.

Figure 26 illustrates the variation in Night-time Land Surface Temperature (NLST) across different cities in Tamil Nadu with varying degrees of urbanization. Cities such as Chennai, Coimbatore, Madurai, Tiruchirappalli, and Salem, which have undergone rapid urban expansion over recent decades, exhibit notably higher NLST values. In contrast, areas with dense vegetation, forest cover, or hilly terrain, including districts like Dindigul, The Nilgiris, and parts of Kodaikanal and Sirumalai hills, show significantly lower NLST, highlighting the cooling benefits of natural ecosystems.

For example, in Tiruchirappalli district, the Kaveri river channel, though historically a cooling element, exhibits elevated temperatures (around 25°C) during summer months when the riverbed is dry. This shows how the loss of surface water and associated moisture can reduce the microclimatic buffering capacity of riparian zones. On the other hand, Sirumalai and Kodaikanal exhibit minimum temperatures in the range of 12°C to 19°C, depending on altitude and forest cover, underlining the role of elevation and vegetation in temperature regulation.

Interestingly, despite being surrounded by hills, Coimbatore's urban areas exhibit peak temperatures similar to other metropolitan zones. Even its reserved forest areas show warming trends, with temperatures nearing 23°C, likely due to encroachment, peri-urban sprawl, and fragmentation of ecological buffers. Across valley regions in Tamil Nadu, NLST ranges between 25.5°C and 27°C, with variability influenced by vegetation cover and land use intensity.

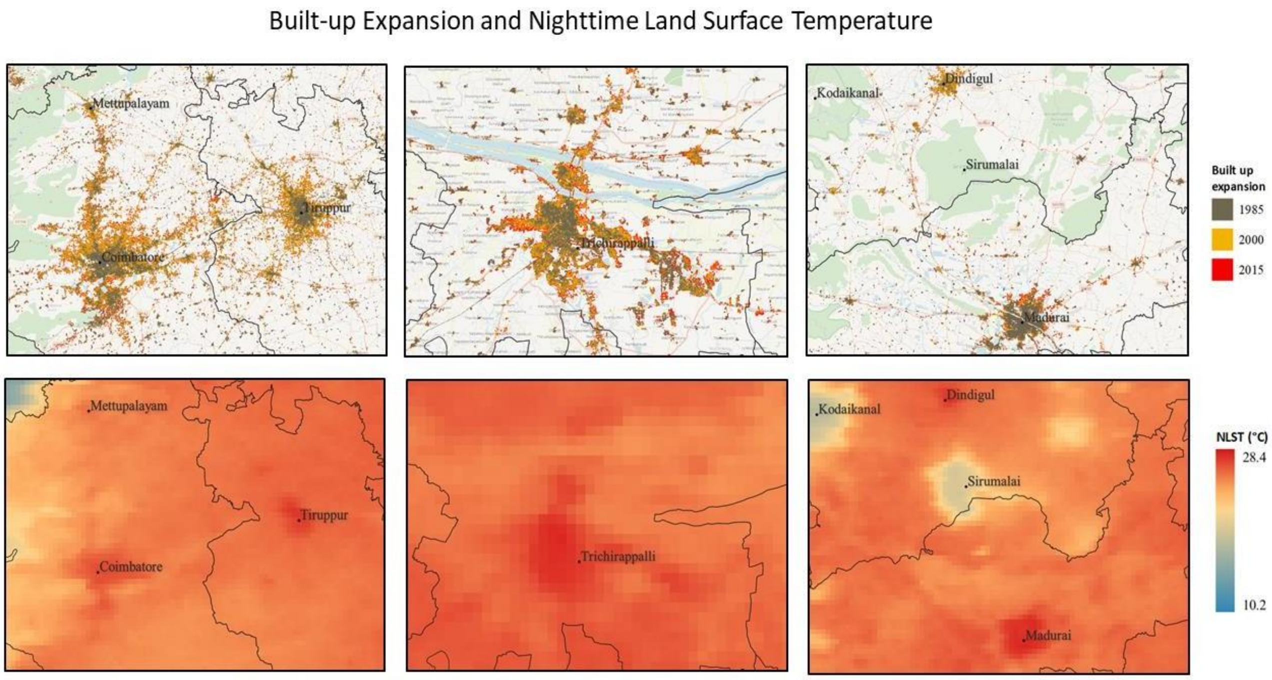


Figure 26 – Comparison of built-up expansion and NLST of various cities

Figure 27 presents a detailed case study of Chennai, showcasing the relationship between its expanding built-up footprint and associated night-time surface temperature distribution. As Tamil Nadu's most urbanized district, Chennai and its surrounding peri-urban zones have undergone rapid and extensive development over the past two decades. The spatial heat distribution map reveals uniformly high NLST values across Chennai, making it the only city in the dataset to exhibit such extreme night-time heat stress across its entire administrative extent.

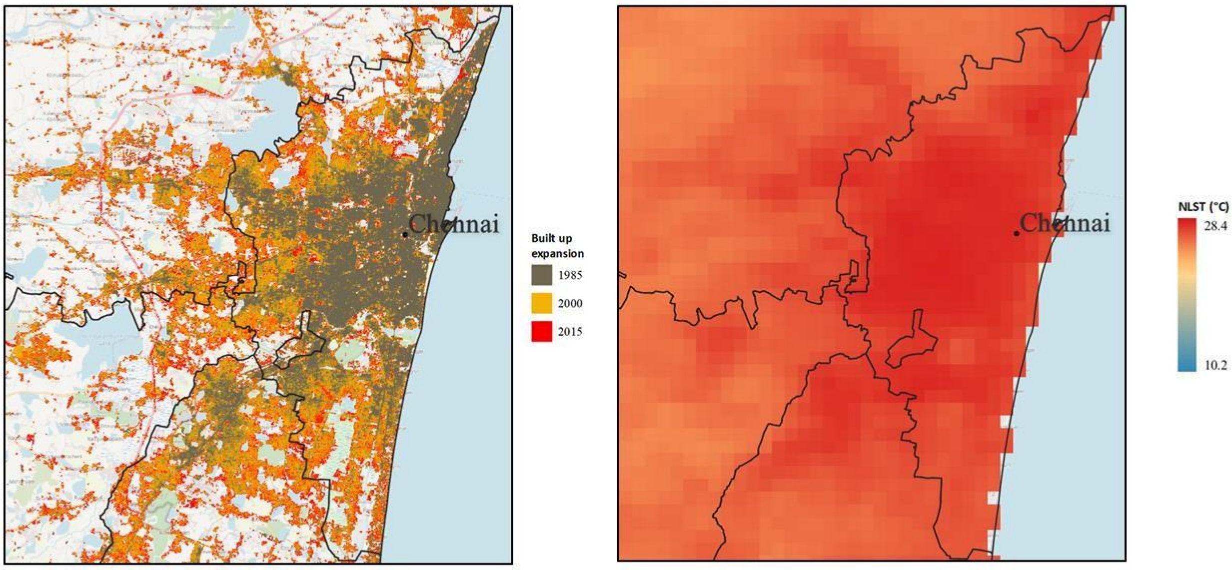


Figure 27 – Comparison of built area expansion and NLST of Chennai

This uniformity in high temperature is symptomatic of a persistent Urban Heat Island (UHI) effect, where the city's dense infrastructure, impervious surfaces, and lack of adequate vegetative cover significantly reduce night-time cooling. The implications of this are serious: residents experience elevated thermal discomfort throughout the night, which can affect public health, energy consumption, and overall urban livability. The situation is particularly severe in low-income and high-density housing areas, where adaptive capacity (e.g., access to cooling, ventilation, green spaces) is often limited.

The combined evidence from scatterplot correlations and spatial comparisons strongly supports the hypothesis that urbanization and Built-up Area expansion are closely associated with rising air and surface temperatures. Blocks and cities with rapid infrastructure development, especially where it has occurred at the cost of natural vegetation, water bodies, and open spaces, show the highest temperature increases and night-time thermal stress. This analysis underlines the need for integrated urban planning that accounts for the thermal footprint of development. Strategic actions such as:

- Promoting urban green cover and tree canopy expansion
- Implementing cool roof technologies and high-albedo surfaces
- Preserving natural water bodies and green buffers
- Enforcing land use zoning to limit urban sprawl into ecologically sensitive areas

8.1. Change in Heat Exposure vs. Change in Building Footprints

To further establish the link between rapid urbanization and increasing temperature trends, this section explores the relationship between Blocks identified as "Highly Heat-Intensified" in the decadal heat exposure analysis and their corresponding increase in Built-up Area. This comparison helps confirm whether Blocks with significant thermal stress over time have also experienced substantial urban growth.

For this overlay analysis, maps depicting building footprint expansion (between 1985 and 2015) were superimposed with Blocks categorized as "Highly Heat-Intensified" from the change in heat exposure analysis. Figure 28 illustrates the result of this comparison, showing the spatial distribution of Blocks that have undergone both rapid urbanization and significant temperature rise. Blocks with an increase of more than 10 square kilometers in Built-up Area over three decades were highlighted to assess urban expansion. These were matched with Blocks classified as heat-vulnerable to assess overlap and identify potential causative patterns.

The analysis shows that over the past 30 years, Chennai's Built-up Area increased by approximately 46 square kilometers, a direct reflection of the city's intense urbanization. More notably, St. Thomas Malai block in Chengalpattu district, adjacent to Chennai, recorded a 105 square kilometer increase in building footprint, making it one of the most rapidly urbanized Blocks in the state, over twice the expansion recorded in Chennai.

Significant urban growth was also observed in the western districts of Tamil Nadu, including Coimbatore, Tiruppur and Erode, where multiple Blocks showed considerable increases in building footprints. Other districts such as Kanchipuram, Krishnagiri, Namakkal, Thanjavur, Thiruvallur and Villupuram also exhibited substantial expansion across several Blocks. Furthermore, individual Blocks in districts like Karur, Dindigul, Ranipet, Salem, Tirunelveli, Tiruchirappalli, Tiruvannamalai, Vellore, and Virudhunagar demonstrated marked increases in urban development.

Of particular interest are Blocks like Kattankolathur, Kundrathur, Poonamallee, Tiruppur, Minjur, Sriperumbudur, Gummidipoondi, Sholavaram, Thiruparankundram, and Tiruvallur, where the Built-up Area in 1985 was less than 5 square kilometers. These Blocks have since experienced rapid and extreme urbanization, as evidenced by their 2015 building footprint values. This transition illustrates how peri-urban regions, especially those surrounding Chennai (such as in Chengalpattu, Kanchipuram, and Tiruvallur), have emerged as urban expansion corridors, now facing elevated heat stress as indicated by their classification in the "Highly Heat-Intensified" category. The bar chart in Figure 28 and the corresponding list of 46 Blocks in Table 7 present detailed insights into the relationship between urban growth and increasing heat stress. These Blocks represent spatial hotspots where the combined effects of land transformation and climate stress converge, posing serious challenges to local populations, urban infrastructure, and ecological systems.

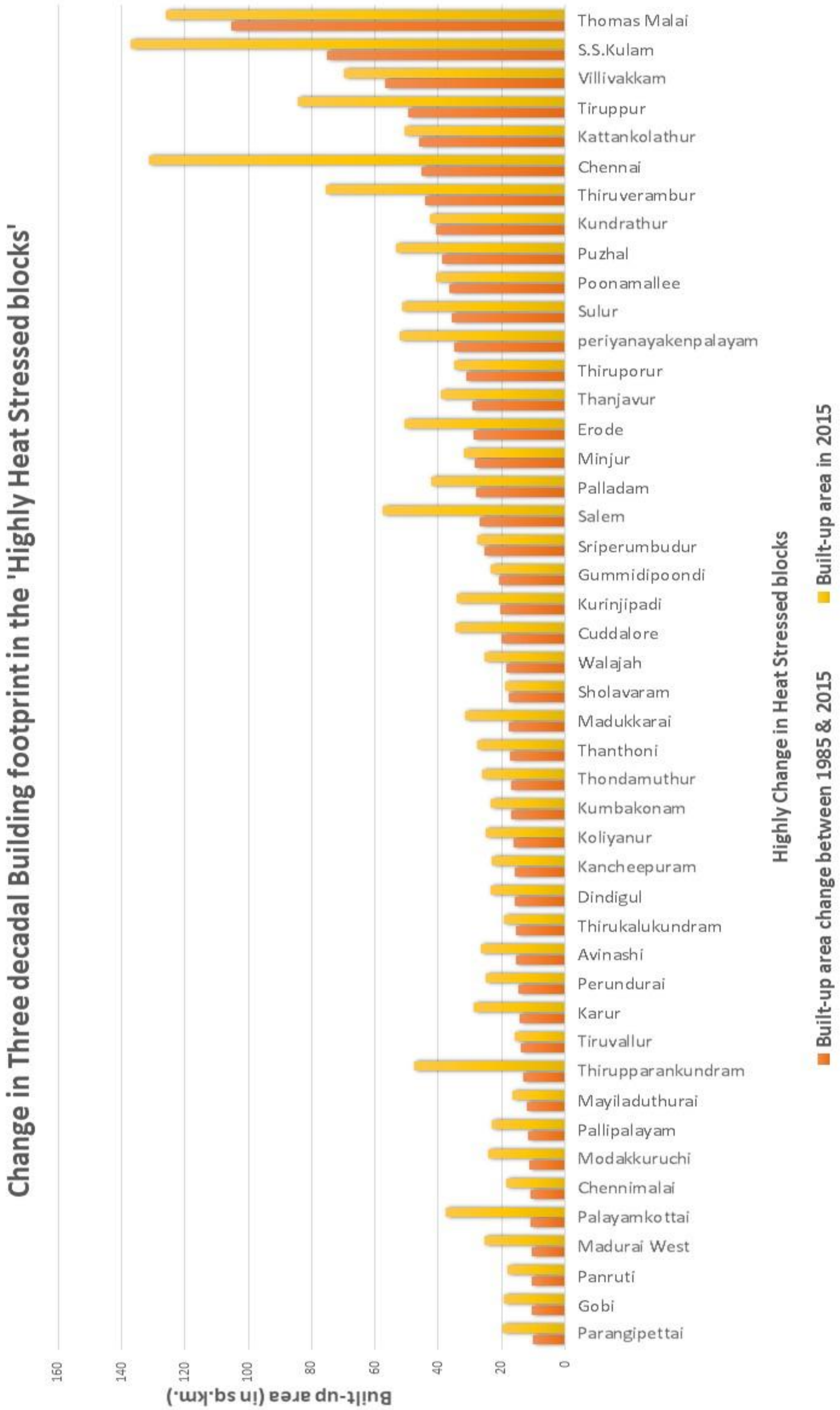


Figure 28- Building Footprint Changes in Highly Heat Stressed Terrain Blocks

S.No	District Name	Blocks with Very High and High change in Decadal heat intensity and also with high change in built area	S.No	District Name	Blocks with Very High and High change in Decadal heat intensity and also with high change in built area
1	Chengalpattu	Thirukalukundram	24	Karur	Karur
2	Chengalpattu	Thiruporur	25	Karur	Thanthoni
3	Chengalpattu	Kattankolathur	26	Madurai	Madurai West
4	Chengalpattu	St. Thomas Malai	27	Madurai	Thirupparankundram
5	Chennai	Chennai	28	Mayiladuthurai	Mayiladuthurai
6	Coimbatore	Thondamuthur	29	Namakkal	Pallipalayam
7	Coimbatore	Madukkarai	30	Ranipet	Walajah
8	Coimbatore	periyanayakenpalayam	31	Salem	Salem
9	Coimbatore	Sulur	32	Thanjavur	Kumbakonam
10	Coimbatore	S.S.Kulam	33	Thanjavur	Thanjavur
11	Cuddalore	Parangipettai	34	Tiruchirappalli	Thiruverambur
12	Cuddalore	Panruti	35	Tirunelveli	Palayamkottai
13	Cuddalore	Cuddalore	36	Tiruppur	Avinashi
14	Cuddalore	Kurinjipadi	37	Tiruppur	Palladam
15	Dindigul	Dindigul	38	Tiruppur	Tiruppur
16	Erode	Gobi	39	Tiruvallur	Tiruvallur
17	Erode	Chennimalai	40	Tiruvallur	Sholavaram
18	Erode	Modakkuruchi	41	Tiruvallur	Gummidipoondi
19	Erode	Perundurai	42	Tiruvallur	Minjur
20	Erode	Erode	43	Tiruvallur	Poonamallee
21	Kanchipuram	Kancheepuram	44	Tiruvallur	Puzhal
22	Kanchipuram	Sriperumbudur	45	Tiruvallur	Villivakkam
23	Kanchipuram	Kundrathur	46	Villupuram	Koliyanur

Table 7 - Blocks with Decadal Very High and High change in heat intensity and also with high change in built area between 1985 & 2015

This dual challenge, of experiencing both rapid urbanization and a significant rise in temperature, warrants urgent attention. These Blocks should be focused immediately for heat mitigation strategies, including:

- Preservation and integration of green infrastructure
- Enforcement of zoning regulations to control haphazard expansion
- Adoption of climate-responsive building practices
- Expansion of urban cooling measures, such as tree-lined avenues, green roofs, and water-sensitive urban design

The overlay of urbanization data with heat exposure assessments provide compelling evidence that land use changes, particularly Built-up Area expansion, are closely associated with rising thermal stress, underscoring the need for integrated urban and climate planning.

The evidence drawn from both the scatterplots and overlay analyses indicates that the interplay between rapid urban expansion and heat intensification is not only observable but also deeply entrenched in Tamil Nadu’s evolving land dynamics. While the dataset highlights several blocks with severe thermal stress and concurrent urbanization, it also reveals a broader spatial trend: clusters of high-heat zones radiating outward from urban cores into previously low-density rural or peri-urban areas. This pattern mirrors what global literature identifies as the “urban heat spillover” effect, where increased development in core areas gradually influences surrounding landscapes due to rising heat emissions and declining vegetation buffers.

Furthermore, the alignment between urbanization and elevated heat levels is especially pronounced in regions where natural water bodies have either shrunk or disappeared entirely. Field-level evidence from blocks such as Kundrathur, Sholavaram, and Sriperumbudur suggests that the disappearance of traditional irrigation tanks and surface water bodies has compounded the local warming trend. Without these water bodies serving as natural thermal regulators, the urban environment becomes more vulnerable to heat accumulation and slower nocturnal cooling, aggravating the urban heat island effect.

A secondary insight emerges in the form of land conversion rates. Many blocks that were primarily agricultural in 1985 have seen over 10 square kilometers of land converted into built-up space by 2015. Such shifts signify a critical transition in land functionality, from resource-generating to heat-retaining surfaces. The implications extend beyond temperature increases to include loss of ecological services, increased surface runoff, and lowered groundwater recharge potential. As urban imperviousness grows, the landscape's ability to mediate climatic extremes diminishes, thereby reducing the region’s climate resilience.

Importantly, the overlay analysis also sheds light on governance and regulatory gaps in peri-urban areas. Blocks that are not officially designated as municipal zones often lack adequate zoning regulations or building codes. As seen in many Tiruvallur and Chengalpattu blocks, uncontrolled land development has progressed without parallel investment in green infrastructure or environmental safeguards. These governance loopholes allow for sprawling, heat-intensive urban forms that neither optimize space nor account for thermal comfort, making them prime candidates for targeted climate-resilient urban planning.

Lastly, the comparative spatial data underscore the need for a paradigm shift in how Tamil Nadu approaches urban development in climate-vulnerable zones. Traditional land-use planning often fails to integrate thermal impact assessments, focusing instead on economic productivity and population density. However, with the mounting threat of heat stress, future development strategies must internalize heat vulnerability as a core planning parameter. By embedding heat exposure assessments in development project appraisals, Tamil Nadu can proactively minimize risk, ensure long-term sustainability, and enhance public health outcomes for its rapidly urbanizing population. The insights from this analysis must therefore inform upcoming revisions to the Tamil Nadu Combined Development and Building Rules and municipal development plans across heat-sensitive blocks.

8.2. Change in Heat Exposure Vs Building Footprints in Hilly Terrain Blocks

While temperature increases in valley and urban regions are well documented, hilly terrain regions of Tamil Nadu have also experienced a gradual but notable rise in temperature over the past few decades. Studies such as Shamsudeen et al. (2022) and Sivakumar et al. (2015) have confirmed the exposure of high-elevation regions to Climate Change, highlighting that altitude is no longer a sufficient buffer against warming trends. Although these regions typically maintain temperatures below the state average due to elevation, recent warming trends, driven by land cover changes, deforestation, and developmental pressures, have begun to erode this climatic advantage.

The change in heat exposure analysis conducted in this study was effective in capturing rising temperature trends in terrain regions. However, these regions were often not highlighted in the current heat intensity analysis, since their temperatures remain comparatively lower than lowland districts and thus fall below the state mean. This discrepancy underscores the importance of decadal change assessments, especially in ecologically sensitive zones.

To identify and analyze hilly terrain Blocks, SRTM (Shuttle Radar Topography Mission) Digital Elevation Model (DEM) data was employed to extract elevation values. For this analysis, Blocks with an average elevation above 330 meters were categorized as hilly terrain Blocks. This threshold was chosen to exclude large Blocks with minimal undulation and to capture Blocks predominantly characterized by elevated topography. The Udhagai block in The Nilgiris recorded the highest average elevation in the state, with a mean of 1714 meters above mean sea level.

From the 94 Blocks categorized under the Highly Heat-Intensified category in decadal change analysis (Section 5) 17 Blocks were identified as hilly terrain Blocks that also exhibited significant increases in building footprints over the last three decades (1985 – 2015). These Blocks are presented in Table 8, and their changes in Built-up Areas are visualized in Figure 29. This dual categorization, based on both thermal change and urbanization pressure, offers insight into the increasing heat exposure of high- altitude ecosystems, which were historically considered more resilient.

Among these, the Sulur block in Coimbatore showed the highest increase in Built-up Area, with a recorded expansion of 36 square kilometers over the study period. This was followed by Palladam (Tiruppur district) and Dindigul block, each of which experienced a Built-up Area increase of approximately 16 square kilometers. Other terrain Blocks such as Avinashi, Annur, Udumalpet, Pongalur, Sultanpet, Palani, Kinnathukadavu, Theni, and Bodinaickanur also recorded moderate increases in building footprints ranging between 5 and 15 square kilometers.

Even in Blocks where urban expansion was relatively limited, such as Kodaikanal, Myladumparai, Chinnamanur, Cumbum, and Andipatti, the change in heat exposure index remains high. This implies that while built-up expansion is a significant factor, other land-use changes such as deforestation, loss of native vegetation, agriculture intensification, and heat spillover from adjacent urbanizing areas may also be contributing to rising temperatures.

These findings are critical for environmental and urban planners. Hilly terrain Blocks are not immune to warming and are increasingly subject to development pressures due to tourism, infrastructure expansion, and real estate growth. Their ecological sensitivity, coupled with limited carrying capacity, makes them especially vulnerable to long-term thermal stress. Therefore, these Blocks must be considered climate-sensitive zones, with development controls and heat mitigation strategies tailored to preserve their unique topography, vegetation cover, and microclimate functions.

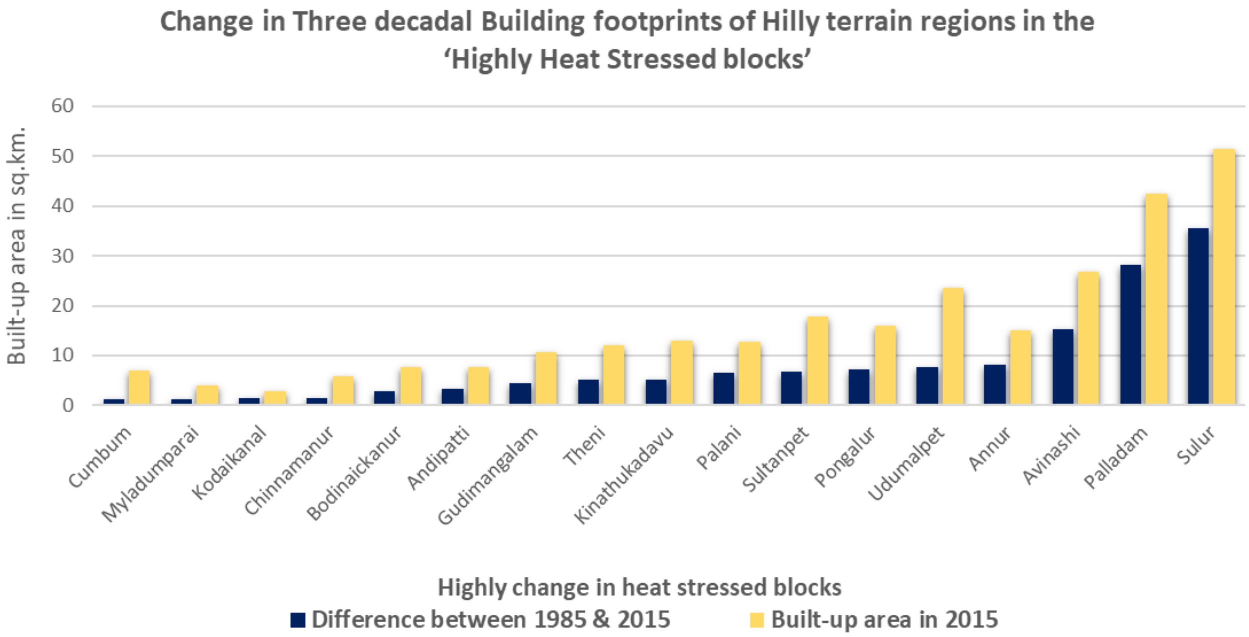


Figure 29 - Building Footprint Changes in Highly Heat Stressed Hilly Terrain Blocks

S.No	District Name	Block Name
1	Coimbatore	Kinathukadavu
2	Coimbatore	Sultanpet
3	Coimbatore	Annur
4	Coimbatore	Sulur
5	Dindigul	Kodaikanal
6	Dindigul	Palani
7	Theni	Cumbum
8	Theni	Myladumparai
9	Theni	Chinnamanur
10	Theni	Bodinaickanur
11	Theni	Andipatti
12	Theni	Theni
13	Tiruppur	Gudimangalam
14	Tiruppur	Pongalur
15	Tiruppur	Udumalpet
16	Tiruppur	Avinashi
17	Tiruppur	Palladam

Table 8 - Blocks that fall under the very high change in Heat-Exposure category also experience an increase in the building footprint increase of terrain Blocks

SUMMARY

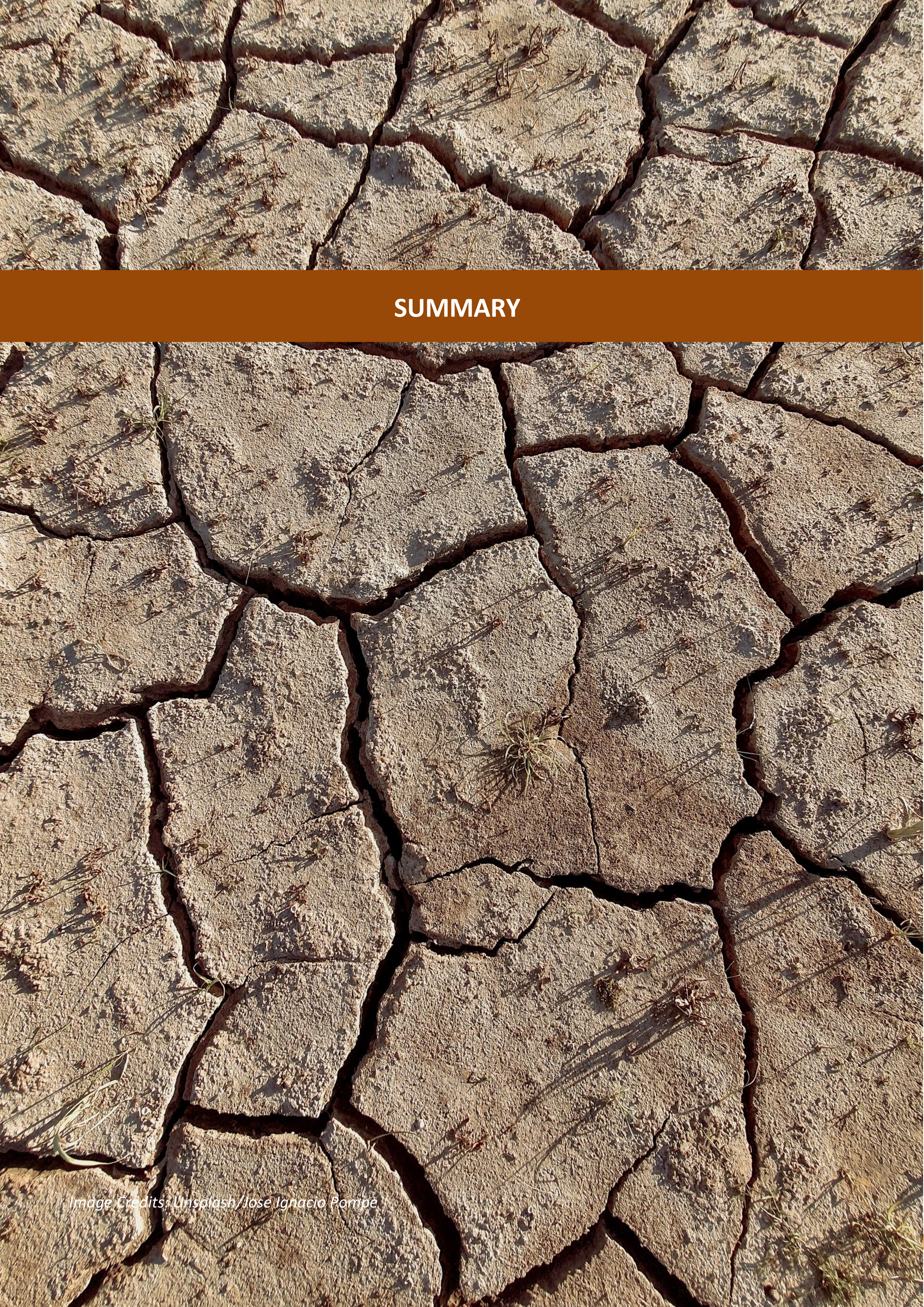


Image Credits: Unsplash/Jose Ignacio Pompe

9. Summary of this Assessment

This study offers a comprehensive assessment of the spatiotemporal patterns of temperature rise and heat exposure across Tamil Nadu, integrating remote sensing datasets, land use changes, elevation data, and climate reanalysis outputs. The following are the key findings:

1. **Rapid Urbanization and Land Conversion**

   Built-up Area expansion has drastically altered the land use pattern across Tamil Nadu. By 2015, Chennai had 74% of its land under built-up cover. St. Thomas Malai (Chengalpattu) recorded 43% Built-up Area, while S.S. Kulam (Coimbatore), Villivakkam (Tiruvallur), Salem, Erode, and Tiruppur Blocks had 30–40% built-up coverage. These figures are likely to have increased further post-2015, underscoring continued urban sprawl.

2. **Temperature Increases Across Seasons**

   Both summer and winter temperatures have shown rising trends. The Nilgiris recorded a 1°C increase in winter temperatures, while districts such as Coimbatore, Tiruppur, Karur, Dindigul, Theni, Madurai, and Tenkasi showed winter temperature increases up to 1.5°C. This mirrors the global warming trend highlighted by the European Space Agency, which reported a 1.5°C increase in global average temperature in 2024, the highest in a century.

3. **Universal Thermal Comfort Stress**

   The Universal Thermal Comfort Index (UTCI) for Tamil Nadu has reached the "strong heat stress" zone. This indicates widespread thermal discomfort, particularly affecting outdoor workers, vulnerable populations, and regions with limited access to cooling infrastructure.

4. **Elevation in Block-Level Temperatures**

   Many Blocks experienced a >1°C increase in both Night-time Land Surface Temperature (NLST) and Maximum Air Temperature (MAT) over two decades, confirming the intensity and distribution of localized warming.

5. **Warming in Hilly Terrain Blocks**

   Traditionally cooler terrain regions such as Kodaikanal, Ooty, Theni, and Yercaud are now witnessing notable warming. Kodaikanal recorded a 0.7°C increase in MAT, and Tiruttani (Thiruvallur) showed the highest block average MAT rise of 1.2°C in Tamil Nadu. The warming in these regions calls for urgent conservation and afforestation measures.

6. **High Change in Heat intensified Blocks**

   Out of 389 Blocks analyzed, 94 Blocks were categorized as having a very High Change in Heat intensified. These include both urbanized zones and ecologically sensitive hill Blocks like Kodaikanal and Myladumparai, indicating that no landscape type is immune to warming.

7. **Emergence of Newly Vulnerable Blocks**

The Current Heat intensity analysis revealed 35 previously un-flagged Blocks where the current average temperature exceeds the state average, but no significant decadal trend was observed. These Blocks might face immediate heat stress, despite being historically cooler.

8. **Districts Classified Based on Heat Risk**

Based on the Change in Heat intensity analysis, 11 districts were identified as having highest heat intensity, with 100% of their Blocks categorized as highly heat intensified. nine of these districts are coastal, underscoring their heightened sensitivity to warming. Likewise, the Current Heat Intensity analysis identified five districts with high heat exposure, three of which are also coastal.

9. **Most Heat Intensified Blocks Identified**

Twenty-five Blocks across 10 districts (as listed in Table 6) were classified as the most heat intensified, being consistently ranked high in both change and current heat intensity analyses. These Blocks require immediate intervention. Districts at Extreme Risk

10. **Districts at Extreme Heat Risk**

At the district level, Chennai, Karur, and Ramanathapuram emerged as the most heat-intensified, appearing in the highly heat intensified categories of both analyses. These districts face the dual challenge of significant warming over time and current temperatures well above state averages.

11. **Strong Link Between Urbanization and Heat**

Scatterplot analyses confirmed a positive correlation between urbanization and temperature rise. All 94 highly heat intensified Blocks also exhibited notable urban expansion. Among them, 17 are in hilly regions, indicating that even high-altitude zones are affected by anthropogenic land use change.

12. **Heat Risk in Peri-Urban Corridors**

Blocks such as Kundrathur, Sriperumbudur, Poonamallee, Minjur, and Thiruparankundram, which had minimal Built-up Areas in 1985, have undergone rapid urbanization and are now classified as highly heat intensified. These peri-urban corridors have emerged as critical heat hotspots requiring focused adaptation strategies.

13. **Heat Sensitivity of Hilly Terrain Development Pressure**

Among the 94 highly heat-intensified Blocks, 17 are hilly terrain Blocks, including those in Coimbatore, Dindigul, Theni, and Tiruppur. Some of these Blocks showed moderate built-up growth, they still recorded high heat intensity, likely due to deforestation, loss of tree cover, and urban urban heat spillover from adjacent lowland regions.

14. Need for Dual Assessment Approach

The comparison between decadal change in heat and current heat intensity confirmed that both analyses are complementary insights. Some Blocks exhibit high present-day temperatures without much historical change, while others show long-term warming trends but remain relatively cooler, both requiring context-specific mitigation strategies to address the distinct challenges posed by both types of heat intensification.

RECOMMENDATIONS

Image Credits: Unsplash/Muzammil Ahmad Karimi

10. Recommendations

The results of this heat intensity assessment provide compelling scientific evidence for enhancing climate-responsive policy and planning across Tamil Nadu. While global warming is a pervasive environmental challenge, this study clearly illustrates those localised factors, such as rapid urbanisation, land use and land cover change, and loss of forest cover, are major contributors to the intensification of surface and air temperature at district and block scales. Therefore, mitigation strategies must go beyond global climate action and address site-specific vulnerabilities using spatially disaggregated data and localised temperature trends.

This report draws on key state-level research and planning frameworks, including the Tamil Nadu Heat Mitigation Strategy (2024), Urban Heat Island Studies (2024), and the Status of Forests in Tamil Nadu Report (2024), as well as land use data compiled by the Tamil Nadu State Land Use Research Board (TNSLURB). Together, these resources highlight the urgent need to integrate climate-adaptive planning, land use regulations, and ecosystem conservation into Tamil Nadu's development pathway.

The block-level heat intensity analysis offers a valuable tool for government officials, planning agencies, disaster management authorities, and researchers. It enables the identification of critical hotspots, informs the allocation of resources, and supports the development of targeted, place-based interventions. To reduce temperature, rise and to protect vulnerable populations, the following strategic recommendations are proposed.

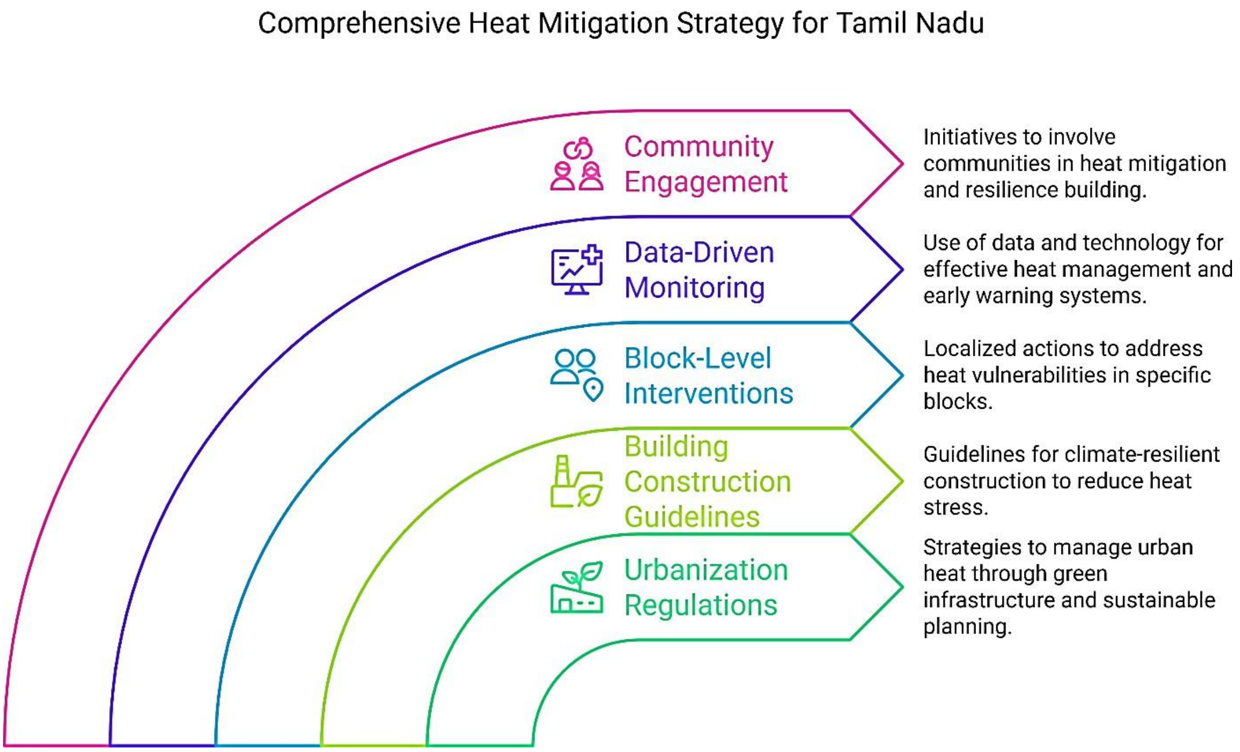


Figure 30 - Comprehensive Heat Mitigation Strategy of Tamil Nadu

10.1. Urbanization Regulations

Unregulated urbanization is a primary contributor to rising land surface temperatures, particularly through the expansion of impervious surfaces and the loss of vegetative cover. Addressing the Urban Heat Island Effect (UHIE) requires a multi-level approach that integrates urban forestry, green infrastructure, and sustainable building practices into planning systems. This section presents key strategies for urban, peri-urban, hilly, and rural areas, based on recent findings and supported by Tamil Nadu's Heat Mitigation Strategy and UHI studies (SPC, 2024).

a. Urban Infrastructure and Land Use Planning

To mitigate heat stress and improve thermal comfort in rapidly urbanizing areas:

- Integrating Blue-Green Infrastructure: Promote the development of urban forests, parks, green roofs, community gardens, wetlands, and permeable pavements to enhance natural cooling.
- Sustainable Urban Design Frameworks: Urban local bodies and planning agencies (GCC, CMDA, DTCP, PWD, and HACA) must:
    - Develop area-specific action plans for climate-resilient building construction.
    - Ensure plans are aligned with goals of heat reduction, socio-economic resilience, and ecological sustainability.
    - Make these guidelines accessible to the public to foster climate-responsive community participation.
- Managing Peri-Urban Expansion:
    - Urban sprawl often extends into peri-urban areas without regulatory oversight.
    - The SPC's study on peri-urban mapping recommends developing a sustainable urban management framework for peri-urban zones to:
        I. Regulate land conversion.
        II. Preserve buffer zones of green cover.
        III. Prevent uncontrolled thermal build-up in transitional landscapes.

b. Urban Building Construction Guidelines

The design and materials used in buildings significantly influence surface temperatures and local heat stress. Climate-resilient construction should become the norm in all new developments.

- Mandatory Green Building Features: Require green roofs, vertical gardens, passive cooling systems, and rainwater gardens in all large-scale construction projects.

- Household-Level Climate Adaptations: Mandate 30% green cover on terraces, cool roof coatings, and rainwater harvesting in residential buildings.
- Evolving Carbon Credit-Based Approval Systems: Introduce a building carbon credit score system that incentivises lower emissions and penalises heat-intensive designs.
- Incorporating Revisions in Tamil Nadu Combined Development and Building Rules to legally enforce these measures across urban and peri-urban construction.

c. Hilly Region Construction Regulations

- Tamil Nadu's hilly districts are ecologically sensitive and increasingly vulnerable to heat due to deforestation and unregulated development.
- Conducting Land Suitability Mapping: Use terrain and slope data to delineate zones suitable for construction. Ensure that approval authorities validate building sites based on ecological risk assessments.
- Implementing Tree Compensation Policy: Enforce a minimum 1:10 tree replacement ratio for vegetation removed during construction.
- Promote Responsible Hill Tourism: Encourage low-impact, eco-tourism models and awareness among tourists and developers.
- Revising HACA Guidelines: Update the Hill Area Conservation Authority (HACA) regulations, which have remained static, to address current challenges such as Climate Change, construction pressure, and forest degradation.

d. Rural Area Construction Standards

- Rural areas are also experiencing shifts in land use, which may lead to future heat intensity if unmanaged.
- Adhering to Open Space Norms: Mandate compliance with DTCP’s open space reservation requirements.
- Incorporating Nature-Based Solutions: Require rainwater harvesting and minimum green space provision for all rural constructions to ensure long-term water security and thermal moderation.

e. Retrofitting Existing Structures

- To address existing urban heat hotspots, especially in older or high-density neighbourhoods,
- Developing Retrofitting Guidelines: Target buildings contributing to UHIE for interventions such as cool roofs, external shading devices, insulation upgrades, and green facades.
- Providing Financial Incentives: Offer tax credits, grant support, or urban heat mitigation subsidies to encourage building retrofits that reduce heat emissions.

10.2. Reducing Heat at the Block Level

Localized interventions are essential to mitigating rising temperatures, particularly in regions with high heat intensity. This section provides a framework for implementing block-level heat reduction strategies, focusing on the integration of green infrastructure, blue infrastructure, and conservation-based measures. These actions are grounded in existing state-level initiatives and scientific studies conducted by the Tamil Nadu State Planning Commission (SPC) and other relevant authorities.

a. Green Infrastructure Development

Green infrastructure, including tree cover, vegetation buffers, and agroforestry systems, plays a vital role in regulating microclimates and enhancing evapotranspiration. The following approaches can guide block-level officials in implementing scalable nature-based solutions:

- **Leveraging SPC's Scientific Frameworks for Nature-Based Solutions (NBS):**

  Utilize insights from the Tamil Nadu Blue-Green Infrastructure Potential Mapping and the Development Framework for Nature-Based Solutions in Tier II Cities to design context-specific interventions aimed at improving climate resilience and reducing local surface temperatures.

- **Utilizing the Green Tamil Nadu Mission and Climate Fund:**

  The Green Tamil Nadu Mission can be effectively deployed at the block level to increase green cover. Funding support may be drawn from the Tamil Nadu Green Climate Fund, which is aimed at climate-resilient afforestation and reforestation efforts.

- **Utilizing Fallow Lands for Greening:**

  Officials should identify permanent fallow lands suitable for afforestation or agroforestry using the SPC's Mapping and Characterization of Fallow Lands in Tamil Nadu study. Once converted into productive green zones with perennial crops, these lands will contribute to:
  - Increasing farmer income.
  - Enhancing block-level carbon stock.
  - Reducing ambient temperatures through sustained evapotranspiration.

- **Implementing Kurungadugal and Strengthening KAVIADP Schemes:**

  Utilize the Kurungadugal scheme to green small or fragmented lands, such as factory spaces, disused mines, and peri-urban corridors. In conjunction with the Kalaignarin All Village Integrated Agriculture Development Programme (KAVIADP), develop farm water resources and support Tree Outside Forest (TOF) plantations in converted fallow lands.

- **Combating Desertification via Agroforestry:**

  Utilize tools like the Bhuvan GROW portal to identify areas undergoing desertification. These lands should be prioritized for village-level agroforestry expansion to prevent further land degradation.

b. Blue Infrastructure Conservation and Rejuvenation

Blue infrastructure, such as rivers, ponds, tanks, and lakes, acts as a natural coolant and plays an indispensable role in local climate regulation.

- **Enforcing Protection of Natural Water Bodies:**

  Implement strict regulations against the encroachment and pollution of ponds, tanks, lakes, and rivers. Long-term waterbody preservation should be institutionalized at the block level.
- **Restoring Wetlands under the Tamil Nadu Wetland Mission:**

  Utilize the Tamil Nadu Wetland Mission to rehabilitate degraded wetlands. These ecosystems provide critical climate services, including surface cooling and groundwater recharge.
- **Introducing Digital Monitoring of Water Bodies:**

  Install monitoring sensors in wetlands and tanks to measure key parameters. Develop real-time dashboards for data visualization and ensure public access to promote transparency and local stewardship.
- **Urban Waterbody Restoration via Smart City Funds:**

  Urban Blocks under Smart City programs should allocate funds for rejuvenating historically significant cascading water systems, which once sustained Tamil Nadu's water resilience.
- **Reviving Minor Irrigation Tanks via the THAI Scheme:**

  Employ the Tamil Nadu Village Habitations Improvement (THAI) Scheme to restore minor irrigation tanks at the village level. These tanks play a crucial role in groundwater recharge and microclimate regulation.

c. Ecological Conservation and Habitat Restoration

Conserving native ecosystems is critical to reducing block-level heat stress while also maintaining biodiversity and landscape health.

- **Tapping the Tamil Nadu Biodiversity Conservation and Greening Project:**

  Utilize this project to restore degraded natural habitats, such as grasslands, groves, and forest fragments. For example, the Chola grasslands, home to endemic species, must be protected from invasive species and degradation.

- **Strengthening Environmental Compliance Mechanisms:**

  Agencies approving development projects should enforce compliance with the Biological Diversity Act (2002) and the Environment Protection Act (1986). Approval for large developments should be conditional upon the installation of Continuous Emission Monitoring Systems (CEMS) and Online Continuous Effluent Monitoring Systems (OCEMS).

- **Ensuring Transparent Pollution Monitoring:**

  CEMS and OCEMS data should be automatically linked to an open-access dashboard monitored by officials and accessible to the public. The system should trigger alerts when pollution exceeds prescribed limits, ensuring real-time accountability.

10.3. Data-Driven Monitoring and Early Warning Systems

Enhancing real-time monitoring and predictive alert systems at the block level is key to anticipating and responding to heat-related risks. Tamil Nadu's spatially variable heat patterns demand high-resolution, location-specific data to support evidence-based decisions. Building on existing infrastructure and state data systems can significantly improve climate resilience.

- **Developing a State-Level Heat Stress Dashboard:**

  Integrate satellite datasets (such as MODIS LST and ERA5) with ground-based monitoring (CEMS, OCEMS, AWS) to enable near real-time visualization of heat patterns and trends at the block level.

- **Developing early warning systems for heatwave conditions:**

  Block-specific temperature thresholds could be configured to trigger alerts, aligned with TN-SMART and local disaster management systems.

- **Strengthening monitoring infrastructure in data-scarce regions:**

  Expanding Automatic Weather Station (AWS) coverage in rural and hilly Blocks can ensure continuous and granular data capture for long-term planning.

- **Facilitating data integration through inter-agency collaboration:**

  Partnering with IMD, NRSC, ISRO, and TN-SDMA would improve spatial and temporal data quality for heat prediction models.

10.4. Integration of Heat Exposure Range into Planning and Governance

Integrating heat exposure analysis and findings into Tamil Nadu's planning and governance systems is essential to enable climate-responsive and equitable development. By embedding exposure indicators into land-use frameworks and district-level interventions, the state can reduce long-term climate risks while safeguarding vulnerable populations.

- **Incorporating exposure range classifications into planning documents:**

  Embed findings from this study into District Development Plans, Master Plans, and Smart City proposals, enabling spatially informed resource allocation. Use heat exposure data to guide zoning decisions, infrastructure planning, and green space management.

- **Encouraging the preparation of block-level Heat Action Plans (HAPs):**

  Blocks with the highest or high levels of exposure should focus on the formulation of HAPs, which outline risk mitigation, green cover targets, and public safety measures.

- **Setting up Block Climate Units for inter-departmental coordination:**

  These units can act as nodal platforms for collaboration between departments such as agriculture, health, urban planning, and rural development at the local level.

- **Revising planning norms to include climate adaptation criteria:**

  Updating existing regulations under the DTCP to mandate features like minimum urban green space, passive cooling design, and water-sensitive planning could support long-term resilience.

10.5. Community-Centric Adaptation and Awareness

Building public awareness and encouraging local action are central to increasing climate resilience. Community-based adaptation, particularly in high-exposure districts, will support behavioural changes, reduce health risks, and improve preparedness during heatwave events.

- **Designing localised awareness campaigns:**

  Engaging schools, SHGs, farmers' groups, and panchayats to spread information on heat stress management, early work timings, and cooling strategies can significantly improve public preparedness.

- **Promoting citizen science and participatory monitoring:**

  Empowering communities to report local heat incidents, resource shortages, and health issues through mobile applications or helplines helps create feedback loops for timely intervention.

- **Encouraging climate-resilient livelihoods:**

  Diversifying rural income sources through agroforestry, drought-resistant crops, or tree-based farming can reduce the economic impact of heat-related shocks.

- **Identifying and adapting community cooling centres:**

  Retrofitting existing public buildings (such as community halls, anganwadis, or health centres) as passive cooling shelters during extreme heat days offers immediate protection to vulnerable populations.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IMPLEMENTATION STRATEGY

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11. Implementation Strategy: Embedding Heat Resilience into Tamil Nadu’s Climate Objectives

The heat exposure assessment provides a granular understanding of temperature anomalies across Tamil Nadu’s Blocks, identifying critical hotspots, terrain-specific vulnerabilities, and links between urban expansion and thermal stress. However, the success of any mitigation effort hinges not just on targeted interventions, but on how well these actions are mainstreamed into existing governance, planning, and financing systems.

This strategy complements Tamil Nadu’s Heat Mitigation Strategy (2024), particularly aligning with its key pillars: Built Environment, Urban Planning, Governance and Institutional Strengthening, and Awareness & Community Engagement. It does not propose new recommendations but focuses on embedding earlier recommendations into state systems through four strategic pathways:

A. Mainstreaming Heat Resilience into Spatial and Development Planning

Tamil Nadu’s Heat Mitigation Strategy emphasises "integrating thermal comfort and heat resilience in the built environment", a direction echoed in this report's findings. However, operationalising this requires the translation of heat exposure data into planning regulations, land-use norms, and building control mechanisms.

- Integrating heat exposure maps into District Spatial Plans, Master Plans, and Local Area Plans, ensuring that zoning decisions, FAR regulations, and infrastructure provisioning account for thermal impacts.
- Revising planning frameworks under DTCP, CMDA, GCC, and HACA to align with climate-responsive guidelines under the Heat Mitigation Strategy’s “Built Environment” chapter.
- Enabling the Tamil Nadu Combined Development and Building Rules to incorporate heat stress adaptation provisions, particularly for green roofs, albedo-sensitive materials, and urban tree canopy targets.
- Encouraging local bodies to adopt Urban Heat Island (UHI) mapping tools as part of their planning decision support systems.

B. Institutional Integration and Inter-Departmental Coordination

Heat mitigation intersects multiple sectors, housing, water, agriculture, health, environment, and infrastructure. Tamil Nadu’s Heat Mitigation Strategy highlights the need for inter-agency coordination but leaves room for stronger district and block-level operationalisation.

- Establishing dedicated Climate and Heat Cells at the District Collectorate level to anchor coordination across line departments. These units would be responsible for integrating heat considerations into ongoing schemes such as Smart Cities, AMRUT, MGNREGA, THAI, KAVIADP, and Wetlands Mission.

- Creating standard operating procedures (SOPs) for each department e.g., Public Works, Rural Development, and Forest Department, linking their mandates with heat mitigation goals.
- Leveraging platforms like State Climate Change Cell and TN-SMART for data exchange, early warning dissemination, and inter-agency decision-making.

C. Financing and Resource Mobilisation for Implementation

While Tamil Nadu's climate finance architecture is evolving, there is a need to consolidate and channel funds specifically for decentralised, block-level climate actions. The Heat Mitigation Strategy outlines the need for localised action but stops short of defining mechanisms for sustained financing.

- Utilising the Tamil Nadu Green Climate Fund (TNGCF) and State Innovation Fund to support green infrastructure projects, especially in high-risk Blocks identified in this study.
- Encouraging convergence of state sectoral schemes (forestry, agriculture, water resources) with climate resilience objectives by tagging "heat mitigation co-benefits" in project appraisals.
- Exploring public-private partnerships for green retrofitting of public buildings, use of cool roofing materials, and data monitoring technologies.
- Aligning district-level plans with potential funding from international climate mechanisms such as the Green Climate Fund (GCF), Adaptation Fund, and NABARD's climate window.

D. Capacity Building, Knowledge Systems, and Behavioural Change

Beyond technical interventions, building the institutional and social ecosystem for climate adaptation is key. Tamil Nadu's Heat Mitigation Strategy stresses community engagement but calls for more structured local-level capacity building.

- Developing training modules for ULB engineers, block officials, and village panchayats on heat-sensitive design, UHI management, and blue-green infrastructure implementation.
- Creating decision-support tools based on block-level heat intensity data to guide officials in climate-responsive planning.
- Collaborating with academic institutions, SPC, and NGOs to promote participatory climate education in heat-affected Blocks.
- Promoting behavioural nudges (e.g., using light-coloured roofs, shifting work hours, hydration drives) through school curricula, SHG networks, and health missions.

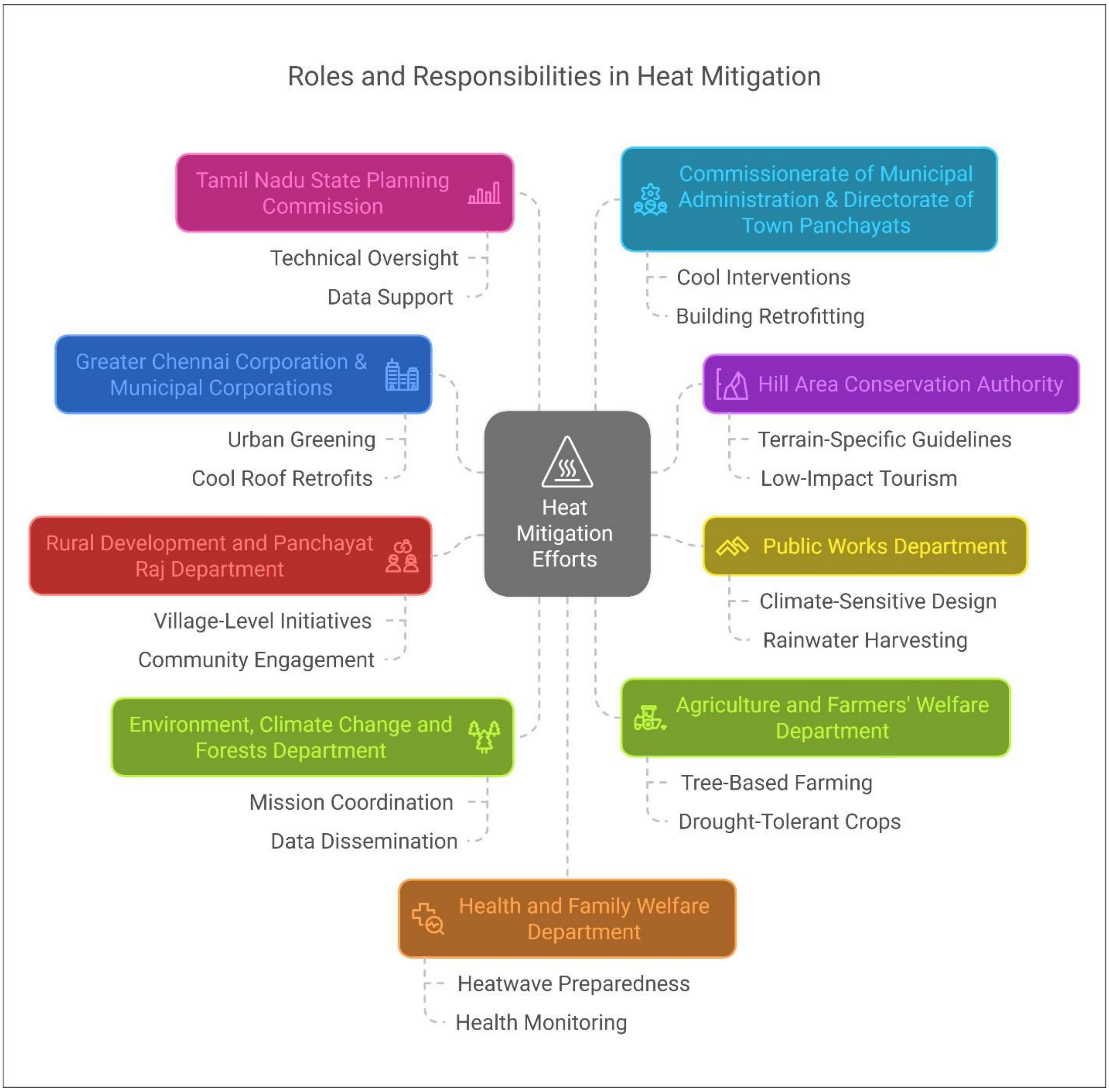

Figure 31 - Roles and Responsibilities in Heat Mitigation of line departments

Aligning with Tamil Nadu's Broader Climate Vision

This heat exposure implementation framework directly advances Tamil Nadu's broader environmental and climate ambitions. It is aligned with the Tamil Nadu Climate Change Mission, the Green Tamil Nadu Movement, the State Action Plan on Climate Change 2.0 (SAPCC 2.0), and key Sustainable Development Goals (SDGs) that address rising temperatures, urban stress, and ecological resilience. As per the NITI Aayog SDG India Index 2023-24, Tamil Nadu currently ranks third in India for overall SDG performance. The state has demonstrated strong progress in climate action, clean energy, and sustainable cities, areas that are central to this heat mitigation effort.

Key SDGs Addressed by the Implementation Framework

SDG	Relevance to Heat Stress	Tamil Nadu's Progress & Strategy
SDG 11: Sustainable Cities and Communities	Addresses urban heat islands, resilient infrastructure, and green public spaces.	Tamil Nadu's Smart Cities are integrating climate resilience, and the state promotes nature-based solutions (NbS) in city planning.
SDG 13: Climate Action	Central to mitigation and adaptation strategies for heat waves and rising temperatures.	Tamil Nadu ranks **first in India** for SDG 13. The Climate Change Mission and SAPCC 2.0 provide strong frameworks.
SDG 15: Life on Land	Supports afforestation, biodiversity conservation, and sustainable land use, crucial for moderating local climates.	The **Green Tamil Nadu Mission** and **Tamil Nadu Biodiversity Conservation Project** are key enablers, with a goal to increase green cover to **33%**.
SDG 6: Clean Water and Sanitation	Water body restoration (blue infrastructure) reduces land temperature and builds climate resilience.	The **Tamil Nadu Wetland Mission** and decentralized water management systems promote cooling through ecological restoration.
SDG 7: Affordable and Clean Energy	Encourages clean energy adoption, which reduces urban heat from carbon emissions and building energy loads.	Tamil Nadu is a leader in renewable energy and is integrating **solar-powered cooling** into public infrastructure.

Table 9 - Key SDGs addressed by the Implementation Framework

Connection to Tamil Nadu's Climate Targets

The heat exposure implementation framework is strongly aligned with Tamil Nadu's climate policy direction, particularly its commitment to reducing emissions and enhancing climate resilience at the sub-national level. Tamil Nadu has announced its ambition to achieve net-zero greenhouse gas emissions ahead of India's national 2070 goal. At the Tamil Nadu Climate Summit

2.0 (2024), the state released its first Greenhouse Gas (GHG) Inventory, revealing an 84% increase in emissions between 2005 and 2019. This inventory provides a scientific baseline to measure and guide the state's transition toward carbon neutrality.

The recommendations from this study also directly complement the thematic pillars of the State Action Plan on Climate Change (SAPCC) 2.0, which emphasizes both mitigation and adaptation across key sectors. The focus areas from SAPCC 2.0 that align with the current heat stress framework include:

- **Resilient Urban Infrastructure** – Strengthening planning norms to reduce heat stress in built environments.
- **Biodiversity and Ecosystem Conservation** – Promoting tree cover expansion and wetland protection to moderate land surface temperatures.
- **Sustainable Land and Forest Management** – Integrating forest data and land use patterns into local climate adaptation strategies.
- **Disaster Risk Reduction and Health Resilience** – Supporting early warning systems and health preparedness to combat heat-related disasters.

Strategic Alignment for Long-Term Impact

For Tamil Nadu to achieve its long-term climate goals while addressing heat exposure, implementation must align with the broader principles of sustainable development, decentralized governance, and climate justice. This requires facilitating a coherent, multi-level approach that strengthens institutional systems while responding to local ecological and climatic conditions. To support this, the following strategic directions are proposed to guide the operationalisation of the heat exposure framework:

- **Enabling district-level action in high-exposure zones:** Districts and Blocks identified as highly vulnerable to heat can be supported with targeted technical assistance, policy focus, and convergence of schemes to ensure that interventions are directed where they are most needed
- **Building institutional capacity at local levels:** Strengthening the capacity of block and municipal planning units through data training, climate literacy programmes, and integration of temperature-related indicators into development planning can ensure science-based decision-making.
- **Mainstreaming heat mitigation into planning and budgeting cycles:** Efforts should be made to incorporate heat-related indicators, such as block-level temperature anomalies, urbanisation intensity, or tree cover, in existing frameworks like District Environmental Plans, Smart City Master Plans, and Gram Panchayat Development Plans (GPDPs).
- **Institutionalising transparent monitoring and data systems:** Platforms like **TN-SMART** and the **Climate Data Cell** under the Tamil Nadu Climate Change Mission can be expanded to host block-level heat data, enabling periodic review, inter-departmental tracking, and public transparency.
- **Promoting community participation and inclusive planning:** Stakeholder consultations, participatory rural appraisals, and local workshops can play a central role in co-designing solutions, particularly in peri-urban, tribal, and ecologically sensitive regions.

By embedding these strategies into the state's broader climate governance framework, Tamil Nadu will be well-positioned to not only meet its heat mitigation goals but also advance its commitments under the State Action Plan on Climate Change 2.0**,** the Tamil Nadu Climate Change Mission**,** and the Sustainable Development Goals**.** This approach fosters long-term resilience by bridging scientific evidence with institutional response and community needs.

CONCLUSION AND WAY FORWARD

12. Conclusion and Way Forward

This study offers a comprehensive and spatially detailed assessment of heat exposure across Tamil Nadu, using block-level data to identify trends, disparities, and drivers of rising temperatures. It integrates multiple layers of analysis, Land Surface Temperature (LST), air temperature from ERA5, Universal Thermal Comfort Index (UTCI), and land use changes, to reveal how both climatic and anthropogenic factors are contributing to heat-related risks. The study also explores the intersection between rapid urban expansion, land degradation, and ecosystem fragility, demonstrating that local-level drivers are critical in understanding climate impacts in a nuanced and actionable manner.

A key insight from this study is that heat exposures is not defined solely by absolute temperature levels. Instead, it emerges from a combination of factors: the rate of temperature increase, the ecological sensitivity of the region, the extent of Built-up Area expansion, and the adaptive capacity of the population. For example, while The Nilgiris may record lower overall temperatures than coastal or central districts, even a 1°C rise in these ecologically fragile regions can be far more detrimental than a 2°C rise in the plains. This layered assessment underscores the need for differential strategies that take into account not only temperature data but also elevation, land cover, and local development dynamics.

The dual approach, assessing both decadal change in heat and current heat exposure level, has helped identify Blocks that are vulnerable due to their long-term temperature rise and those that currently experience extreme heat stress, even if their historical change has been modest. This distinction is vital for ensuring that no vulnerable area is overlooked, and that policy actions are guided by both temporal trends and present-day exposure. Additionally, the integration of building footprint data offers strong evidence that urbanisation, especially in peri-urban areas, plays a direct role in increasing heat risk.

These findings are highly relevant for Tamil Nadu's ongoing efforts under the Tamil Nadu Climate Change Mission, State Action Plan on Climate Change 2.0, and Green Tamil Nadu Movement, as well as the state's alignment with key Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities), SDG 13 (Climate Action), and SDG 15 (Life on Land). As one of the top-performing states in India's SDG Index, Tamil Nadu has both the opportunity and responsibility to lead in sub-national climate resilience planning.

To translate this evidence into meaningful outcomes, a structured implementation framework has been outlined, grounded in equity, institutional capacity, and cross-sectoral collaboration. The strategy recommends targeted heat mitigation in the most affected Blocks, integration of temperature-related indicators into development planning, and the promotion of green and blue infrastructure across urban and rural landscapes. Moreover, data transparency and community engagement are highlighted as cornerstones of effective and inclusive climate governance.

As Tamil Nadu moves toward its net-zero vision, the insights from this study can serve as a foundational tool for designing interventions that are both climate-resilient and people-centered. The approach must remain dynamic, responsive to emerging data, community feedback, and ecological thresholds. By embedding heat stress into its planning ecosystem, Tamil Nadu can ensure that climate resilience is not an abstract policy goal but a lived reality for its communities and ecosystems.

In conclusion, the study calls for a shift from reactive to proactive climate action, supported by scientific evidence, multi-stakeholder coordination, and sustained political will. The pathways laid out here offer Tamil Nadu a robust framework to address one of the most pressing and immediate climate risks, extreme heat, while building a long-term foundation for sustainable, inclusive, and adaptive development.

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Annexure

1. Categorization of Blocks based on the Decadal Change in Heat Exposure

1.1. Blocks Listed under 'Very High Change in Heat Intensity'

S.No	District	Block	S.No	District	Block
1	Chengalpattu	Kattankolathur	48	Ramanathapuram	R.S. Mangalam
2	Chengalpattu	St. Thomas Malai	49	Ramanathapuram	Ramanathapuram
3	Chengalpattu	Thirukalukundram	50	Ramanathapuram	Thiruppullani
4	Chennai	Chennai	51	Ramanathapuram	Thiruvadanai
5	Coimbatore	Annur	52	Ramanathapuram	Kadaladi
6	Coimbatore	Kinathukadavu	53	Ramanathapuram	Kamuthi
7	Coimbatore	Madukkarai	54	Ramanathapuram	Mandapam
8	Coimbatore	periyanayakenpalayam	55	Sivagangai	Devakottai
9	Coimbatore	Pollachi(N)	56	Sivagangai	Ilayangudi
10	Coimbatore	Pollachi(S)	57	Sivagangai	Singampunari
11	Coimbatore	S.S.Kulam	58	Sivagangai	Sivagangai
12	Coimbatore	Sultanpet	59	Sivagangai	Thiruppuvanam
13	Coimbatore	Sulur	60	Theni	Andipatti
14	Coimbatore	Thondamuthur	61	Theni	Chinnamanur
15	Coimbatore	Anaimalai	62	Theni	Cumbum
16	Dindigul	Kodaikanal	63	Theni	Myladumparai
17	Dindigul	Palani	64	Theni	Theni
18	Dindigul	Thoppampatti	65	Theni	Bodinaickanur
19	Kanchipuram	Kancheepuram	66	Tiruchirappalli	Lalgudi
20	Kanchipuram	Kundrathur	67	Tiruchirappalli	Manachanallur
21	Kanniyakumari	Agastheeswaram	68	Tiruchirappalli	Manapparai
22	Kanniyakumari	Killiyoor	69	Tiruchirappalli	Manikandam
23	Kanniyakumari	Kurunthancode	70	Tiruchirappalli	Marungapuri
24	Kanniyakumari	Melpuram	71	Tiruchirappalli	Thiruverambur
25	Kanniyakumari	Munchirai	72	Tiruchirappalli	Andanallur
26	Kanniyakumari	Rajakkamangalam	73	Tiruchirappalli	Musiri
27	Kanniyakumari	Thiruvattar	74	Tiruchirappalli	Vaiyampatty
28	Kanniyakumari	Thovalai	75	Tirunelveli	Palayamkottai
29	Kanniyakumari	Thuckalay	76	Tirunelveli	Radhapuram
30	Karur	Kadavur	77	Tiruppur	Avinashi
31	Karur	Karur	78	Tiruppur	Gudimangalam
32	Karur	Krishnarayapuram	79	Tiruppur	Palladam
33	Karur	Kulithalai	80	Tiruppur	Pongalur
34	Karur	Thanthoni	81	Tiruppur	Tiruppur
35	Karur	Thogamalai	82	Tiruppur	Madathukulam
36	Madurai	Madurai East	83	Tiruppur	Udumalpet
37	Madurai	Madurai West	84	Tiruvallur	Ellapuram
38	Madurai	Melur	85	Tiruvallur	Minjur
39	Madurai	Thirupparankundram	86	Tiruvallur	Poonamallee
40	Nagapattinam	Nagapattinam	87	Tiruvallur	Puzhal
41	Pudukkottai	Kunnandarkoil	88	Tiruvallur	Sholavaram
42	Pudukkottai	Manamelkudi	89	Tiruvallur	Tiruvallur
43	Pudukkottai	Viralimalai	90	Tiruvallur	Villivakkam
44	Ramanathapuram	Bogalur	91	Tuticorin	Udangudi
45	Ramanathapuram	Mudukulathur	92	Tuticorin	Vilathikulam
46	Ramanathapuram	Nainarkoil	93	Villupuram	Thiruvennainallur
47	Ramanathapuram	Paramakudi	94	Virudhunagar	Watrap

1.2. Blocks listed under 'High Change in Heat Intensity'

S.No	District	Block	S.No	District	Block
1	Chengalpattu	Madurantakam	39	Karur	K Paramathi
2	Chengalpattu	Thiruporur	40	Mayiladuthurai	Kollidam
3	Cuddalore	Annagramam	41	Mayiladuthurai	Kuthalam
4	Cuddalore	Cuddalore	42	Mayiladuthurai	Mayiladuthurai
5	Cuddalore	Kammapuram	43	Mayiladuthurai	Sembanarkoil
6	Cuddalore	Kurinjipadi	44	Mayiladuthurai	Sirkali
7	Cuddalore	Melbhuvanagiri	45	Nagapattinam	Keelaiyur
8	Cuddalore	Panruti	46	Nagapattinam	Kilvelur
9	Cuddalore	Parangipettai	47	Nagapattinam	Thalainayar
10	Cuddalore	Kattumannar Koil	48	Nagapattinam	Thirumarugal
11	Cuddalore	Srimushnam	49	Nagapattinam	Vedaranyam
12	Dharmapuri	Nallampalli	50	Namakkal	Kabilarmalai
13	Dharmapuri	Palacode	51	Namakkal	Kollihills
14	Dharmapuri	Pennagaram	52	Namakkal	Mallasamudram
15	Dharmapuri	Eriyur	53	Namakkal	Namagiripet
16	Dindigul	Athoor	54	Namakkal	Pallipalayam
17	Dindigul	Batlagundu	55	Namakkal	Rasipuram
18	Dindigul	Dindigul	56	Namakkal	Tiruchengode
19	Dindigul	Guziliamparai	57	Namakkal	Vennandur
20	Dindigul	Nilakottai	58	Pudukkottai	Arantangi
21	Dindigul	Oddanchatram	59	Pudukkottai	Avudayarkoil
22	Dindigul	Reddiarchatram	60	Pudukkottai	Karambakkudi
23	Dindigul	Shanarpatti	61	Ranipet	Arakonam
24	Dindigul	Vadamadurai	62	Ranipet	Arcot
25	Dindigul	Vedasandur	63	Ranipet	Kaveripakkam
26	Erode	Ammapet	64	Ranipet	Nemili
27	Erode	Bhavani	65	Ranipet	Thimiri
28	Erode	Chennimalai	66	Ranipet	Walajah
29	Erode	Erode	67	Salem	Ayothiyapattinam
30	Erode	Gobi	68	Salem	Gangavalli
31	Erode	Kodumudi	69	Salem	Idappady
32	Erode	Modakkuruchi	70	Salem	Kadayampatti
33	Erode	Perundurai	71	Salem	Kolathur
34	Erode	T.N. Palayam	72	Salem	Konganapuram
35	Kanchipuram	Sriperumbudur	73	Salem	Mac. Choultry
36	Kanchipuram	Uthiramerur	74	Salem	Mecheri
37	Kanchipuram	Walajabad	75	Salem	Nangavalli
38	Karur	Aravakurichi	76	Salem	Panamarathupatti

High Change in Heat Intensity					
S.No	**District**	**Block**	**S.No**	**District**	**Block**
77	Salem	Salem	116	Tirupathur	Jolarpet
78	Salem	Sankari	117	Tirupathur	Natrampalli
79	Salem	Tharamangalam	118	Tirupathur	Thirupathur
80	Salem	Veerapandy	119	Tiruppur	Dharapuram
81	Salem	Yercaud	120	Tiruppur	Kangayam
82	Tenkasi	Alankulam	121	Tiruppur	Kundadam
83	Tenkasi	Kadayam	122	Tiruppur	Mulanur
84	Tenkasi	Kadayanallur	123	Tiruppur	Uthukuli
85	Tenkasi	Keelapavoor	124	Tiruppur	Vellakoil
86	Tenkasi	Kuruvikulam	125	Tiruvallur	Gummidipoondi
87	Tenkasi	Melaneelithanallur	126	Tiruvannamalai	Anakkavoor
88	Tenkasi	Shencottai	127	Tiruvannamalai	Arni
89	Tenkasi	Tenkasi	128	Tiruvannamalai	Cheyyar
90	Tenkasi	Vasudevanallur	129	Tiruvannamalai	Peranamallur
91	Thanjavur	Ammapet_TNJ	130	Tiruvannamalai	Vembakkam
92	Thanjavur	Budalur	131	Tiruvannamalai	West Arni
93	Thanjavur	Kumbakonam	132	Tiruvarur	Koradacheri
94	Thanjavur	Madukkur	133	Tiruvarur	Kodavasal
95	Thanjavur	Orathanadu	134	Tiruvarur	Mannargudi
96	Thanjavur	Papanasam	135	Tiruvarur	Muthupettai
97	Thanjavur	Pattukkottai	136	Tiruvarur	Nannilam
98	Thanjavur	Peravurani	137	Tiruvarur	Needamangalam
99	Thanjavur	Sethubavachatram	138	Tiruvarur	Thiruthuraipoondi
100	Thanjavur	Thanjavur	139	Tiruvarur	Thiruvarur
101	Thanjavur	Tiruppanandal	140	Tiruvarur	Valangaiman
102	Thanjavur	Thiruvaiyaru	141	Tuticorin	Alwarthirunageri
103	Thanjavur	Thiruvidaimarudur	142	Tuticorin	Karungulam
104	Thanjavur	Thiruvonam	143	Tuticorin	Kayathar
105	The Nilgiris	Gudalur	144	Tuticorin	Kovilpatti
106	Theni	Periyakulam	145	Tuticorin	Ottapidaram
107	Tiruchirappalli	T.Pet	146	Tuticorin	Pudur
108	Tiruchirappalli	Uppiliyapuram	147	Tuticorin	Sattankulam
109	Tirunelveli	Ambasamudram	148	Tuticorin	Srivaikuntam
110	Tirunelveli	Cheranmahadevi	149	Tuticorin	Thoothukudi
111	Tirunelveli	Kalakadu	150	Tuticorin	Tiruchendur
112	Tirunelveli	Manur	151	Villupuram	Kandamangalam
113	Tirunelveli	Nanguneri	152	Villupuram	Koliyanur
114	Tirunelveli	Pappakudi	153	Virudhunagar	Sattur
115	Tirunelveli	Valliyoor	154	Virudhunagar	Vembakottai

1.3. Blocks listed under Moderate Change in Heat Intensity

S.No	District	Block	S.No	District	Block
1	Ariyalur	Andimadam	48	Namakkal	Mohanur
2	Ariyalur	Jayamkondam	49	Namakkal	Namakkal
3	Ariyalur	Sendurai	50	Namakkal	Paramathy
4	Ariyalur	T Palur	51	Namakkal	Puduchatram
5	Ariyalur	Thirumanur	52	Namakkal	Sendamangalam
6	Ariyalur	Ariyalur	53	Perambalur	Alathur
7	Chengalpattu	Acharapakkam	54	Perambalur	Perambalur
8	Chengalpattu	Chithamur	55	Pudukkottai	Arimalam
9	Chengalpattu	Lathur	56	Pudukkottai	Gandarvakottai
10	Coimbatore	Karamadai	57	Pudukkottai	Pudukkottai
11	Cuddalore	Keerapalayam	58	Pudukkottai	Thiruvarankulam
12	Cuddalore	Kumaratchi	59	Pudukkottai	Annavasal
13	Cuddalore	Vridhachalam	60	Pudukkottai	Ponnamaravathi
14	Cuddalore	Nallur	61	Pudukkottai	Thirumayam
15	Dharmapuri	Dharmapuri	62	Ranipet	Sholinghur
16	Dharmapuri	Harur	63	Salem	Attur
17	Dharmapuri	Karimangalam	64	Salem	Omalur
18	Dharmapuri	Kadathur	65	Salem	P.N.Palayam
19	Dharmapuri	Pappireddipatti	66	Salem	Valapady
20	Dharmapuri	Morappur	67	Sivagangai	Kallal
21	Dindigul	Natham	68	Sivagangai	Kannangudi
22	Erode	Anthiyur	69	Sivagangai	Sakkottai
23	Erode	Bhavanisagar	70	Sivagangai	Kalaiyarkoil
24	Erode	Nambiyur	71	Sivagangai	Manamadurai
25	Erode	Talavadi	72	Sivagangai	S.Pudur
26	Kallakuruchi	Thirunavalur	73	Sivagangai	Thiruppathur
27	Krishnagiri	Bargur	74	Tenkasi	Sankarankoil
28	Krishnagiri	Hosur	75	The Nilgiris	Coonoor
29	Krishnagiri	Kaveripattinam	76	The Nilgiris	Kotagiri
30	Krishnagiri	Kelamangalam	77	The Nilgiris	Udhagai
31	Krishnagiri	Krishnagiri	78	Theni	Uthamapalayam
32	Krishnagiri	Mathur	79	Tiruchirappalli	Pullampady
33	Krishnagiri	Shoolagiri	80	Tiruchirappalli	Thottiam
34	Krishnagiri	Thally	81	Tiruchirappalli	Thuraiyur
35	Krishnagiri	Uthangarai	82	Tirupathur	Alangayam
36	Krishnagiri	Veppanapalli	83	Tirupathur	Kandhili
37	Madurai	Alanganallur	84	Tirupathur	Madhanur
38	Madurai	Chellampatti	85	Tiruvallur	Kadambathur
39	Madurai	Kallikudi	86	Tiruvallur	Pallipet
40	Madurai	Kottampatti	87	Tiruvallur	R.K.Pet
41	Madurai	Sedapatti	88	Tiruvallur	Tiruvalangadu
42	Madurai	T.Kallupatty	89	Tiruvallur	Tiruttani
43	Madurai	Thirumangalam	90	Tiruvallur	Poondi
44	Madurai	Usilampatti	91	Tiruvannamalai	Jawadumalai
45	Madurai	Vadipatti	92	Tiruvannamalai	Polur
46	Namakkal	Elacipalayam	93	Tiruvannamalai	Thellar
47	Namakkal	Erumapatty	94	Tiruvannamalai	Vandavasi

S.No	District	Block	S.No	District	Block
95	Tiruvarur	Kottur	107	Villupuram	Olakkur
96	Vellore	Anaicut	108	Villupuram	Vallam
97	Vellore	Gudiyatham	109	Villupuram	Vanur
98	Vellore	K.V. Kuppam	110	Villupuram	Vikravandi
99	Vellore	Kaniyambadi	111	Virudhunagar	Aruppukottai
100	Vellore	Katpadi	112	Virudhunagar	Kariapatti
101	Vellore	Pernambet	113	Virudhunagar	Narikudi
102	Vellore	Vellore	114	Virudhunagar	Rajapalayam
103	Villupuram	Gingee	115	Virudhunagar	Sivakasi
104	Villupuram	Kanai	116	Virudhunagar	Srivilliputhur
105	Villupuram	Mailam	117	Virudhunagar	Thiruchuli
106	Villupuram	Merkanam	118	Virudhunagar	Virudhunagar

1.4. Blocks listed under low change in Heat Intensity

S.No	District	Block	S.No	District	Block
1	Cuddalore	Mangalore	13	Salem	Thalaivasal
2	Erode	Sathy	14	Tiruvannamalai	Chengam
3	Kallakuruchi	Chinnasalem	15	Tiruvannamalai	Chetpet
4	Kallakuruchi	Kallakurichi	16	Tiruvannamalai	Kalasapakkam
5	Kallakuruchi	Kalrayanhills	17	Tiruvannamalai	Kilpenathur
6	Kallakuruchi	Rishivandiyam	18	Tiruvannamalai	Pudupalayam
7	Kallakuruchi	Sankarapuram	19	Tiruvannamalai	Thandrampet
8	Kallakuruchi	Thiyagadurgam	20	Tiruvannamalai	Thurinjapuram
9	Kallakuruchi	Thirukoilur	21	Tiruvannamalai	Tiruvannamalai
10	Kallakuruchi	Ulundurpet	22	Villupuram	Melmalayanur
11	Perambalur	Veppanthattai	23	Villupuram	Mugaiyur
12	Perambalur	Veppur			

2. Categorization of Blocks Based on the Current Heat Intensity Assessment

2.1. Blocks listed under Critical Heat Intensity class

S.No	District Name	Block Name	S.No	District Name	Block Name
1	Chengalpattu	St. Thomas Malai	33	Ramanathapuram	R.S. Mangalam
2	Dindigul	Guziliamparai	34	Ramanathapuram	Ramanathapuram
3	Dindigul	Vedasandur	35	Ramanathapuram	Thiruppullani
4	Erode	Chennimalai	36	Ramanathapuram	Thiruvadanai
5	Erode	Kodumudi	37	Salem	Salem
6	Karur	Aravakurichi	38	Salem	Sankari
7	Karur	K Paramathi	39	Salem	Veerapandy
8	Karur	Kadavur	40	Sivagangai	Devakottai
9	Karur	Karur	41	Sivagangai	Kalaiyarkoil
10	Karur	Krishnarayapuram	42	Sivagangai	Kallal
11	Karur	Thanthoni	43	Sivagangai	Kannangudi
12	Karur	Thogamalai	44	Sivagangai	Sakkottai
13	Madurai	Kallikudi	45	Sivagangai	Sivagangai
14	Madurai	Thirumangalam	46	Thanjavur	Sethubavachatram
15	Madurai	Thirupparankundram	47	Tiruchirappalli	Manachanallur
16	Namakkal	Elacipalayam	48	Tiruchirappalli	Manikandam
17	Namakkal	Erumapatty	49	Tiruchirappalli	Musiri
18	Namakkal	Kabilarmalai	50	Tiruchirappalli	T.Pet
19	Namakkal	Mallasamudram	51	Tiruchirappalli	Thiruverambur
20	Namakkal	Mohanur	52	Tiruchirappalli	Thottiam
21	Namakkal	Namakkal	53	Tiruchirappalli	Vaiyampatty
22	Namakkal	Pallipalayam	54	Tirunelveli	Palayamkottai
23	Namakkal	Paramathy	55	Tiruppur	Mulanur
24	Namakkal	Puduchatram	56	Tiruppur	Vellakoil
25	Namakkal	Rasipuram	57	Tiruvallur	Poonamallee
26	Namakkal	Tiruchengode	58	Tiruvallur	Villivakkam
27	Pudukkottai	Arantangi	59	Tuticorin	Sattankulam
28	Pudukkottai	Avudayarkoil	60	Tuticorin	Thoothukudi
29	Pudukkottai	Manamelkudi	61	Virudhunagar	Kariapatti
30	Pudukkottai	Viralimalai	62	Virudhunagar	Narikudi
31	Ramanathapuram	Kadaladi	63	Virudhunagar	Sivakasi
32	Ramanathapuram	Kamuthi	64	Virudhunagar	Thiruchuli

2.2. Blocks listed under 'High Heat Intensity" class

S.No	District Name	Block Name	S.No	District Name	Block Name
1	Ariyalur	Ariyalur	42	Karur	Kulithalai
2	Ariyalur	Sendurai	43	Krishnagiri	Uthangarai
3	Ariyalur	T Palur	44	Madurai	Chellampatti
4	Ariyalur	Thirumanur	45	Madurai	Kottampatti
5	Chengalpattu	Kattankolathur	46	Madurai	Madurai East
6	Chengalpattu	Thirukalukundram	47	Madurai	Madurai West
7	Chengalpattu	Thiruporur	48	Madurai	Melur
8	Chennai	CHENNAI	49	Madurai	T.Kallupatty
9	Coimbatore	Annur	50	Madurai	Usilampatti
10	Coimbatore	Madukkarai	51	Madurai	Vadipatti
11	Coimbatore	Sulur	52	Mayiladuthurai	Sembanarkoil
12	Cuddalore	Kammapuram	53	Mayiladuthurai	Sirkali
13	Cuddalore	Kurinjipadi	54	Nagapattinam	Keelaiyur
14	Cuddalore	Mangalore	55	Nagapattinam	Thalainayar
15	Cuddalore	Nallur	56	Namakkal	Sendamangalam
16	Cuddalore	Parangipettai	57	Namakkal	Vennandur
17	Cuddalore	Vridhachalam	58	Perambalur	Alathur
18	Dharmapuri	Pennagaram	59	Perambalur	Perambalur
19	Dharmapuri	Eriyur	60	Pudukkottai	Annavasal
20	Dindigul	Nilakottai	61	Pudukkottai	Arimalam
21	Dindigul	Oddanchatram	62	Pudukkottai	Gandarvakottai
22	Dindigul	Thoppampatti	63	Pudukkottai	Karambakkudi
23	Dindigul	Vadamadurai	64	Pudukkottai	Kunnandarkoil
24	Erode	Ammapet	65	Pudukkottai	Ponnamaravathi
25	Erode	Bhavani	66	Pudukkottai	Pudukkottai
26	Erode	Bhavanisagar	67	Pudukkottai	Thirumayam
27	Erode	Erode	68	Pudukkottai	Thiruvarankulam
28	Erode	Gobi	69	Ramanathapuram	Bogalur
29	Erode	Modakkuruchi	70	Ramanathapuram	Mandapam
30	Erode	Nambiyur	71	Ramanathapuram	Mudukulathur
31	Erode	Perundurai	72	Ramanathapuram	Nainarkoil
32	Erode	T.N. Palayam	73	Ramanathapuram	Paramakudi
33	Kallakuruchi	Thiyagadurgam	74	Ranipet	Arakonam
34	Kallakuruchi	Thirunavalur	75	Ranipet	Arcot
35	Kallakuruchi	Ulundurpet	76	Ranipet	Kaveripakkam
36	Kanchipuram	Kundrathur	77	Ranipet	Thimiri
37	Kanchipuram	Sriperumbudur	78	Ranipet	Walajah
38	Kanchipuram	Walajabad	79	Salem	Attur
39	Kanniyakumari	Agastheeswaram	80	Salem	Idappady
40	Kanniyakumari	Kurunthancode	81	Salem	Kadayampatti
41	Kanniyakumari	Rajakkamangalam	82	Salem	Kolathur

High Heat Intensity					
S.No	District Name	Block Name	S.No	District Name	Block Name
83	Salem	Konganapuram	123	Tirunelveli	Pappakudi
84	Salem	Mac. Choultry	124	Tirunelveli	Radhapuram
85	Salem	Mecheri	125	Tirunelveli	Valliyoor
86	Salem	Nangavalli	126	Tiruppur	Avinashi
87	Salem	Omalur	127	Tiruppur	Dharapuram
88	Salem	Panamarathupatti	128	Tiruppur	Kangayam
89	Salem	Tharamangalam	129	Tiruppur	Kundadam
90	Sivagangai	Ilayangudi	130	Tiruppur	Palladam
91	Sivagangai	Manamadurai	131	Tiruppur	Pongalur
92	Sivagangai	S.Pudur	132	Tiruppur	Tiruppur
93	Sivagangai	Singampunari	133	Tiruppur	Uthukuli
94	Sivagangai	Thiruppathur	134	Tiruvallur	Puzhal
95	Sivagangai	Thiruppuvanam	135	Tiruvallur	Sholavaram
96	Tenkasi	Alankulam	136	Tiruvallur	Tiruvallur
97	Tenkasi	Kadayam	137	Tiruvannamalai	Arni
98	Tenkasi	Keelapavoor	138	Tiruvannamalai	Thandrampet
99	Tenkasi	Kuruvikulam	139	Tiruvannamalai	Tiruvannamalai
100	Tenkasi	Melaneelithanallur	140	Tiruvannamalai	Vembakkam
101	Tenkasi	Sankarankoil	141	Tiruvannamalai	West Arni
102	Thanjavur	Ammapet_TNJ	142	Tiruvarur	Needamangalam
103	Thanjavur	Budalur	143	Tiruvarur	Valangaiman
104	Thanjavur	Kumbakonam	144	Tuticorin	Karungulam
105	Thanjavur	Madukkur	145	Tuticorin	Kayathar
106	Thanjavur	Orathanadu	146	Tuticorin	Kovilpatti
107	Thanjavur	Papanasam	147	Tuticorin	Ottapidaram
108	Thanjavur	Pattukkottai	148	Tuticorin	Pudur
109	Thanjavur	Peravurani	149	Tuticorin	Srivaikuntam
110	Thanjavur	Thanjavur	150	Tuticorin	Tiruchendur
111	Thanjavur	Thiruvaiyaru	151	Tuticorin	Udangudi
112	Thanjavur	Thiruvonam	152	Tuticorin	Vilathikulam
113	Theni	Andipatti	153	Vellore	Vellore
114	Tiruchirappalli	Andanallur	154	Villupuram	Gingee
115	Tiruchirappalli	Lalgudi	155	Villupuram	Kanai
116	Tiruchirappalli	Manapparai	156	Villupuram	Merkanam
117	Tiruchirappalli	Marungapuri	157	Virudhunagar	Aruppukottai
118	Tiruchirappalli	Pullampady	158	Virudhunagar	Sattur
119	Tiruchirappalli	Thuraiyur	159	Virudhunagar	Vembakottai
120	Tirunelveli	Cheranmahadevi	160	Virudhunagar	Virudhunagar
121	Tirunelveli	Manur	161	Virudhunagar	Watrap
122	Tirunelveli	Nanguneri			

2.3. Blocks listed under Moderate Heat Intensity Class

Moderately Heat Intensified Blocks					
S.No	District Name	Block Name	S.No	District Name	Block Name
1	Ariyalur	Andimadam	41	Kallakuruchi	Chinnasalem
2	Ariyalur	Jayamkondam	42	Kallakuruchi	Kallakurichi
3	Chengalpattu	Acharapakkam	43	Kallakuruchi	Kalrayanhills
4	Chengalpattu	Chithamur	44	Kallakuruchi	Rishivandiyam
5	Chengalpattu	Lathur	45	Kallakuruchi	Sankarapuram
6	Chengalpattu	Madurantakam	46	Kallakuruchi	Thirukoilur
7	Coimbatore	Karamadai	47	Kanchipuram	Kancheepuram
8	Coimbatore	Kinathukadavu	48	Kanchipuram	Uthiramerur
9	Coimbatore	periyanayakenpalayam	49	Kanniyakumari	Killiyoor
10	Coimbatore	Pollachi(N)	50	Kanniyakumari	Melpuram
11	Coimbatore	Pollachi(S)	51	Kanniyakumari	Munchirai
12	Coimbatore	S.S.Kulam	52	Kanniyakumari	Thiruvattar
13	Coimbatore	Sultanpet	53	Kanniyakumari	Thovalai
14	Coimbatore	Thondamuthur	54	Kanniyakumari	Thuckalay
15	Coimbatore	Anaimalai	55	Krishnagiri	Bargur
16	Cuddalore	Annagramam	56	Krishnagiri	Kaveripattinam
17	Cuddalore	Cuddalore	57	Krishnagiri	Kelamangalam
18	Cuddalore	Keerapalayam	58	Krishnagiri	Krishnagiri
19	Cuddalore	Kumaratchi	59	Krishnagiri	Mathur
20	Cuddalore	Melbhuvanagiri	60	Krishnagiri	Shoolagiri
21	Cuddalore	Panruti	61	Krishnagiri	Thally
22	Cuddalore	Kattumannar Koil	62	Krishnagiri	Veppanapalli
23	Cuddalore	Srimushnam	63	Madurai	Alanganallur
24	Dharmapuri	Dharmapuri	64	Madurai	Sedapatti
25	Dharmapuri	Harur	65	Mayiladuthurai	Kollidam
26	Dharmapuri	Karimangalam	66	Mayiladuthurai	Kuthalam
27	Dharmapuri	Kadathur	67	Mayiladuthurai	Mayiladuthurai
28	Dharmapuri	Nallampalli	68	Nagapattinam	Kilvelur
29	Dharmapuri	Palacode	69	Nagapattinam	Nagapattinam
30	Dharmapuri	Pappireddipatti	70	Nagapattinam	Thirumarugal
31	Dharmapuri	Morappur	71	Nagapattinam	Vedaranyam
32	Dindigul	Athoor	72	Namakkal	Kollihills
33	Dindigul	Batlagundu	73	Namakkal	Namagiripet
34	Dindigul	Dindigul	74	Perambalur	Veppanthattai
35	Dindigul	Natham	75	Perambalur	Veppur
36	Dindigul	Palani	76	Ranipet	Nemili
37	Dindigul	Reddiarchatram	77	Ranipet	Sholinghur
38	Dindigul	Shanarpatti	78	Salem	Ayothiyapattinam
39	Erode	Anthiyur	79	Salem	Gangavalli
40	Erode	Sathy	80	Salem	P.N.Palayam

Moderate Heat Intensity					
S.No	**District Name**	**Block Name**	**S.No**	**District Name**	**Block Name**
81	Salem	Thalaivasal	119	Tiruvannamalai	Chetpet
82	Salem	Valapady	120	Tiruvannamalai	Cheyyar
83	Salem	Yercaud	121	Tiruvannamalai	Jawadumalai
84	Tenkasi	Kadayanallur	122	Tiruvannamalai	Kalasapakkam
85	Tenkasi	Shencottai	123	Tiruvannamalai	Kilpenathur
86	Tenkasi	Tenkasi	124	Tiruvannamalai	Peranamallur
87	Tenkasi	Vasudevanallur	125	Tiruvannamalai	Polur
88	Thanjavur	Tiruppanandal	126	Tiruvannamalai	Pudupalayam
89	Thanjavur	Thiruvidaimarudur	127	Tiruvannamalai	Thellar
90	Theni	Bodinaickanur	128	Tiruvannamalai	Thurinjapuram
91	Theni	Chinnamanur	129	Tiruvannamalai	Vandavasi
92	Theni	Cumbum	130	Tiruvarur	Koradacheri
93	Theni	Myladumparai	131	Tiruvarur	Kottur
94	Theni	Periyakulam	132	Tiruvarur	Kodavasal
95	Theni	Theni	133	Tiruvarur	Mannargudi
96	Theni	Uthamapalayam	134	Tiruvarur	Muthupettai
97	Tiruchirappalli	Uppiliyapuram	135	Tiruvarur	Nannilam
98	Tirunelveli	Ambasamudram	136	Tiruvarur	Thiruthuraipoondi
99	Tirunelveli	Kalakadu	137	Tiruvarur	Thiruvarur
100	Tirupathur	Alangayam	138	Tuticorin	Alwarthirunageri
101	Tirupathur	Jolarpet	139	Vellore	Anaicut
102	Tirupathur	Kandhili	140	Vellore	Gudiyatham
103	Tirupathur	Madhanur	141	Vellore	K.V. Kuppam
104	Tirupathur	Natrampalli	142	Vellore	Kaniyambadi
105	Tirupathur	Thirupathur	143	Vellore	Katpadi
106	Tiruppur	Gudimangalam	144	Vellore	Pernambet
107	Tiruppur	Madathukulam	145	Villupuram	Kandamangalam
108	Tiruppur	Udumalpet	146	Villupuram	Koliyanur
109	Tiruvallur	Ellapuram	147	Villupuram	Mailam
110	Tiruvallur	Gummidipoondi	148	Villupuram	Melmalayanur
111	Tiruvallur	Kadambathur	149	Villupuram	Mugaiyur
112	Tiruvallur	Pallipet	150	Villupuram	Olakkur
113	Tiruvallur	R.K.Pet	151	Villupuram	Thiruvennainallur
114	Tiruvallur	Tiruvalangadu	152	Villupuram	Vallam
115	Tiruvallur	Tiruttani	153	Villupuram	Vanur
116	Tiruvallur	Poondi	154	Villupuram	Vikravandi
117	Tiruvannamalai	Anakkavoor	155	Virudhunagar	Rajapalayam
118	Tiruvannamalai	Chengam	156	Virudhunagar	Srivilliputhur

2.4. Blocks listed under Low Heat Intensity class

S.No	District Name	Block Name	S.No	District Name	Block Name
1	The Nilgiris	Coonoor	5	The Nilgiris	Kotagiri
2	The Nilgiris	Gudalur	6	Tiruvallur	Minjur
3	Krishnagiri	Hosur	7	Erode	Talavadi
4	Dindigul	Kodaikanal	8	The Nilgiris	Udhagai

Urban Growth and Thermal Stress:
A Decadal Assessment of Built-Up Area and Climate Interactions in Tamil Nadu

Heat has become a major threat to human health and biodiversity, with 2024 recorded as the hottest year globally and February 2025 as the hottest month in India in 125 years. In response to the rising fatalities caused by extreme heat, the Government of Tamil Nadu declared heat a **State-Specific disaster** in October 2024.

Local impacts of climate change, such as Urban Heat Islands and rising rural temperatures, can be addressed through Nature-Based Solutions. Effective implementation of these measures depends on the scientific identification of heat-vulnerable areas.

Chennai, Karur, and Ramanathapuram have been identified as the most heat-stressed districts, based on decadal temperature trends and current heat intensity analysis. Warming trends are also evident in hilly regions like Ooty, which has experienced a 1°C rise in winter air temperatures over the past two decades.

This report serves as a **Decision Support System**, offering spatial data and practical recommendations for policymakers to enable targeted climate resilience across Tamil Nadu

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