



# Urban Heat Island Assessment and Strategic Guidelines for Urban Cooling in Tamil Nadu

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FEBRUARY 2026

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# **Urban Heat Island Assessment and Strategic Guidelines for Urban Cooling in Tamil Nadu**

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“Climate-induced heat stress is among the most urgent challenges confronting our cities today. Tamil Nadu has responded through dedicated institutions, integrated governance, and forward-looking policies; translating science into people-centric solutions that protect public health and build long-term climate resilience in the community. These efforts emphasise our continued commitment to climate action and sustainable development”

**Thiru M K Stalin**

**The Honourable Chief Minister, Government of Tamil Nadu**





“Extreme heat is an urgent and growing challenge for our cities. Through initiatives like the Tamil Nadu Climate Change Mission (TNCCM) and the Tamil Nadu Heat Mitigation Strategy, supported by evidence based, localized studies, the state is guiding cities to strengthen urban heat resilience and safeguard the well-being of our communities.”

## **Thiru Thangam Thennarasu**

**The Honourable Minister for Finance, Environment and  
Climate Change, Government of Tamil Nadu**





“Tamil Nadu has been a frontrunner in heat mitigation, becoming the first Indian state to formally notify heatwaves as a ‘state-specific disaster’ and among the first to establish a dedicated Heat Resilience Center to coordinate mitigation efforts. Studies such as this reinforce that leadership by providing critical evidence to advance hyper-local urban cooling solutions and strengthen climate-resilient urban planning.”

**Tmt. Supriya Sahu, I.A.S.,**  
**Additional Chief Secretary to Government,**  
**Environment, Climate Change & Forests Department**



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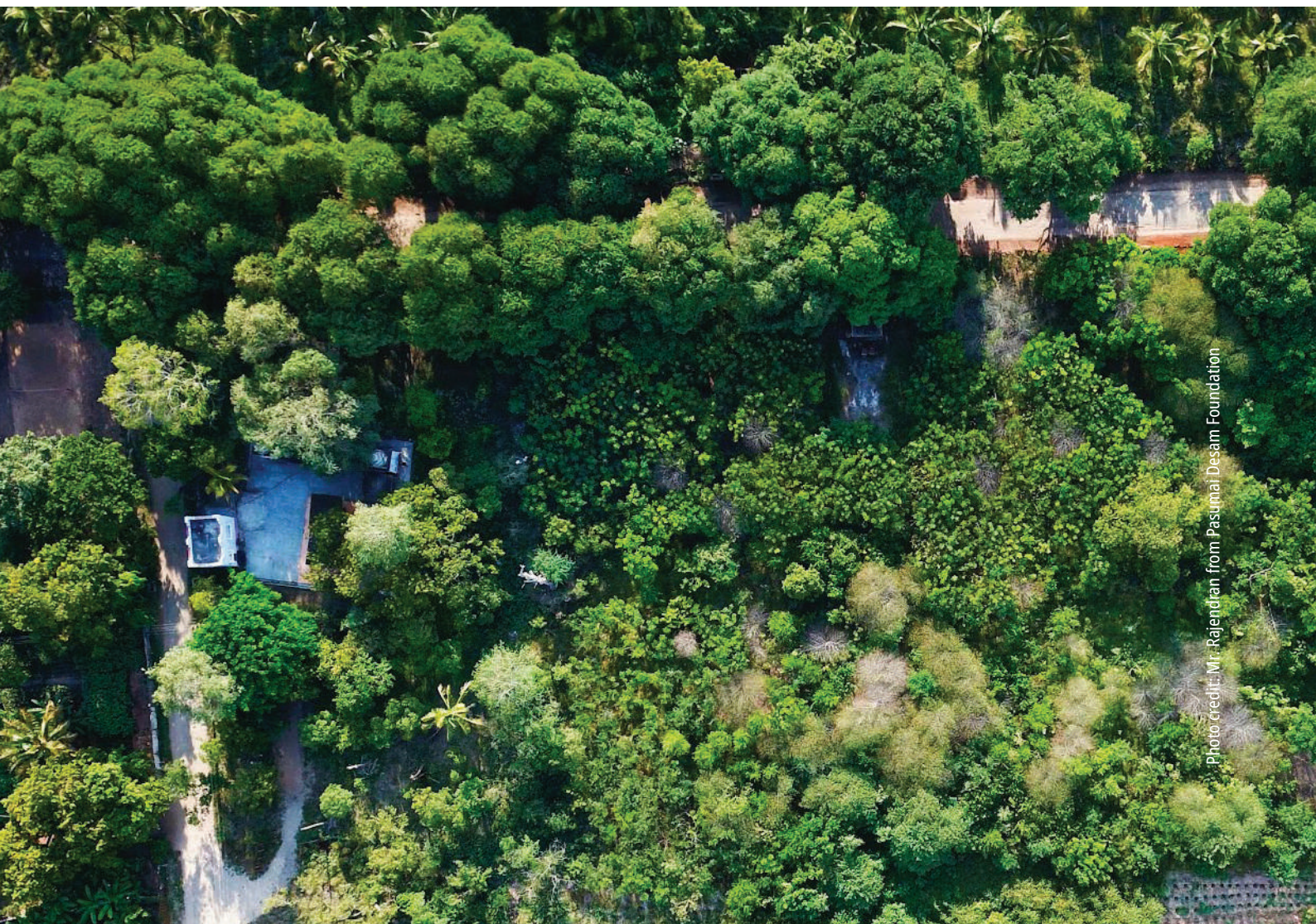


Photo credit: Mr. Rajendran from Pasupai Desam Foundation

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# Abbreviations

AMC	Ahmedabad Municipal Corporation
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AWS	Automatic Weather Station
BMC	Brihanmumbai Municipal Corporation
CCMC	Coimbatore City Municipal Corporation
CMDA	Chennai Metropolitan Development Authority
CMA	Commissionerate of Municipal Administration
CRCAP	Climate Resilient City Action Plan
CSR	Corporate Social Responsibility
DCS	District Cooling System
DTCP	Directorate of Town and Country Planning
ECBC	Energy Conservation Building Code
FAR	Floor Area Ratio
GCC	Greater Chennai Corporation
GIS	Geographic Information System
GRIHA	Green Rating for Integrated Habitat Assessment
GTM	Green Tamil Nadu Mission
HVAC	Heating Ventilation and Air Conditioning
ICF	Integral Coach Factory
IGBC	Indian Green Building Council
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
LIU	Local Implementation Unit
LSE	Land Surface Emissivity
LST	Land Surface Temperature
LULC	Land Use Land Cover
MAWS	Municipal Administration and Water Supply Department
MIR	Mid- Infrared
MLA	Member of Legislative Assembly

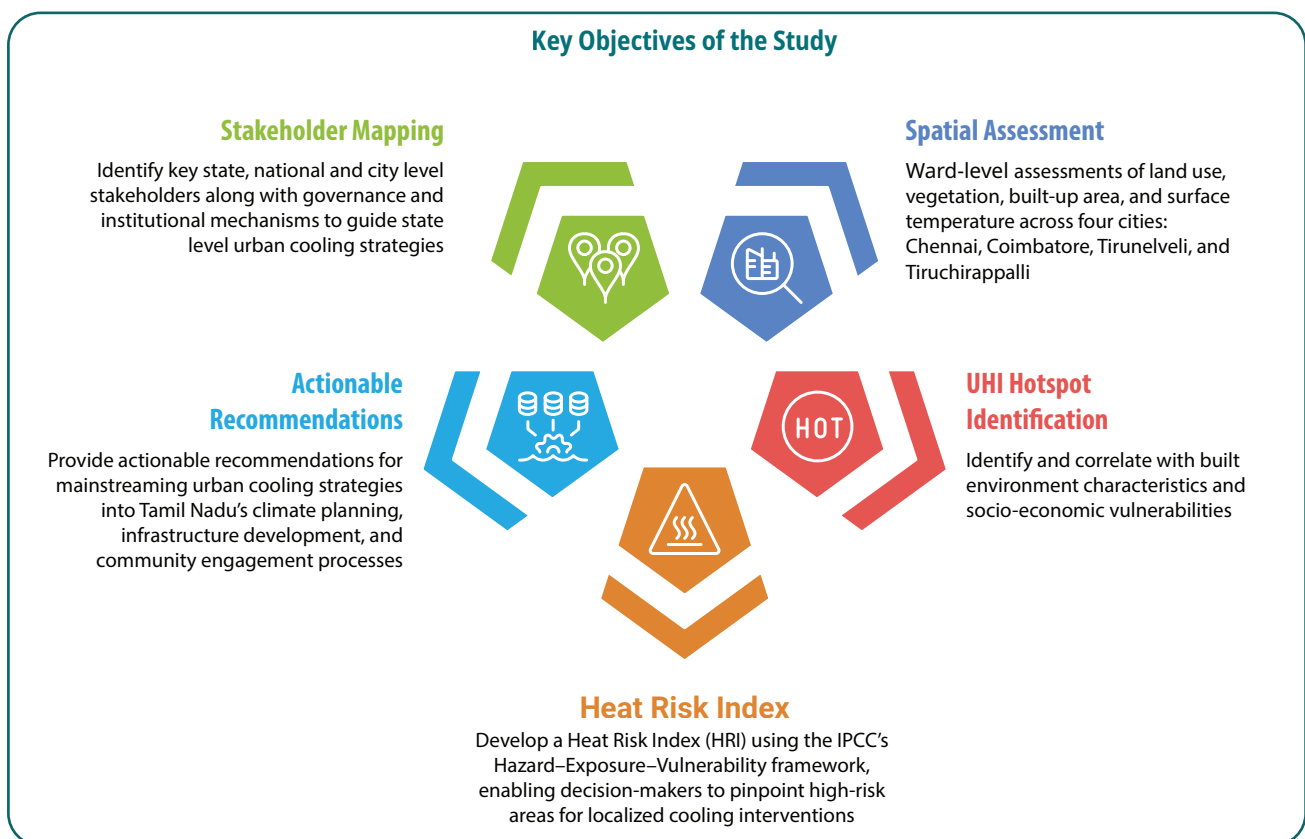
MLC	Maximum Likelihood Classification
MNDWI	Modified Normalized Difference Water Index
MoHUA	Ministry of Housing and Urban Affairs
MP	Member of Parliament
MSME	Micro Small Medium Enterprises
NBS	Nature Based Solutions
NCAP	National Cooling Action Plan
NDBI	Normalized Difference Built-up Index
NDVI	Normalized Difference Vegetation Index
NIUA	National Institute of Urban Affairs
NGO	Non-Governmental Organization
NIR	Near Infrared
OSR	Open Space Reservation
PMAY	Pradhan Mantri Awas Yojana
PWD	Public Works Department
RWA	Resident Welfare Association
SCAP	State-Level Cooling Action Plan
SSP	Shared Socio Economic Pathways
TIR	Thermal Infrared
TIDCO	The Tamil Nadu Industrial Development Corporation
TNCBDR	Tamil Nadu Combined Building Development Rules
TNEB	Tamil Nadu Electricity Board
TNECBC	Tamil Nadu Energy Conservation Building Code
TNGCC	Tamil Nadu Green Climate Company
TNRIDC	Tamil Nadu Road Infrastructure Development Corporation
TNSAPCC	Tamil Nadu State Action Plan on Climate Change
TNSPC	Tamil Nadu State Planning Commission
TNUCA	Tamil Nadu Urban Cooling Authority
TNUDF	Tamil Nadu Urban Development Fund
TNUIFSL	Tamil Nadu Urban Infrastructure Financial Services Limited
TNUHDB	Tamil Nadu Urban Habitat Development Board
UHI	Urban Heat Island
ULB	Urban Local Body
WHO	World Health Organization

# Executive Summary

Tamil Nadu, one of India's most urbanized and climate-vulnerable states, is experiencing an intensification of the Urban Heat Island (UHI) effect due to rapid urbanization, diminishing green cover, and the expansion of impervious built surfaces. Climate projections indicate an increase in the number of thermal discomfort days<sup>1</sup> to over 200–250 days annually by 2050<sup>2</sup>. Cities such as Chennai have already seen a rise in mean Land Surface Temperature (LST) from 29.4°C in 2000 to 33.6°C in 2020<sup>3</sup>. In 2023 alone, the state reported 12 heatwave-related deaths<sup>4</sup>, underscoring the urgent need for a comprehensive, spatially informed approach to urban heat mitigation.

## Objective and scope of the study

This study was conducted with the objective of bridging key knowledge and policy gaps in Tamil Nadu's response to urban heat by assessing ward level Heat Risk Index and identifying tailored solutions in four sample cities. While previous state-level assessments—such as the Tamil Nadu Heat Mitigation Strategy (2023) and the Urban Heat Island (UHI) hotspot analysis by the State Planning Commission (2024)—provided valuable macro-level insights, they could be strengthened with granular, ward-level data necessary for targeted interventions.



1. A thermal discomfort day is a day when the temperature is outside the thermal comfort range, which is typically between 18°C and 24°C
2. Center for Climate Change and Disaster Management, Anna University, 2024, Climate Risk Assessment and Adaptation Plan of Tamil Nadu, Accessed June 2024
3. Mohammed Faizan, 2020, Assessment of Urban Heat Island using GIS and Remote Sensing -A Case Study of Chennai City, India, Accessed April 2025
4. Tamil Nadu State Planning Commission, 2023, Tamil Nadu heat mitigation strategy, Accessed Jan 2025

## Methodology

Using remote sensing data and spatial mapping, the study assessed the spatial distribution of the following parameters at the ward level for each of the four cities:

- Land Use Land Cover (LULC) - Denotes land cover types like impervious surfaces, built-up, vegetation, water and wetlands
- Normalized Difference Vegetation Index (NDVI) - Denotes the presence and health of green vegetation
- Normalized Difference Built-up Index (NDBI) - Denotes built-up and urban areas
- Land Surface Temperature (LST) - Denotes the temperature of the earth's land surface
- Urban Heat Island hotspots- Denotes areas which have a high UHI intensity

**Correlation analysis:** This study also included a regression analysis to statistically model the correlation between NDBI, NDVI, and LST at the ward level for the 4 cities.

**Ward-level Heat Risk Index:** A key feature of the study is the development of a Ward-level Heat Risk Index for each city based on the IPCC's Hazard–Exposure–Vulnerability framework. This localized index identifies high-risk wards with precision, revealing critical overlaps between low green cover, high built-up density, and socio-economic vulnerability.

## Key Findings

The ward-level geospatial analysis conducted by ICLEI South Asia across Chennai, Coimbatore, Tiruchirappalli and Tirunelveli provided key insights into wards having the highest vulnerability to urban heat island impacts, based on an analysis of factors such as built-up index, vegetation, access to parks, healthcare infrastructure, proportion of old and young population. These insights reveal priority areas where targeted urban cooling strategies—such as greening, heat-resilient infrastructure, and improved public amenities—can significantly reduce heat stress and enhance climate resilience.

**Solid waste dump yard sites were found to fall under high heat zones:** Wards with dump yards were found to fall under high heat zones across all the cities. These included the Kodungaiyur dump yard (ward 37) and Perungudi Dump yard in Chennai (ward 189), Vellalore Compost yard in Coimbatore (ward 99) and Ariyamangalam dump yard in Tiruchirappalli (ward 36). This highlights the need for cities to reduce waste sent to landfills and convert existing landfills into green spaces through bio-remediation to reduce urban heat

**Vulnerable Communities, green inequity and high heat stress:** Low-income areas and vulnerable communities exhibited high heat risk and vulnerability, owing to poor vegetation, limited access to healthcare, parks, water bodies, roads and other infrastructure. For example, areas like Nochikuppam and Ayothikuppam in Chennai which are low-income and slum-dominated, show very low NDVI (0–0.1) and extremely high UHI intensity, with minimal green cover and inadequate access to parks (less than 1 park per sq. km). This indicates the need to focus on equitable distribution of green spaces and integrate cooling solutions within affordable housing plans.

**Industrial Activity and Heat Stress:** High LSTs were found in MSME-heavy areas such as Rathinapuri (wards 45–47) and SIDCO industrial estate (ward 100) in Coimbatore and Ambattur Industrial Estate (ward 89) in Chennai. These areas also had high NDBI and low NDVI, indicating intense built-up and sparse vegetation. Thus, cooling infrastructure such as tree lined buffers, reflective materials, cool roofs and green roofs should be integrated into industrial redevelopment plans. MSMEs can also be supported to integrate passive and active cooling solutions through financial and technical capacity building.

**Blue-Green Potential in vacant lands:** The study exposed those wards with vacant land such as ward 89 in Coimbatore, ward 8 in Tiruchirappalli and ward 36 in Tirunelveli, exhibited high temperatures and heat risk. This indicates the need for cities to assess existing land parcels, particularly those under Open Space Reservation and integrate them into blue-green development plans.

## Policy and Planning Recommendations

The report includes several recommendations across sectors such as urban greening, transport, water resource management and built infrastructure as well as community involvement and awareness creation. To support these recommendations, the guidelines also included recommendations on institutional and governance structures for implementation, including;

- Development of a State-Level Cooling Action Plan (SCAP) that integrates cooling demand assessments, urban green cover mapping, UHI monitoring, and sector-specific strategies.
- Local Urban Cooling plans at the city level to tailor interventions based on localized risk assessments.
- Institutional mechanisms such as a dedicated Urban Cooling Authority at the state, supported by Local Implementation Units (LIUs) in each city.
- Cross-sectoral stakeholder engagement involving government agencies, ULBs, academic institutions, private developers, and community organizations.

## Conclusion

Tamil Nadu stands at a pivotal moment where the achievement of the targeted trillion-dollar economy by 2030 is contingent on the transformation of its cities into climate-resilient urban centres. By mainstreaming urban cooling into policy, infrastructure, and community planning, the state can significantly reduce its vulnerability to rising temperatures. This guideline can serve as a tool for the state of Tamil Nadu as well as the four cities to understand the interlinkages between urban heat, vegetation, built infrastructure and socio-economic factors at the ward level and operationalize this vision, making Tamil Nadu a leader in urban heat resilience in India.



# 1. Introduction

As urbanization accelerates and climate change progresses, the phenomenon of UHI, where city environments become significantly warmer than their rural counterparts, has become a critical concern globally. This is attributed to the higher heat storage capacities of concrete structures and impermeable surfaces as well as heat from industries and vehicles. For example, a study by the European Commission's Joint Research Centre measured that cities were 10-15°C hotter than their rural surroundings<sup>5</sup>.

Higher temperatures increase energy consumption, greenhouse gas emissions, and pose more significant health risks due to heat stress. In India, the impact of UHI is increasingly evident. The Indian Meteorological Department has reported a rise in average temperatures in major cities by 0.5°C to 2.0°C over recent decades<sup>6</sup>. Focusing on Tamil Nadu, one of India's most urbanized states, the situation reflects similar challenges. The state regularly faces soaring temperatures greater than 40°C for a significant portion of the year. Home to major cities such as Chennai, Coimbatore, and Madurai, Tamil Nadu sees a significant urban heat impact with cities likely to experience around 200-250 thermal discomfort days<sup>7</sup> by 2050. The average number of annual heatwave days in the state increased from 15 to 30 days between 2011 and 2019, while the maximum temperature has increased by 1.5°C since 1981<sup>8</sup>. Taking the case of Chennai, reports indicate that the number of annual heatwave days are likely to increase from 42 to 81 by 2050<sup>9</sup>. This temperature rise exacerbates the UHI effect, leading to thermal discomfort and increased heatwave related health impacts among the urban population, with 12 heatwave-related deaths reported in the state in 2023<sup>10</sup>.

This calls for urgent measures to support "Urban cooling", which refers to the intentional reduction of ambient air and surface temperatures in urban areas through interventions such as vegetation (e.g., urban forests, green roofs, green spaces, avenue plantations), high-albedo materials (e.g., cool roofs and pavements), water features, and strategic urban design. These measures aim to mitigate the urban heat island effect, enhance thermal comfort, and improve overall climate resilience in cities.

## 1.1. Study Objective

Tamil Nadu has proactively initiated several policy measures to address the escalating challenges of urban heat. Addressing the critical need to tackle heatwaves, the Disaster Management Authority prepared a heatwave action plan in 2019, with strategies to enhance public awareness, early warning systems, and healthcare preparedness to mitigate heatwave impacts.

However, tackling the compounding effects of heatwaves across sectors requires a systemic, multisectoral approach, focusing on policy development and capacity building. In response to this, the Tamil Nadu State Planning Commission

5. EU 2022. Cities are often 10-15°C hotter than their rural surroundings, Accessed June 2024.
6. Khaiwal et al 2024. Temperature projections and heatwave attribution scenarios over India: A systematic review, Accessed June 2024
7. A thermal discomfort day is a day when the temperature is outside the thermal comfort range, which is typically between 18°C and 24°C
8. Tamil Nadu State Planning Commission, 2023, Tamil Nadu heat mitigation strategy, Accessed Jan 2025
9. Center for Climate Change and Disaster Management, Anna University, 2024, Climate Risk Assessment and Adaptation Plan of Tamil Nadu, Accessed June 2024
10. Tamil Nadu State Planning Commission, 2023, Tamil Nadu heat mitigation strategy, Accessed Jan 2025

(TNSPC) prepared a heat mitigation strategy in 2023<sup>11</sup>, which provided a state level analysis of air temperatures, thermal comfort and nighttime Land Surface Temperature (LST). Derived through a consultative approach, the strategy provides recommendations addressing three important action areas, namely health and wellbeing, economic productivity and built environment.

Following this, in October 2024, the Tamil Nadu government declared heatwaves as a state-specific disaster, ensuring ₹4 lakh relief for victims' families<sup>12</sup>. This landmark move provided a greater impetus to heatwave planning and related research in the state. In the same year, the State Planning Commission also released a report on urban heat island hotspot analysis for Tamil Nadu in 2024. The report maps district wise heat zones using LST data and includes a deep dive of two cities: Thoothukudi and Madurai, comprising of a correlation analysis between LST, Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) and Modified Normalized Difference Water Index (MNDWI).

While the existing reports provide crucial insights into the Urban Heat Island effect in Tamil Nadu at the district and state level, there is a lack of ward-level analysis of heat hotspots to aid localized interventions. Additionally, the hotspot analysis presented in the SPC report is limited to only two cities, leaving gaps in understanding urban heat dynamics across other major urban centers in Tamil Nadu.

To address these gaps, ICLEI South Asia has supported Tamil Nadu Green Climate Company (TNGCC) to develop this study on **“Urban Heat Island Assessment and Strategic Guidelines for Urban Cooling in Tamil Nadu”**. The study includes a spatial distribution of NDVI, NDBI, LST and Urban Heat Island Effect at the ward level for four cities in Tamil Nadu; Chennai, Tirunelveli, Coimbatore and Tiruchirappalli. The study also includes a ward-level heat risk index analysis to pinpoint the wards in each city that are most vulnerable to urban heat. The index was developed using the Intergovernmental Panel on Climate Change (IPCC's) Hazard, Exposure and Vulnerability framework<sup>14</sup>. The ward-level analysis was used to inform recommendations for urban cooling in the state, spanning thematic areas like policy, institutionalization, community involvement, awareness, urban greening, water resources management and heat resilient built infrastructure.

The study also provides a gap analysis of state and national policies to identify gaps related to addressing heat mitigation and includes a stakeholder mapping of key city and state level stakeholders to support effective implementation of heat mitigation actions. This will enable coordinated and stakeholder driven heat mitigation efforts at the local level.

By providing a more granular assessment, the study aims to support local governments in identifying heat prone wards and zones and develop actionable recommendations tailored to local urban planning and climate adaptation needs, ensuring better preparedness and resilience against heatwaves in Tamil Nadu.

11. Madhya Pradesh Biomass Policy, 2011, <https://mprenewable.nic.in/StateGOVTpolicyforpromotion.pdf>

12. Madhya Pradesh State Water Policy, 2003, <https://www.ielrc.org/content/e0307.pdf>

13. Madhya Pradesh State Environment Policy, 1999, <https://www.mppcb.mp.gov.in/proc/environmental-policy-1999.pdf>

14. IPCC, 2018, Determinants of Risk: Exposure and Vulnerability, Accessed April 2025

## 2. Approach and Methodology

### 2.1. Selection of Cities

The foundational studies conducted by the Tamil Nadu State Planning Commission (TNSPC), such as the 2023 Heat Mitigation Strategy and the 2024 UHI Hotspot Analysis for Tamil Nadu districts have established clear evidence of spatial heat risk disparities at the state, district and city level in Tamil Nadu and the compounding effect of reduced green cover, increased impervious surfaces, and climate change on rising urban heat vulnerability. Building on this, secondary research has also reinforced the need for city-level and ward-level heat assessments for Tamil Nadu cities. CEEW's Climate Vulnerability Index indicate that Tamil Nadu scored 12 out of 28 states in overall climate risk<sup>15</sup>. An analysis of heat stress and heatwave in 4 metropolitan cities (Chennai, Kolkata, Mumbai and Delhi) showed that the risk of extreme heat stress and heat stroke events were higher in Chennai compared to the other three cities during heatwave periods, owing to high temperatures and relative humidity<sup>16</sup>. Another study on heat health risk in 37 Indian cities, highlighted that Chennai was amongst the cities with a high heat risk, while 6 cities including Tirunelveli, had a medium heat exposure<sup>17</sup>. Several studies have also highlighted a rise in land surface temperatures for Tiruchirappalli<sup>18</sup> and Coimbatore<sup>19</sup> owing to an increase in built-up areas and reduction in vegetation, further underscoring the need to include them in this study.

In response, TNGCC and ICLEI South Asia selected Chennai, Coimbatore, Tiruchirappalli, and Tirunelveli for its detailed Urban Heat Island Assessment and Strategic Guidelines for Urban Cooling in Tamil Nadu. These cities were chosen for their diverse geography, urban typologies, and climatic conditions. Chennai, being a coastal metropolitan city faces compounded heat and humidity challenges along with rapid urbanization. Coimbatore, a fast-growing industrial hub, and Tiruchirappalli, located in the hot, dry interior region, both have expanding built-up areas with declining tree cover. Tirunelveli, while smaller, was chosen for its mixed urban-rural typology. These four cities, therefore, serve as strategic pilots for heat risk assessment and urban cooling interventions, providing replicable models for other urban centers in Tamil Nadu.

### 2.2. Selection of factors influencing Urban Heat Island Effect

To effectively address the UHI phenomenon, developing a robust methodology that identifies and establishes correlations between various parameters contributing to urban heating is crucial. Within urban areas, built environments like pavements and concrete and green spaces, can impact LST and UHI<sup>20</sup>.

This study analyses the impact of key factors on Urban Heat Island effect, namely, Normalized Difference Built-up Index (NDBI), a geospatial technology used to identify and map built-up areas (like buildings and roads) and Normalized Difference Vegetation Index (NDVI), which maps the health and density of vegetation. These parameters were chosen because they can be derived from widely available remote sensing data with high spatial resolution and were mapped at the ward level for the chosen cities.

15. CEEW,2021, Mapping India's climate vulnerability, Accessed May 2025

16. Priyankar et al, 2022, Analysis of heat stress and heat wave in the four metropolitan cities of India in recent period, Accessed May 2025

17. Kaushik et al, 2024, Evaluating heat health risk in Indian cities: Geospatial and socio-ecological analysis, Accessed May 2025

18. Deepthi et al, 2024, Evaluating Urban Heat Island to Achieve Sustainable Development Goals: A Case Study of Tiruchirappalli City, India, Accessed May 2025

19. Saravanan et al, 2018, Impacts of Land Use/Land Cover Changes on Surface Urban Heat Islands: A Case Study of Coimbatore, India, Accessed May 2025

20. Md Nuruzzaman, 2015, Urban Heat Island: Causes, Effects and Mitigation Measures -A Review, Accessed June 2024

## 2.3. Data collection and Analysis

### 2.3.1. Land Use Land Cover (LULC) analysis

This study generated a spatially detailed Land Use Land Cover (LULC) map derived from Landsat 8 OLI multispectral data<sup>21</sup> using supervised Maximum Likelihood Classification (MLC)<sup>22</sup> with spectrally distinct signatures for thermally relevant land cover classes like impervious surfaces, built-up, vegetation, water and wetlands for each of the study cities. LULC accuracy was ensured through initial Google Earth Pro validation and subsequent ground truthing with digital refinement using remote sensing techniques. The resulting ward-level LULC map provides a crucial spatial inventory of surface materials and vegetation, essential for identifying UHI source areas and potential cooling zones, thus enabling correlation analyses with thermal data to inform targeted UHI mitigation strategies.

### 2.3.2. Normalized Difference Vegetation Index (NDVI) analysis

The Normalized Difference Vegetation Index (NDVI), derived from LANDSAT satellite imagery utilizing Near infrared and Red-light spectral bands, serves as a key biophysical parameter for assessing the relationship between vegetation and urban thermal conditions. High NDVI values, indicative of dense green cover, correlate with enhanced evapotranspiration, a significant mechanism for localized cooling. Conversely, low NDVI values denote sparse vegetation or prevalent impervious surfaces, which contribute to the UHI effect through increased solar radiation absorption. Ward-level NDVI mapping facilitates the spatial identification of areas with high, medium, and low green cover, providing a data-driven approach for urban cooling strategies by enabling city officials to prioritize greening interventions in thermally vulnerable wards characterized by low NDVI. The formula for calculating NDVI is provided in [Annexure 1](#).

### 2.3.3. Normalized Difference Built-up Index (NDBI) analysis

The Normalized Difference Built-Up Index (NDBI), calculated from LANDSAT data using Mid Infrared (MIR) and Near Infrared (NIR) bands, quantifies built-up density based on spectral reflectance. High NDBI values signify prevalent impervious surfaces, major contributors to the UHI effect due to high solar absorption. Ward-level NDBI spatially identifies areas with varying built-up intensity. This enables city officials to pinpoint thermally vulnerable wards with high NDBI. Consequently, targeted interventions to integrate heat resilience into built infrastructure can be prioritized in these areas to effectively mitigate UHI. The formula for calculating NDBI is provided in [Annexure 1](#).

### 2.3.4. Land Surface Temperature (LST) analysis

The Land Surface Temperature (LST), a key indicator of urban heat, was derived by incorporating Land Surface Emissivity (LSE), estimated from NDVI, into radiative transfer equations applied to satellite thermal infrared (TIR) data. The data used in this study is Landsat 8 and 9 OLI/TIRS thermal infrared (band 10) remote sensing data. The Landsat 8 and 9 (OLI/TIRS) data was downloaded from the US Geological Survey (USGS) website (<https://earthexplorer.usgs.gov>). The Landsat has two science instruments, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). The TIRS has the resolution of 30 m to collect LST data. The cloud-free data from April 2016 (23-04-2016) and 2024 (19-04-2024) have been chosen to avoid the impact of cloud effects in the study area analysis.

21. The data is obtained from <https://earthexplorer.usgs.gov/>, an open-source platform.

22. MLC is a supervised classification technique used to extract thematic information from multispectral satellite images and classify land use land cover, based on Bayes theorem.

The resulting ward-level LST spatially quantifies surface thermal patterns, identifying UHI hotspots with high LST. This spatially resolved data is crucial for understanding the city's thermal landscape. Consequently, it enables the prioritization of targeted cooling interventions in wards exhibiting elevated surface temperatures. The formula for calculating LST is provided in [Annexure 1](#).

### 2.3.5. Correlation Analysis between NDVI, NDBI AND LST

Following this, regression analysis was carried out to statistically model the correlation between NDBI, NDVI, and LST at the ward level. This quantitative method aimed to understand how land surface characteristics influence surface temperatures. The resulting statistical relationships enable data-driven prioritization of cooling interventions. For example, a positive correlation between LST and NDBI, alongside a negative correlation with NDVI, would technically support prioritizing greening in wards with high built-up and low vegetation. This allows for targeted, evidence-based urban heat mitigation strategies.

### 2.3.6. Urban Heat Island analysis

Following the LST analysis, UHI hotspots were identified through a spatial statistical evaluation of the ward-level LST data. Wards were quantitatively categorized into high, medium, and low heat zones based on their LST values relative to the city-wide distribution, often using methods like standard deviations or percentile thresholds. The resulting UHI hotspot maps provide a spatially explicit delineation of thermally vulnerable areas, indicating wards with the highest LST and thus the greatest UHI intensity. These maps serve as a critical visual and analytical tool for urban planners, enabling the focused implementation of targeted cooling strategies in the most affected areas. The formula for calculating UHI is provided in [Annexure 1](#).

### 2.3.7. Ward-level heat risk index analysis

A ward-level Heat Risk Index was developed across four cities, employing the IPCC's Hazard-Exposure-Vulnerability framework<sup>23</sup> (endorsed by the Ministry of Environment, Forest and Climate Change, Government of India) to guide localized mitigation strategies.

The integrated ward-level Heat Risk Index provides a spatially explicit tool for policymakers to identify vulnerable wards requiring targeted urban cooling interventions, such as increasing green infrastructure or implementing cool pavement strategies, to reduce both heat exposure and vulnerability.

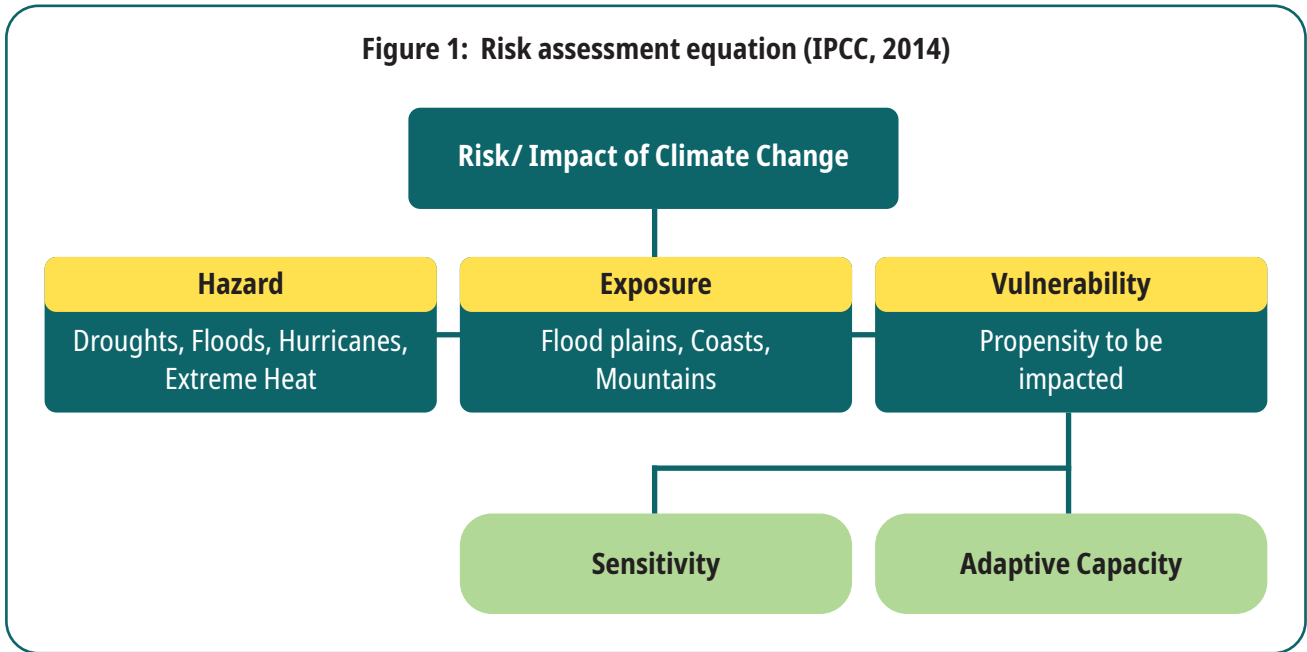
**Hazard** in this context refers to the climatological factors contributing to urban heat, such as the intensity and frequency of heatwaves (LST), potentially amplified by the Urban Heat Island (UHI) effect.

**Exposure** quantifies the presence of populations and critical urban assets (e.g., energy infrastructure susceptible to heat stress) within these warmer areas.

**Vulnerability** assesses the susceptibility of the urban population to urban heat (considering socioeconomic and physiological factors) and the adaptive capacity of the built environment (e.g., availability of green spaces for cooling (parks, Open Space Reservation (OSR) sites, open space) to these heat hazards.

23. IPCC, 2014, AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability, Accessed April 2025

Figure 1: Risk assessment equation (IPCC, 2014)



### Selection of Indicators for hazard, exposure and vulnerability analysis

The first step in the evaluation method was to identify indicators for hazard, exposure, and vulnerability and classify their relationship to heat risk (Direct or Inverse). Indicators can be useful for tracking and evaluating systems when looked at over time. Indicators help assess the relative position of a unit compared to others, in relation to a phenomenon. The indicators for this study were shortlisted based on a comprehensive review of secondary literature and inputs from existing city level heat action plans such as Thane<sup>24</sup> and Ahmedabad<sup>25</sup>. The indicators were then finalized based on stakeholder discussions around data availability at the ward level. The following table provides an overview of the indicators for hazard, exposure and vulnerability along with their correlation to heat risk. The data for indicators were collected from municipal departments.



Photo by Ahamed Sameel on Unsplash

24. Council on Energy, Environment and Water (CEEW) 2024, Heat Action Plan for Thane City, Accessed March 2025  
 25. AMC, 2015, Ahmedabad Heat Action Plan, Accessed March 2025

**Table 1: List of indicators chosen for the heat risk index analysis**

Framework	Indicator	Rationale	Relation to heat Risk	Source
<b>Hazard</b>	Land surface Temperature	Land Surface Temperature (LST) analysis provides a quantitative and spatially explicit method for identifying thermal anomalies indicative of UHI hotspots, which represent regions exhibiting significantly elevated surface temperatures due to altered energy balance within the urban environment	Direct	Analysis by ICLEI
<b>Exposure</b>	Population density	High population density in urban areas amplifies urban heat exposure via concentrated impervious surfaces and limited cooling access, often exacerbated by socioeconomic inequalities	Direct	Municipal Corporation data
	Percentage of built up area to total geographical area	UHIs, characterized by high levels of man-made impervious surfaces like buildings and roads, lead to higher temperatures due to heat trapping	Direct	Municipal Corporation data
	Building density	Increased building density intensifies the UHI effect through enhanced solar radiation absorption, longwave re-radiation, and reduced advective cooling due to impede airflow	Direct	Analysis by ICLEI
<b>Vulnerability Indicators</b>	<b>Indicators for adaptive capacity</b>			
	Number of parks per sq. km,	Parks effectively mitigate urban heat islands by providing localized cooling through shading and evapotranspiration from vegetation, thus creating more temperate microclimates for residents	Inverse	Municipal Corporation data
	Normalized Difference Vegetation Index (NDVI)	NDVI is a remote sensing index used to assess vegetation health, with higher values indicating dense, healthy vegetation and cooling green spaces.	Inverse	Municipal Corporation data
	Access to road network	Increased road density enhances accessibility and mobility, enabling access to essential services like medical care, water, and cooling centers during extreme heat events.	Inverse	Municipal Corporation Data
	Number of automatic weather stations (AWS) per sq. km.	The increased number of AWS enhances local meteorological data recording, enabling timely alerts for extreme heat, and contributes to long-term forecasting systems.	Inverse	Municipal Corporation data

Framework	Indicator	Rationale	Relation to heat Risk	Source
<b>Vulnerability Indicators</b>	Number of health centers per sq. km.	Urban health centers are crucial in providing medical care and safety information, empowering individuals and communities to cope with extreme heat and mitigate its health impacts.	Inverse	Municipal Corporation data
	Access to water sources	Access to water sources is crucial in hot weather as they reduce heat risk by evaporating water and lowering temperatures in specific areas.	Inverse	Analysis by ICLEI
	<b>Indicators for sensitivity</b>			
	Proportion of young population to total population (below 6 years)	Young and old populations are more susceptible to extreme heat due to physiological factors, pre-existing health conditions and limited adaptive capacity.	Direct	Municipal Corporation data
	Proportion of old population to total population (above 60 years)			
	Proportion of population with chronic health conditions	Heatwaves can cause severe dehydration, acute cerebral accidents, and thrombogenesis, increasing risks for chronic diseases, older individuals, and children according to the World Health Organization (WHO).	Direct	Municipal Corporation data
	Total slum population	Slum populations are highly susceptible to extreme heat due to inadequate nutrition, poor housing, lack of vegetation, substandard living conditions, and lack of basic amenities like clean water and sanitation.	Direct	Municipal Corporation data
Sex ratio	Women remain more vulnerable to disasters. Factors like gender-based inequalities in access to healthcare, education and other opportunities can further exacerbate their impacts.	Direct	Municipal Corporation data	

The indicators were standardized by adjusting them to a common scale. To ensure they were unit-free, the min-max normalization technique was applied to indicators related to exposure, vulnerability, and hazard, where normalized values of an indicator range between 0–1. This normalization process was based on the functional relationship between each indicator and vulnerability.

For directly related indicators, i.e., where heat risk increases with an increase in the value of the indicator, the following formula was used:

$$\text{Normalized value} = (X_{ij} - \text{Min } X_{ij}) / (\text{Max } X_{ij} - \text{Min } X_{ij})$$

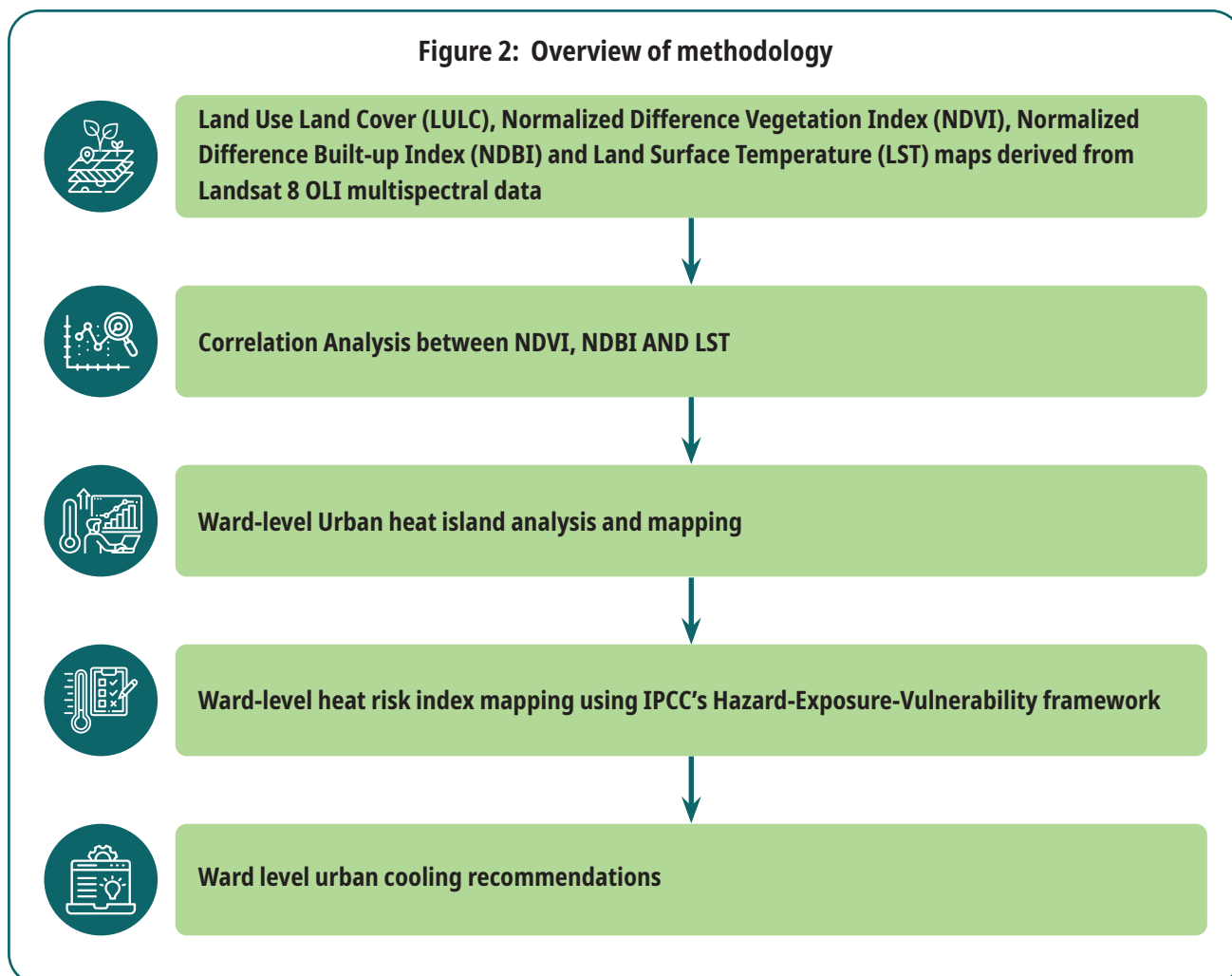
For inversely related indicators, i.e., where heat risk decreases with an increase in the value of the indicator, the following formula was used:

$$\text{Normalized value} = (\text{Max } X_{ij} - X_{ij}) / (\text{Max } X_{ij} - \text{Min } X_{ij})$$

Finally, a heat risk score was given to each ward after normalization of the indicators across Hazard (H), Exposure (E) and vulnerability (V). The wards were then classified based on “high”, “medium” and “low” risk and geographically plotted.

$$\text{Risk score} = \sqrt[3]{(H * E * V)}$$

Lastly, recommendations to enhance urban cooling were provided based on the results from the urban heat island mapping and ward-level risk assessment. This was supported by secondary data collection and policy analysis from review of literature, government reports, and global case studies of urban cooling projects. An overview of the data collection and analysis methodology is provided in Figure 2.



## 3. Case study: Greater Chennai Corporation

### 3.1. Study Area

Chennai's natural environment consists of three primary rivers—Kosasthalaiyar, Cooum, and Adyar—as well as five significant wetlands, including Pallikaraini Marsh, Pulicat Lake, Kattupalli Island, Madhavaram and Manali Jheels, and the Adyar Estuary Creek. Additionally, the city is home to six forested regions that contribute to its ecological diversity. The city experiences a tropical climate, with peak temperatures reaching between 38°C and 42°C during the summer months of April to June. Maximum and minimum temperatures in Chennai are expected to increase by 2.9°C and 3.3°C, on average respectively, by the end of the century, indicating the potential for greater urban heat island risk.

On average, Chennai receives approximately 1,300 mm of rainfall annually. However, recent years have seen an increase in climate-related challenges, such as intense downpours over short periods leading to urban flooding and weakened monsoon patterns contributing to drought conditions. Chennai's annual rainfall is expected to decrease by 5% by 2050. These risks are expected to intensify with ongoing urban expansion and economic development, directly impacting urban heat island effect. An analysis of the city's greenhouse gas (GHG) emissions in 2018 revealed that energy consumption in the buildings sector contributed 71% to total emissions, mainly due to the reliance on thermal power for urban cooling, highlighting the need to incorporate heat resilience and energy efficient cooling into built infrastructure<sup>26</sup>. Chennai's per capita green cover of 8.75 sq.m. is also less than the WHO standards of 9.5 sq.m. per person, with reports suggesting that Chennai's vegetation declined by 22% over the last two decades<sup>27</sup>. Given its rapid urbanization and shrinking natural resources, it is imperative to analyze the ward-level vulnerability to Urban Heat Island Effect.

### 3.2. LULC Analysis

The LULC map for Greater Chennai Corporation (GCC) is shown in Figure 3, taken from data provided by TNSPC. A vast portion of the map is orange, depicting a majority of built-up area (Table 2). The continuous spread of built-up areas can also depict urban sprawl. Forests are majorly seen in the southern and central parts of the city, while agricultural lands are more scattered. Waste lands, which offer potential for urban greenery, are seen in the periphery of urban zones. The breakup of various categories and their total area is given below.

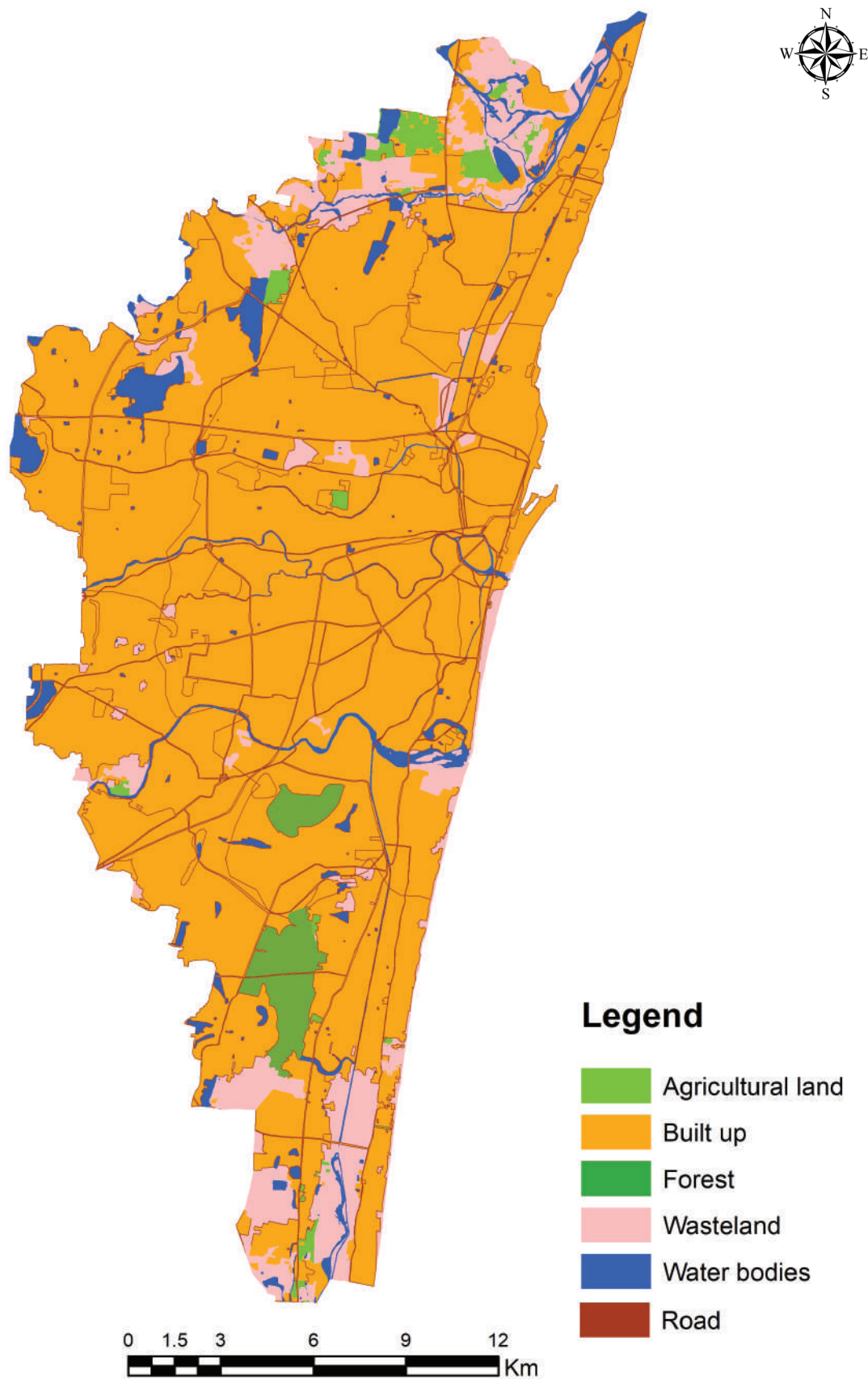
**Table 2: LULC breakup for GCC**

LULC category	Area (Ha)	Percentage
Agricultural land	609.2	1%
Built-up	35108.75	81%
Forest	1001.72	2%
Waste land	4365.72	10%
Water body	2309.6	5%
<b>Total</b>	<b>43394.99</b>	

26. C40 cities, 2023, Chennai Climate Action Plan, Accessed March 2025

27. The Nature Conservancy, 2019, Green print for Chennai – Integrating Natural Infrastructure in City Planning, Accessed March 2025

Figure 3: LULC map for GCC (2023)



### 3.3. NDVI Analysis

The minimum and maximum NDVI values for each ward were analyzed and spatially plotted to understand the distribution of vegetation in each ward for 2024 (Figure 4). The ward clusters with lowest and highest NDVIs along with the areas covered<sup>28</sup> are provided in Table 3.

**Table 3: Overview of wards and areas with low and high NDVI in GCC**

NDVI	Wards	Areas covered
Wards with predominantly very low NDVI (0-0.1)	Cluster 1: 54,55,56,57 Cluster 2: 73,76,77,78 Cluster 3: 62,63 Along the coast spanning wards 60, 114,116,120 and 125	Peddanaickenpet, Asirvada puram, Sowcarpet Purasaiwakkam, Choolai, Pattalam, Pulianthope, mount road Nochikuppam, Ayothikuppam
Wards with predominantly low NDVI (0.1-0.2)	Cluster 1: 64,65,66,67,68, Cluster 2: 79,80,81,82 Cluster 3: 160,161,162,163,164, 185,166,167, and 186	Kolathur, Perambur Oragadam, Ambattur, Kallikuppam Alandur, Pazhavanthangal, BV Nagar, Nanganallur
Wards with predominantly high NDVI (0.2-0.4)	Cluster 1: 16,17,18 Cluster 2: 197,199,200 Others: 172,158	Manali new town, Vaikkadu, Uthandi, Semmancheri, Adyar, Nandambakkam, St Thomas Mount
Wards having some areas with very high NDVI (0.4-0.55)	189,191	Pallikarnai marsh wetland

The NDVI map was compared with ward-level google satellite maps provided by the Greater Chennai Corporation to identify the possible causes resulting in high NDVI. For example, ward 58 has a higher NDVI than the nearby cluster (wards 54-57), possibly due to the presence of the My lady's garden park. Ward 189 was also found to have high NDVI, possibly due to the Pallikarnai marshland, which is one of the last remaining natural wetlands in Chennai, home to 625 species of plants and animals<sup>29</sup>. Ward 174 also had high NDVI, which can be attributed to its proximity to the Besant Nagar beach and the presence of large swathes of green areas such as the Besant gardens and Theosophical society.

**Areas with low NDVI also had the least number of parks per sqkm. For example, wards 54,56 and 57 had 1 park and ward 55 had no parks in place. Whereas ward 58, with a higher NDVI had 6 parks per sqkm.**

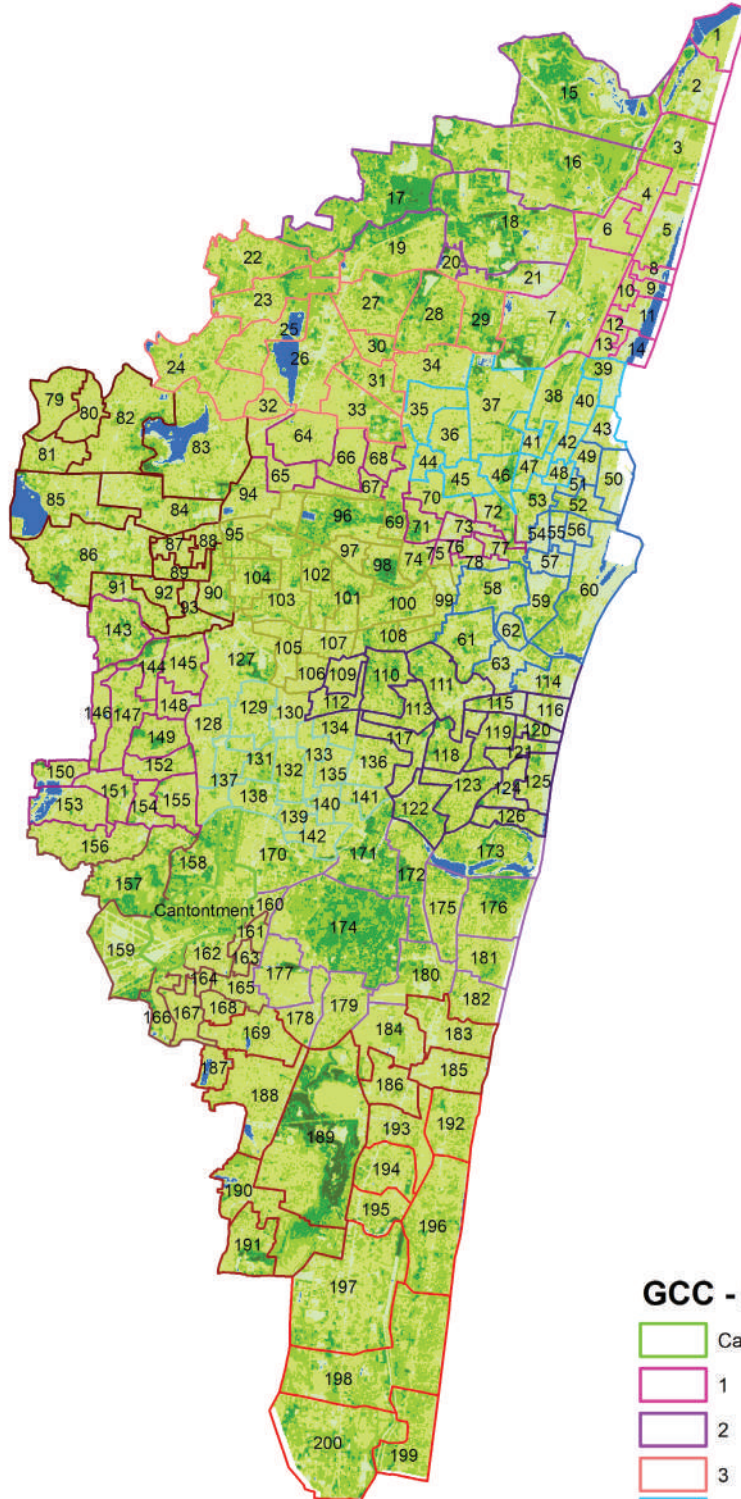
**Taking assumptions of a park size of 5 ha, as per the WHO guidelines of 9 sqm green space per person, a city should roughly have atleast 3-4 parks per sqkm.**

**Low-income areas were found to have low NDVI:** Areas near the Marina beach, housing slum households such as Nochikuppam and Ayothikuppam were found low NDVIs, indicating the need to increase accessible green spaces in low-income areas, who remain the most vulnerable.

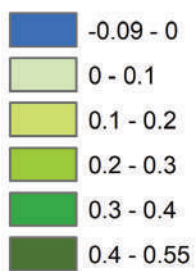
28. Areas were identified from the ward level maps provided by GCC website

29. Tamil Nadu Wetlands Mission, The Pallikarnai Marsh, Accessed March 2025

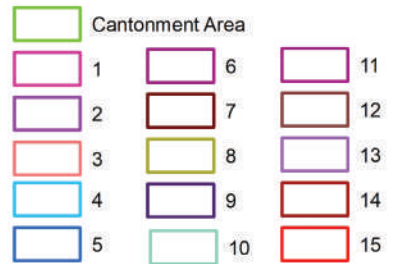
**Figure 4: NDVI map for Greater Chennai Corporation, 2024**



**Legend**



**GCC - Zone**



### 3.4. NDBI analysis

The minimum and maximum NDBI values for each ward were analyzed and spatially plotted to understand the distribution of built-up area in each ward (Figure 5). The ward clusters with the highest NDBI along with the areas covered<sup>30</sup> are provided in the table 4. A comparison of the NDVI and NDBI maps showed that some of the wards with the lowest NDVI also had the highest NDBI, signifying a correlation between low vegetation and high built-up area.

**Table 4: Overview of wards and areas with high NDBI in GCC**

NDBI	Wards	Areas covered
<b>Wards with predominantly high NDBI (0.02-0.12)</b>	Cluster 1: 54,55,56,57 Cluster 2: 73,76,77,78 Cluster 3: 62,63	Peddanaickenpet, Asirvada puram, Sowcarpet Purasaiwakkam, Choolai, Pattalam, Pulianthope, mount road, Nochikuppam, Ayothikuppam
	Along the coast spanning wards 60,114, 116,120 and 125	Nochikuppam, Ayothikuppam
	Certain areas of ward 37	Kodungaiyur
	Certain areas of ward 103	Anna nagar
	Certain areas of ward 127	Koyembedu
	Certain areas of ward 189	Pallikarnai
	Certain areas of ward 159	Meenambakkam

The NDBI analysis showed clearly high NDBI values in certain clusters, while certain wards had small pockets with high NDBI values. The locations of these high NDBI pockets were compared with the ward maps from the GCC's website to identify the possible causes for the same, given in the table below. **High NDBI areas included areas with dump yards, markets, and the airport.**

**Table 5: Possible causes of high NDBI in identified ward pockets**

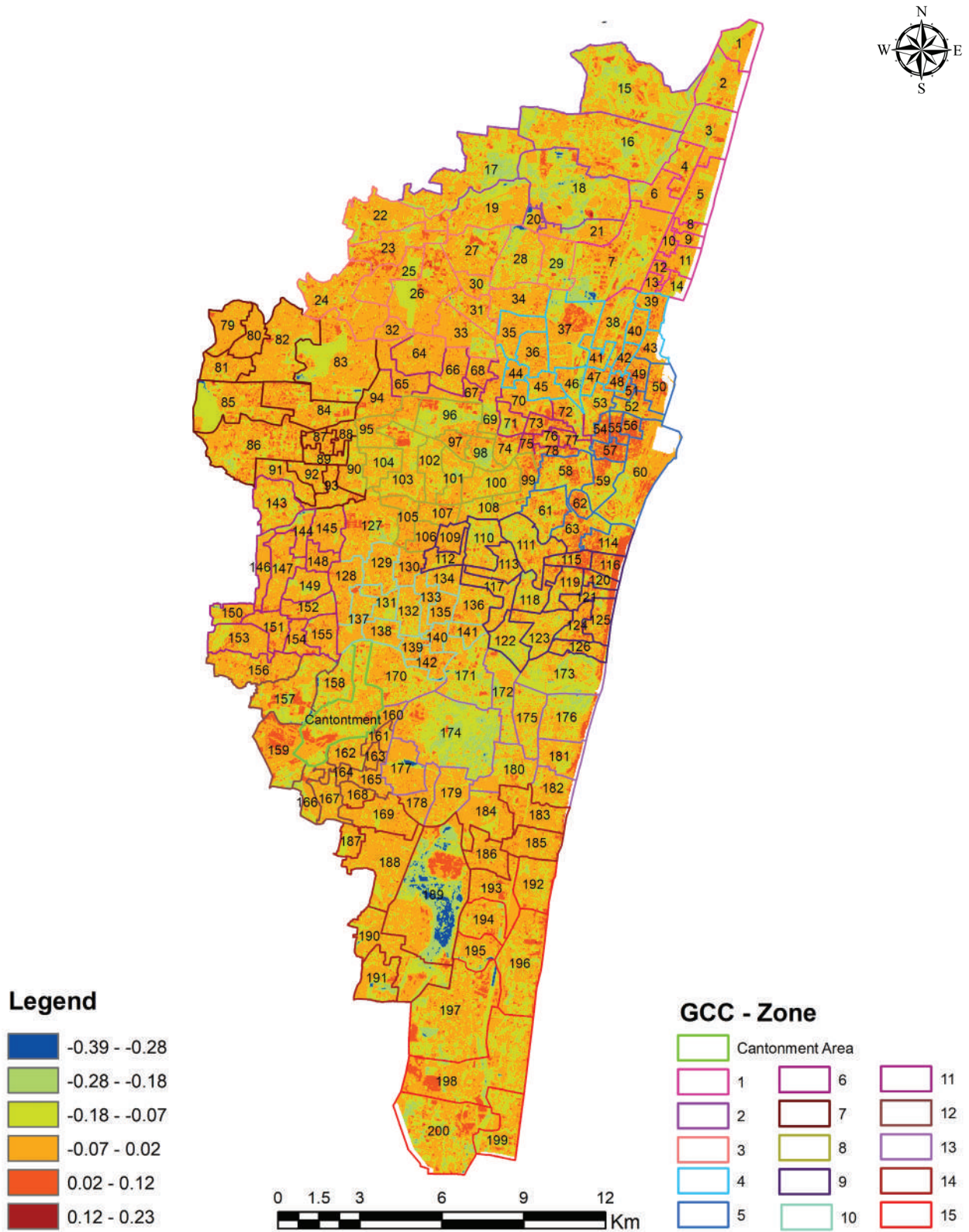
Areas with high NDBI	Possible Identified causes
<b>Certain areas of ward 37</b>	Kodungaiyur dump yard
<b>Certain areas of ward 127</b>	Koyembedu market
<b>Certain areas of ward 189</b>	Perungudi dumpyard and waste disposal site
<b>Certain areas of ward 159</b>	Chennai International and Domestic airport
<b>Certain areas of ward 103</b>	Integral Coach Factory LHB manufacturing unit

### 3.5. LST Analysis

The Land Surface Temperature analysis was carried out for 2 years (2016 and 2024) to understand the changes in LST over the period. A ward-level analysis of changes in LST can help pinpoint LST hotspots where interventions like cool roofs, urban greening, or reflective pavements are most needed. Table 6 highlights the wards and areas with the highest LSTs, along with the possible causes, identified through a comparison with google satellite maps provided on the corporation website.

30. Areas were identified from the ward level maps provided by GCC website

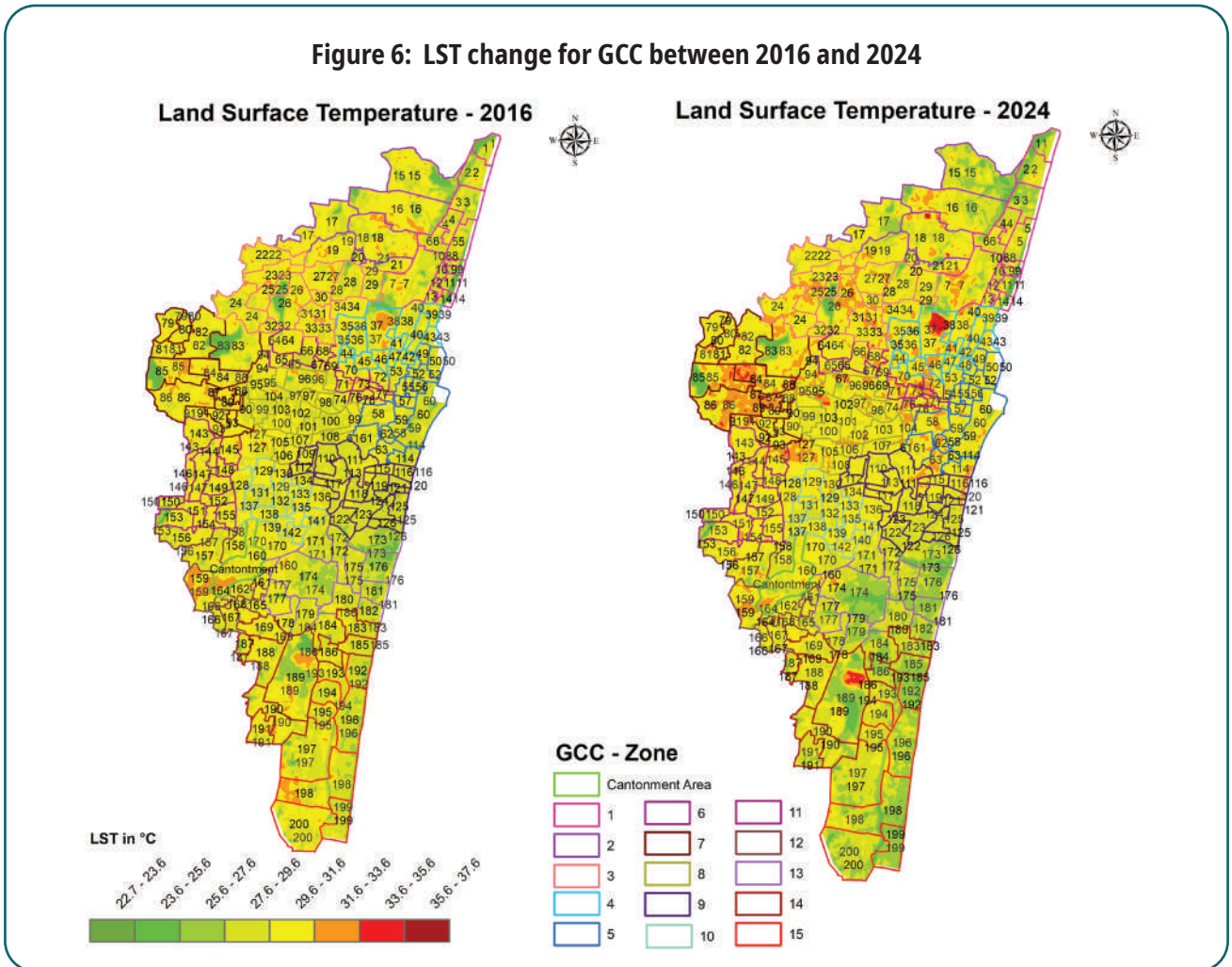
Figure 5: NDBI map for Greater Chennai Corporation, 2024



**Table 6: Wards and areas with high LSTs in 2024 with possible causes**

High LST ranges	Wards	Areas	Possible causes
<b>LST between 31.6°C - 33.6 °C</b>	Cluster 1: 84,85,86,87	Pattavakkam, ramapuram, Athipet	Ward 86- Ambattur Industrial Estate
	Cluster 2: 145,127	Koyembedu	Ward 127- Koyembedu market, CMBT bus stand
	Ward 159	Meenambakam	Ward 159- Chennai international airport
<b>LST 33.6°C - 35.6°C</b>	Parts of wards 84,189,37 and 103	Pattavakkam, Pallikarnai, Kodungaiyur Koyembedu	Ward 84- MSME cluster Ward 189- Perungudi dumpyard and waste disposal site Ward 37- Kodungaiyur dump yard Ward 103- Integral Coach Factory LHB manufacturing unit
<b>LST between 35.6°C - 37.6°C</b>	Parts of wards 37 and 18	Kodungaiyur Manali	Ward 37- Kodungaiyur dump yard Ward 18- Manali factories (International Steel Processors, Shipping container freight station, petrochemicals)

**Figure 6: LST change for GCC between 2016 and 2024**



Several wards show a clear increase in LST between 2016 and 2024, possibly due to industrial and urban growth and decrease in green cover.

**Wards with MSME clusters showed an increase in LST:** For example, the maximum LST increased from 32.5°C to 35.1°C in ward 84 and from 33.4°C to 35°C in Ward 86 between 2016 and 2024. These wards comprise of several MSME clusters, notably the Ambattur Industrial Estate. The number of MSME units in the Ambattur Industrial Estate has grown by approximately 2000 units in 2014<sup>31</sup> to over 2400 major units and 20,000 smaller units in 2020. This growth can be a contributing factor to the increase in LST in these wards.

**Wards with markets and bus terminals marked an increase in LST:** Similarly, an increase in LST was observed in ward 127, with maximum LST increasing from 32.37°C to 34.37°C. A possible cause for this can be the increase in activity within the Koyambedu market and the Chennai Mofussil Bus Terminal (CMBT).

**Wards with dump yards showed an increase in LST:** The areas around the Kodungaiyur dump yard in ward 37 and the Perungudi landfill in Ward 189 also see an increase in LST, with the maximum LST increasing from 33.32°C to 36.33°C in Ward 37 and from 33.16°C to 35.09°C in Ward 189 between 2016 and 2024. The dumpsites have a legacy waste of almost 94 cu.mt. (64 lakh cu. mt. in Kodungaiyur, and 30 lakhs cu.mt in Perungudi), with 80% of new waste generated still being dumped<sup>32</sup>.

Certain wards have shown a **decrease in LST by 1-2°C** in the same period, denoting lower temperatures, possibly due to interventions such as urban greening and water body restoration. These include the following wards 180,183,184,185,192,193,197,198,199 and 200.

### 3.6. UHI Analysis

A distribution of heat island effect in the form of extremely low, low, medium, high and extremely high heat zones was mapped for GCC based on the LST analysis. The wards falling under high heat and extremely high heat zones are given in the table below. 68 wards lie in the high heat zone while 12 wards have some areas under extremely high heat zones.

**Table 7: Wards in GCC falling under high heat and extremely high heat zones**

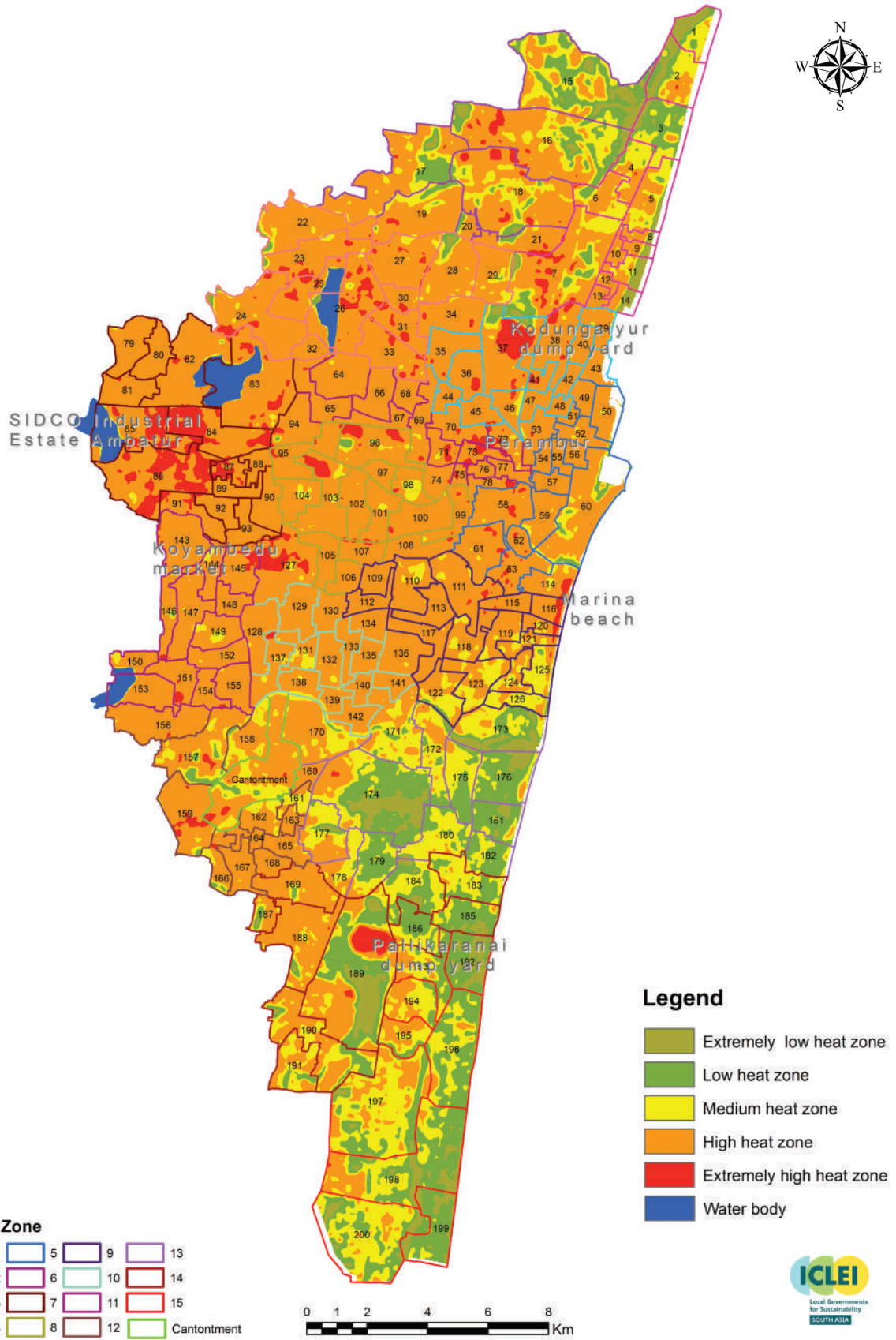
UHI Zone	Ward
High heat zone	16,18,19,21,7,23,24,25,26,27,30,31,33,34,35,36,37,41,46,53,58,61,62,63,70,71,72,73,74,75,78,81,82,83,84,85,86,87,91,95,96,98,99,100,101,102,103,107,108,111,114,115,118,120,125,127,137,145,146,151,154,156,157,159,166,174,189,198
Wards having some Extremely high heat zones	37,84,85,86,127,189,159,60,114,116,120,125

Amongst these wards, high heat zone areas were found in wards 37 (surrounding the Kodungaiyur dump yard), 84,85,86 (Ambattur industrial estate areas), 127 ( Koyembedu market), 159 (airport), 189 (Near Perungudi dumpyard) and slum areas along the coast spanning wards 60,114,116,120 and 125, in line with the LST analysis.

31. Firdouse Rahman Khan 2013, Growth, Genesis and Profile of Industrial Estates of Chennai, Accessed March 2025

32. C40 cities, 2023, Chennai Climate Action Plan, Accessed March 2025

Figure 7: UHI map for GCC (2024)



### 3.7. Ward-Level Heat Risk Index for Greater Chennai Corporation

The heat risk assessment for GCC has been carried out at the ward level using a composite index based on three components: Hazard, Exposure, and Vulnerability. The resulting Heat Risk Index (HRI) helps identify areas most at risk from extreme heat events and supports the prioritization of resilience-building interventions.

#### 3.7.1. Hazard

The wards were spatially mapped based on whether the potential of the hazard (high LST) was very low, low, medium, high or very high, to help identify wards with high LST. As per the hazard map, the northern and central parts of the city exhibit a higher heat hazard, particularly wards such as 22–28,64–66, 83–86, and parts of 159–164. These areas correspond to dense urbanized zones with high impervious surface cover, limited vegetation, and urban heat island effects. Conversely, southern and coastal wards, including 1–6, 189–200, show relatively lower hazard levels.

**Table 8: Different hazard categories of wards for GCC (2024)**

Risk of hazard	Ward numbers
<b>Very Low</b>	1,3,173,176,181,185,192,174,199
<b>Low</b>	2,15,9,11,14,175,180,182,183,184,179,189,186,193,196,197,198,200
<b>Medium</b>	16,17,4,5,6,7,10,12,28,121,122,123,124,125,126,171,172,158,157,150,153,161,162,163,165,177,178,169,187,188,190,191,194,195
<b>High</b>	18,19,20,21,29,34,30,27,22,23,25,26,24,82,79,83,85,66,13,39,40,42,49,51,52,53,59,60,114,116,119,118,61,111,113,117,136,141,140,142,139,138,132,131,129,128,149,151,152,154,155,156,143,144,146,147
<b>Very High</b>	80,81,84,86,32,64,65,94,95,87,89,92,93,145,148,127,105,107,106,130,107,97,31,33,35,36,37,68,67,69,44,45,79,71,72,73,75,78,99,58,62,63,115,159,

Amongst the wards with a very high potential of being impacted by the hazard (high LST), wards 37,84,86,127 also fall under extremely high heat zones, based on the UHI mapping analysis, highlighting the need to prioritize urgent cooling measures in these wards to reduce UHI.

#### 3.7.2. Exposure

A spatial mapping of wards based on exposure revealed that wards 12,13,44,67,32,97,75,76,78,54,55,56,51,41,42,47,49,116,120,139,140,163 and 168 fall into the highest exposure category, attributed to their higher population and built-up densities.

**Table 9: Different exposure categories of wards in GCC (2024)**

Exposure	Ward numbers
<b>Very low</b>	1,2,3,5,15,16,18,11,17,27,28,25,26,23,17,17,83,85,86,96,60,111,171,174,172,158,157,159,189,188,190,191,197,198,200,199
<b>Low</b>	4,6,29,34,37,38,79,81,82,84,33,64,102,103,101,100,58,61,59,145,144,147,151,153,156,110,113,117,114,122,123,173,176,181,182,189,184,186,185,192,196,194,195,179,178,177,169,165,162,167,166,187,169

Exposure	Ward numbers
Medium	8,9,11,14,39,66,65,95,94,104,88,89,87,81,92,93,148,128,137,131,132,133,134,135,136,175,126,125,50,52,53,72,70,71,74,98
High	10, 35, 36, 45, 68, 40, 43, 62, 115, 124,141,142,154,150,146,80,175,164
Very high	12,13,44,67,32,97,75,76,78,54,55,56,51,41,42,47,49,116,120,139,140,163,168

Amongst these, wards 44,67,75,78 also scored very high in the hazard category, indicating high LST and high built-up areas.

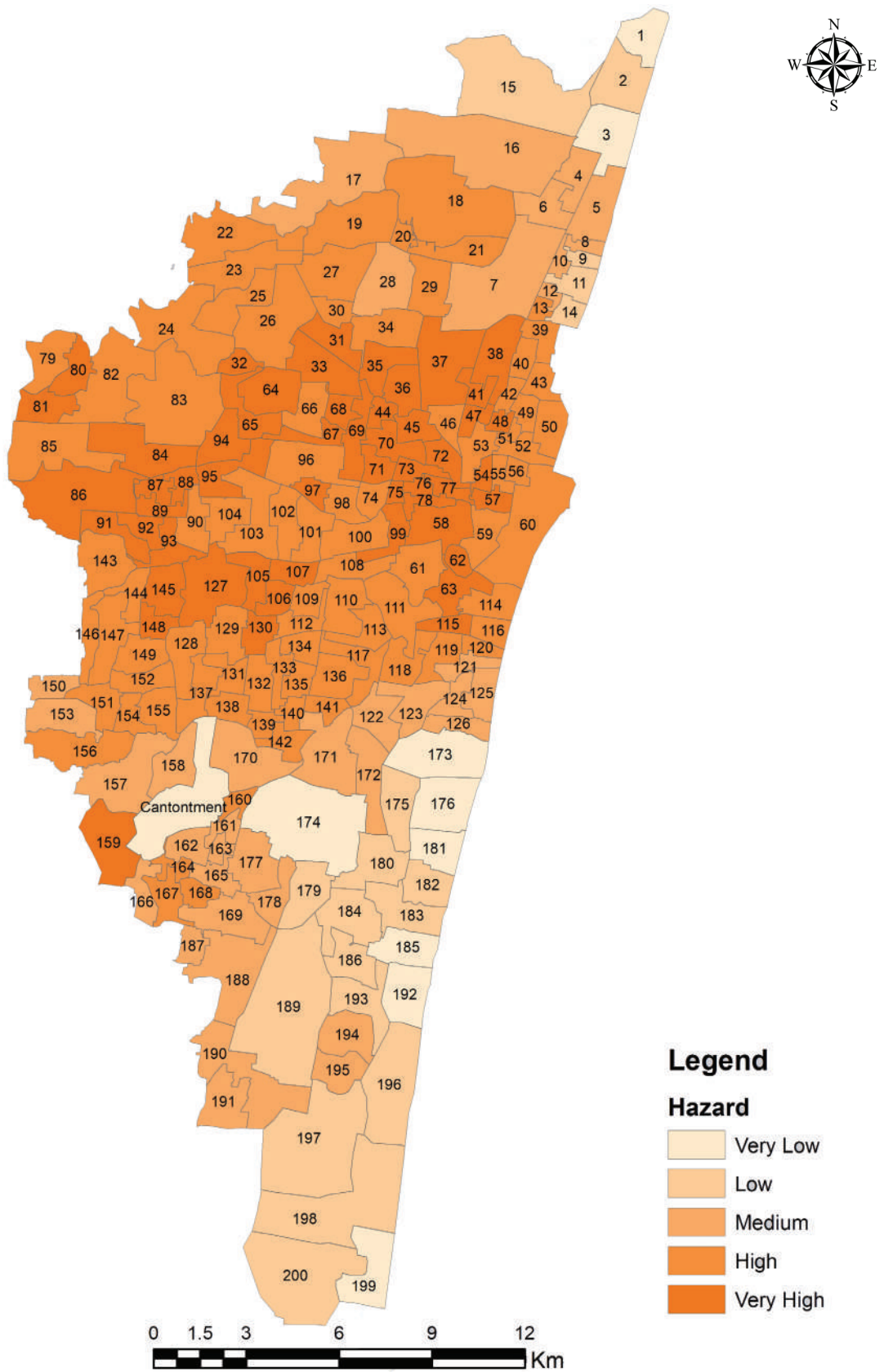
### 3.7.3. Vulnerability

14 wards were found to have very high vulnerability, possessing lower adaptive capacity. These wards are particularly vulnerable due to a higher number of slum populations, inadequate road infrastructure, less NDVI, less parks, and limited medical facilities, culminating in a significant reduction in their adaptive potential. The extremely low vulnerability wards are 120 and 175. These wards exhibit a strong adaptive capacity.

**Table 10: Different vulnerability categories of wards in GCC (2024)**

Vulnerability	Ward Numbers
Very Low	120,175
Low	28,53,77,76,89,90,91,149,131,132,139,112,113,118,119,123,122,126,173,176,180,171,174,179,131,132,139,180
Medium	5,11,39,40,42,43,41,48,19,46,47,51,52,55,20,29,34,31,33,35,36,44,45,79,80,81,82,85,83,84,64,65,66,68,70,71,74,75,96,97,98,100,99,101,102,103,92,93,143,144,147,146,152,153,155,158,128,127,129,130,137,138,158,170,177,169,167,187,189,190,185,190,191,185,115,116,121,124,125,109,110,111,134,133,135,136,140,142
High	1,2,3,4,6,7,37,38,12,13,14,8,9,10,59,63,15,16,17,18,19,25,26,27,30,94,104,145,148,86,150,151,154,156,157,161,162,164,164,166,168,72,73,78,54,56,59,63,105,107,106,108,141,181,184,186,192,196,197,195,188
Very High	21,22,23,57,60,114,159,172,183,193,194,199,198,200

Figure 8: Hazard map for GCC (2024)



**Figure 9: Exposure map for GCC (2024)**

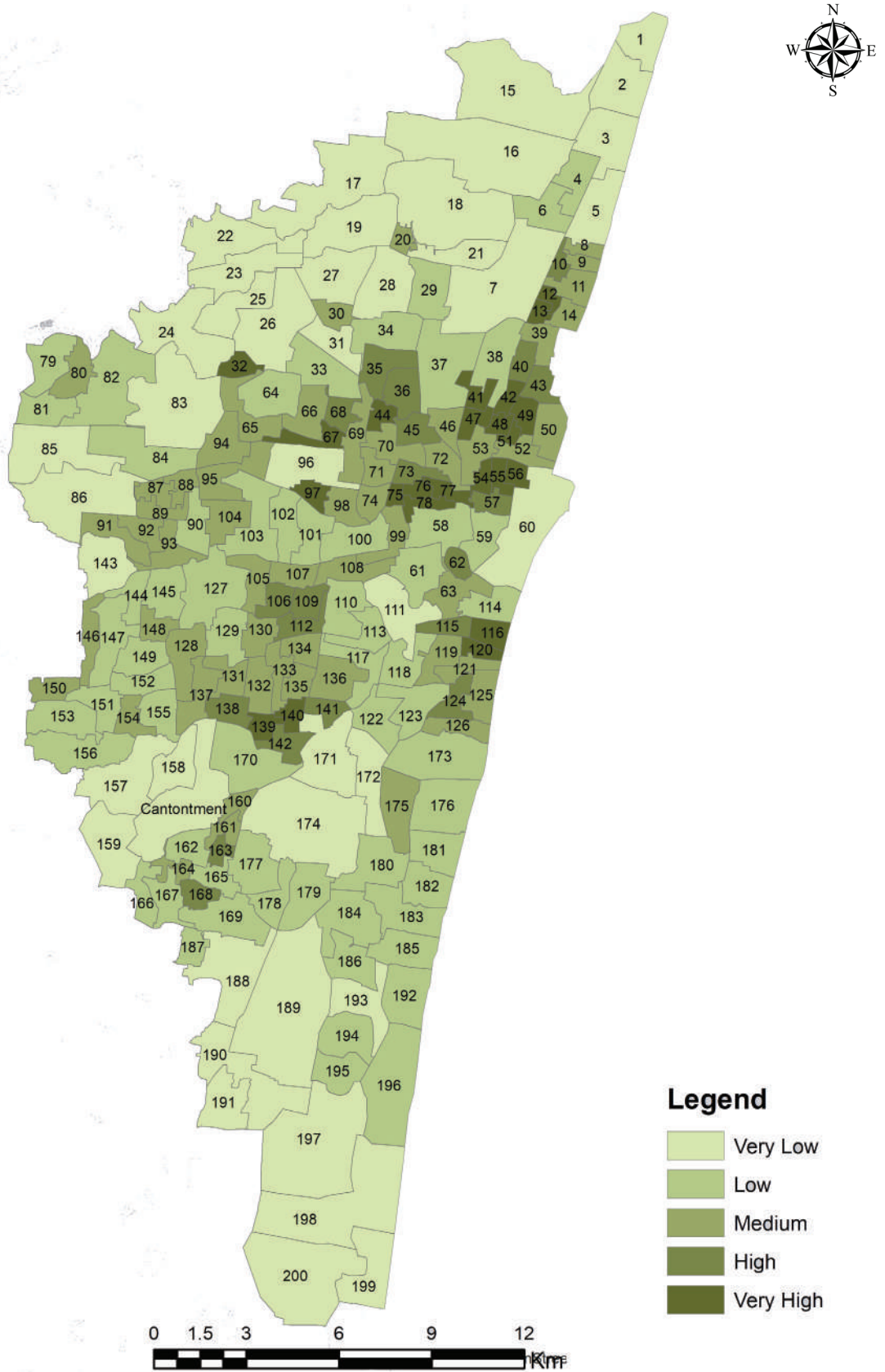
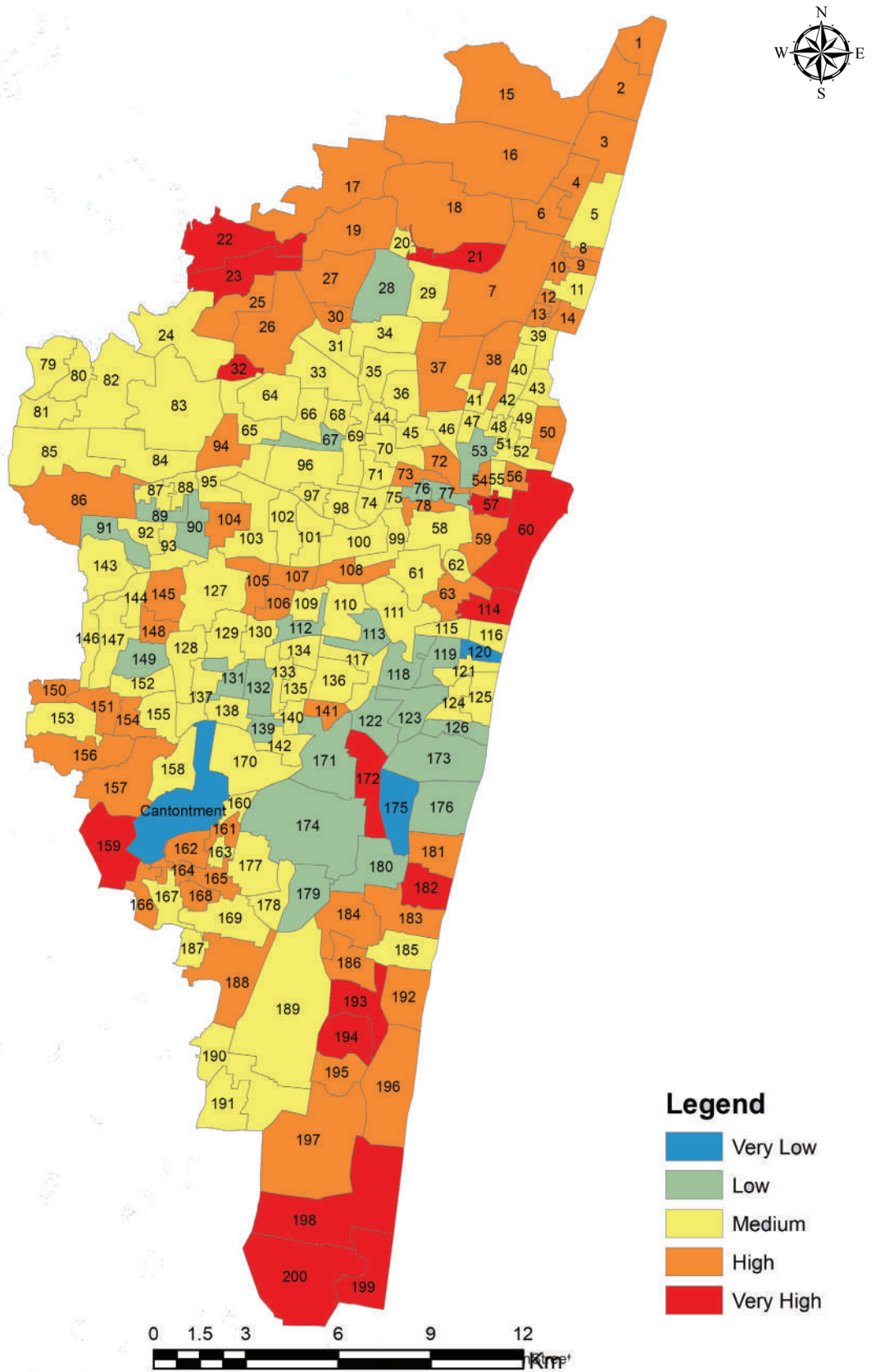


Figure 10: Vulnerability map for GCC (2024)



### 3.7.4. Heat risk index

Equal weightages were used for each of three components (i.e. hazard, exposure, and vulnerability), to provide an overall heat risk score for each ward, to estimate wards that have very high risk of being impacted by UHI.

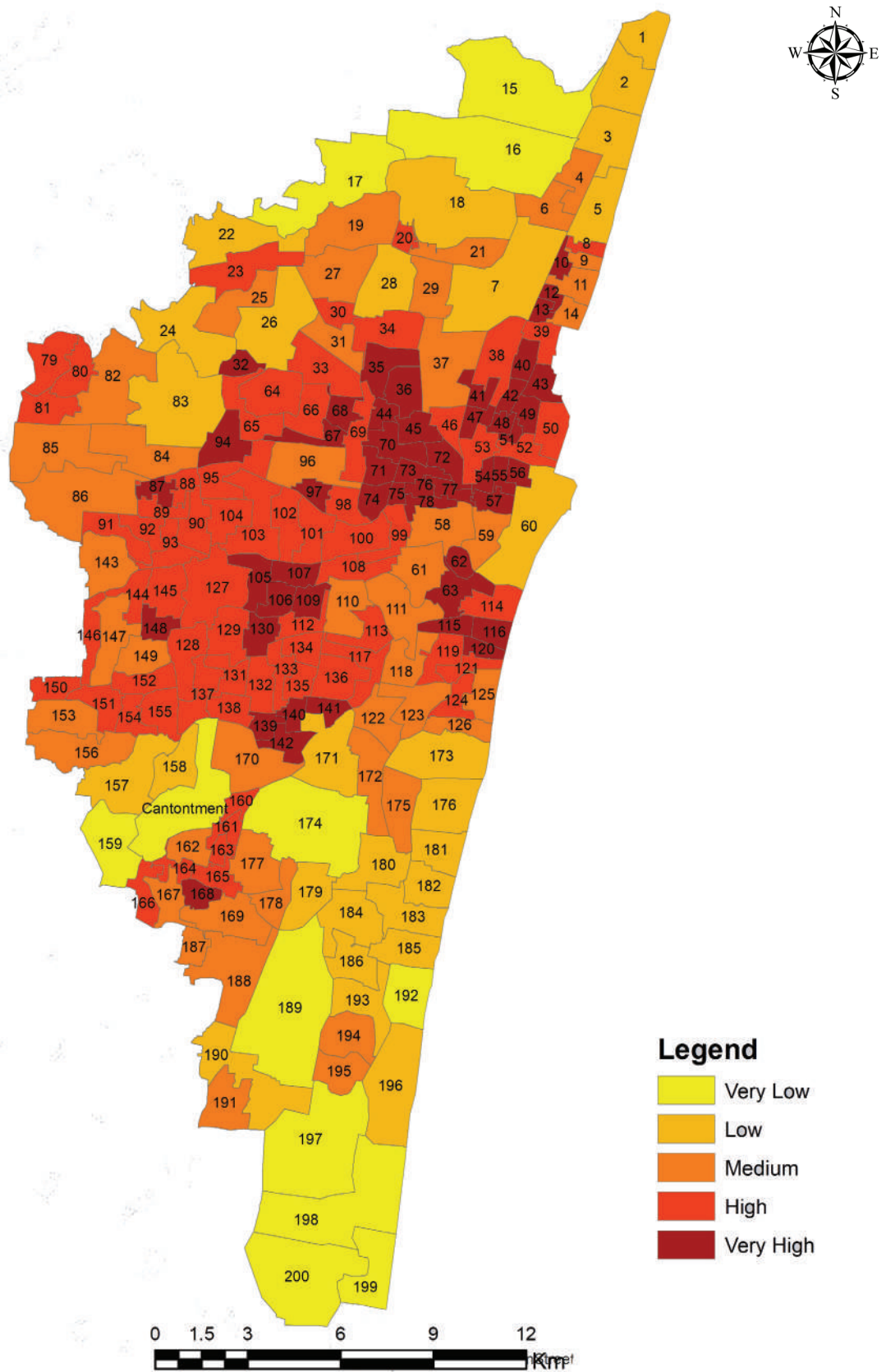
**25% of the wards (50 wards) had a very high heat risk index. These wards accounted for 30% of GCC's total population and covered 12% of the total city area.**

**Table 11: Different heat risk categories of wards in GCC (2024)**

Heat Risk Index	Ward Numbers
Very Low	197,16,200,189,174,198,17,199,15,159,192
Low	186,28,5,60,182,180,184,26,179,183,193,196,190,22,171,24,83,185,158,157,7,173,181,2,176,18,1,3
Medium	9,84,194,125,162,37,126,58,147,167,82,61,6,187,59,110,178,156,149,31,86,4,118,123,177,25,29,153,195,111,169,143,19,96,27,122,170,21,14,188,85,172,175,191,11
High	88,99,65,112,46,39,69,108,66,154,30,138,163,128,136,80,164, 92,134,53,146,137,52,133,95,104,114,38,124,8,121,89,93,131,160,150,50,98,135,91,144,64,79,81,129,101,34,151,145,155,20, 102,103,152,161,165,23,127,166,113,119,90,117,100,132,33
Very High	75,32,51,44,54,76,55,78,57,48,56,73,42,97,77,106,47,45,41,12,116,13,105,49,62,68,140,115,141,35,109,36,87,43,130,142,168,72,67,40,139,148,94,63,71,107,10,70,74,120



Figure 11: Ward-level heat risk assessment for GCC (2024)

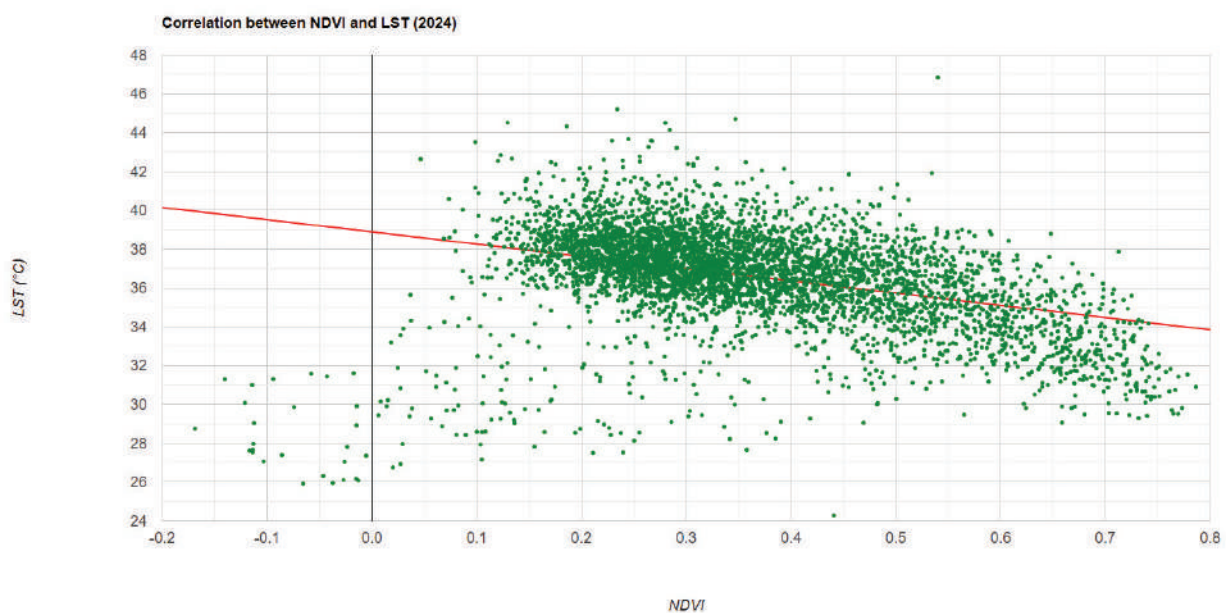


### 3.8. Correlation Analysis between NDVI, NDBI and LST

#### 3.8.1. Correlation Analysis between LST and NDVI

Understanding the relationship between NDVI and LST is crucial for effective urban planning and the development of heat action plans. The scatter plot for Chennai reveals a clear negative correlation between LST and NDVI, indicating that increased vegetation cover is associated with lower land surface temperatures, highlighting the cooling effect of vegetation. The downward-sloping red trendline visually reinforces this inverse relationship. While a general trend exists, the spread of data points suggests that factors beyond vegetation density also influence LST.

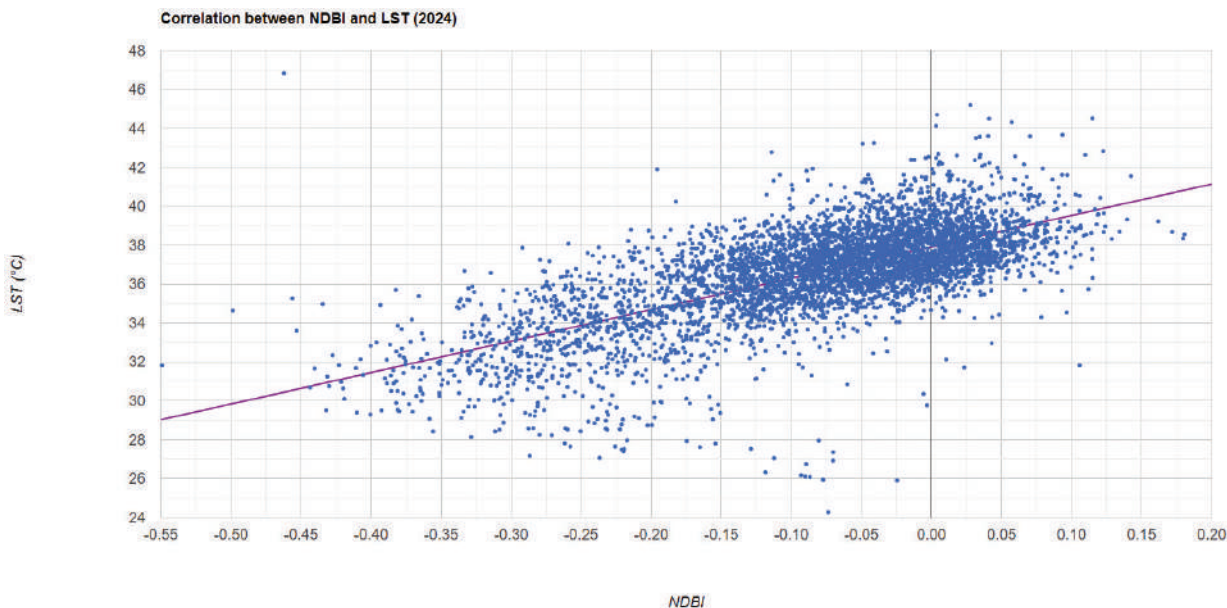
**Figure 12: Correlation between LST and NDVI for Chennai**



#### 3.8.2. Correlation Analysis between LST and NDBI

The relationship between NDBI (Normalized Difference Built-up Index) and LST (Land Surface Temperature) is crucial for urban planning and sustainable development. It helps mitigate the UHI effect by informing strategies to increase green spaces and reduce temperatures in built-up areas. The scatter plot reveals a positive correlation between NDBI and LST, indicating that increased built-up areas are associated with higher surface temperatures, supporting the urban heat island effect. The equation  $LST = 17.211 * NDBI + 38.051$  quantifies this relationship, suggesting LST rises with built-up density. While a trend exists, data scatter implies other factors influence LST. Overall, urbanization's thermal impact is evident.

**Figure 13: Correlation analysis between NDBI and LST for Chennai**



### 3.9. Ward Level Urban Cooling Interventions

Based on the above analysis, urban cooling recommendations for certain very high-risk wards in the city are provided in the table below.

**Table 12: Ward level urban cooling interventions for very high risk wards in Chennai**

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Cool roofs (white/reflective, green or modular roofs)</b>	Built infrastructure	73,75,44	Highest LST values (>31°C) very low NDVI (~0.12) indicating minimal vegetation and dense built-up. These wards also have high population density and a concentration of slum/low-income settlements. Cool roofs should be prioritized in low-income wards and integrated into building codes
<b>Street Tree Plantation, micro forests and green corridors</b>	Nature based	54,55,56,57	These wards have very low NDVI (0.1) and high LST (~31.0°C). Wards 54–57,73, and 75 are also known for high slum concentrations, especially along riverbanks and canals. Increasing green cover will directly benefit slum communities, who remain highly vulnerable to urban heat.
<b>Pocket parks and community gardens</b>	Nature based	32,44,54,56,55,57,76,78	These high-density wards have low NDVI and limited open space. Wards 44,54–57, and 32 are documented to have large, notified slum populations. The number of parks per sq km in these wards is significantly below the city average (<1 park per sq km, compared to the city average of about 1.5 parks per sq km).

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Bioswales, Rain Gardens, Waterbody Restoration</b>	Nature based	32,44,76,78	These wards have high LST, low NDVI, and water stress. They are also located near the Buckingham canal and face frequent waterlogging and have slum settlements along the riverbanks. Integrating rain gardens and restoring the canal edges will help mitigate both heat and flood risk for these vulnerable populations.
<b>High-Albedo/ Reflective Pavements</b>	Built infrastructure	54,55,56,57 and 73	These wards comprise of commercial areas (Example ward 54- Sowcarpet) with high pedestrian footfall. Cool pavements can be piloted in these wards.
<b>Vertical gardens/ green walls</b>	Nature based and built infrastructure	32,44,76,78	These are highly built-up, space-constrained wards with high slum density. Vertical gardens can be incorporated into building retrofits and new urban developments.
<b>Heat shelters and shading (bus stops, markets, schools, etc)</b>	Built infrastructure	44,48,52,55, 73,75	These wards combined include 45 schools, 11 markets and 35 bus stops, highlighting the need for shading structures in public spaces to improve thermal comfort of commuters, pedestrians and children.
<b>Cooling interventions for MSMEs</b>	Built infrastructure	32,44,48,51,54, 56,57,63,73,75, 104,109,105, 130,168	These wards have several MSMEs particularly in the auto components, garments and food processing sectors. Interventions such as cool roofs, landscaping, energy efficient cooling appliances and solar rooftops, reflective pavements and support for Energy Conservation Building Code (ECBC) ratings can be provided.



Photo by Adityan Ramkumar on Unsplash

## 4. Case study: Coimbatore City Municipal Corporation

### 4.1. Study Area

The city of Coimbatore is nestled along the banks of the River Noyyal and encircled by the majestic Western Ghats. As part of this globally recognized biodiversity hotspot, Coimbatore is home to a diverse array of natural ecosystems that support rich and varied flora and fauna. The city features 28 wetlands, primarily sustained by the River Noyyal, serving as vital ecological assets. Notable among these are Singanallur Lake, Selvachinthamani Lake, Ukkadam Lake, and Perur Lake, which contribute significantly to the region's biodiversity, water security, and ecological balance<sup>33</sup>.

Coimbatore, celebrated for its thriving textile industry and rich natural heritage, has emerged as a prominent urban center in Tamil Nadu. With a growing population of 2.3 million as of 2021, the city is a significant economic driver, underpinned by a robust and diversified industrial landscape that includes textiles, engineering, information technology, and manufacturing. The city contributed towards 4 million TCO<sub>2</sub>e of GHG emissions in 2021-22, with residential, commercial and institutional buildings contributing to 37% of emissions mainly due to electricity consumption contributing to 26% of emissions, mainly due to electricity consumption.

However, the city faces several challenges due to rapid urbanization and insufficient resources to cater to the growing population. As per IMD data from 1981 to 2022, the city's annual average air temperature has been rising by 0.014°C per decade while its annual rainfall has decreased from 1,025 mm in 1981 to 1,022 mm in 2022. Coimbatore's net-zero climate action plan, 2024 also highlighted a predicted increase in maximum temperature (1.3°C to 3.1°C) and minimum temperature (1.2°C to 3.3°C) by the end of the century. Blessed with rich green cover, well over WHO's limit of 9 sqm per person, it is important to understand the role of blue-green and built infrastructure in shaping Coimbatore's urban heat resilience.

### 4.2. LULC Analysis

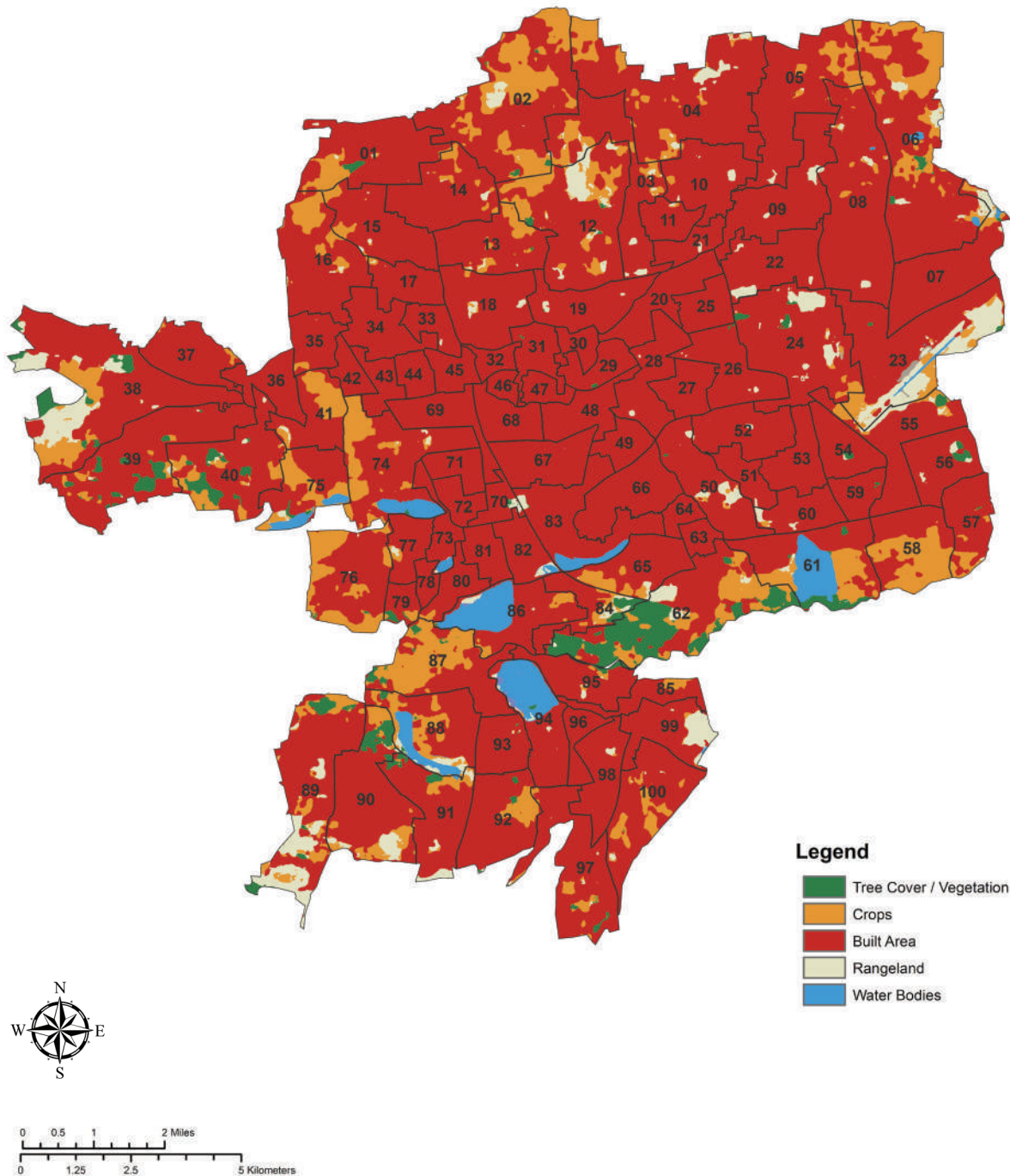
The Land Use Land Cover Analysis for Coimbatore City Municipal Corporation (CCMC) highlighted that 81% of the city area constituted built-up area, 2% water bodies, 2% tree cover and 11% crops. A vast portion of the land-use consists of built-up areas (Table 13 and Figure 14). Crop land and water bodies are seen in the southeast periphery (wards 61 and 58). The breakup of various categories and their total area is given below.

**Table 13: LULC breakup for Coimbatore City Municipal Corporation (2024)**

LULC category	Area (Sq. km.)	Percentage
Water body	5.24	2%
Built up	210.15	81%
Crops	28.13	11%
Tree cover	6.15	2%
Rangeland	9.39	4%
<b>Total</b>	<b>259.06</b>	

33. ICLEI South Asia 2024, Coimbatore Climate Resilient City Action Plan, Accessed March 2025

**Figure 14: LULC map for Coimbatore city (2024)**



### 4.3. NDVI Analysis

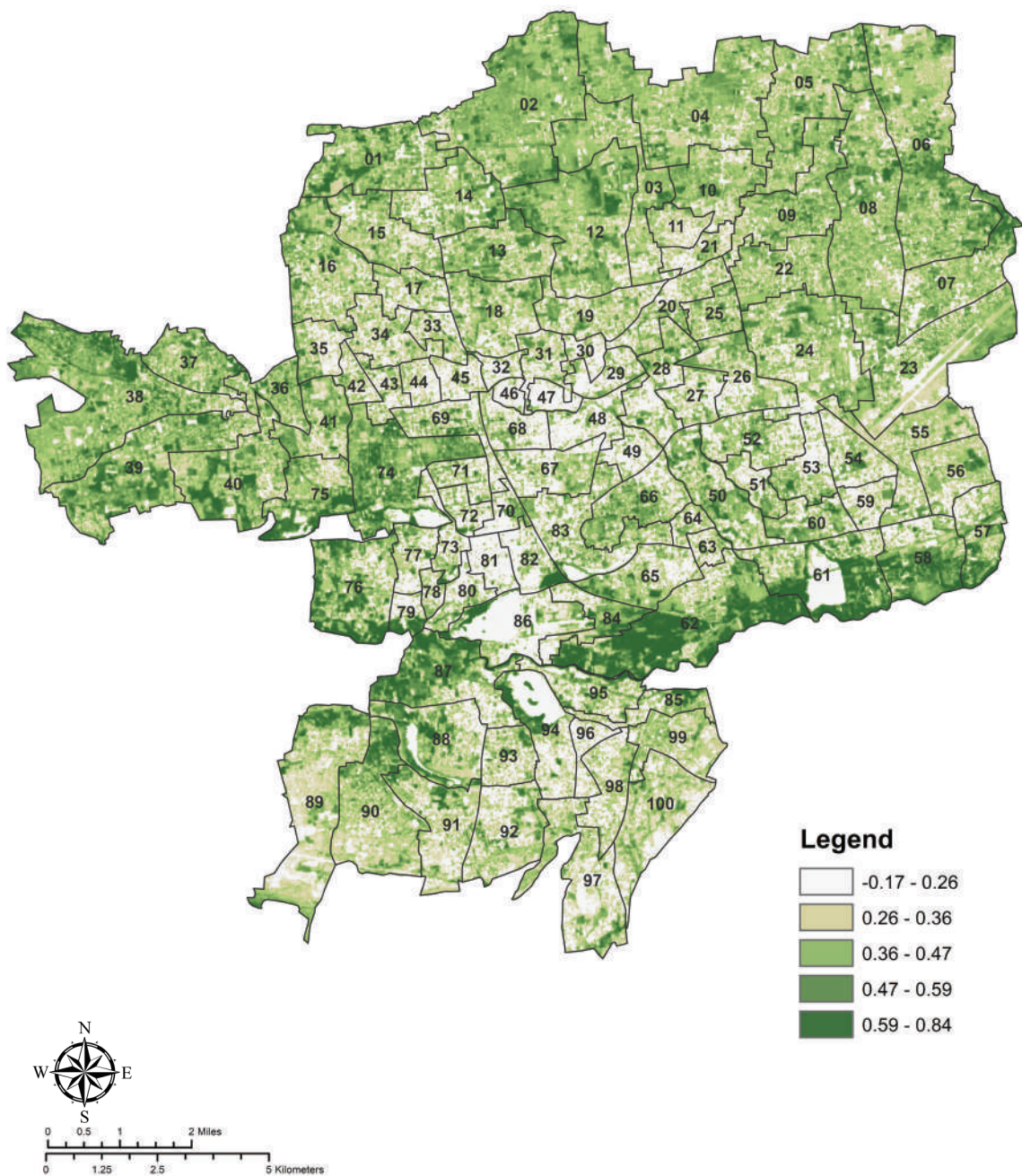
The minimum and maximum NDVI values for each ward were analyzed and spatially plotted to understand the distribution of vegetation in each ward for 2024 (Figure 15). The ward clusters with lowest and highest NDVIs along with the areas covered<sup>34</sup> are provided in Table 14.

34. Areas were identified from the ward level google satellite maps provided by Coimbatore City Municipal Corporation website

**Table 14: Overview of wards and areas with low and high NDVI in CCMC**

NDVI	Wards	Areas covered
Wards with predominantly low NDVI (0.1-0.2)	Cluster 1: 81,86 Cluster 2: 94,96 Cluster 3: 46,47	Aathuppalam, Karumbukadai, Townhall Sundharapuram, Machampalayam Rathinapuri
Wards with predominantly high NDVI (0.4-0.5)	Cluster 1: 74,76 Cluster 2: 38,39 Others: 40,58,87,62	Telungupalyam, Poosaripalayam, Vadavalli, Veerakeralam, Nanjundapuram, Saamedu, Nantha Nagar, Singanallur Sunnambu Kaalvai

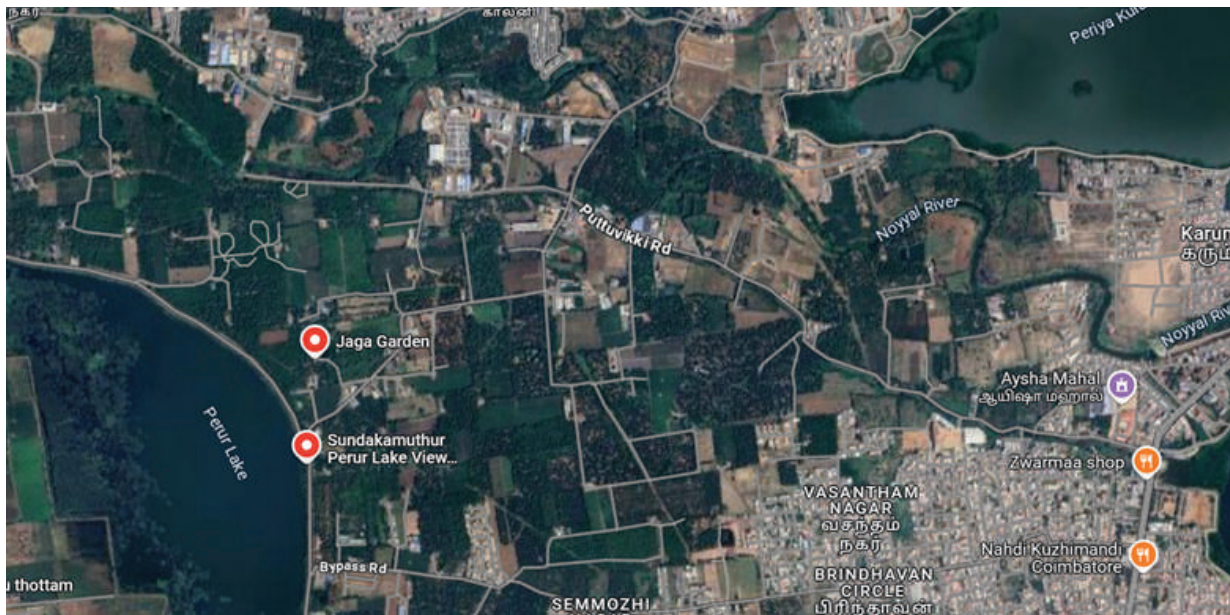
**Figure 15: NDVI map for Coimbatore city (2024)**



The NDVI maps were compared with ward level google satellite maps provided by the CCMC along with google earth maps, to identify possible causes for high NDVI. For example, ward 87 has a high NDVI due to the presence of dense farms, adjacent to the Sundakamuthur Perur Lake. The portion of ward 38 with high NDVI is possibly due to the presence of vegetation in Bharathiyar University. The university is regarded as a green campus, home to 335 species of flora and fauna<sup>35</sup>.

Moreover, some of the wards with low NDVI were also found to have negligible parks. For example, wards 86 and 94 had only 1 park each, highlighting the need to expand accessible green spaces in these wards.

**Figure 16: Aerial view of farmlands and gardens in Ward 87 (Google maps)**



#### 4.4. NDBI Analysis

The minimum and maximum NDBI values for each ward were analyzed and spatially plotted on the map to understand the distribution of built-up areas in each ward (Figure 17). The ward clusters with the highest NDBIs along with the areas covered<sup>36</sup> are provided in Table 15. A comparison of the NDVI and NDBI maps showed that some of the wards with the lowest NDVI (46,47,81 and 96) had the highest NDBI, signifying a positive correlation between low vegetation and high built-up area.

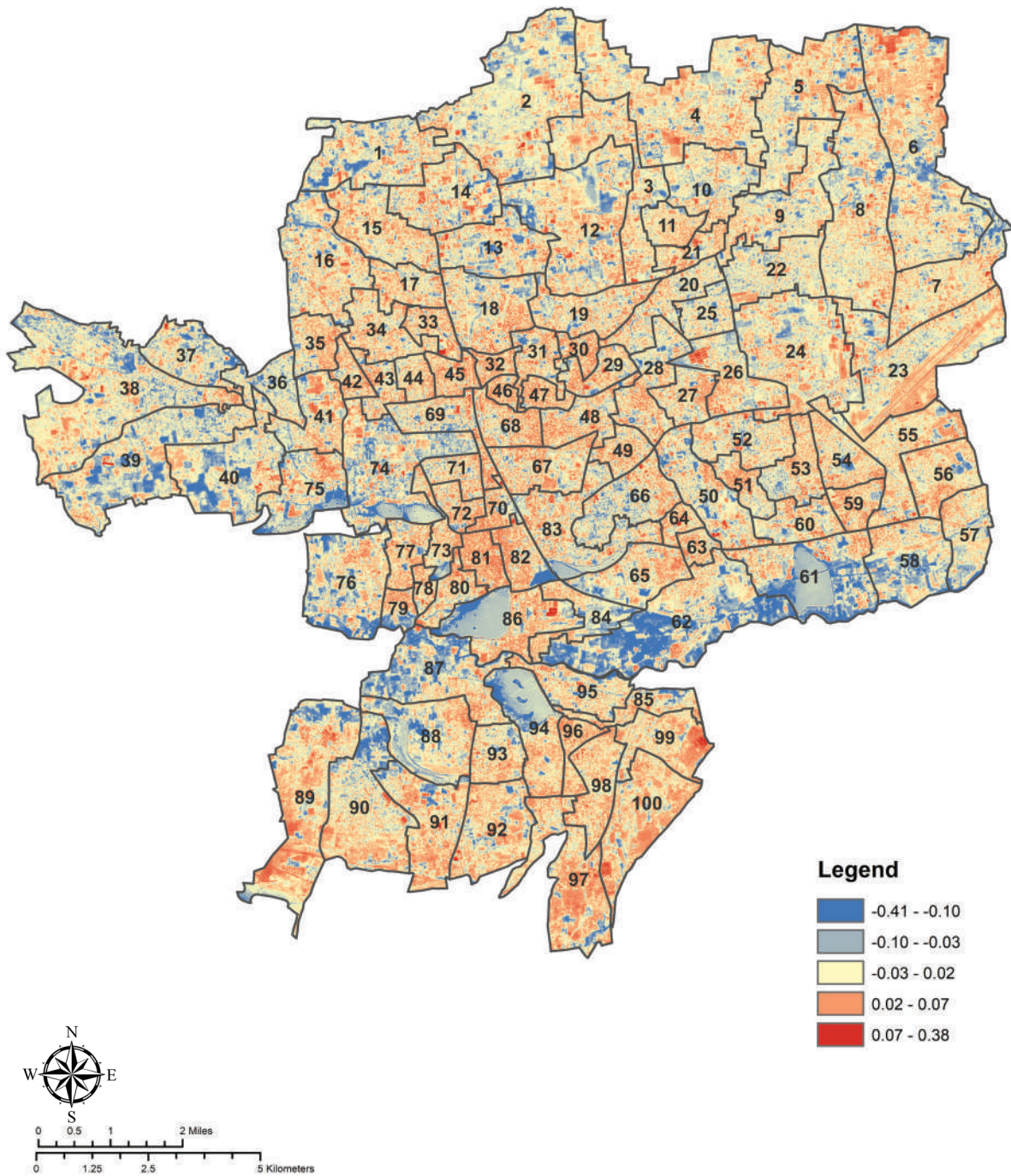
**Table 15: Overview of wards and areas with high NDBI in CCMC**

NDVI	Wards	Areas covered
Wards with predominantly high NDBI (0.54-0.58)	Cluster 1: 99,100 Cluster 2: 30,32 Cluster 3: 45,46,47 Others: 57,96,81	Podanur Ganesapuram, Sanganur, Ganapathy, Saibhabhacovil, Rathinapuri, Nesavalur colony, Ondipur, Sundharapuram, Townhall

35. Rajendran et al 2014, Biodiversity of Bharathiar University campus India, a floristic approach, Accessed March 2025

36. Areas were identified from the ward level maps provided by Coimbatore City Municipal Corporation

**Figure 17: NDBI map for Coimbatore city (2024)**



The NDBI maps were compared with ward level google satellite maps provided by the Coimbatore City Municipal Corporation along with google earth maps, to identify possible causes for high NDBI. The causes are provided below. **High NDBI causes mapped include the compost yard, SIDCO industrial estate, MGR market and MSME clusters.**

**Table 16: Wards with high NDBI and possible causes in CCMC**

Wards with High NDBI	Possible causes
99	Compost yard, Vellalore
100	SIDCO Private Industrial Estate
30	Foundry MSMEs
45	MGR market
81	MSMEs like Sri Visalachi enterprises, Karpaga chemicals, Ghayathri chemicals, city polymers, kovai plastics, Sonali Metal Industries LLP, etc.

**Figure 18: Aerial view of Ward 99 with high NDBI possibly due to compost yard**

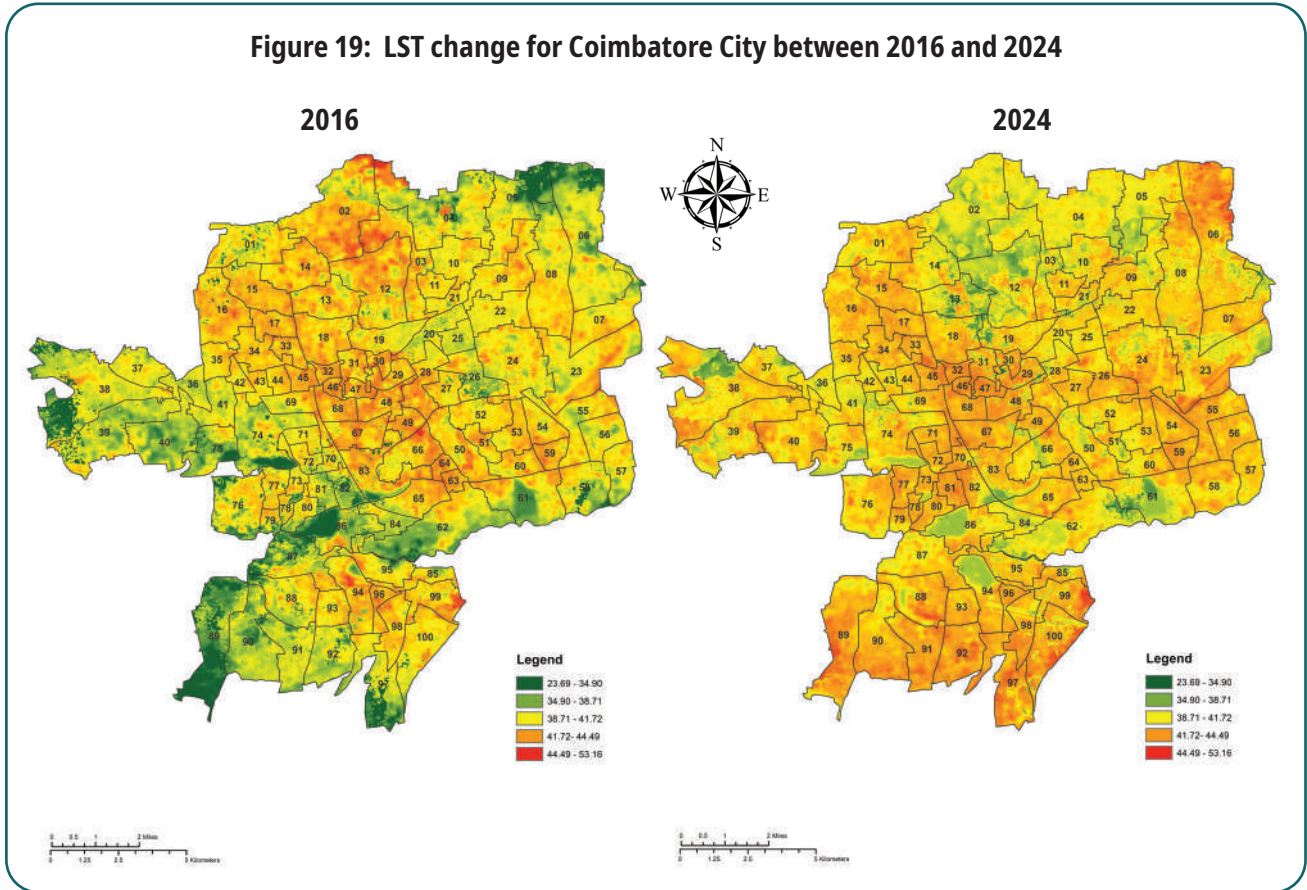
## 4.5. LST Analysis

The Land Surface Temperature analysis was carried out for 2 years (2016 and 2024) to understand the changes in LST over the time period. A ward-level analysis of changes in LST can help pinpoint **LST hotspots**, for urban cooling interventions. Table 17 highlights the wards and areas with the highest LSTs along with the possible causes, identified through a comparison with google satellite maps provided by the corporation website.

**Areas with high LST were shown to correspond with locations of sites like industries, markets, compost yards and the airport.** Coimbatore also is also a well-known foundry MSME hub, with industrial clusters spread across areas like Arasur, Annur, Avinashi Road, Ganapathy, Kanuvai, Manikkampalayam, Mettupalayam, Peelamedu and SIDCO Industrial Estate<sup>37</sup>.

37. TERI, 2015, Cluster profile, Coimbatore Foundries, Accessed March 2025

**Figure 19: LST change for Coimbatore City between 2016 and 2024**



**Table 17: Wards and areas with high LSTs in 2024 with possible causes**

High LST ranges	Wards	Areas	Possible causes
Mean LST between 44.49.1 °C -53.16 °C	Cluster 1: 45,46,47	Saibhabhacovil, Rathinapuri	Ward 29, 30- Foundry MSMEs Ward 45- MGR market Ward 81: MSMEs like Sri Visalachi enterprises, Karpaga chemicals, Ghayathri chemicals, city polymers, kovai plastics, Sonali Metal Industries LLP, etc.
	Cluster 2: 29,30,32,33	Sanganur, Ganapathy, Edayarpalayam	Ward 89- Large plots of vacant land
	Others: 81,89,91,92	Townhall, Sundakkamuthur Vivekanandapuram	Ward 92- Jayalakshmi engineering works
Mean LST between 41.72 °C -44.49 °C	Cluster 1: 96,97,98, 99,100	Podanur Ganesapuram Sundharapuram, Madukarai road, Sithapadur	Ward 99- Compost yard, Vellore Ward 100- SIDCO Private Industrial Estate
	Others: 48, 59,31,55, 23,34	Airport	Ward 23- Airport
	Parts of ward 6	Neelikonaampalayam Vilankurichi	Ward 6: Emami Aerocity

The large plots of vacant land in ward 89, which correspond to a high LST, offer immense potential for converting them into urban blue-green spaces. Several of them have already been reserved for park development<sup>38</sup>. While doing so, the corporation should ensure that the parks have inclusive infrastructure, is disabled friendly and have adequate walking paths.

There was a high LST zone in ward 6, which upon examining on the map corresponded to the **Emami Aerocity, a residential complex**, which showed sparse greenery, indicating the need to integrate urban greening within this residential housing complex.

**Figure 20: Aerial overview of high LST zone in ward 6 corresponding to Emami Aerocity residential complex**



Several wards showed a notable increase in LST between 2016 and 2024. For example, **the mean LST for wards 47 and 81 increased by 4.1°C** between 2016 and 2024, indicating rapid urbanization and industrial expansion of small industrial units.

**Similarly, the mean LST of wards 67 and 82 increased by 3.7°C in the same duration.** This comprises of rapidly urbanizing areas like Town hall and Ram nagar.

#### 4.6. UHI Analysis

A distribution of heat island effect in the form of extremely low, low, medium, high and extremely high heat zones was mapped for Coimbatore City Municipal Corporation based on the LST analysis. The wards falling under high heat zone and extremely high heat zones are given below:

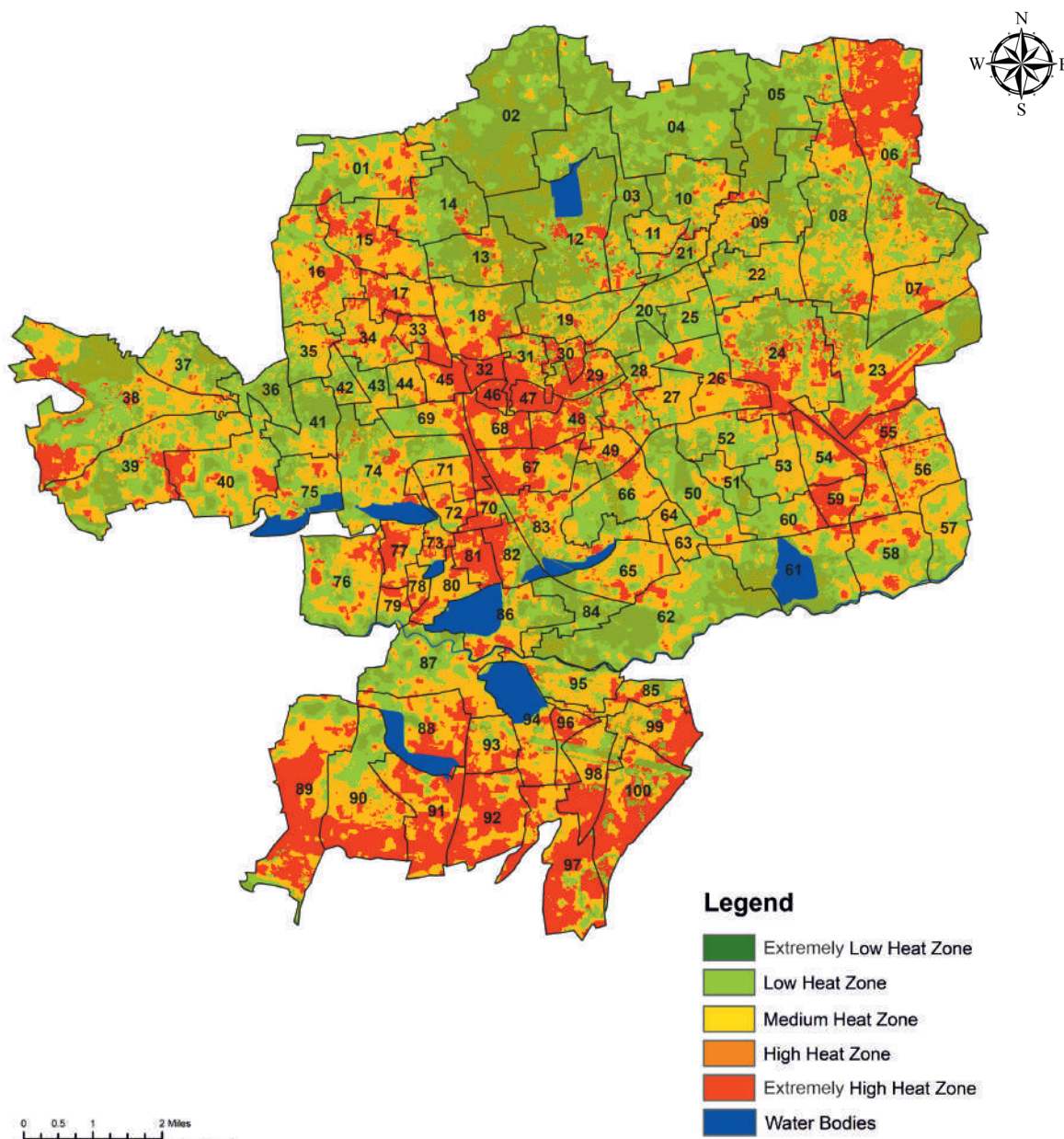
38. Coimbatore Corporation- South Zone, Approved Lay Out Reserve Site- Ward 89, Accessed March 2025

**Table 18: Wards in CCMC falling under high heat and extremely high heat zones**

UHI Zone	Ward
High heat zone	54,26,49,27,92,28,18,24,17,56,82,77,6,100,78,72,70,91,11,44,64,19,42,80,21,35,8,45,46,47,48,59,29,30,31,32,33
Extremely high heat zone	6,15,16,45,32,46,47,70,81,77,89,90,91,92,96,97,98,99,100,23,55

Amongst these wards, high heat zone areas were found in wards 29, 30 (presence of foundry MSME cluster), ward 45 (MGR market area), ward 100 (SIDCO private industrial estate), 89 (vacant land plots), 99 (Vellalore Compost yard) and wards 23 and 55 (near the airport)

**Figure 21: UHI map for Coimbatore City (2024)**



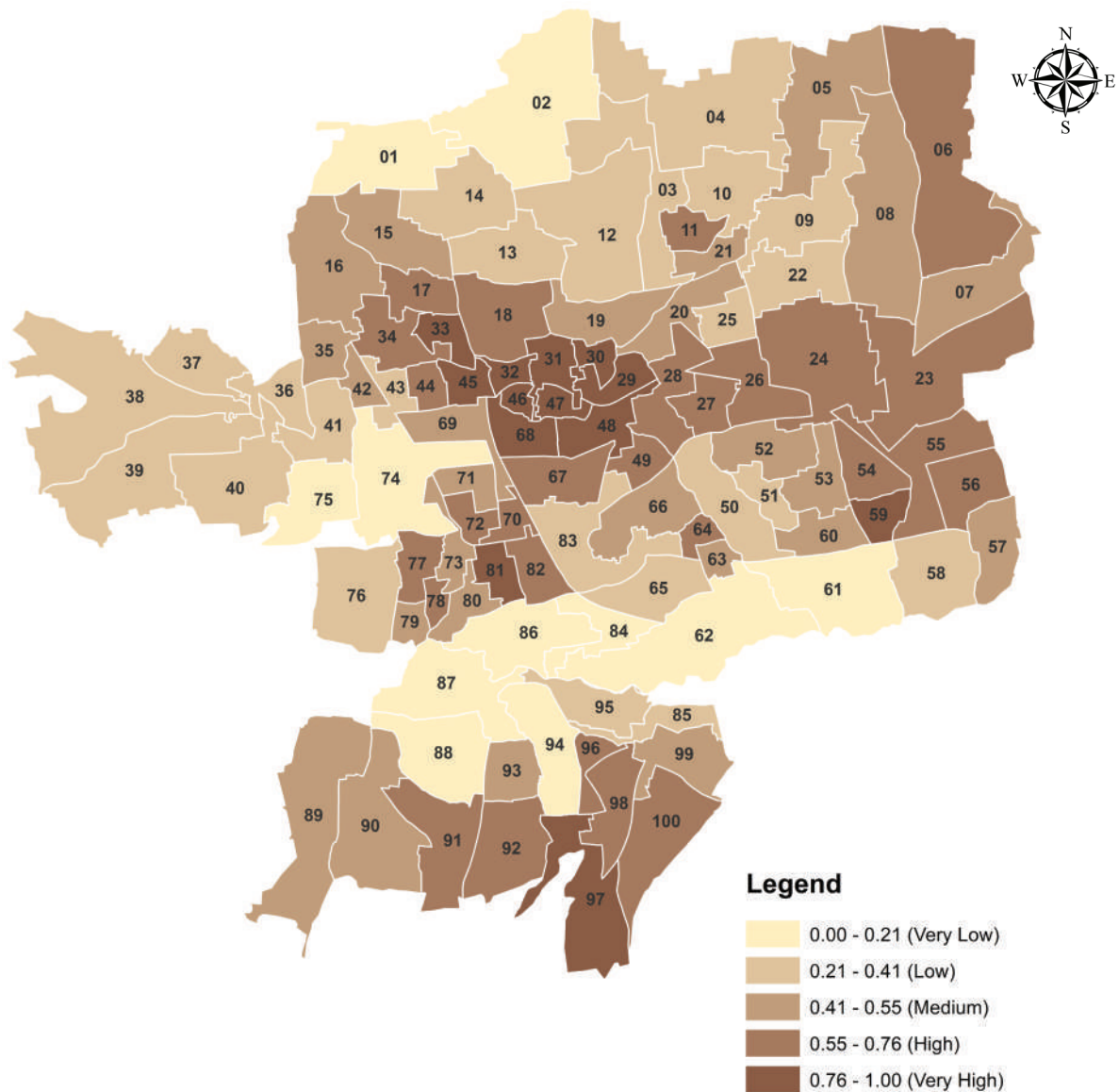
## 4.7. Ward-level Heat Risk Index for Coimbatore City Municipal Corporation

### 4.7.1. Hazard

The wards were spatially mapped based on whether the potential of the hazard ( high LST) was very low, low, medium, high or very high, to provide an overview of wards which have a very high potential of high LST.

There is a very high risk of hazard in 13 wards, and 8 of them are more likely to be affected by high heatwaves. These are wards 46,30,47,33,29,32,45, and 81. LST was highest in these wards, getting as high as 42.7 to 43.3°C. Wards 1,74,75,2,84,86,87,61,62,88 and 94 have very low risk levels because their lowest LST is between 37.5 and 38.7°C.

**Figure 22: Hazard map for CCMC (2024)**



**Table 19: Different hazard categories of wards for CCMC (2024)**

Risk of hazard	Ward Numbers
Very Low	1,74,75,2,84,86,87,61,62,88,94
Low	10,13,36,43,22,40,95,12,14,37,3,4,39,58,50,51,76,85,25,38
Medium	7,52,71,89,93,53,69,90,99,16,63,66,15,20,57,60,73,5,79,9,41,65,83
High	98,23,55,96,34,26,54,67,27,49,17,18,24,28,92,56,77,82,6,70,72,78,91,100,11,44,64,19,21,42,80
Very High	46,30,47,33,29,32,45,81,48,59,31,68,97

Amongst the wards with a very high potential of being impacted by the hazard (high LST), wards 46,47,32,45,81,97 also fall under extremely high heat zones, based on the UHI mapping analysis, highlighting the need to prioritize urgent cooling measures in these wards.

### 4.7.2. Exposure

Based on the spatial analysis of exposure, among the wards in Coimbatore ward number 46,64,63,32,78,70,47,30 & 81 fall into the highest exposure category, attributed to their higher population and built-up densities.

**Table 20: Different exposure categories of wards in CCMC (2024)**

Exposure	Ward numbers
Very Low	2,12,6,23,58,61,62,86,87,88,94,90,89,74,75,76,38
Low	92,24,55,100,1,5,13,39,65,91,3,16,99,4,84,40,41,90
Medium	36,52,67,21,26,56,98,18,19,60,37,85,95,9,10,22,8,15,50,83,97,7,14,57
High	45,49,33,42,59,80,43,51,68,96,48,82,31,73,29,35,79,53,54,71,11,20,25,27,28,69,77,17,34,66,93,44,72
Very High	46,64,63,32,78,70,47,30,81

Amongst these, wards 46,47 and 81 also scored very high in the hazard category, indicating high LST and high built-up areas, such as the presence of MSME clusters identified in ward 81.

### 4.7.3. Vulnerability

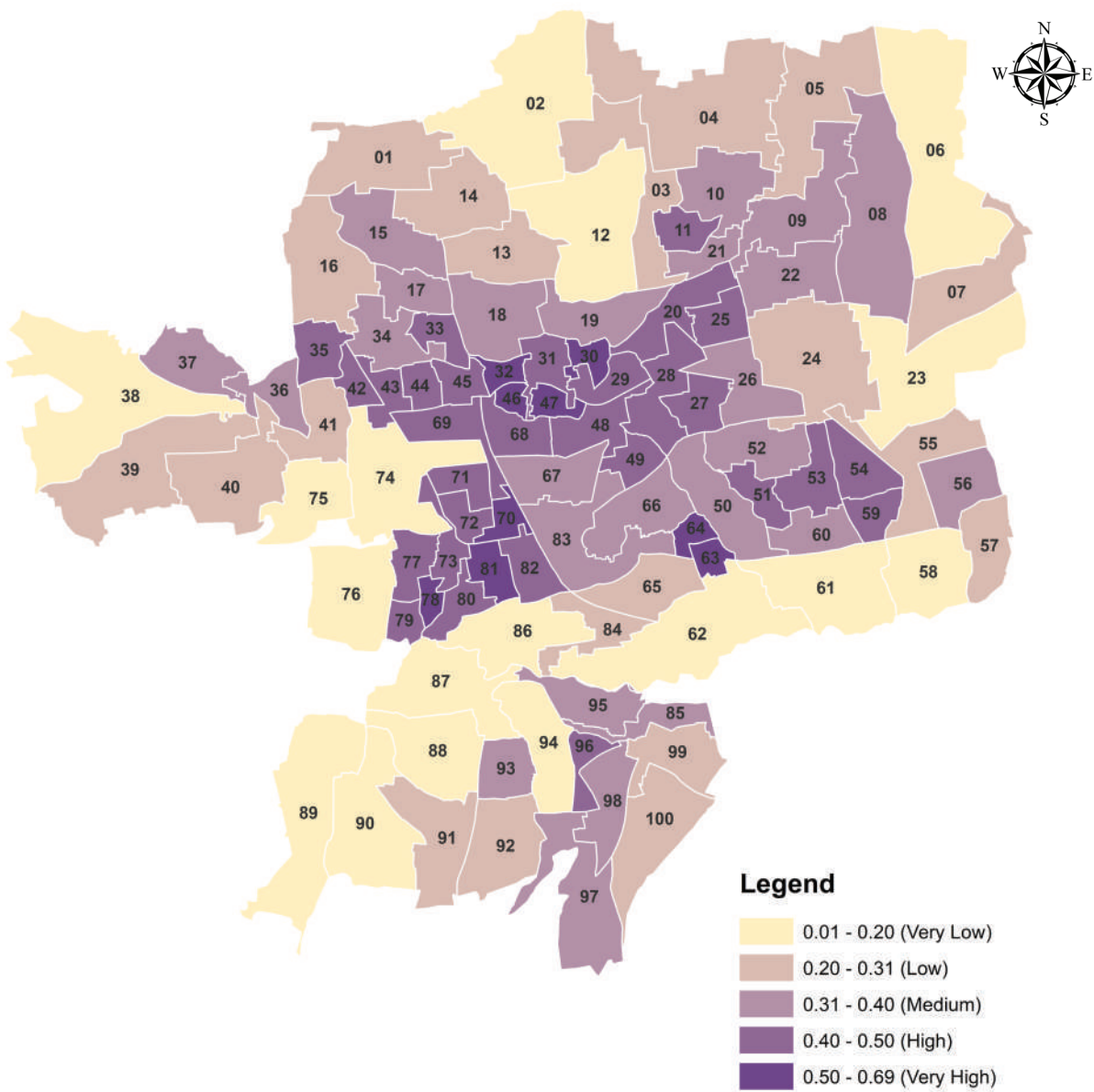
11 wards were found to have very high vulnerability, possessing lower adaptive capacity. These wards are particularly vulnerable due to a higher number of slum populations, inadequate road infrastructure, less NDVI, less parks, and limited medical facilities, culminating in a significant reduction in their adaptive potential. The extremely low vulnerability wards are 64,63,46 and 32. These wards exhibit a strong adaptive capacity.

**Table 21: Different vulnerability categories of wards in CCMC (2024)**

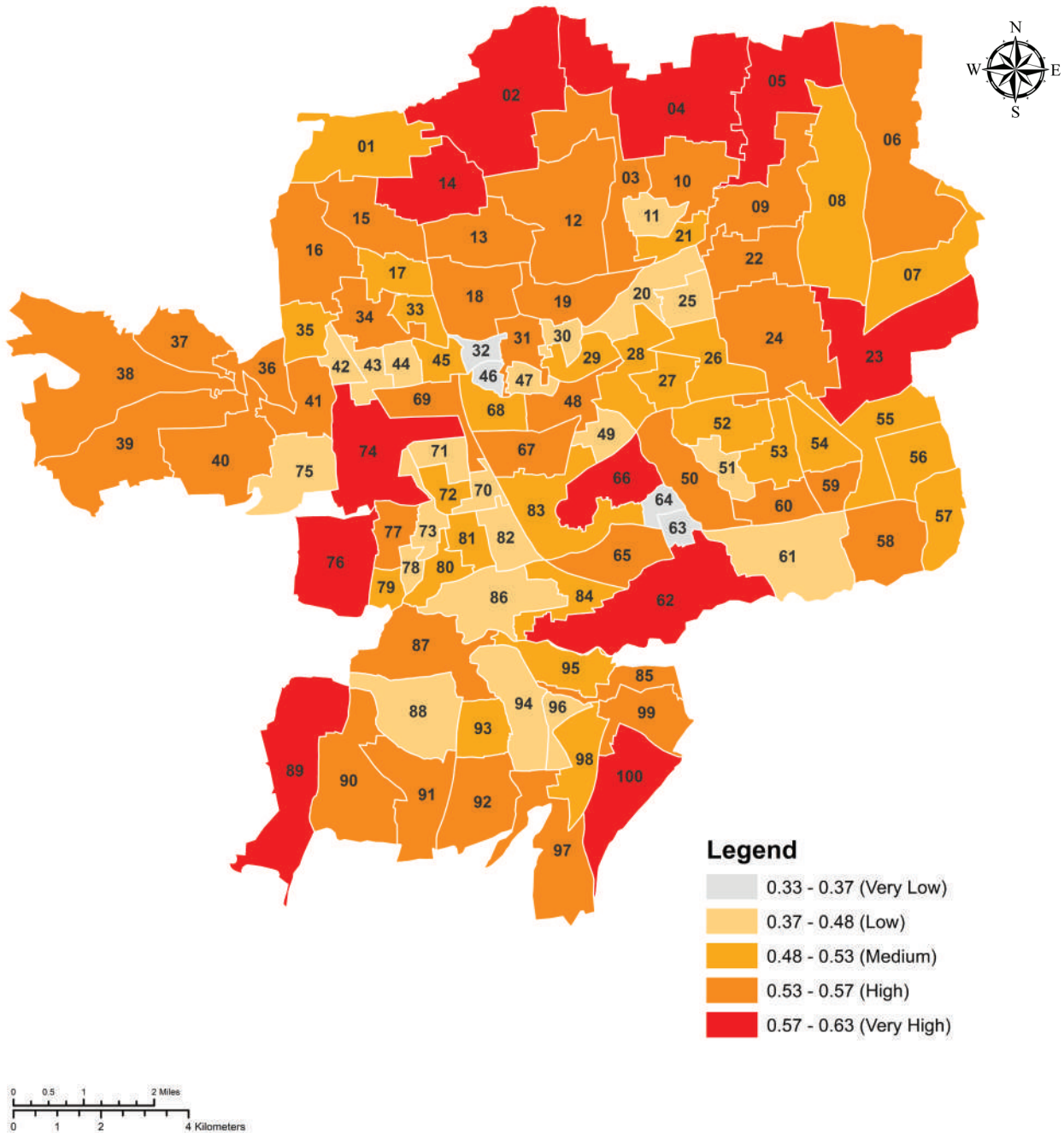
Exposure	Ward numbers
Very Low	64,46,32,63
Low	3,70,71,94,42,44,51,78,96,61,82,11,25,30,88,47,20,49,73,75,86

Exposure	Ward numbers
Medium	53,51,7,8,21,26,28,29,35,81,52,53,54,55,56,72,80,83,84,93,95,17,27,79,98,33
High	3,12,18,34,58,65,67,91,24,39,40,41,50,60,85,97,99,6,9,15,19,22,31,36,48,59,69,77,45,57,68,10,13,16,37,38,87,90,92
Very High	74,2,4,62,5,14,100,66,76,23,89

Figure 23: Exposure map for CCMC (2024)



**Figure 24: Vulnerability map for CCMC (2024)**



**Ward 46 (Rathinapuri area) scored high in terms of hazard and exposure but had low vulnerability. This can be attributed to the presence of good health care and green space access (2.43 hospitals per sqkm and 12 parks per sqkm)**

#### 4.7.4. Heat Risk Index

Equal weightages were used for each of three components, to provide an overall heat risk score for each ward, to estimate wards that have very high risk of being impacted by UHI.

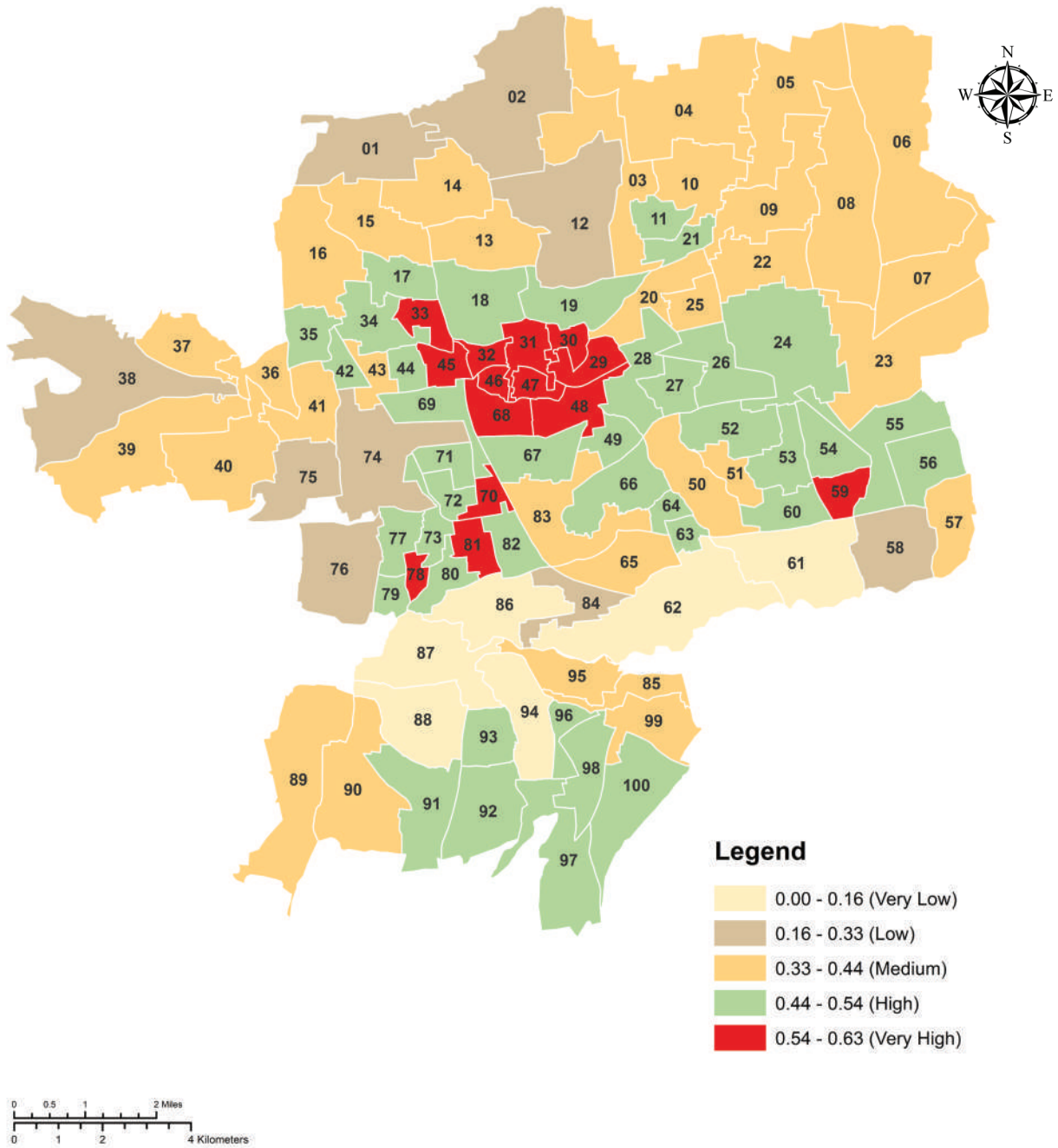
**14 wards (14% of total wards) in Coimbatore are classified as having a 'very high heat risk index,' despite moderate susceptibility; yet exposure and hazard levels in these wards are exceedingly high. These wards accounted for 5% of the total city area and housed 17.5% of the total city population.**

**Table 22: Different heat risk categories of wards in CCMC (2024)**

Heat Risk Index	Ward Numbers
Very Low	61,88,62,86,87,94
Low	12,76,1,38,74,2,58,75,84
Medium	7,10,36,9,15,20,57,5,16,37,83,99,14,22,51,65,95,6,13,23,85,90,25,50,3,4,39,41,40,89
High	54,67,26,27,28,77,98,17,18,44,64,80,82,97,42,35,56,21,55,66,69,11,19,53,63,92,93,100,24,52,1,60,73,79,91,8,34,49,72,96
Very High	81,30,45,46,47,33,59,29,32,48,31,68,70,78



**Figure 25: Ward-level heat risk index assessment for CCMC (2024)**



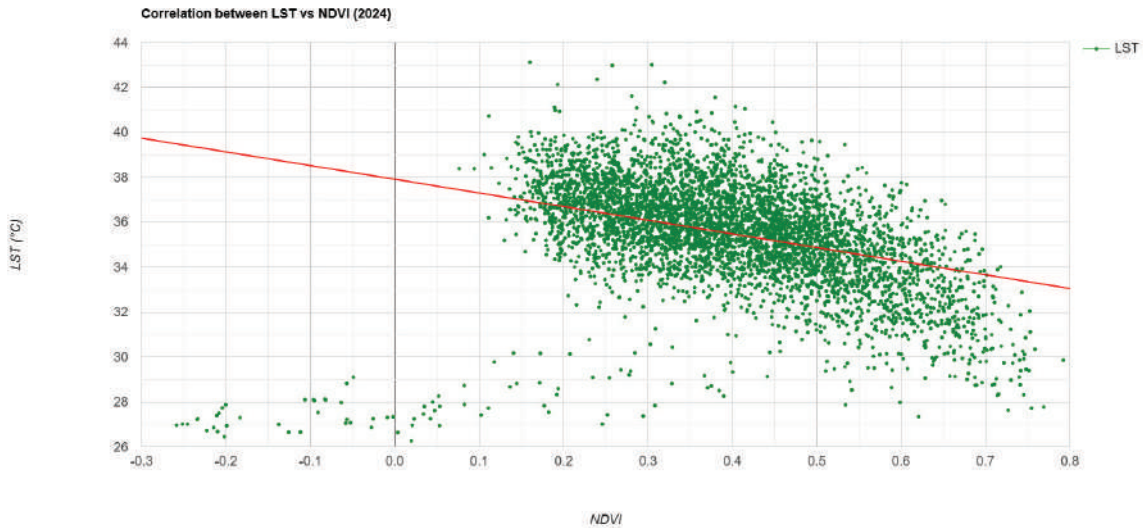
## 4.8. Correlation Analysis between NDVI, NDBI and LST

### 4.8.1. Correlation Analysis between LST and NDVI

Understanding the relationship between NDVI and LST is crucial for effective urban planning and the development of heat action plans. The scatter plot for Coimbatore reveals a clear negative correlation between LST and NDVI, indicating that increased vegetation cover is associated with lower land surface temperatures, highlighting the

cooling effect of vegetation. The downward-sloping red trendline visually reinforces this inverse relationship. While a general trend exists, the spread of data points suggests that factors beyond vegetation density also influence LST.

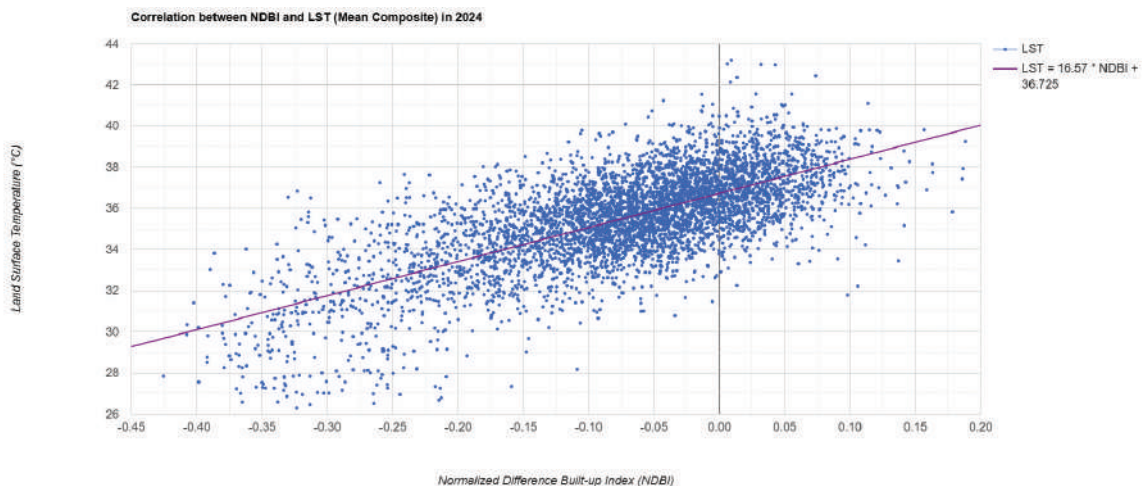
**Figure 26: Correlation between NDVI and LST for Coimbatore**



#### 4.8.2. Correlation Analysis between LST and NDBI

The relationship between NDBI (Normalized Difference Built-up Index) and LST (Land Surface Temperature) is crucial for urban planning and sustainable development. It helps mitigate the Urban Heat Island (UHI) effect by informing strategies to increase green spaces and reduce temperatures in built-up areas. The scatter plot reveals a composite that shows a positive correlation between NDBI and LST, indicating that increased built-up areas are associated with higher surface temperatures, supporting the urban heat island effect. The equation  $LST = 17.211 * NDBI + 38.051$  quantifies this relationship, suggesting LST rises with built-up density. While a trend exists, data scatter implies other factors influence LST. Overall, urbanization’s thermal impact is evident.

**Figure 27: Correlation between NDBI and LST for Coimbatore**



### 4.9. Ward Level Urban Cooling Interventions

Based on the above analysis, interventions have been recommended for some of the very high heat risk wards.

**Table 23: Ward level urban cooling interventions for very high risk wards in Coimbatore**

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Cool roofs (reflective paints, coatings, sheets)</b>	Built infrastructure	81,30,45,46,47,33,59,29,32,48,31,68,70,78	Wards have high LST (up to 43.3°C), high built-up density (NDBI up to 0.586), and low NDVI (as low as 0.084). Many buildings are low-rise or informal, with large slum populations (e.g., Ward 48: 6,609 slum residents). Cool roofs reduce indoor temperatures by 2–5°C, improving comfort and reducing energy bills for vulnerable groups
<b>Energy efficiency and cooling in MSMEs (cool roofs, solar PV, energy efficient equipment, etc)</b>	Built infrastructure	46,47,70	Ward 70 (Big Bazaar Street area) is particularly known for wholesale and retail trading, as well as textile and garment-related MSMEs. Ward 46 and 47 are part of central Coimbatore’s commercial core, hosting a mix of textile, engineering, and service MSMEs.
<b>Green Cover Enhancement (Tree Plantation, Park Development)</b>	Nature based	81,31,78	These wards have very low NDVI <0.12 and very low number of parks (~2). These wards should prioritize urban greening measures and park development.
<b>Bus shelters and shade nets at junctions</b>	Built infrastructure	46,47,70,81,32	These are commercial and transit-heavy wards with high NDBI and LST, exposing commuters and workers to extreme heat. They also have high average NDBIs ~0.5.
<b>Reflective pavements</b>	Built infrastructure	46,47,70,81,29	These wards have high traffic, commercial activity, and built-up area. Permeable and reflective pavements must be accompanied by tree shading, water kiosks, etc
<b>Awareness campaigns</b>	Capacity building	All very high heat risk wards	Vulnerable populations (children, elderly, outdoor workers) in these wards are at heightened risk due to high LST, low NDVI, and high density. Awareness campaigns particularly on impacts of heatwaves can reduce exposure and improve health outcomes

## 5. Case Study: Tiruchirappalli City Municipal Corporation

### 5.1. Study Area

Tiruchirappalli is the fourth most populous city in Tamil Nadu. The current population is 1.025 million, reflecting a 13.8% rise from 0.917 million in 2011. The city encompasses an area of 167.23 square kilometers, with a population density of 62 individuals per hectare<sup>39</sup>. Initially established as a fortified city adjacent to the Cauvery and Kollidam rivers in the sixteenth century, it has now expanded radially in all directions. It predominantly experiences a dry summer tropical savanna climate, with temperatures between 28.9°C and 43.9°C, annual precipitation of 841.9 mm, and humidity at 70%. Annual average maximum temperatures is projected to rise between 1.6 °C to 3.3°C by the end century, highlighting the need for urban heat mitigation.

The economic advancement of Tiruchirappalli is particularly linked to industrialization within and surrounding the city boundaries. The pre-independence establishment of rail links and the Golden Rock Railway workshop catalysed infrastructural and economic advancement in the region. Additionally, Bharat Heavy Electricals Limited (BHEL), The Heavy Alloy Penetrator Factory (HAPF) and Ordnance Factory Tiruchirappalli (OFT), established post-independence, serve as the foundation for small-scale MSMEs in the Tiruchirappalli Urban Agglomeration.

Additionally, the city contributed to 1.43 million tonnes CO<sub>2</sub>e emissions in 2022-23. A significant portion of these emissions comes from the built environment, particularly energy usage for cooling in buildings. Between 2018 and 2023, the built-up area of Tiruchirappalli increased by 1.19%. The city's per capita green cover of 10.57 sq.km exceeds WHO guidelines of 9.5 sq.km per person, however, many wards have limited access to green spaces, exceeding 1.5km. This scenario highlights the essential requirement to examine Tiruchirappalli's urbanization trends and their impact on the Urban Heat Island Effect<sup>40</sup>.

### 5.2. LULC Analysis

The Land Use Land Cover Analysis for Tiruchirappalli City Municipal Corporation highlighted that 59% of the city area constituted built-up area, 29% crops and 3% tree cover. Crop land and water bodies are seen in the urban periphery. The breakup of various categories and their total area is given below.

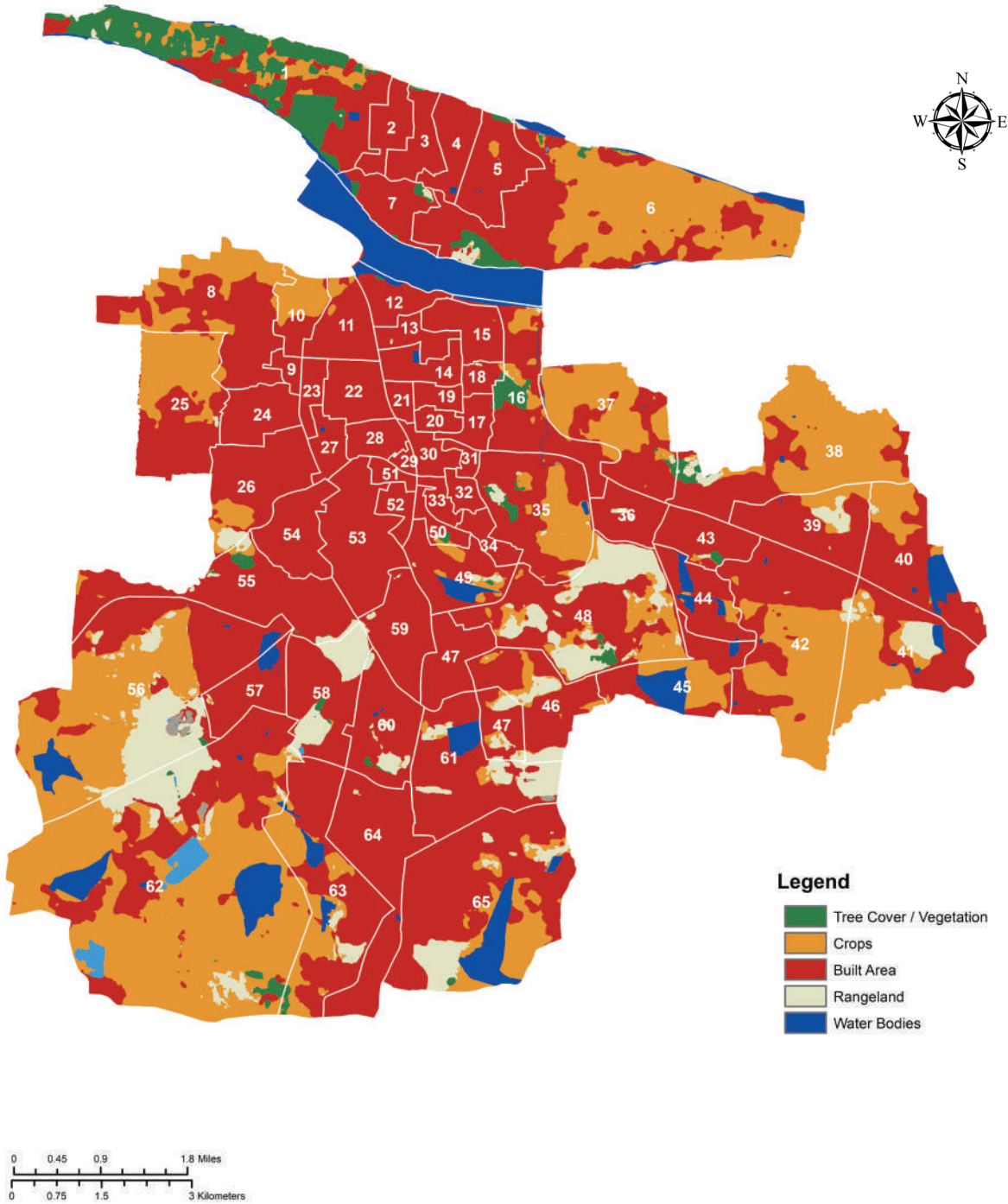
**Table 24: NDVI analysis LULC breakup for Tiruchirappalli City Municipal Corporation (2024)**

LULC category	Area (Ha)	Percentage
Tree cover/ vegetation	4.38	3%
Crops	43.093	29%
Built area	86.56	59%
Rangeland	10.47	7%
Water bodies	2.66	2%
<b>Total</b>	<b>147.20</b>	

39. TNUSSP, 2018. Sanitation Situation Assessment: Tiruchirappalli, Accessed April 2025

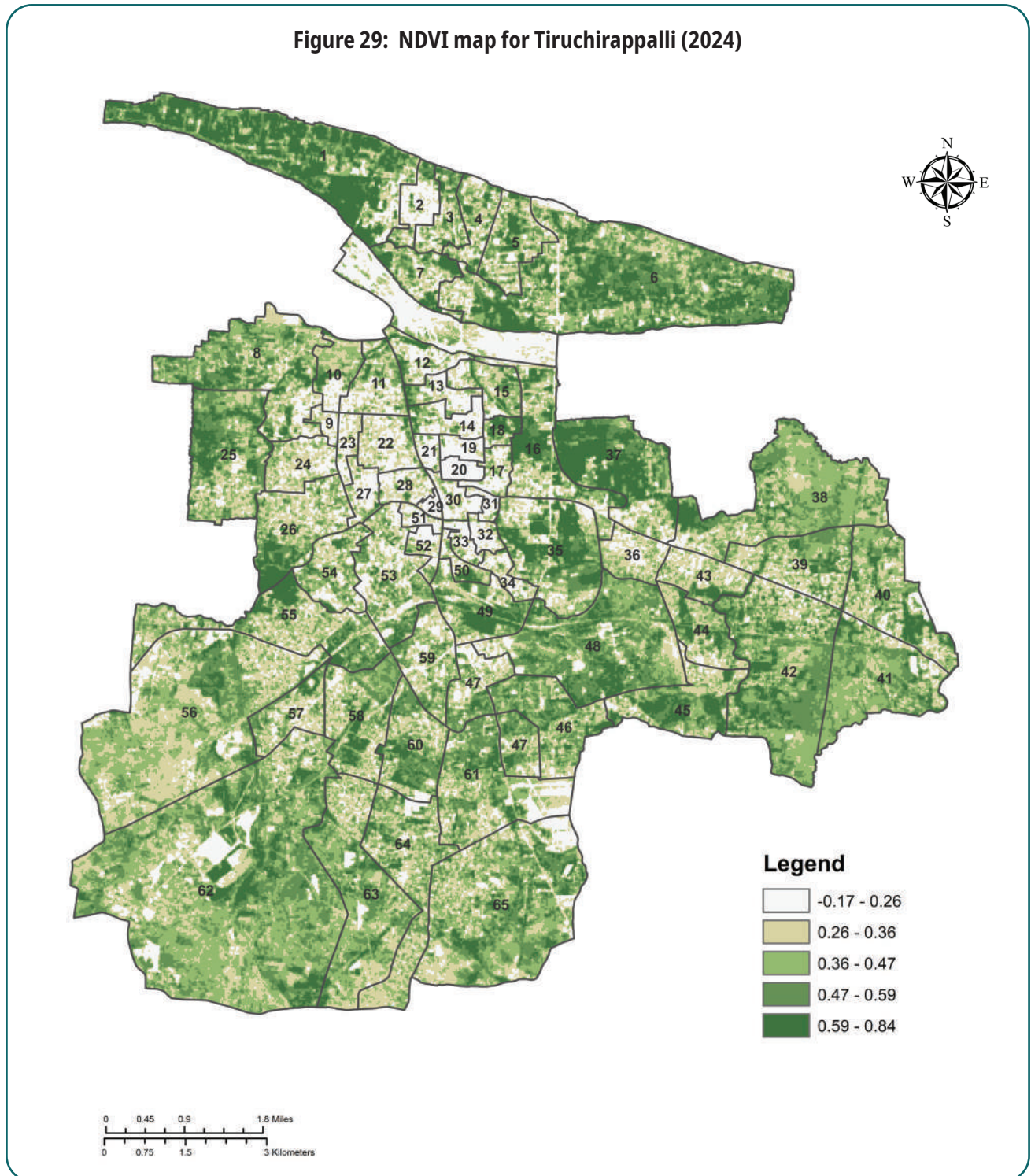
40. ICLEI South Asia, 2024, Net-zero Climate Resilient City Action Plan for Tiruchirappalli, Accessed March 2025

Figure 28: LULC map for Tiruchirappalli (2024)



### 5.3. NDVI Analysis

The minimum and maximum NDVI values for each ward were analyzed and spatially plotted to understand the distribution of vegetation in each ward for 2024 (Figure 29). The ward clusters with lowest and highest NDVI along with areas covered<sup>41</sup> are provided below.



41. Areas were identified from the ward level google satellite maps

**Table 25: Overview of wards and areas with low and high NDVI in Tiruchirappalli**

NDVI	Wards	Areas covered
Wards with predominantly very low NDVI (-0.17 -0.26))	14,19,20,21,29,30,31,32	Near Mela Ambikapuram, Anthoniyar temple, Boologanathar temple
Wards with predominantly low NDVI (0.26-0.36)	9,21,23,33,34,51	Bheema nagar, Tenner, Puthur, Bharathi Nagar, Palakarai, Ganam Colony etc
Wards with Moderately NDVI (0.36-0.47)	2,3,4,5,6,7,8,10,11,12,13,15,16,17,22,24, 27,28,36,37,43,44,45,47,48,50,52,53,54,6, 25,26,35,38,39,40,41,42,45,46,49,55	Srirangan temple, Anna nagar, Thiruvanai kaval
Wards having some areas with high NDVI (0.59-0.84)	1,18,37	Cauvery River, Kamaraj Nagar, Anna Nagar

The NDVI map was correlated with google satellite maps to identify possible causes for high NDVI. For example, ward 1 showed high NDVI due to the presence of several gardens including the tropical butterfly conservatory near the Cauvery River. Ward 18 showed dense green cover, especially close to the Kurinji college.

Moreover, some of the wards with low NDVI were also found to have negligible parks. For example, wards 20,21, 29,30 and 31 had no parks, highlighting the need to expand accessible green spaces in these wards.

**Figure 30: Aerial view of ward 18**



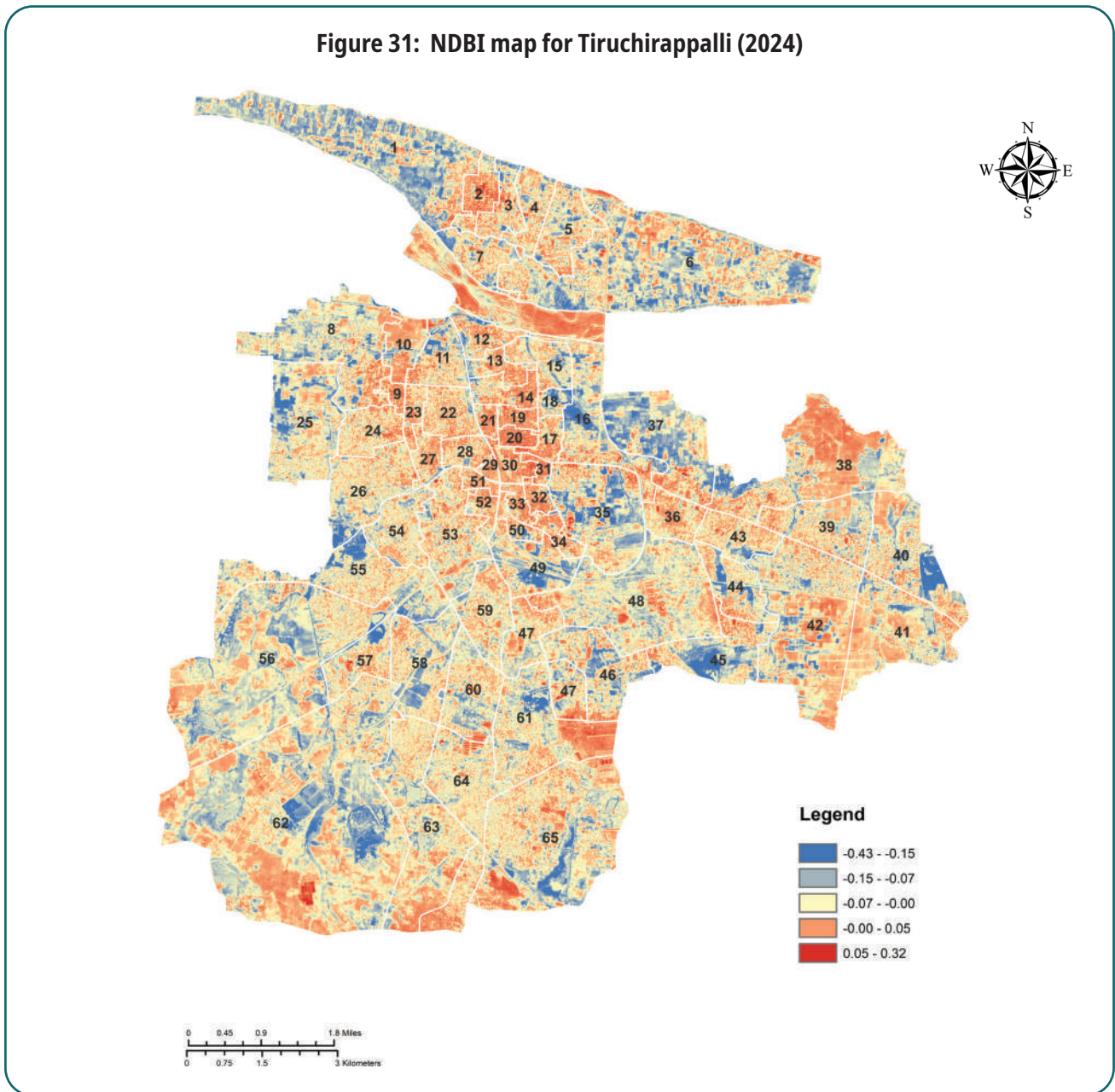
### 5.4. NDBI Analysis

The minimum and maximum NDBI values for each ward were analyzed and spatially plotted on the map to understand the distribution of built-up area in each ward (Figure 31). The ward clusters with the highest NDBIs along with the areas covered<sup>42</sup> are provided below.

**Table 26: Overview of wards and areas with high NDBI in Tiruchirappalli**

NDBI	Wards	Areas covered
Wards with predominantly high NDBI (0.05-0.32)	Cluster: 20,19 Others: 29,30 Parts of ward 65 and 61	Bheema nagar, Bharathi Nagar, Palakarai, Ganam Colony, Sanjeev nagar

**Figure 31: NDBI map for Tiruchirappalli (2024)**



42. Areas were identified from google satellite maps

A comparison of the NDVI and NDBI maps showed that wards with the lowest NDVI (19,20,29,30) had the highest NDBI, signifying a positive correlation between low vegetation and high built-up area. The NDBI maps were compared with google earth maps, to identify possible causes for high NDBI.

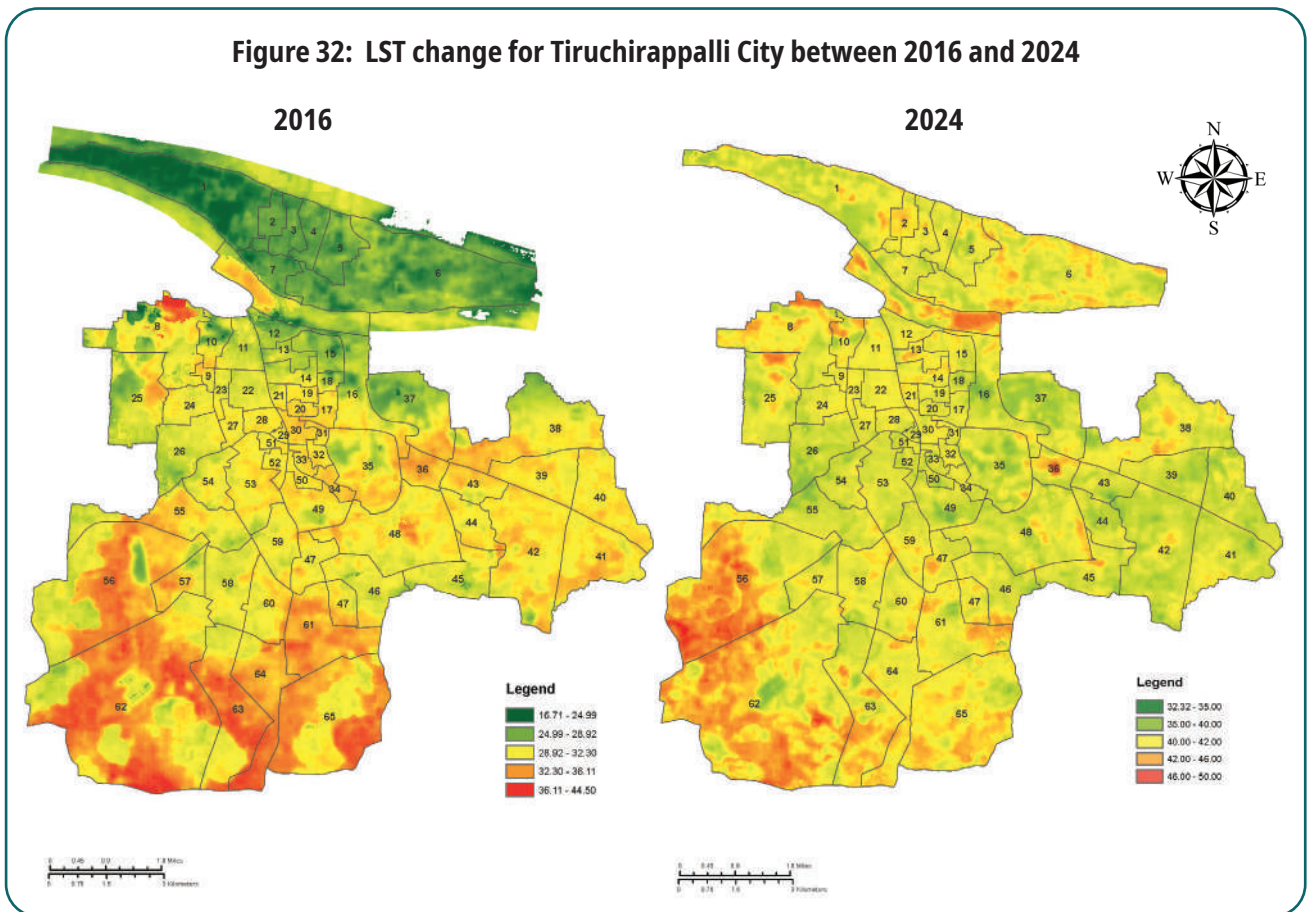
**Table 27: Wards with high NDBI and possible causes for Tiruchirappalli**

Wards with High NDBI	Possible causes
61	Airport
63	Industries like Ultratech RMC plant
20	Gandhi market

### 5.5. LST Analysis

The Land Surface Temperature analysis was carried out for 2 years (2016 and 2024) to understand the changes in LST over the time period. A ward-level analysis of changes in LST can help pinpoint **LST hotspots**, for urban cooling interventions. Table 28 highlights the wards and areas with the highest LSTs along with the possible causes, identified through a comparison with google satellite maps.

**Figure 32: LST change for Tiruchirappalli City between 2016 and 2024**



**Table 28: Wards and areas with high LSTs in 2024 with possible causes**

High LST ranges	Wards	Areas	Possible causes
<b>LST between 46 °C to 50 °C</b>	56,62,63,65,8,2,56,61,64,9,4,6,25	Rettamalai ondikaruppu, new bus stand, STP, Panjappur, Masi Periyamma Kovil, Ariyamangalam dumping yard, Srirangam temple	Ward 36- Ariyamangalam compost yard Ward 61- airport Ward 25- Uyyakondan Thirumalai temple Ward 65- Industries like lakshmi ceramics, Pupa ceramics
<b>LST Between 42 °C to 46 °C</b>	11,12,3,13,10,25,58,23,60,15,47,57,24,7,4,21,22,59	Thiruvanaikaval, Thillai nagar, Anna nagar, Devar colony, uraiyur, Puthur etc	Ward 59- Central bus stand

The Central Bus Terminal, Ariyamangalam Dumping Site (ward no 36), industrial estates, Gandhi Market, Paalpannai, Chindamani and other areas (more built-up areas) demonstrate elevated Land Surface Temperature (LST) due to various activities such as transportation, solid waste disposal, industrial operations and built-up area of most of the wards respectively.

#### Several wards exhibited an increase in LST between 2016 and 2024.

Wards 1,2,3,4,5,6, and 7 had average temperatures ranging from 16.7 to 29°C in 2016 and from 32.3 to 40°C in 2024. The corporation utilities (water supply and its related activities) increased in the wards adjacent to the Srirangam temple, resulting in an intensified floating population density that has further raised the land surface temperature. Moreover, the ward numbers 56,61,62,63,65, near the regional transport office and the recently established bus terminal (construction activities) also showed an increase in LST. Also, Panjappur area showed increased land surface temperatures, possibly due to the prevalence of barren terrain lacking vegetation.

## 5.6. UHI Analysis

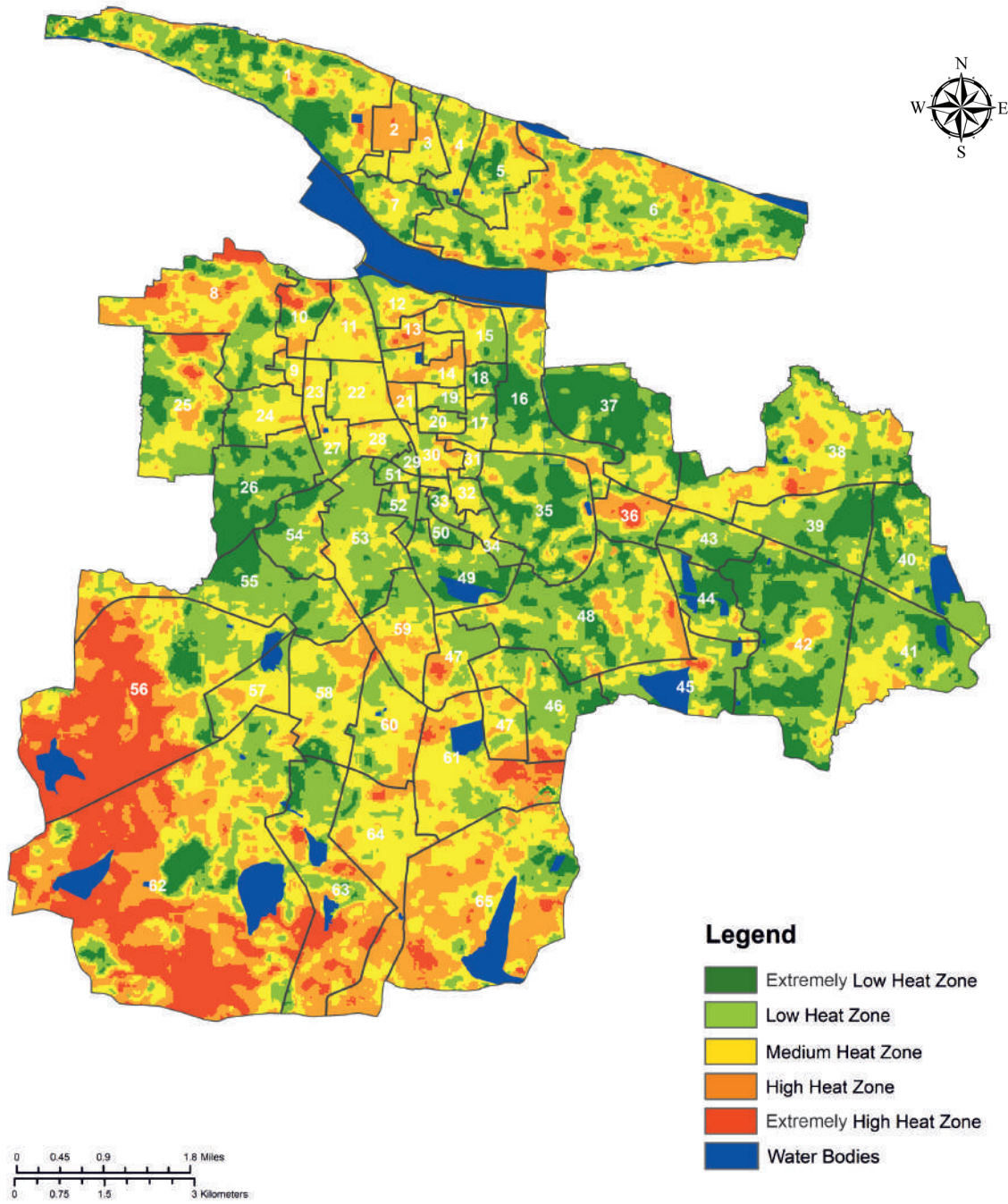
A distribution of heat island effect in the form of extremely low, low, medium, high and extremely high heat zones was mapped for Tiruchirappalli City Municipal Corporation based on the LST analysis. The wards falling under high heat zone and extremely high heat zones are given below:

**Table 29: Wards falling under high and very high heat zones in Tiruchirappalli**

UHI Zone	Ward
High heat zone	2,6,25,58,47,13,14,21,42,10,25
Extremely high heat zone	63,8,56,36,62,65,47,61,8,5,61,64

Amongst these wards, extremely high heat zone areas were found in wards 36 (Ariyamangalam compost yard), ward 61 (airport), wards 56 and 62 (Tiruchirappalli corporation sewage treatment plant and new bus stand) and ward 8 (vacant land parcel) to name a few.

**Figure 33: UHI map for Tiruchirappalli (2024)**

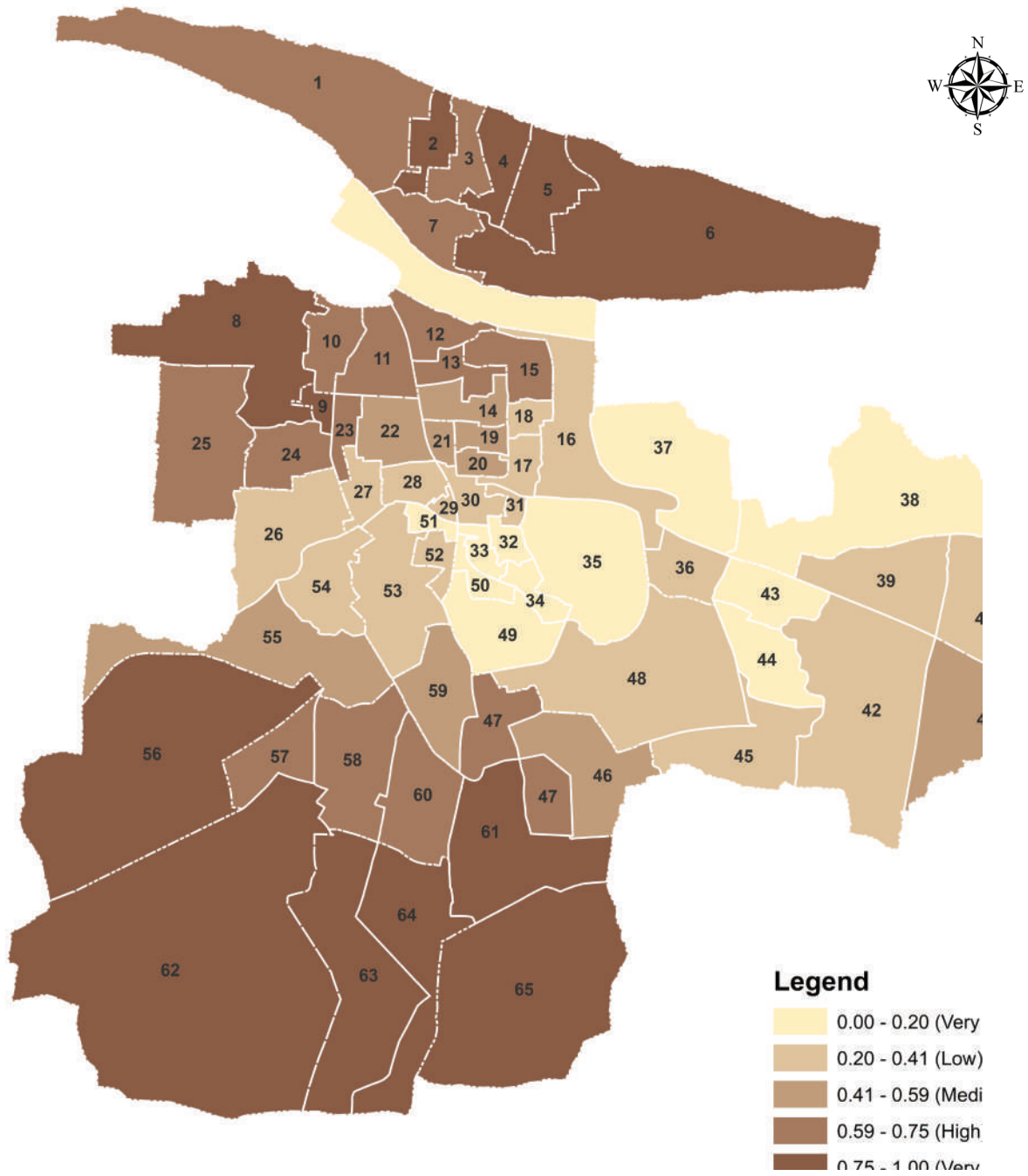


## 5.7. Ward-level heat risk index for Tiruchirappalli City Municipal Corporation

### 5.7.1. Hazard

The wards were spatially mapped based on whether the potential of the hazard ( high LST) was very low, low, medium, high or very high, to provide an overview of wards which have a very high potential of high LST.

**Figure 34: Hazard map for Tiruchirappalli (2024)**



There is a very high risk of hazard in 12 wards, mainly, 56,61,62,63,65,64,8,9,2,4,5 and 6. Among these 56,62,63,65 wards are most susceptible due to high LST.

**Table 30: Different hazard categories of wards in Tiruchirappalli (2024)**

Risk of hazard	Ward numbers
Very Low	44,51,43,33,34,50,37,49,32,35
Low	40,17,27,30,36,42,45,53,26,54,48,16,29,31,18,39,52,38
Medium	22,59,19,46,41,20,55,28
High	3,13,25,10,58,23,60,15,47,57,24,1,7,14,21
Very High	56,62,63,65,8,2,64,5,61,9,4, 6,11,12

Amongst the wards with a very high potential of being impacted by the hazard (high LST), wards 63,65,8,56,62,61 and 5 also fall under extremely high heat zones, based on the UHI mapping analysis, highlighting the need to prioritize urgent cooling measures in these wards to reduce UHI.

### 5.7.2. Exposure

Among the wards in Tiruchirappalli, ward number 18 and 30 have very high exposure owing to higher population densities and percentage of built-up area to geographical area.

**Table 31: Different exposure category of wards in Tiruchirappalli (2024)**

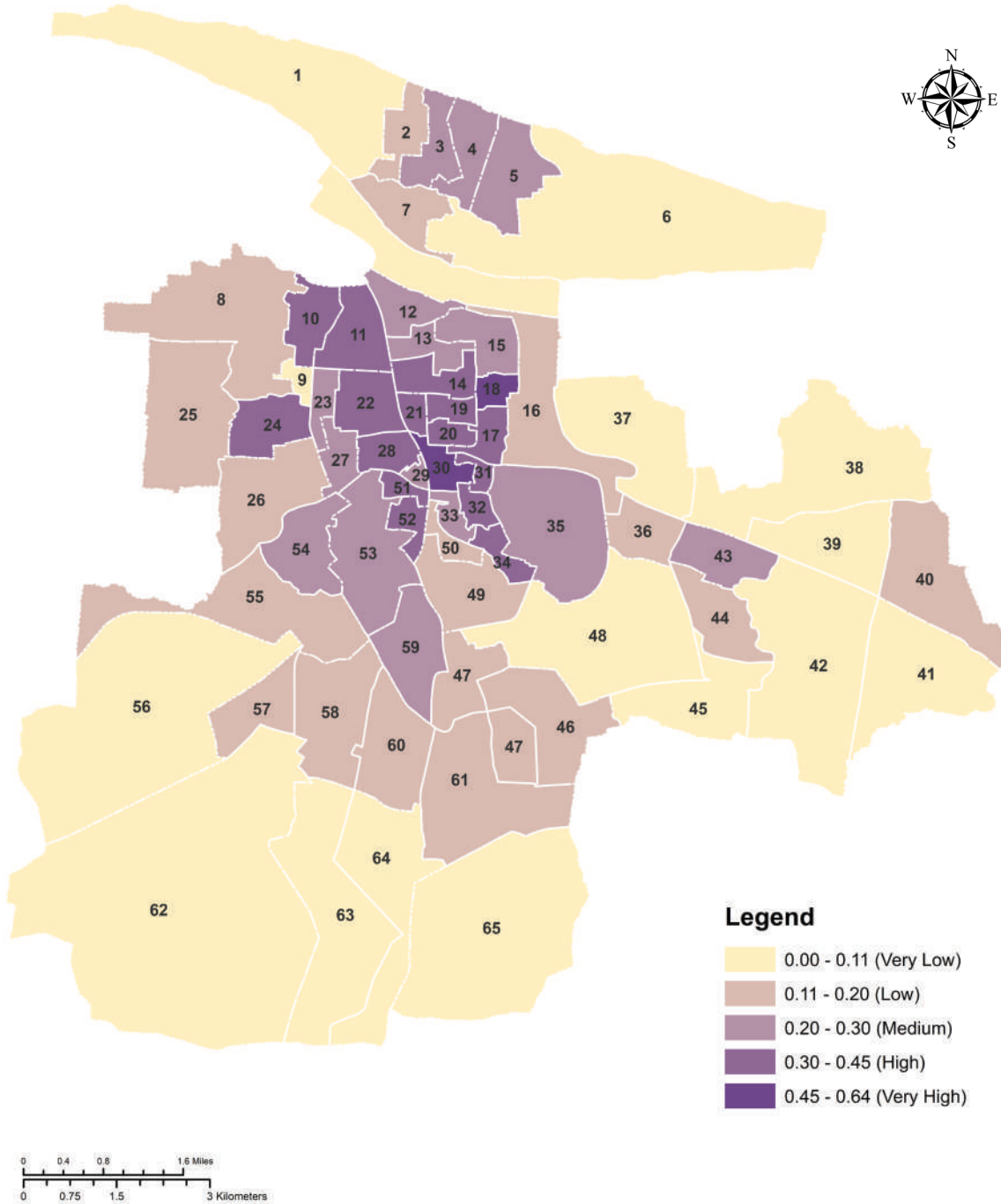
Exposure	Number of Wards
Very Low	45,63,1,6,42,56,62,41,38,65,37
Low	60,44,26,57,61,16,55,58,7,8,47,25,36,49,40,46,50,64,9,48,39,2
Medium	53,3,5,23,35,33,4,15,13,27,59,12,54,43,
High	10,11,24,22,14,21,19,20,28,51,52,31,32,34,17
Very High	18,30

### 5.7.3. Vulnerability

The ward-level vulnerability analysis considers not just exposure to extreme temperatures, but also the socio-economic and infrastructural capacity of each ward to cope with heat stress. Wards with limited access to green spaces, poor road facility, high population density, percentage of built-up areas to geographical area and a large proportion of vulnerable populations such as the elderly, children, and slum are particularly at risk. Hence urban cooling is crucial.

7 wards were found to have very high vulnerability, possessing lower adaptive capacity. These wards are particularly vulnerable due to a higher number of slum populations, inadequate road infrastructure, less NDVI, less parks, and limited medical facilities, culminating in a significant reduction in their adaptive potential.

**Figure 35: Exposure map for Tiruchirappalli (2024)**



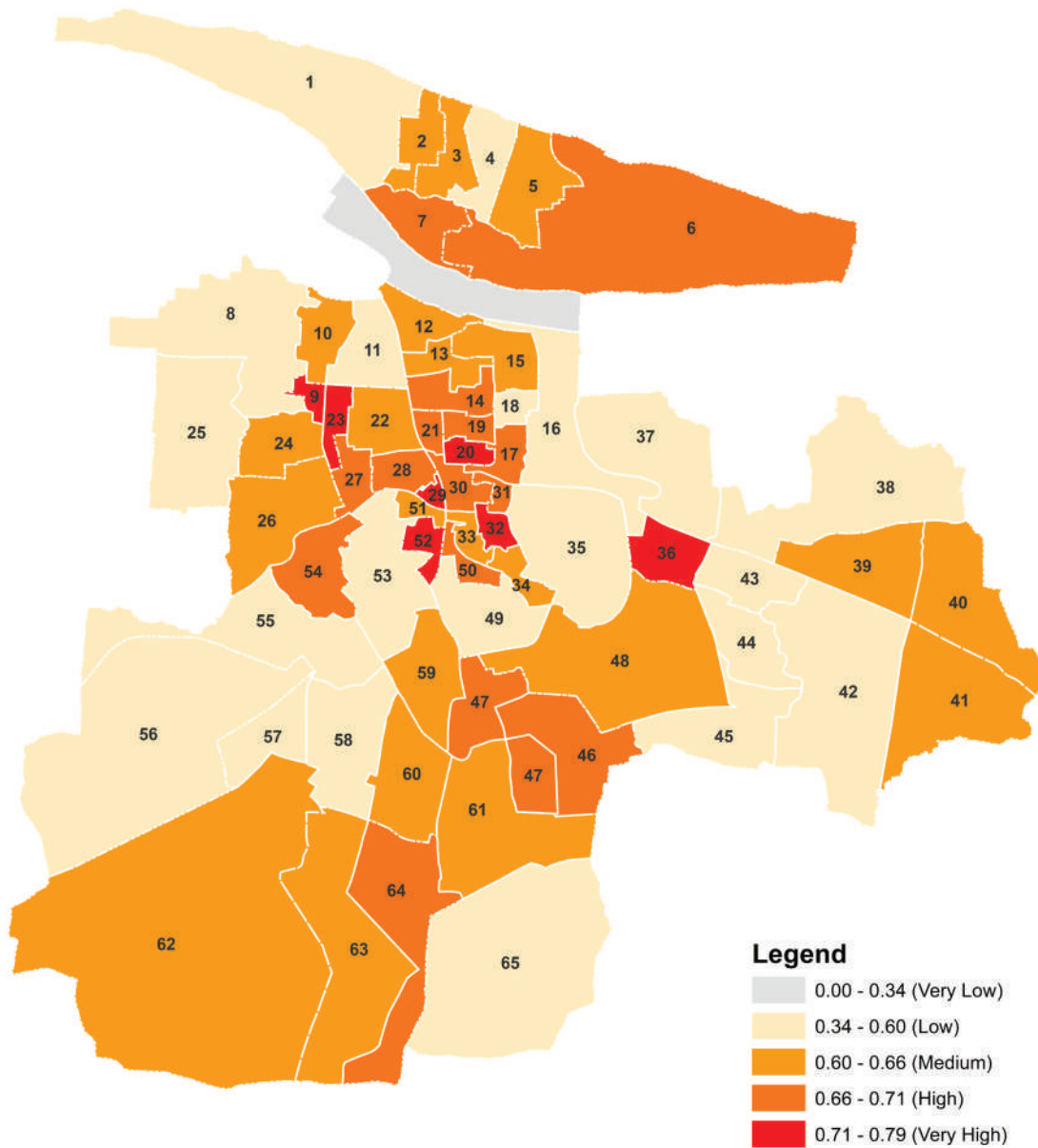
**Table 32: Different vulnerability categories of wards in Tiruchirappalli (2024)**

Category	Ward numbers
Very Low	No wards found
Low	1,8,16,18,25,35,37,38,43,44,45,53,55,56,65
Medium	3,4,5,10,11,12,22,24,26,33,39,40,41,42,48,49,57,58,59,61,62,63

Category	Ward numbers
High	6,13,14,15,17,19,21,27,28,30,31,34,46,47,50,51,54,60,7,64
Very High	9,20,23,29,32,36,52

Ward 8 scored high in terms of hazard but had low vulnerability. This can be attributed to the presence of green space access (Ward 8 has 27 parks per sqkm)

Figure 36: Vulnerability map for Tiruchirappalli (2024)



#### 5.7.4. Heat risk index

Equal weightages were used for each of three components, to provide an overall heat risk score for each ward, to estimate wards that have very high risk of being impacted by UHI.

**Table 33: Different heat risk categories of wards for Tiruchirappalli (2024)**

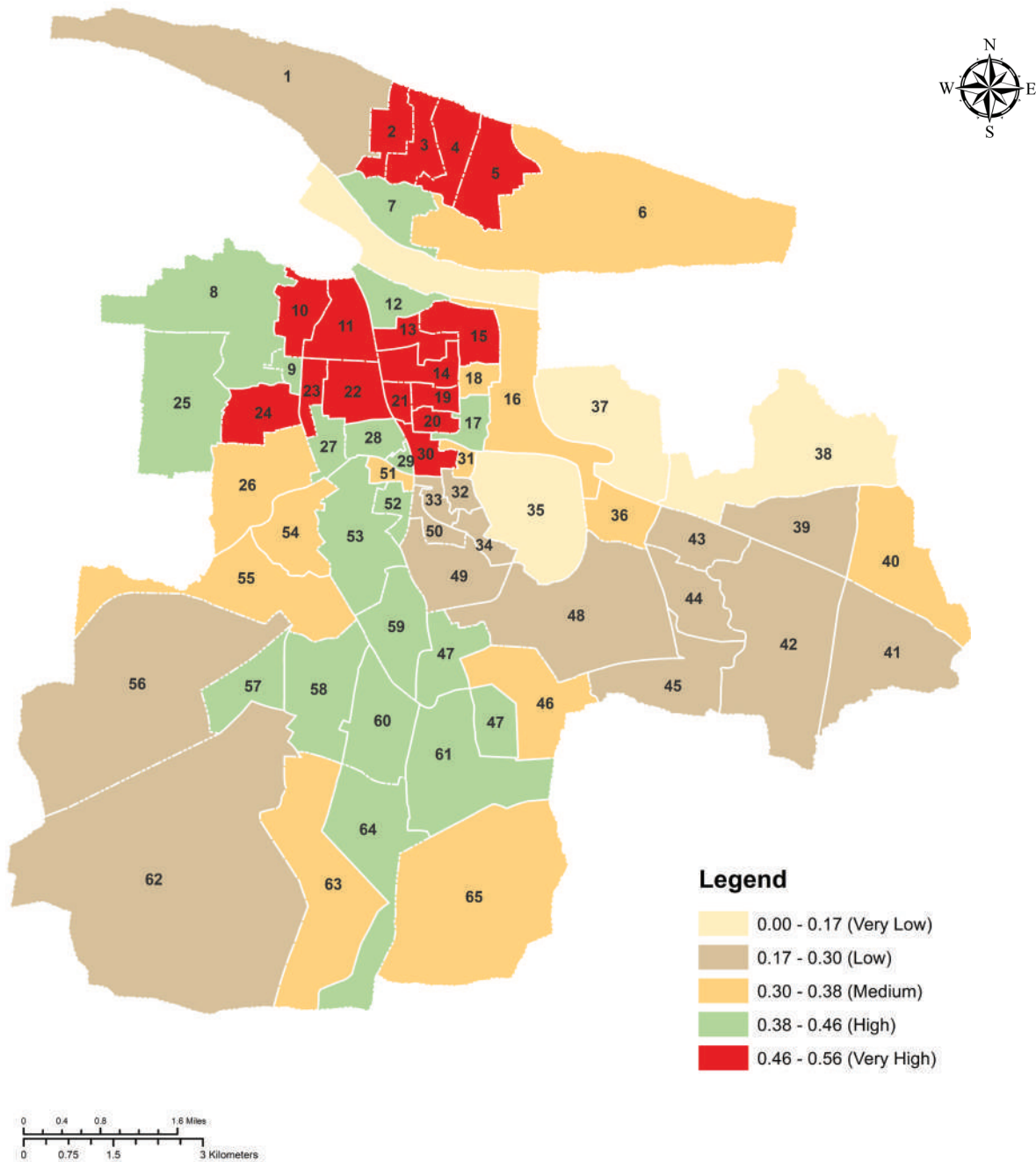
Heat risk index	Ward numbers
Very Low	35,37,38
Low	32,33,34,39,41,42,43,44,45,48,49,50,56,62
Medium	1,6,16,26,36,40,46,51,54,55,63,65
High	7,8,9,12,17,18,25,27,28,29,31,47,52,53,57,58,59,60,61,64
Very High	2,3,4,5,10,11,13,14,15,19,20,21,22,23,24,30

**16 wards (25% of total wards) are classified as having a ‘very high heat risk index,’ despite moderate susceptibility; yet exposure and hazard levels in these wards are exceedingly high. These wards accounted for 5% of the total population and 10% of the total city area.**

The study identified that approximately 50% of the city’s wards fall under the categories of *high to very high vulnerability* when it comes to exposure, hazard and vulnerability to heatwaves. These findings underscore a critical public health and environmental concern that demands urgent attention.



**Figure 37: Heat risk index map for Tiruchirappalli (2024)**



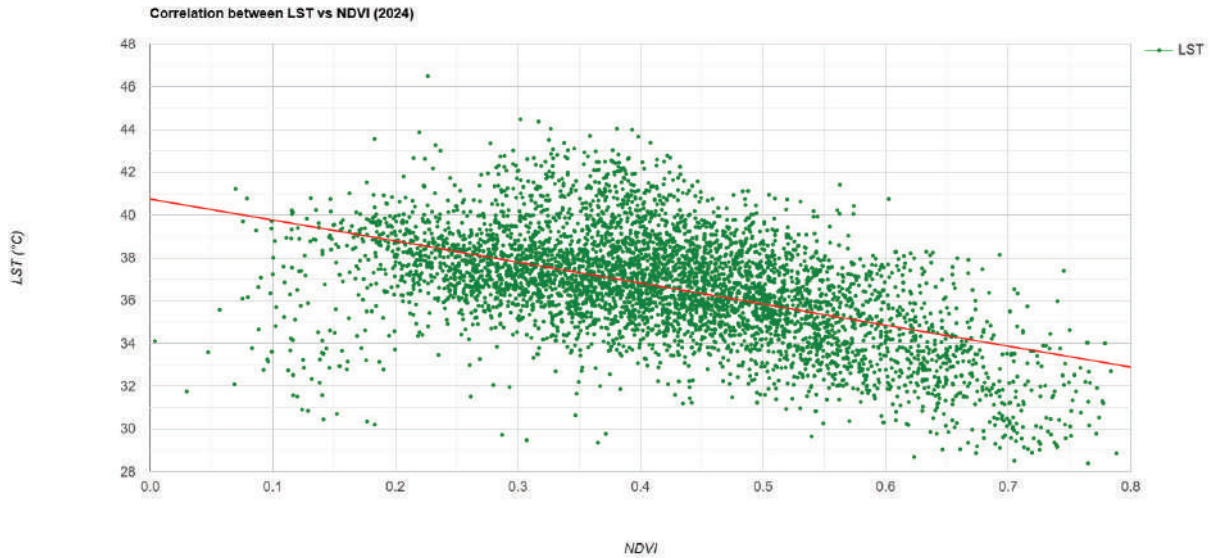
## 5.8. Correlation analysis between NDVI, NDBI and LST

### 5.8.1. Correlation Analysis between LST and NDVI

Understanding the relationship between NDVI and LST is crucial for effective urban planning and the development of heat action plans. The scatter plot reveals a clear negative correlation between LST and NDVI, indicating that increased vegetation cover is associated with lower land surface temperatures, highlighting the cooling effect of

vegetation. The downward-sloping red trendline visually reinforces this inverse relationship. While a general trend exists, the spread of data points suggests that factors beyond vegetation density also influence LST.

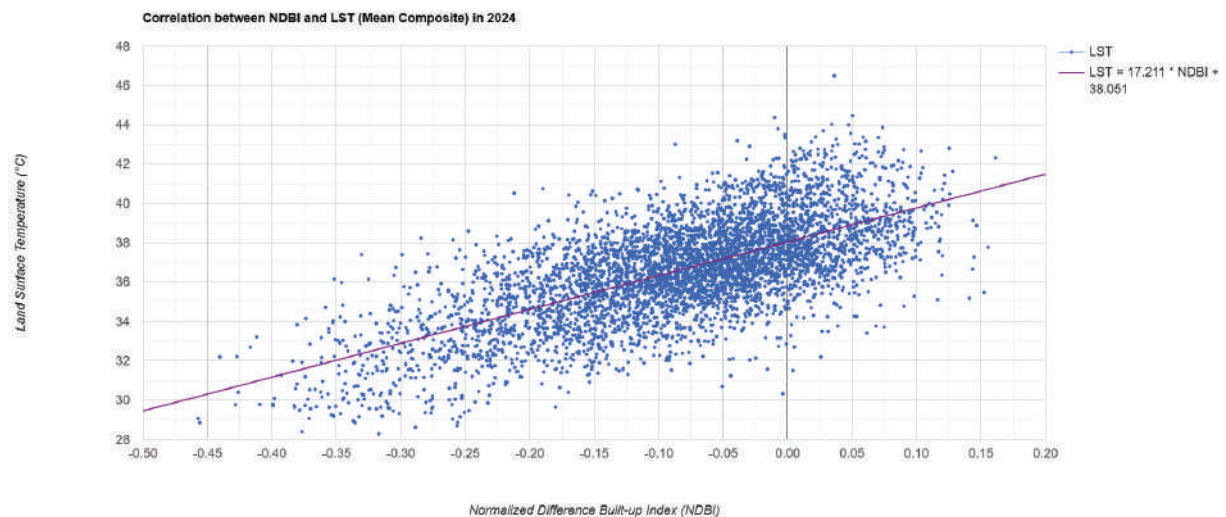
**Figure 38: Correlation between NDVI and LST for Tiruchirappalli**



### 5.8.2. Correlation Analysis between LST and NDBI

The relationship between NDBI (Normalized Difference Built-up Index) and LST (Land Surface Temperature) is crucial for urban planning and sustainable development. It helps mitigate the Urban Heat Island (UHI) effect by informing strategies to increase green spaces and reduce temperatures in built-up areas. The scatter plot reveals a positive correlation between NDBI and LST, indicating that increased built-up areas are associated with higher surface temperatures, supporting the urban heat island effect. The equation  $LST = 17.211 * NDBI + 38.051$  quantifies this relationship, suggesting LST rises with built-up density. While a trend exists, data scatter implies other factors influence LST. Overall, urbanization’s thermal impact is evident.

**Figure 39: Correlation between NDBI and LST for Tiruchirappalli**



## 5.9. Ward Level Urban Cooling Interventions

Based on the above analysis, interventions have been recommended for some of the very high heat risk wards.

**Table 34: Ward level urban cooling interventions for very high risk wards in Tiruchirappalli**

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Cool roofs (reflective paints, coatings, sheets), green roofs and walls.</b>	Built infrastructure	2,3,4,5,10,11, 13,14,15,19, 20,21,22,23, 24,30	These wards have very high built-up density (NDBI close to 1 in core areas, e.g., Ward 3 has 100% built-up area), high LST, and low NDVI (as low as 4.8% in some wards). These are also in the periphery of the srirangam temple.
<b>Urban cooling interventions for markets and commercial hubs</b>	Built infrastructure	2,3,4,5,14	These wards have high transit footfall and have key markets, such as wards 2,3,4 which include some parts of the Gandhi market and ward 14 which comprises of Thillai Nagar, a major shopping hub. Interventions can include reflective pavements, shaded stalls, water kiosks, cooling shelters, fans and electric freight vehicle pilots.
<b>Energy efficiency and cooling in MSMEs (cool roofs, solar PV, energy efficient equipment, fans for workers, etc)</b>	Built infrastructure	2,3,4,5,10,11, 13,14	These wards have high built-up density (NDBI ~0.8–1.0) and host engineering, fabrication, and service MSMEs. Energy-efficient equipment and improved ventilation reduce both ambient and indoor temperatures, benefiting workers and reducing emissions.
<b>Community parks and green spaces</b>	Nature based	2,4,5,13,14, 21,22,23	Most very high heat risk wards in Tiruchirappalli have fewer parks than the city average, with many having none or just one small park.
<b>Heat resilient retrofits for slums</b>	Built infrastructure	2,3,4,5,10,11, 13,14,15,19, 20,21,22,23, 24,30	These wards have high slum population which are characterized by poor housing, poor ventilation, limited greening, etc. Interventions can include cool roofs, improved thermal ventilation (fans, windows), urban greening, parks, etc.
<b>Enhanced Health Surveillance &amp; Heat Illness Clinics</b>	Capacity building	2,3,4,5,10,11, 19,20,21,22, 23,24,30	These wards have the highest slum populations, lowest NDVI, and lack immediate access to major hospitals. Interventions can include mobile clinics, training for doctors, etc.
<b>Water body rejuvenation</b>	Nature based	23,2,3,4,5,10, 11,13,14,15, 19,20,21,22, 24,30	These wards have no significant water body present. Water body restoration can include promoting rainwater harvesting, bioswales, retention ponds and revival of tanks like the Kollankulam tank in ward 23.

## 6. Case study: Tirunelveli City Municipal Corporation

### 6.1. Study Area

Tirunelveli is situated on the banks of Thamirabarani River that originates from the Western Ghats and drains into the Bay of Bengal in the Southern part of Tamil Nadu. The city has a rich cultural heritage and has been the epicenter of urbanization and development in the Southern districts of Tamil Nadu beyond Madurai. Tirunelveli city experiences a hot semi-arid climate with majority of its rainfall being received during the North-East Monsoon season between October and December. The annual average rainfall of the city is only around 669 mm (in 2022) as it is rain-shadowed by Agasthya hills in the Western Ghats. Despite low precipitation levels, the city faces flooding risks from Thamirabarani River following heavy rainfall in the River's upper catchment areas. The city also experiences urban flooding during cloudbursts or heavy rainfall due to poor urban planning and lack of adequate stormwater drainage network. In recent years, the city experiences heatwaves during the summer months, another climate risk for the city.

Tirunelveli's GHG emissions for the year 2017-18 amounted to 0.73 million TCO<sub>2</sub>e, with 37% of the emissions coming from residential buildings, necessitating the need to shift towards energy efficiency for the buildings sector. Urbanization has driven significant changes in land use and land cover (LULC), with residential and mining areas expanding while agricultural and dense scrub lands have declined. Between 2018 and 2023, the built-up area of Tirunelveli increased by 2.57%. This shift, closely tied to population growth, has reduced the capacity of natural landscapes to absorb rainfall, exacerbating flooding and straining water resources<sup>43</sup>. Temperature projections also reveal that under the Shared Socio Economic Pathways (SSP5) 8.5 scenario, the annual average maximum temperature increases by 1.8°C at the end of century while in the SSP2 4.5 scenario, it increases by 0.7°C, indicating the need for urban heat mitigation measures.

### 6.2. LULC Analysis

The Land Use Land Cover (LULC) analysis of Tirunelveli city reveals a dynamic interplay between urbanization and natural ecosystems. The study categorizes the region into built-up areas (55.52%), agricultural land (30.05%), vegetation cover (19.4%), barren land (10.93%) and water bodies (3.64%). Table 35 indicates that the urban expansion has been particularly pronounced in the northeastern and southwestern zones, driven by population growth and infrastructural development projects. The loss of permeable surfaces has exacerbated urban flooding during monsoon seasons, particularly in low-lying areas like Palayamkottai.

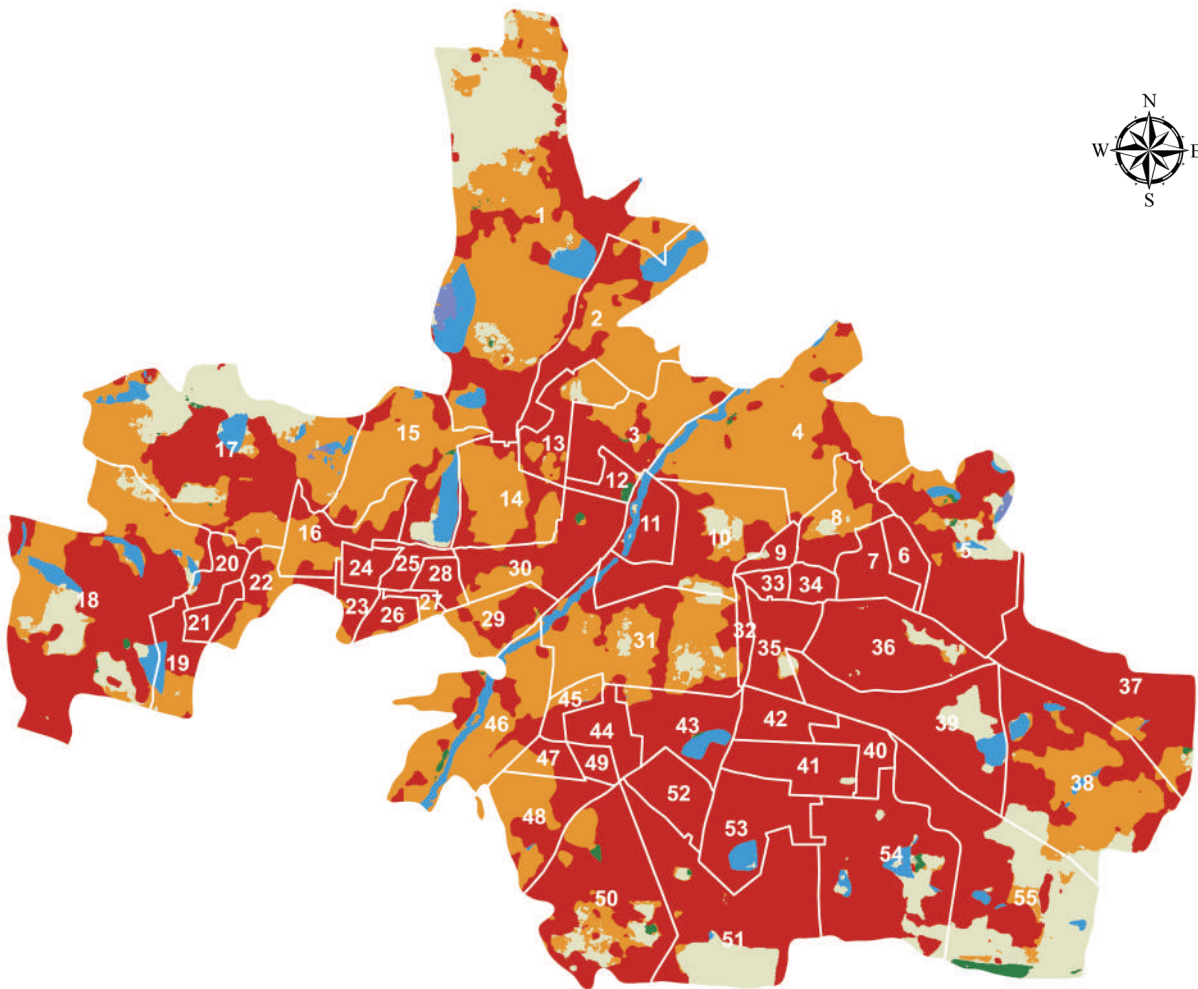
**Table 35: LULC breakup for TCMC (2024)**

LULC category	Area (Ha)	Percentage
Trees	0.45	0.39%
Crops	33.99	30%
Built up area	62.79	55.52%
Rangeland	11.76	10.39%

43. ICLEI South Asia, 2024, Net-zero Climate Resilient City Action Plan 2070 for Tirunelveli, Accessed March 2025

LULC category	Area (Ha)	Percentage
Water	4.12	3.64%
<b>Total</b>	<b>113.11</b>	

**Figure 40: LULC map for TCMC (2024)**



**Legend**

- Tree Cover / Vegetation
- Crops
- Built Area
- Rangeland
- Water Bodies

### 6.3. NDVI Analysis

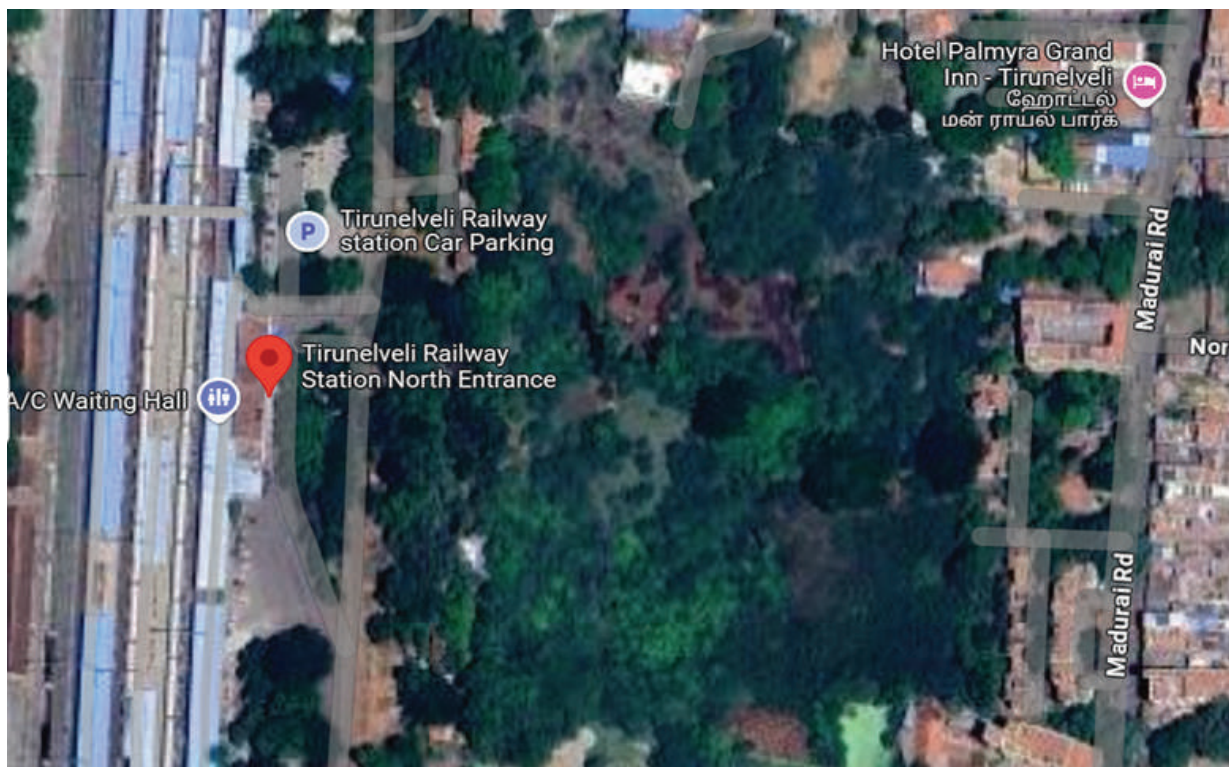
The minimum and maximum NDVI values for each ward in Tirunelveli City Municipal Corporation (TCMC) were analyzed and spatially plotted to understand the distribution of vegetation in each ward for 2024. The ward clusters with lowest and highest NDVIs along with the areas covered<sup>44</sup> are provided below.

**Table 36: Overview of wards and areas with low and high NDVI in TCMC**

NDVI	Wards	Areas covered
Wards with predominantly low NDVI (0.26-0.35)	Cluster 1: 33,34 Cluster 2: 21,24,25,28 Others: 49,44	Palayamkottai, Pettai town area surrounding Cheranmahadevi Road, Manakavalampillai Nagar, Tirunelveli town area surrounding Nellaippar Temple, Melapalayam town
Wards with predominantly high NDVI (0.5-0.59)	Cluster 1: 2,3,4,8,10 Cluster 2: 14,15 Others: 16,13,46,31, 22,29	Thatachallur, Rediyapatti road, Shanthi nagar, Palayamkottai, Muppudathi amman kovil

Ward 14 and 15 in Tirunelveli have the highest NDVI (Normalized Difference Vegetation Index) values, which could be due to the green spaces close to the Tirunelveli Railway station and the vegetation close to the Nainar Kulam Lake. Wards 2, 3 and 4 showed large green spaces and agricultural land close to the Thamirabarani river. Ward 29 showed the presence of private plantations.

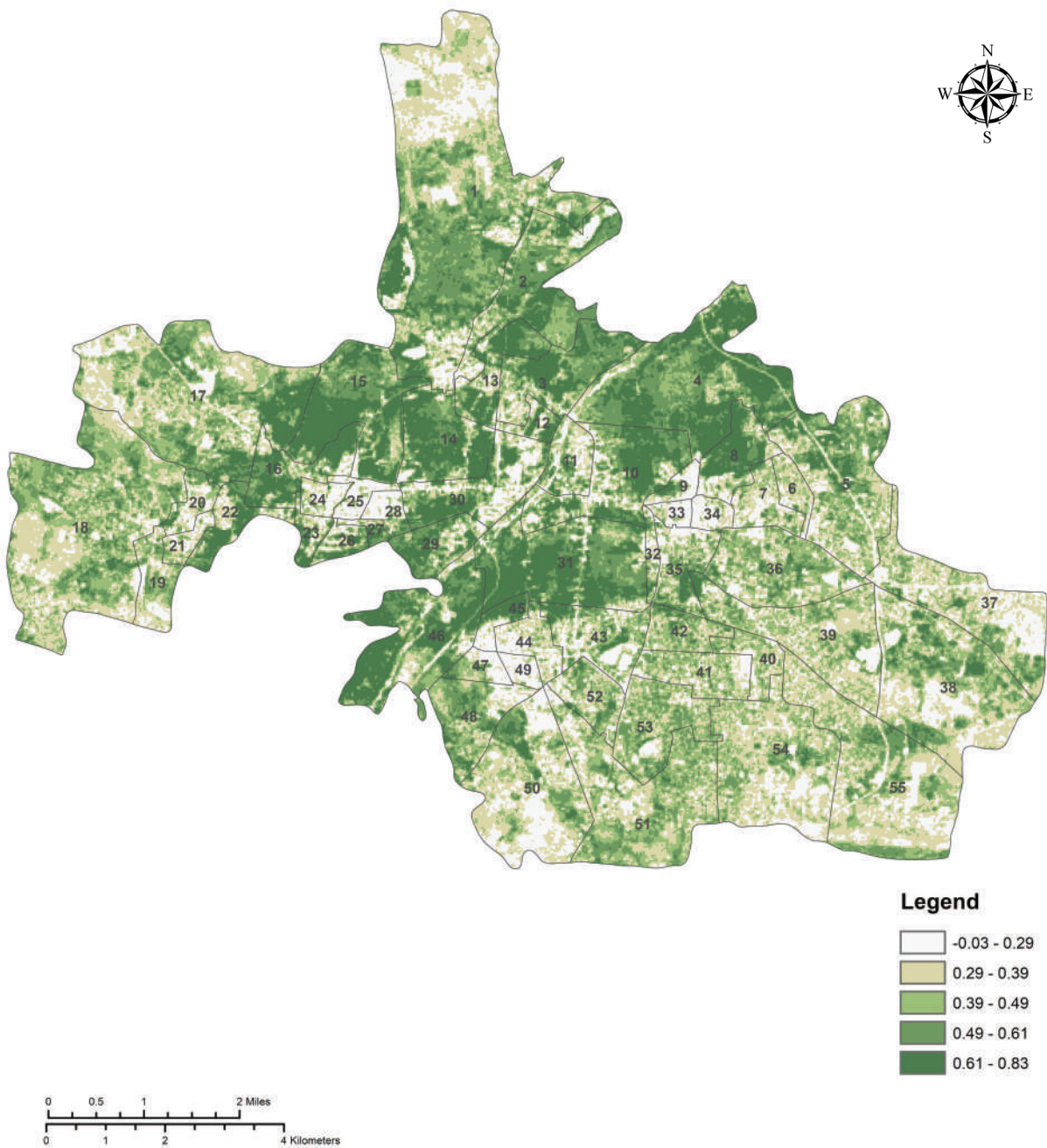
**Figure 41: Aerial view of ward 14 near the Tirunelveli Railway Station**



44. Areas were identified from the ward level google satellite maps and the Tirunelveli Climate Action Plan 2023

In Tirunelveli, analysis of NDVI values across wards reveal distinct patterns in park availability. Wards with low NDVI values ( $\leq 0.368$ ) show an average of 5.33 parks per square kilometer, while those with high NDVI values ( $\geq 0.487$ ) average only 1.38 parks. This inverse relationship between vegetation density and park infrastructure suggests urban planning priorities might favor park development in less vegetated areas, possibly as compensatory green spaces. For example, Ward 15, despite having the highest NDVI, has only 1 park per sq km, suggesting that extensive natural vegetation or agricultural land, rather than formal parks, drives its high greenness. Conversely, some wards with more parks, like Ward 54 (10 parks per sq km), have lower NDVI values, likely due to higher urban density or less contiguous green space.

**Figure 42: NDVI map for TCMC (2024)**



This pattern highlights that while parks contribute to urban greenery, the overall land use particularly the balance between built-up and vegetated areas—plays a more significant role in determining NDVI. Thus, the highest NDVI values are found in areas where natural vegetation dominates, rather than simply where parks are most numerous.

## 6.4. NDBI Analysis

The minimum and maximum NDBI values for each ward were analyzed and spatially plotted on the map to understand the distribution of built-up area in each ward. The ward clusters with the highest NDBIs along with the areas covered<sup>45</sup> are provided in the table below. Ward 15 in Tirunelveli has the highest NDVI (Normalized Difference Vegetation Index) value of 0.593, indicating the most abundant vegetation cover among all wards. The ward shows a negative NDBI (Normalized Difference Built-up Index) of -0.127, indicating minimal built-up areas compared to vegetation cover. The strong negative correlation between NDVI and NDBI (-0.95) across all wards confirms that vegetation decreases as urban development increases.

**Table 37: Overview of wards and areas with high NDBI in TCMC**

NDVI	Wards	Areas covered
Wards with predominantly high NDBI	Cluster 1: 32,33,34,37 Cluster 2: 21,24,25,28 Cluster 3: 6,7,9 Others: 44,49	Palayamkottai town and market area, South Bazaar Road, Tiruchendur Road and Sivalaperi Road, Murugankurichi, Shanthi Nagar, Samathanapuram, Manakavalampillai Nagar Tirunelveli town area surrounding Nellaiappar Temple, Melapalayam town area surrounding Anna Veethi and Nethaji Road

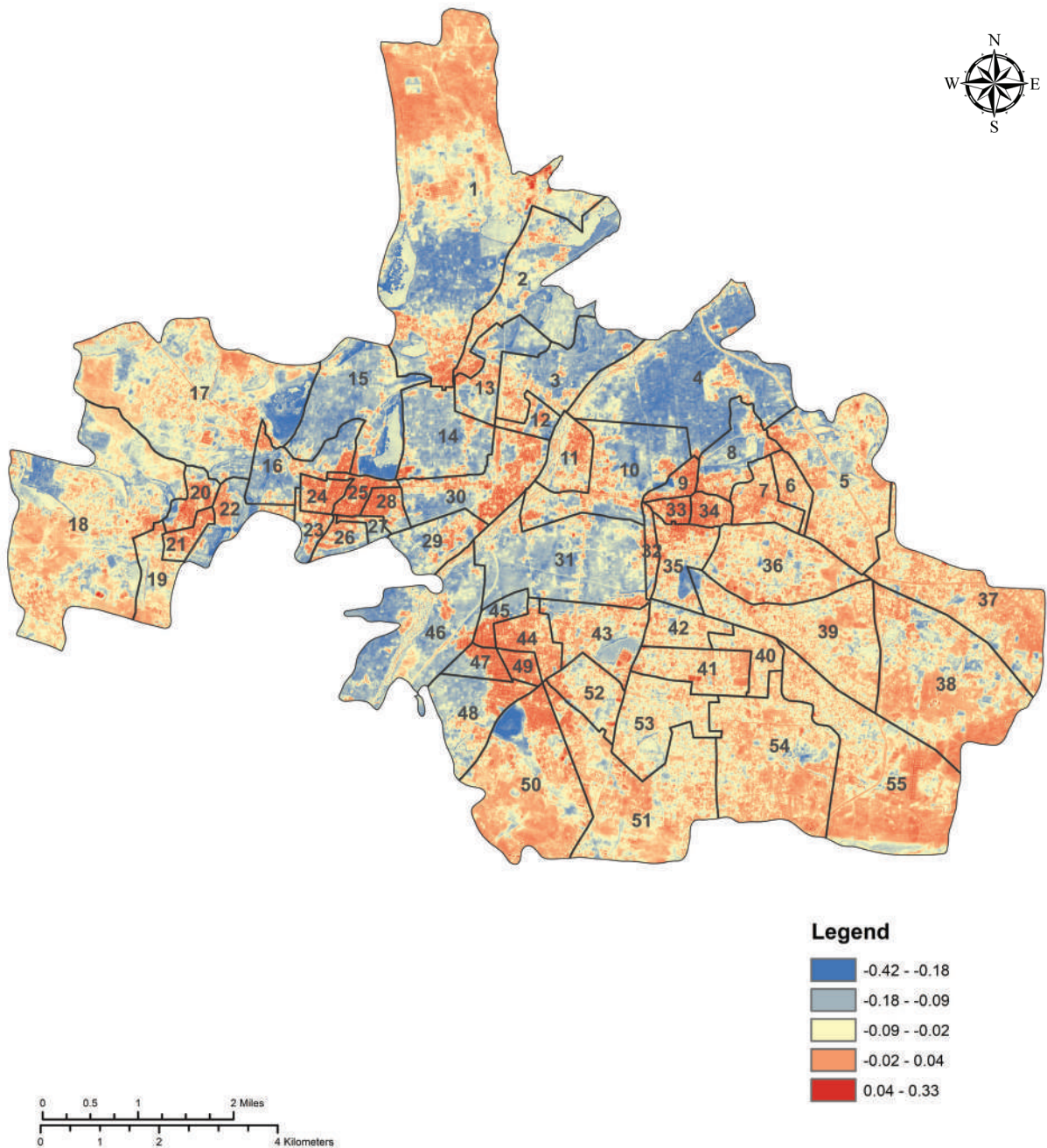
The NDBI maps were compared with ward level google satellite maps and maps from Tirunelveli's climate action plan to identify possible causes for high NDBI. The causes are provided below.

**Table 38: Wards with high NDBI and possible causes in TCMC (2024)**

High LST ranges	Wards
32	Palayamkottai bus stand
37	KTC nagar bus depot
24,25,28	Core city area near Nellaiappar Temple, nethaji bose market

45. Areas were identified from the ward level google satellite maps and the Tirunelveli Climate Action Plan 2023 as ward-level maps were not available in the corporation website.

**Figure 43: NDBI map for TCMC (2024)**

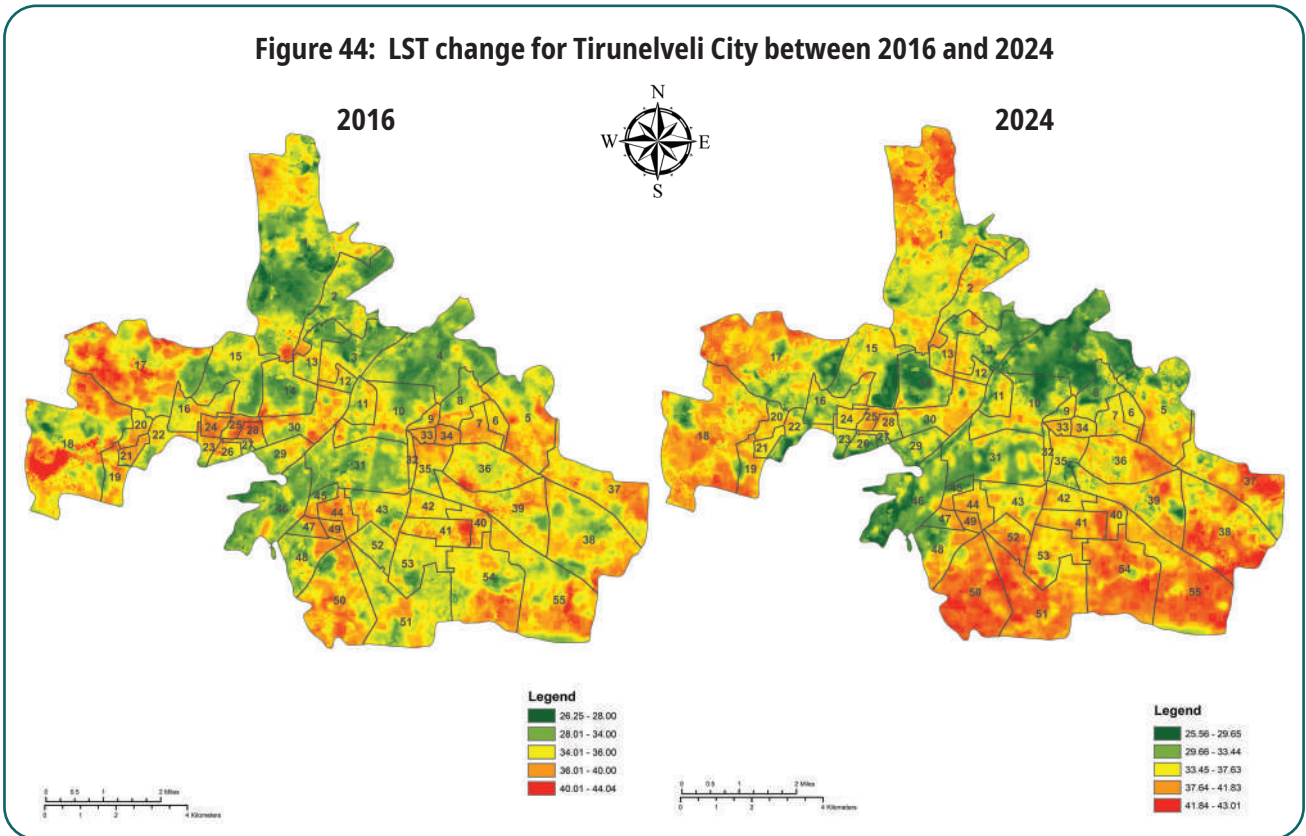


## 6.5. LST Analysis

The Land Surface Temperature analysis was carried out for 2 years (2016 and 2024) to understand the changes in LST over the period. A ward-level analysis of changes in LST can help pinpoint **LST hotspots**, for urban cooling interventions.

Several wards in Tirunelveli, such as Ward 25, Ward 24, Ward 28, Ward 34, Ward 49, Ward 33, and Ward 44, exhibit notably high Land Surface Temperature (LST) values, with 2024 readings consistently above 45°C. Additionally,

**Figure 44: LST change for Tirunelveli City between 2016 and 2024**



the NDBI (Normalized Difference Built-up Index) values in these wards are positive and relatively high, confirming extensive built-up surfaces that absorb and retain more heat compared to vegetated or water-covered areas. This pattern is reinforced by the urban heat island effect, which is more pronounced in densely built environments with limited parks or water bodies to provide cooling. In contrast, wards with lower LST typically have higher NDVI values, more parks, and a greater proportion of water bodies, all of which contribute to moderating surface temperatures.

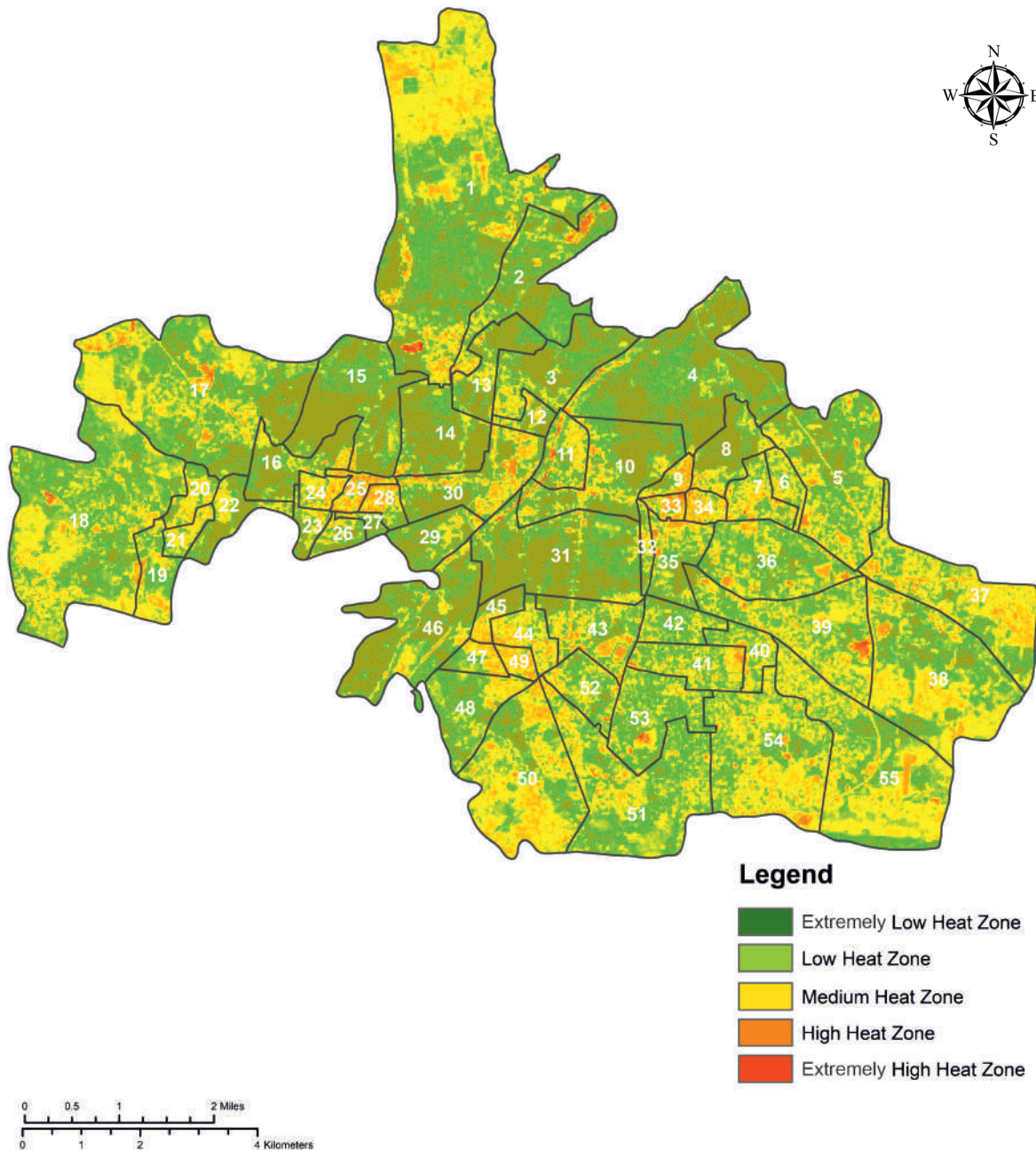
Wards such as 17,18,24,25,28,33,34 and 36 and 13 also saw an increase in LST over the time period due to built-up area expansion.

**Table 39: Wards and areas with high LSTs in 2024 with possible sources**

High LST ranges	Wards	Areas	Possible sources
Mean LST between 44.3.1 °C -45.2 °C	Cluster 1: 24, 25, 28 Cluster 2: 33, 34 Others: 44, 49 Parts of ward 36	Tirunelveli town area surrounding Nellaiappar Temple, Palayamkottai, Melapalayam, Murugankurichi, Shanathi Nagar, Samathanapuram, Manakavalampillai Nagar	Core city area near Nellaiappar Temple Ward 36- Tirunelveli medical college and Anna stadium
Mean LST between 43.4 °C -44.4 °C	Cluster 1: 40,41 Others: 7, 21, 50, 17, 18, 9	Pettai town area, Dr. MGR New Bus Stand area , Xavier colony	MGR new bus stand, Proximity to SIDCO Industrial Estate in Pettai Ward 18- MTD Hindu college

Several areas of the city showed large portions of vacant land. Portions of ward 36 near the Tirunelveli medical college showed large areas of sparse greenery and vacant land, contributing to high LST. This area provides immense opportunity for urban greening and can be explored.



**Figure 46: UHI map for Tirunelveli city (2024)**

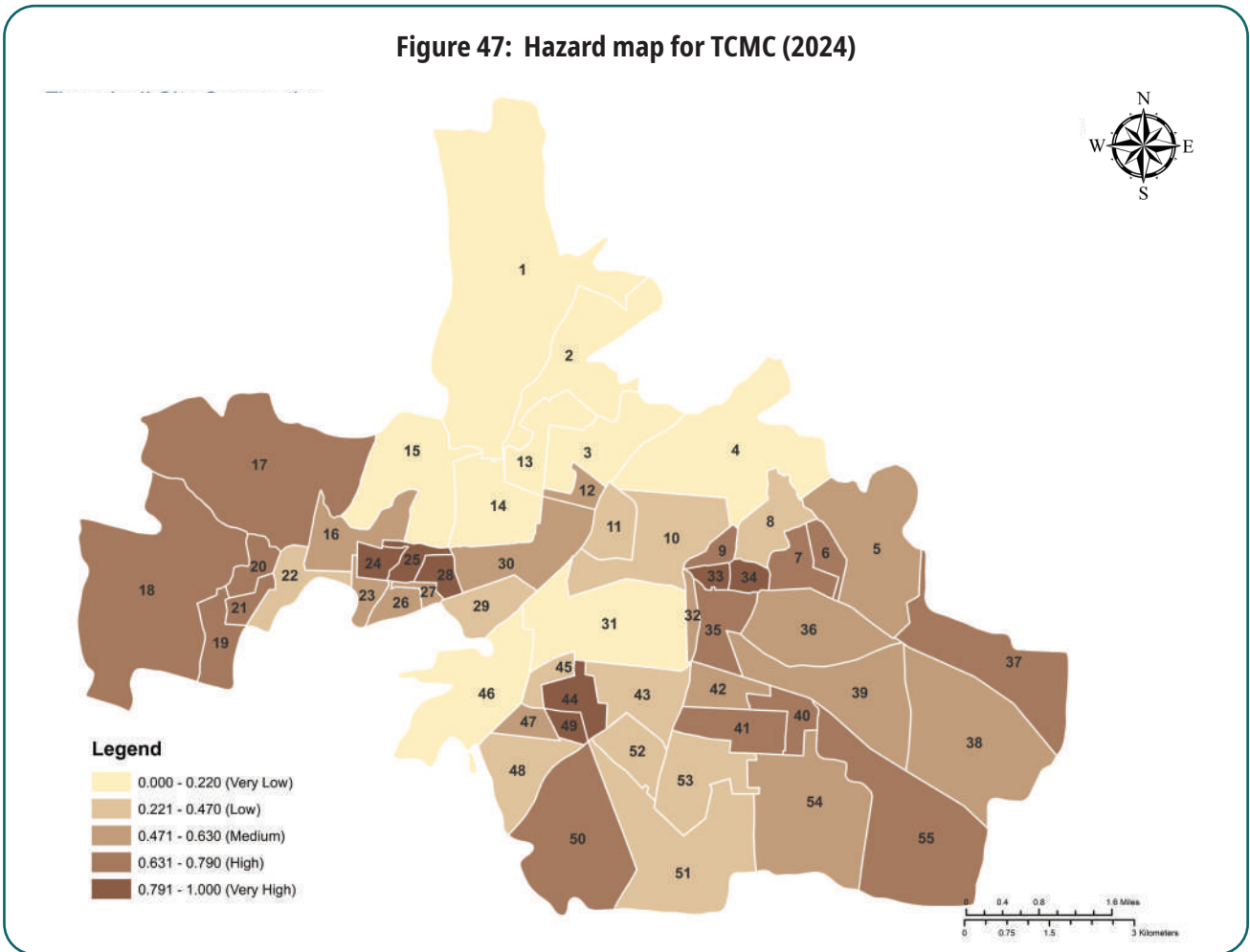
## 6.7. Ward-level Heat risk index for Tirunelveli Municipal Corporation

### 6.7.1. Hazard

The wards were spatially mapped based on whether the potential of the hazard (high LST) was very low, low, medium, high or very high, to provide an overview of wards which have a very high potential of high LST.

Wards exhibiting a very high hazard index—with values ranging between 0.79 and 1.00—include **wards 24,25,28, 33,34,44, and 49**. These elevated hazard levels are primarily attributed to extensive barren land and built-up areas,

which contribute to significantly higher land surface temperatures. **In contrast, wards 1,2,3,4,13,14,15,46 and 31** displayed very low hazard index.



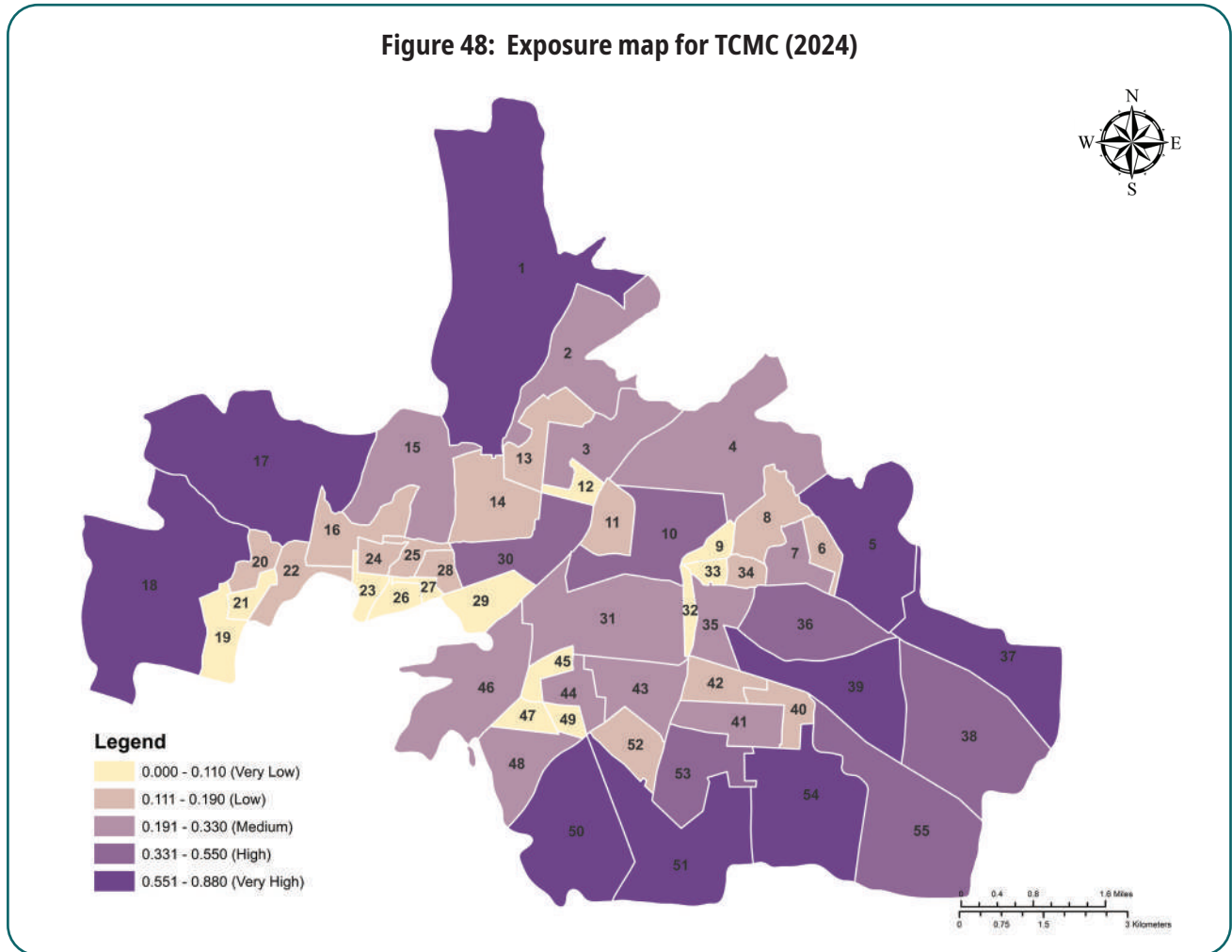
**Table 41: Different hazard categories of wards for TCMC (2024)**

Risk of Hazard	Ward Numbers
Very low	1,2,3,4,13,14,15,46,31
Low	11,43,51,8,45,29,48,52,53,10
Medium	30,54,39,23,36,5,42,47,26,38,12,16,27,22
High	41,40,17,50,6,9,37,18,19,20,55,35,32
Very high	25,24,28,34,49,33,44

The wards corresponding to high hazard also correspond to those which fall under high heat UHI zones.

### 6.7.2. Exposure

Among the wards in Tirunelveli, Wards 18,1,51,54,5,39,17,50, and 37 fall within the highest exposure category, with exposure index values ranging from 0.55 to 0.88. These elevated values can be primarily attributed to the higher population densities and the substantial proportion of built-up area relative to the total geographical area within these wards.



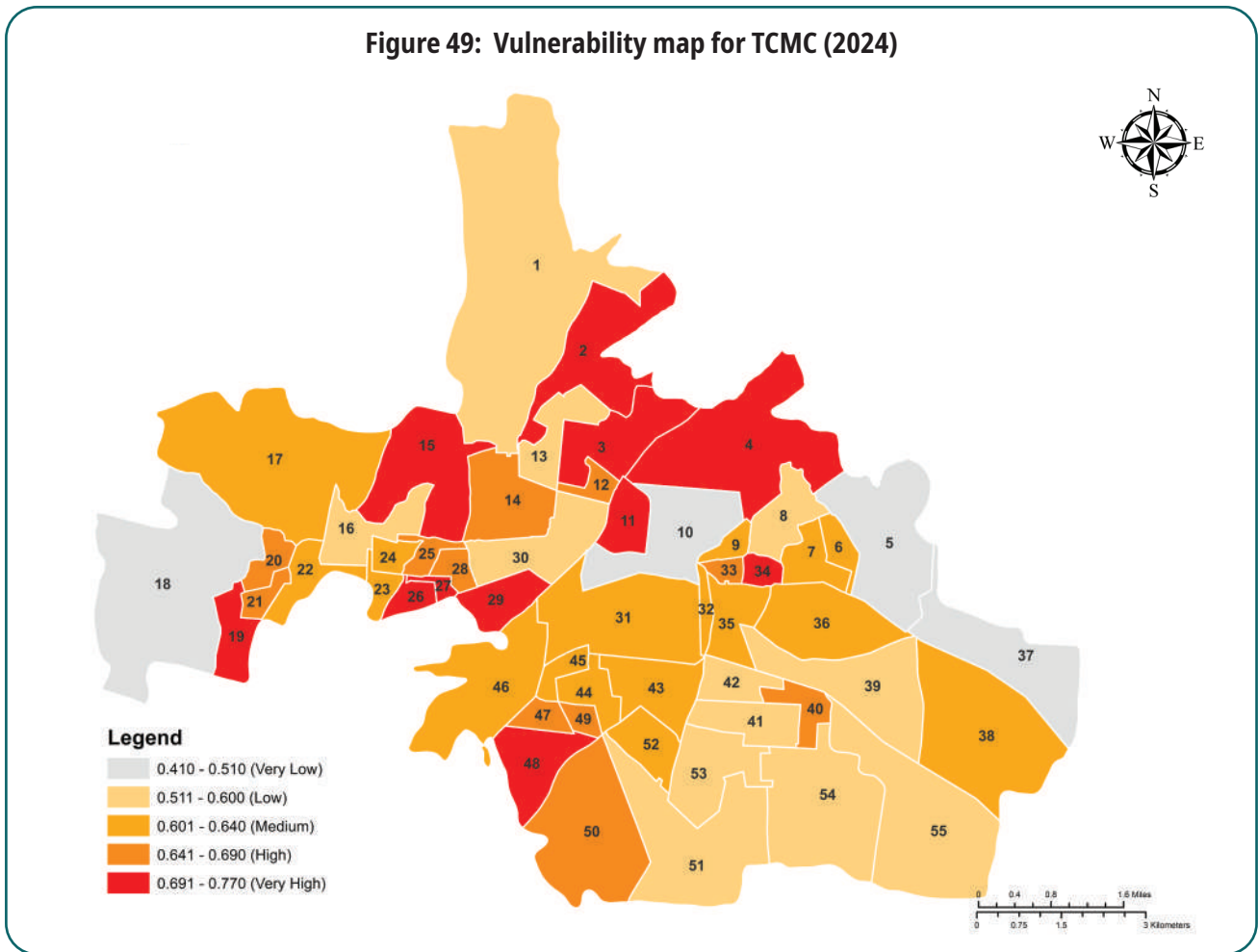
**Table 42: Different exposure categories of wards for TCMC (2024)**

Exposure	Ward Number
Very Low	19,21,23,26,27,29,47,45,49,12,9,32,33
Low	11,16,42,13,14,25,20,22,24,40,6,28,34
Medium	43,2,31,35,44,41,4,7,3,48,46,15,8,52
High	55,30,36,38,10,53
Very high	1,17,18,50,51,54,39,5,37

Conversely, Wards 19,21,23,26,27,29,47,45,49,12,9,32,33 are categorized under the lowest exposure group, exhibiting index values between 0.0 and 0.11. The low exposure levels in these wards are largely due to their lower population densities and a smaller percentage of built-up area in relation to their overall geographical area. **Wards 49 and 33 had a high hazard risk but low exposure, due to lower population and built-up densities.**

### 6.7.3. Vulnerability

Wards 15,48,4,29,11,26,3,19,2,37 and 34 demonstrate heightened vulnerability, which can be attributed to a combination of inadequate medical infrastructure, limited green cover, absence of an automatic weather station, and a constrained road network—all of which contribute to a reduced adaptive capacity. Additionally, these wards are characterized by a significant proportion of the youth population and recorded high scores on the Heat Risk Index (HRI), further intensifying their susceptibility to heatwave impacts.



**Table 43: Different vulnerability categories of wards in TCMC (2024)**

Vulnerability	Ward Number
Very low	10,37,18,5
Low	1,13,41,42,30,53,8,16,51,55,39,54,
Medium	52,9,17,32,35,43,45,6,24,31,36,7,22,23,46
High	47,20,25,14,21,50,12,28,33,49,40,38,44
Very high	15,48,4,29,11,26,3,19,2,27,34

Wards 18,5 and 37 showed very high exposure due to high built-up area but showed very low vulnerability (higher adaptive capacity) due to relatively low slum population, reduced proportion of young residents, lower incidence of chronic health conditions, well-developed road networks, and greater green cover—factors that collectively enhance their ability to cope with heat-related health risks.



Overall, approximately 20% of the wards (10 out of 55) were classified under the highest heat risk category, accounting for 20% of total city population and 33% of total city area, while 14.6% (8 out of 55) of the wards were found to possess high heat risk indices primarily due to the impact of heatwaves. Furthermore, nearly 40% of the city—equivalent to 22 out of 55 wards—were identified as facing medium levels of heatwave risk.

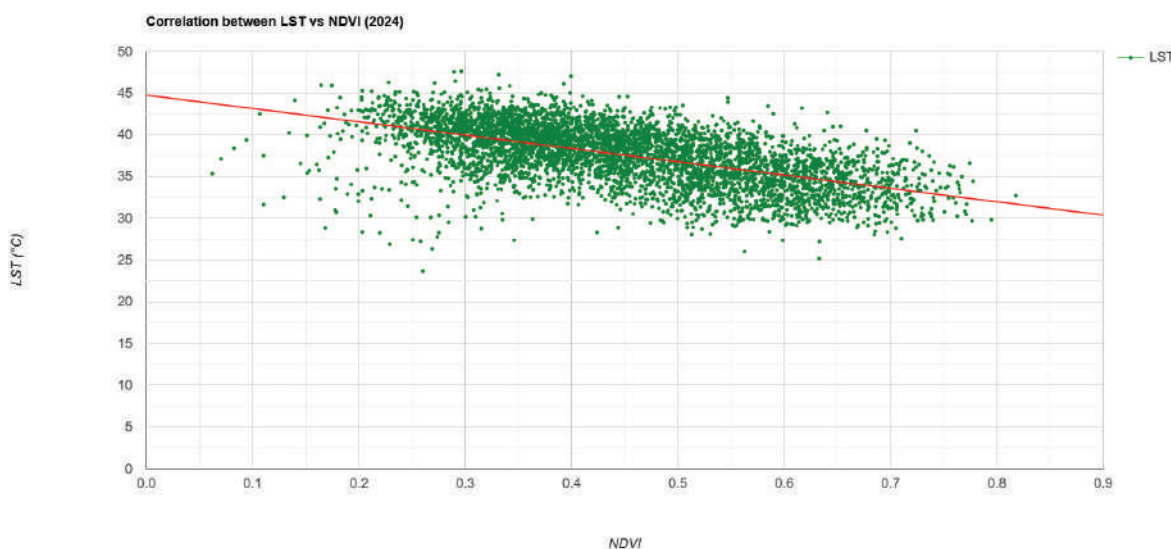
Approximately 35% of the city’s wards fall under high to very high vulnerability categories and 40 % of the wards fall under medium in terms of exposure, hazard, and adaptive capacity to heatwaves. These findings highlight a pressing public health and environmental challenge that necessitates immediate policy and planning interventions.

## 6.8. Correlation Analysis between NDVI, NDBI and LST

### 6.8.1. Correlation Analysis between LST and NDVI

Understanding the relationship between NDVI and LST is crucial for effective urban planning and the development of heat action plans. The scatter plot for Tirunelveli reveals a clear negative correlation between LST and NDVI, indicating that increased vegetation cover is associated with lower land surface temperatures, highlighting the cooling effect of vegetation. The downward-sloping red trendline visually reinforces this inverse relationship. While a general trend exists, the spread of data points suggests that factors beyond vegetation density also influence LST.

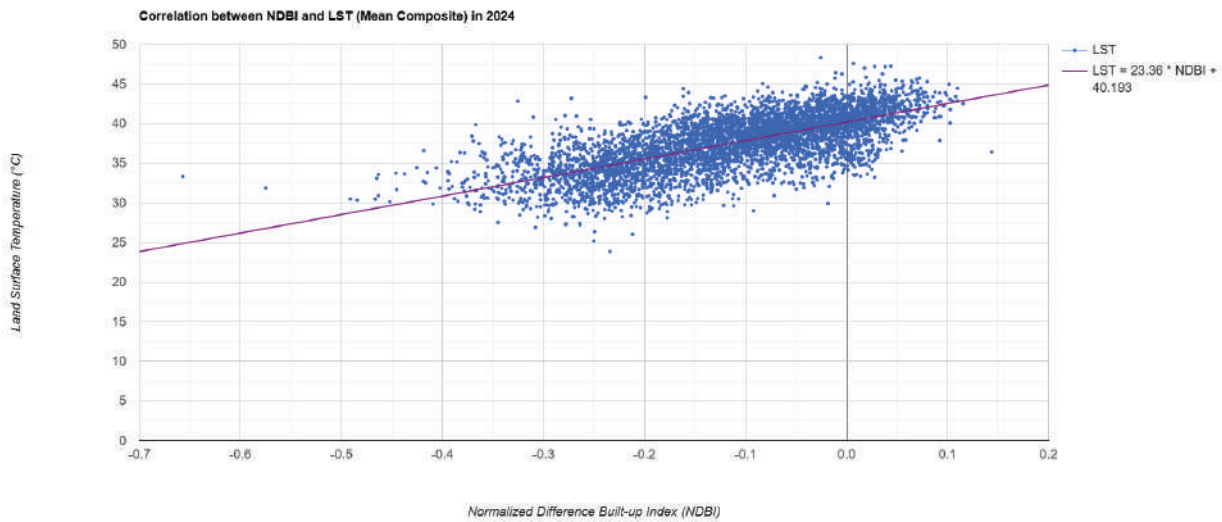
Figure 51: Correlation between NDVI and LST for Tirunelveli



### 6.8.2. Correlation Analysis between LST and NDBI

The relationship between NDBI (Normalized Difference Built-up Index) and LST (Land Surface Temperature) is crucial for urban planning and sustainable development. It helps mitigate the Urban Heat Island (UHI) effect by informing strategies to increase green spaces and reduce temperatures in built-up areas. The scatter plot reveals a composite that shows a positive correlation between NDBI and LST, indicating that increased built-up areas are associated with higher surface temperatures, supporting the urban heat island effect. The equation  $LST = 17.211 * NDBI + 38.051$  quantifies this relationship, suggesting LST rises with built-up density. While a trend exists, data scatter implies other factors influence LST. Overall, urbanization’s thermal impact is evident.

**Figure 52: Correlation between NDBI and LST for Tirunelveli**



### 6.9. Ward Level Urban Cooling Interventions

Based on the above analysis, interventions have been recommended for some of the very high heat risk wards.

**Table 45: Ward level urban cooling interventions for very high risk wards in Tirunelveli**

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Urban Forests &amp; Street Trees</b>	Nature based	17,18,50,37,24	High built-up density (NDBI >0.35) with <15% green cover. These wards also have high population density (6.85–7.42/ha) and low park density (3–5 parks/km <sup>2</sup> ). NDVI is moderate (0.362–0.445), but LST exceeds 43°C. Mature trees reduce air temperatures through evapotranspiration
<b>Cool and green Roof Implementation</b>	Built Infrastructure	50,30,54,39,55	Wards 50, 30, 54, 39, and 55 have high slum populations (1,043–4,648 residents) and moderate-to-high LST (42.66–43.82°C). NDVI is also low indicating limited natural cooling. Roofs constitute 38-45% of the surface area in these wards, offering potential for cool and green roofs.
<b>Permeable and reflective pavements, shaded structures</b>	Built Infrastructure	17,18,50	Wards 17, 18, and 50 have high population density (4.04–7.42/ha) and LST (43.41–43.82°C). These are high pedestrian footfall zones with >80% impervious surfaces Reflective and permeable pavements on major roads will reduce surface temperatures and enhance evaporative cooling through water infiltration. Shaded structures like at junctions can also be implemented.

Intervention Type	Category	Target Wards	Implementation Rationale
<b>Riverfront Development</b>	Nature based	39,54,55	These wards are close to the Thamirabarani River. Water bodies have a 600m cooling radius, reducing adjacent temperature.
<b>Rainwater harvesting</b>	Nature based and built infrastructure	18,36,37,51	Rainwater harvesting systems will improve water security and support microclimate cooling in these water-scarce areas.
<b>Pocket Parks Development in vacant land</b>	Nature based	36	This ward has a lot of barren land which offer potential for park conversion.



## 7. Summary of Findings from the Four Cities

The following table provides an overview of the analysis from the 4 cities, along with a list of wards with a very high urban heat risk index.

**Table 46: Summary of UHI analysis in the four cities**

City	Parameter	Analysis
<b>Greater Chennai Corporation</b>	Very Low NDVI	Wards with low NDVI had the least number of parks per sqm Low-income wards exhibited low NDVI.
	High NDBI	Wards with high NDBI included areas with dump yards, markets, airport and industries.
	LST between 31.6°C - 33.6°C	Areas like MSME clusters (Ambattur), Koyembedu market and the CMBT bus stand showed the highest increase in LST between 2016 and 2024.
	Extremely high heat zones	Found in wards with key markets, industries and airport
	<b>Wards with very high heat risk index</b>	<b>75,32,51,44,54,76,55,78,57,48,56,73,42,97,77,106,47,45,41,12, 116,13,105,49,62,68,140,115,141,35,109,36,87,43,130,142,168,72, 67,40,139,148,94,63,71,107,10,70,74,120</b>
<b>Coimbatore City Municipal Corporation</b>	Very Low NDVI	Wards with low NDVI were located in the city center and had negligible parks per sqm
	High NDBI	High NDBI causes mapped include the compost yard, SIDCO industrial estate, MGR market and MSME clusters.
	LST between 44.49.1°C - 53.16°C	Correlated with the presence of foundry industries, MGR market, MSMEs and wards with large plots of vacant land
	Extremely high heat zones	Extremely high heat zone areas were found in wards with the presence of foundry MSME cluster, wards with market areas, industrial areas like SIDCO private industrial estate, wards with vacant land plots, Vellalore dump yard and the city airport.
	<b>Wards with very high heat risk index</b>	<b>81,30,45,46,47,33,59,29,32,48,31,68,70,78</b>

City	Parameter	Analysis
<b>Tiruchirappalli City Municipal Corporation</b>	Very Low NDVI	Areas adjacent to temples showed low NDVI and negligible park infrastructure
	High NDBI	High NDBI was seen in wards with the city airport, industries like Ultratech RMC plant and markets like the Gandhi market.
	LST between 46°C - 50°C	The Central Bus Terminal, Ariyamangalam Dumping Site , industrial estates, Gandhi Market, Paalpannai, Chindamani demonstrated elevated Land Surface Temperature (LST)
	Extremely high heat zones	Corresponded to areas close to the Ariyamangalam compost yard, airport, Tiruchirappalli corporation sewage treatment plant and new bus stand and wards with vacant plots.
	<b>Wards with very high heat risk index</b>	<b>2,3,4,5,10,11,13,14,15,19,20,21,22,23,24,30</b>
<b>Tirunelveli City Municipal Corporation</b>	Very Low NDVI	Wards with low NDVI had a high number of parks, whereas wards with high NDVI were dominated by natural vegetation, but fewer parks
	High NDBI	Correspond to areas like Palayamkottai bus stand, KTC nagar bus depot and the core city area near Nellaiappar Temple, nethaji bose market
	LST between 44.3.1°C - 45.2°C	Wards comprising of the core city area near Nellaiappar temple, Tirunelveli medical college and Anna stadium showed higher LSTs.
	Extremely high heat zones	High heat zones were found in proximity to industrial areas like SIDCO industrial estate
	<b>Wards with very high heat risk index</b>	<b>50,17,18,54,39,55,37,30,36,51</b>



Prithivi Rajan on Unsplash

## 8. Strategies and Actions for Tamil Nadu

This chapter presents targeted short, medium and long-term strategies to mitigate UHI for urban areas of Tamil Nadu across various thematic areas, grounded in the detailed ward-level risk analysis across four Tamil Nadu cities. By identifying spatial patterns of heat vulnerability and exposure, the analysis highlights priority areas where interventions can have the greatest impact. The following recommendations are designed to guide state and local governments, urban planners, and policymakers in implementing equitable and evidence-based cooling solutions.

### 8.1. Strategies to Increase Green Cover

Increasing green cover significantly reduces urban heat, creating more relaxed and more comfortable urban environments. This section focuses on urban forestry, green roofs and walls, and community gardens and parks, leveraging best practices from India and abroad. Each recommendation includes a timeframe and proposed stakeholders to coordinate and support implementation.

#### 8.1.1. Develop mini forests in cities, in line with the Karunkadugal initiative

**Description:** The state government has recently launched the “Karunkadugal initiative” to develop mini forests, typically 100-30 sqm in size, within cities. This can be strengthened further through the following:

- Developing a comprehensive urban forestry master plan with short, medium and long-term targets, with dedicated budget and the establishment of a multistakeholder steering committee to oversee implementation.
- Developing city level inventories of Open Space Reservation- it is usually controlled by government after developers hand them over lands and its status to monitor encroachment, identify vacant spaces available for parks and green spaces and their ownership status.
- Providing state level guidelines and specifications for the mini forests, including type of plantations, inclusion of walking tracks, furniture, frequency of maintenance, etc.
- Develop a dashboard or registry to monitor the health and survival rates of the forests under this scheme.
- Encourage private sector and communities to maintain these forests through public private partnerships or models like “Adopt a forest” models.
- Integrate these mini forests within proposed city and district level master plans and zonal plans.

**Implementing stakeholders:** Department of Environment, Climate Change and Forests, Tamil Nadu, TNGCC, TN Forest Department, Department of Horticulture and Plantation Crops, Directorate of Town and Country Planning (DTCP), Tamil Nadu Urban Habitat Development Board (TNUHDB), Green Tamil Nadu Mission (GTM), Commissionerate of Municipal Administration (CMA), ULBs, NGOs, Private organizations, Tamil Nadu Smart Cities Mission.

**Timeframe: Medium term**

#### 8.1.2. Support GIS driven tree cover mapping and inventories in cities

**Description:** The state governments should work with cities to develop tree inventories. Conducting detailed inventories of existing urban trees to assess their health and determine areas where new trees are needed. This helps in planning and prioritizing tree planting efforts, ultimately leading to a more strategic reduction in urban temperatures. Cities can use GIS mapping to identify the type of trees, age, girth, height, etc. across each ward. Applications can be developed to encourage community participation for tree tagging.

**Implementing stakeholders:** Department of Environment, Climate Change and Forests, Tamil Nadu, TNGCC, TN Forest Department, Department of Horticulture and Plantation Crops, GIS departments and garden departments in ULBs, NGOs, Technology developers, universities.

**Timeframe: Short term**

### 8.1.3. Enforce and promote the integration of green roofs in all public and private infrastructure

**Description:** Green roofs and walls are innovative solutions to increase green cover in densely built urban environments. These structures provide insulation, reduce the urban heat island effect, and improve air quality. Currently, there is no state level mandate or policy for green roofs. The state government can take the following measures to promote the uptake of green roofs:

- Mandate green roofs in the Tamil Nadu Combined Development and Building Rules of 2019 (TNCBDR) with specifications on structural design, vegetation type, and minimum roof area.
- Include green roofs as a requirement in the state's single window building approval system.
- Incentivize adoption through Floor Area Ratio (FAR) bonuses, subsidies, and free saplings for developers.
- Retrofit public buildings in major cities to demonstrate feasibility and leadership.
- Integrate green roof training into existing programs by CMA, Anna Institute, and TNUHDB to upskill architects, builders, and planners.
- Develop pilot/demonstration sites to showcase benefits and build public awareness.
- Monitor impact using land surface temperature data and energy consumption metrics.
- Integrate green roofs within MSMEs and industries
- Include green roofs in affordable housing schemes wherever feasible.

**Implementing stakeholders:** Department of Environment, Climate Change and Forests, Tamil Nadu, TNGCC, TN Forest Department, Department of Horticulture and Plantation Crops, GIS departments and garden departments in ULBs, NGOs, universities, TNUHDB, DTCP, IGBC, Real estate developers, GTM.

**Timeframe: Medium term**

### 8.1.4. Develop inclusive community parks and gardens across the state

**Description:** The state government can work with cities to ensure the expansion of parks and gardens, particularly in wards which are currently having limited access to green spaces, mainly in low-income areas. They can encourage the following

- Direct cities to develop a spatial map of access to green space at the ward level
- Develop standard guidelines and benchmarks based on city size and population density, for number of parks per sqm, size of parks, location, etc.
- Involve communities in mapping underutilized or vacant land for new parks and gardens
- Conduct city level audits of current parks to identify issues with access and infrastructure
- Leverage CSR and public private partnership for park management
- Integrate parks within new housing developments, commercial areas, and transportation hubs
- Monitor the impacts by conducting UHI studies at the ward level

**Implementing stakeholders:** Department of Environment, Climate Change and Forests, Tamil Nadu, TNGCC, TN Forest Department, Department of Horticulture and Plantation Crops, GIS departments and garden departments in ULBs, NGOs, universities, TNUHDB, DTCP, IGBC, Real estate developers, GTM

**Timeframe: Medium-Long term**

## BEST PRACTICE: TORONTO'S ROOFTOPS ARE GOING GREEN

Toronto has a Green Roof Bylaw, which mandates green roofs in buildings greater than 2000m<sup>2</sup> in gross floor area, with gradual targets for coverage of available roof space. The mandate covers residential, commercial and industrial buildings and includes a provision for the developer to pay a small fee in case the size of the green roof is lower than the requirements. In 2023 alone, 43 projects were successfully completed, resulting in an additional 78,000 square meters of green roof space. The green roofs have also resulted in an estimated reduction in cooling demand by 2200 MWH per year.

## 8.2. Strategies for Enhancing Access to Water Resources

Water management is a key strategy for mitigating urban heat, improving thermal comfort, and enhancing the overall sustainability of urban environments. Effective water management techniques, including the integration of water features and urban waterways, rain gardens and bioswales, and permeable surfaces, can significantly reduce the urban heat island effect by enhancing evaporative cooling, reducing surface temperatures, and improving water management.

### 8.2.1. Enhance the availability of potable water particularly during heatwaves

**Description:** The state government can direct cities to take immediate measures to ensure availability of water particularly during the summers

- Guarantee the provision of potable water across all wards during the summer season, particularly in high heat zones
- Provide access to clean drinking water facilities in public areas, including bus terminals, labor hubs, marketplaces, and parks.
- Establish water kiosks at designated high-traffic locations.
- Regularly rectify and maintain mechanical and electrical malfunctions in the water supply prior to the season.
- Open water dispensers in areas that have been identified as hot spots.

**Implementing stakeholders:** Water Resources Department, Government of Tamil Nadu, Department of Environment, Climate Change and Forests, Tamil Nadu, TNGCC, CMA, ULBs, NGOs, Private Sectors, Municipal Administration and Water Supply Department (MAWS)

**Timeframe:** Short term

### 8.2.2. Strengthen the implementation of proposed blue-green centers in the state

**Description:** The state government is planning to establish 10 blue-green centers, designed as nature-based solutions that combine green infrastructure (trees, parks, gardens) with blue infrastructure (ponds, lakes, water bodies). Integrating water features such as fountains, ponds, and artificial lakes in public spaces and parks can enhance evaporative cooling and reduce nearby temperatures. The state can further take some actions to strengthen this initiative:

- Develop clear design guidelines for real estate developers and urban planners for the proposed blue-green centers, including guidelines for walkways, pervious footpaths, roof top gardens, cooling shade structures, seating and furniture, play areas, etc.
- Conduct a ward-level mapping of UHI risk in other cities, similar to this study, to identify potential locations for blue-green center pilots.
- Integrate blue-green centers within low-income areas, which remain at the highest risk of heatwaves, embedded within Pradhan Mantri Awas Yojana (PMAY) projects and TNUHDB projects.
- Ensure the use of treated wastewater and rainwater harvesting in these blue-green centers.
- Provide training for urban planners, landscape architects, and municipal workers on the benefits and implementation of water features.
- Monitor and evaluate the impact of water features on urban temperatures and thermal comfort

**Implementing stakeholders:** TNUHDB, Water Resources Department, Government of Tamil Nadu, Department of Environment, Municipal Administration and Water Supply Department (MAWS), Climate Change and Forests, Tamil Nadu, TNGCC, CMA, ULBs, NGOs, Private Sectors

**Timeframe: Long term**

### 8.2.3. Integrate raingardens and bioswales within urban planning

**Description:** Implementing rain gardens and bioswales in urban areas can help manage stormwater, reduce flooding, and provide cooling effects through evaporation and transpiration. The state government can:

- Develop and implement guidelines for bioswales and rain gardens to be integrated within the Tamil Nadu Combined Development and Building Rules of 2019
- Bioswales and gardens along with pervious pavements can be integrated within Chennai's complete street planning manual<sup>46</sup> and incorporated into similar policies for other cities.
- Establish pilot projects to demonstrate the benefits of rain gardens and bioswales for urban cooling and stormwater management.
- Monitor and evaluate the impact of rain gardens and bioswales on urban temperatures and stormwater management.
- Provide training for urban planners, landscape architects, and municipal workers on the design and maintenance of rain gardens and bioswales.
- Establish pilot projects to demonstrate the benefits of rain gardens and bioswales for urban cooling and stormwater management.
- Developers, architects and urban planners can be incentivized to incorporate rain gardens and bioswales into their projects. Industrial parks can also be incentivized to include nature based solutions within their plans.

**Implementing stakeholders:** TNUHDB, Highways and Minor Ports Department, Tamil Nadu Road Infrastructure Development Corporation (TNRIDC), Tamil Nadu Urban Infrastructure Financial Services Ltd (TNUIFSL), Municipal Administration and Water Supply Department (MAWS), CMDA, ULBS

**Timeframe: Medium term**

46. ITDP, 2020, Complete Street Planning Manual, Accessed March 2025

### 8.3. Strategies for Integrating cooling solutions into built infrastructure

Integrating active and passive cooling solutions within built infrastructure is essential to enhance thermal comfort and improve energy efficiency in buildings and infrastructure. Implementing solutions for ventilation, roofing, building materials, orientation, shading, can significantly contribute towards improving the heat resilience of buildings and mitigating the urban heat island effect.

#### 8.3.1. Developing a cool roof policy for Tamil Nadu

**Description:** Telangana is the only state in India with a cool roof policy<sup>47</sup>, with Kerala's policy under development<sup>48</sup>. Tamil Nadu can implement a similar policy to promote cool roofs in the state. The policy can include the following components:

- Mandates for cool roofs in government, commercial and large-scale residential buildings.
- Cool roof targets (for example, in sqkm of roof area) for all tier 1 and tier 2 cities
- Mandate to implement cool roofs in low-income housing projects, particularly within PMAY scheme
- Integrate cool roof materials like cool roof tiles, clay tiles, white coating, etc in the Public Works Department Schedule of rates.
- Incentives to retrofit existing buildings (tax rebates, subsidies, increased floor area ratio, expedited approval, etc)
- Integration of cool roofs within the Tamil Nadu Combined Development and Building Rules, 2019.
- Integrate cool roofs in all industrial clusters across the state
- Training and awareness programs for architects, real estate developers, house owners, local government engineers

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, City municipal corporations, TN PWD, DTCP, cool roof vendors, TN Remote Sensing Agency,

**Timeframe:** Medium term

#### 8.3.2. Implement pilot cool roof projects across cities

**Description:** Cool roof pilots can be implemented across cities particularly in municipal buildings, small scale industries and affordable housing. First, the building must be selected, and awareness meetings have to be conducted with households. This should be followed by training personnel in paint applications and maintenance. The state government can support with funding for thermal mapping using drones and satellite imagery in collaboration with TN Remote Sensing Agency, to identify areas for these pilots.

**Best practice:** A pilot in Satyam Learning Centre, Hyderabad, resulted in an increased roof reflectance from 0.1-0.7, with 26% savings in electricity for cooling. Temperatures in low-income housing in Ahmedabad also decreased by 3°C<sup>49</sup>.

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, City municipal corporations, TN PWD, DTCP, cool roof vendors, Natural Resources Defence Council, TN Remote Sensing Agency,

**Timeframe:** Short term

47. Municipal Administration and Urban Development Department of Telangana, 2023, Telangana cool roof policy 2023-28, Accessed March 2025

48. WRI India, 2024, Stakeholder Consultation: Drafting Kerala's Cool Roof Policy, Accessed March 2025

49. Natural Resources Defense Council 2023, Advancing Deployment of Cool Roofs in India, Accessed March 2025

### 8.3.3. Implement Cool pavement pilots in cities

**Description:** Cities can implement cool pavements, designed to reflect more light, made from materials like cool asphalt and concrete mixes. These can include:

- Cool materials like light colored cements, porous asphalt cement, reinforced grass pavements, etc.
- Applying reflective coatings. Studies have shown that reflective coatings can reduce pavement surface temperatures by 10-15°C.
- Permeable and vegetated pavements also allow for water filtration and reduce heat absorption<sup>50</sup>.

These pilots should be monitored to evaluate the impact of cool pavements on urban heat and surface temperatures. Cities can also support this by developing standards and specifications for cool pavements and incorporate them into infrastructure planning and development.

**Implementing stakeholders:** TNHB, TNUHDB, City municipal corporations, TN MAWS, TN PWD, DTCP, cool roof vendors, Natural Resources Defence Council

**Timeframe:** Short term

### 8.3.4. State level guidelines for heat resilient, green buildings

**Description:** Tamil Nadu can come out with a guideline on incorporating passive and active cooling measures in buildings and integrate it within TNCDBR. The guidelines can include measures to improve thermal comfort, ventilation, built form, building orientation, landscaping and other measures to improve heat resilience.

The state government can support cities to undertake pilots to design buildings to be heat resilient by maximizing ventilation through vents and fans, reducing heat retention through green and cool roofs, shading and glazed windows.

Cities should also encourage the adoption of green building certifications such as IGBC and LEED through incentives like increased FAR, tax rebates and faster approval processes. They can also enter into MOUs with organizations like IGBC to implement green buildings. Cities can also collaborate with EESL to avail subsidized energy efficient equipment like BLDC fans and energy efficient chillers.

Studies have shown that LEED-certified buildings can reduce energy consumption by up to 25% and improve indoor comfort. This can be supported by training for architects, engineers, builders, etc. on green building certification and energy efficient building design

**Best practice:** ITC Grand Chola in Chennai achieved a 5-star GRIHA rating through the use of low energy materials like plywood and MDF boards with recycled fabric, installing 12,600 kWp of wind power, using energy efficient fixtures and ensuring 99% of area was daylit, amongst others<sup>51</sup>.

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, City municipal corporations, TN MAWS, TN PWD, DTCP, IGBC, LEED, GRIHA, Architects

**Timeframe:** Medium term

50. Global Cool Cities Alliance, 2012, A practical guide to cool roofs and cool pavements, Accessed March 2025

51. GRIHA, 2018, A collection of sustainable buildings in South India, Accessed March 2025

**Figure 53: Overview of green building actions by ITC Grand Chola in Chennai (GRIHA, 2018)**

Grand Chola,  
ITC Hotels Limited

Location	: Chennai
Site Area	: 32,330 sq.m
Total Built-up Area	: 1,32,598 sq.m
Air- conditioned Area	: 1,32,598 sq.m
Non Air-conditioned Area	: NA
Energy Consumption Reduction	: 41.5% reduction from GRIHA benchmark
Water Consumption Reduction	: 50.7% reduction from GRIHA benchmark
Energy Performance Index (EPI)	: 186 kWh/sq.m/year
Occupancy Hours	: 24 hours/day (24x7)
Renewable Energy Installed on Site	: 12600 kWp
GRIHA Final Rating	: 5 Star

### 8.3.5. Retrofit roofs with recycled materials for heat resilience

**Description:** Cities can implement innovative solutions such as recycling plastic into heat control systems to increase the roof's thermal mass and reduce temperatures inside the house. Plastic bottles filled with water can be sealed and secured to the roof. Similar structures have been implemented in Pune and Bangalore<sup>52</sup>. These can also be included within affordable housing projects.

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, City municipal corporations, NGOs and consultants like CBalance

**Timeframe: Medium term**

52. Dialogue earth 2021, 5 sustainable solutions to help tackle extreme heat in South Asia, Accessed March 2025

### 8.3.6. Develop cooling shelters within high-risk wards

**Description:** Cities can implement cooling shelters particularly in wards with a high risk of heatwaves. State government can support these and integrate the same within urban development plans.

- Install cooling centers in major public spaces like markets, junctions, and bus stands. These centers should provide clean drinking water, ORS (Oral Rehydration Solution), and refreshments.
- Set up temporary shades and shelters at markets, traffic signals, and other locations where people are exposed to the sun.
- Provide adequate shelter facilities for homeless individuals to protect them from extreme heat.
- Set up temporary resting centers specifically for fishermen to provide them with a place to cool down and rehydrate.
- Establish temporary rest facilities along major roads for online food and other delivery workers who are particularly vulnerable to heat exposure.

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, City municipal corporations, TN PWD, DTCP, cool roof vendors

**Timeframe:** Medium term

### 8.3.7. District cooling system (DCS) pilots in cities

**Description:** District cooling is a centralized system that produces and distributes chilled water or any other medium to several buildings through a network of underground pipes. The chilled water after circulation is returned back to the plant for re-cooling. This centralized system allows for energy efficient cooling and lower greenhouse gas emissions.

A flagship district cooling project in Chennai is planned at Fintech City in Nandambakkam, which is set to become the first infrastructure in Tamil Nadu to implement a DCS. The Tamil Nadu Industrial Development Corporation (TIDCO) is spearheading this initiative, with infrastructure development underway and expected to be completed soon. The DCS is projected to reduce the air-conditioning energy load by 40–50% and cut power bills by 20% for the development<sup>53</sup>.

A techno-economic viability study is in progress, and tenders for appointing a district cooling developer are being prepared<sup>54</sup>. The system will serve finance-related companies and institutions in the new business district, with plots being allocated on a long-term lease.

Similar projects can be piloted in other cities, particularly in proposed tech parks or Information Technology hubs, universities or housing clusters. The TN government can support this by providing land, integrating district cooling into Tamil Nadu's State Energy Conservation Building Code (ECBC) and convening a state level committee to implement district cooling pilots.

**Implementing stakeholders:** TNHB, TNUHDB, TN Housing and Urban Development Department, TNEB, TEDA, MAWS, TNUIFSL, TNGCC, City municipal corporations, TN PWD, DTCP

**Timeframe:** Long term

53. UNEP-TNGCC-SPC consultations

54. TIDCO, 2024, Call for consultant for techno economic viability study and transaction advisory services for the Development of District Cooling System (DCS) at fintech city in Nandambakkam, Chennai, Accessed May 2025

## 8.4. Strategies for Awareness and Community Involvement

### 8.4.1. Education and awareness

**Workshops and seminars for awareness creation:** Municipal governments or private agencies can **conduct seminars and workshops** to educate residents, local businesses, industries, private real estate developers and government officials about the UHI effect, its consequences (e.g., increased energy consumption, health risks, reduced productivity), and the strategies to mitigate it.

**Training sessions for state and local government officials on integration of urban cooling solutions into planning:** A recent report<sup>55</sup> identified that 35% of Members of Legislative Assembly (MLAs) in Tamil Nadu had a very basic or inadequate understanding of climate science topics. In particular, 10 out of 20 MLAs interviewed had not heard of nature-based solutions while 4 had heard of it but were not aware of its meaning. This highlights the need to provide technical trainings for state MLAs, Members of Parliament (MPs), District collectors, Mayors, Municipal Commissioners and city level engineers on urban cooling solutions, with a focus on nature based solutions and how to integrate them within urban planning.

**Technical training sessions on green building practices:** Technical training can be provided to builders, real estate developers, construction workers, etc on how to integrate cooling interventions within building layouts and plans, principles of green buildings and how to avail certification and its benefits. This can also be done in collaboration with IGBC, GRIHA, universities or think tanks who are experts in this field.

**Training sessions on urban greening and scientific management:** Technical sessions can be provided to garden department officials and other relevant officials on current urban forestry methods, types of plants, survival rates and various business and community driven models for their maintenance. Best practice case studies from other cities within and outside India can also be provided.

**Social Media awareness creation:** Use social media platforms, blogs, documentaries, advertisements, etc to reach a broader audience on how UHI is impacting life in cities and how residents can reduce it by adopting green roofs, planting trees, and using reflective materials.

The Garden Department of the Brihanmumbai Municipal Corporation (BMC), in collaboration with WRI India, launched a greening Mumbai handbook which provides guidance for homeowners, resident welfare associations (RWAs), organizations, and municipal authorities – on planting saplings across all scales – from balcony gardens to large plots.

### 8.4.2. Community Outreach

**Community driven tree Planting and Green Spaces:** Engage local residents in tree planting initiatives, creating and maintaining urban green spaces like parks and community gardens.

Engage schools and business to implement such community greening initiatives. Several cities such as Kochi also conducted “mapathons” to involve citizens in mapping out areas for potential new green spaces.

55. Shankar Prakash, A. 2024. “Understanding the level of climate literacy and environmental attitudes among selected members of Tamil Nadu legislative assembly”, Accessed May 2025

ICLEI South Asia recently joined hands with Amazon to launch a network of urban food gardens, built on India's School Nutrition Garden Scheme, to improve nutrition for children in municipal schools in India.

**Neighborhood Partnerships:** Collaborate with neighborhood associations and resident welfare associations to ensure upkeep and maintenance of local parks and gardens. Bengaluru Mahanagara Palike plans to introduce a scheme funded by CSR funds, where local communities will play a key role in managing parks and gardens in the city.

**Recognition Programs:** Provide incentives and recognition for citizens, businesses or communities who display their commitment to tackling UHI through interventions such as urban greening, restoring water bodies, retrofitting their houses, etc.

**Community pilot projects:** Cities can implement pilot projects in schools, hospitals, community centers, residential complexes, etc to implement heat resilience interventions and understand the impacts, learning from the case study. Innovative interventions like air cooled helmets for policemen can also be piloted.

ICLEI South Asia is implementing a pilot study in a school in Vijayawada to identify factors contributing to increased heat risk and identify solutions to strengthen resilience and reduce impacts on students.

## 8.5. Strategies on Financial Incentives and Business Models

### 8.5.1. Incentives for urban greening

State and city governments can provide incentives to support interventions tackling UHI such as;

**Incentives to support urban greening:** Tamil Nadu is providing subsidized rooftop garden kits to support terrace gardens. Similarly, incentives can be provided for local plantations, community gardens, vertical greenery in commercial complexes, etc. Other examples of incentives can include tax rebates for homeowners installing green roofs, increased FSI for development projects which have a certain percentage of green cover and community grants to convert vacant municipal plots into green spaces. Under the Tamil Nadu Urban Development Fund (TNUDF), the state government has allocated financial incentives for creating urban parks and green belts. This needs to be monitored and effectively utilized.

Tree banking scheme in Meenangadi Kerala is an innovative approach where once a sapling is planted, after 3 years, farmers can mortgage the trees for a 10-year interest-free loan from the council which only has to be paid back if any of the trees are cut down. As of 2022, 172,000 saplings have been planted by 780 farmers.

**Incentives for green buildings:** Several cities have implemented various incentives and mandates to promote green buildings such as tax rebates, collaboration with private stakeholders and rating agencies like IGBC, integration of green building certification with online building permission systems, etc. The state government should work closely with municipal governments to implement and monitor the ECBC regulations and ensure improved ventilation and greening in buildings.

### 8.5.2. Business models

Local governments and State Government Departments can also engage in innovative business models to support the implementation of urban cooling solutions; such as;

**Public private partnerships:** Urban local bodies (ULBs) can provide land or co-financing, while private entities invest in, build, and maintain green/blue assets. For example, the Nageshwara Rao Park in Chennai has been maintained by Sundaram Finance for nearly two decades, during which they implemented several initiatives like rebuilding the pathway, restoring damaged trees and organizing events for children.

**NGO collaboration:** Local Governments can collaborate with NGOs to execute and maintain lake or park restoration projects. The local government and state government departments like PWD or Water Resources Department usually have ownership of the lakes or parks, can provide capital funding through government budgets or schemes and facilitate necessary permissions. NGOs can play a role in providing technical support, enable community engagement and additional fund raising for on ground implementation. Successful examples include the city level engagement with NGOs like Environmentalist Foundation of India in Tamil Nadu for several lake restoration projects. NGOs like Nizhal have also played an instrumental role in designing and maintaining the Kotturpuram Urban Forest in Chennai.

**Climate bonds and green finance:** Cities can issue green bonds for funding urban cooling projects such as canal restoration, urban forests, etc. For example, the Tamil Nadu Urban Finance and Infrastructure Development Corporation (TUFIDCO) or City Municipal Corporations can act as bond issuers and the Tamil Nadu Infrastructure Development Board (TNIDB) could facilitate project pipelines and certification. Cities can also bundle smaller projects into a single green bond issuance to attract investors and minimize risk. They can ensure that the bonds are certified by agencies such as Climate Bonds Initiative to ensure better visibility and attractiveness.



## 9. Stakeholder and Policy Landscape Analysis

### 9.1. Stakeholder Mapping

Several stakeholders play key roles in implementing urban heat mitigation strategies and policies to reduce the impacts of urban heat island effect. The following table provides an overview of key stakeholders and their roles. Implementing the recommendations provided in this study requires collaboration and engagement between all these agencies at the municipal, state and national levels.

**Table 47: Overview of government and non-governmental stakeholders and their role in heat mitigation**

Type	Agency/Department	Possible Role of Stakeholder
<b>Government Agencies and Departments</b>	Directorate of Town and Country Planning (DTCP)	Integrate cooling into town planning and zoning regulations.
	Chennai Metropolitan Development Authority (CMDA)	Incorporating urban cooling strategies into metropolitan planning and regulations
	Public Works Department (PWD)	Enforce the use of cooling building materials, green spaces and active and passive cooling measures in public infrastructure
	Water Resources Department, Government of Tamil Nadu	Rejuvenate water bodies and restore wetlands for microclimate regulation, improve accessibility through walking pathways
	Department of Horticulture and Plantation Crops	Promoting urban greening initiatives, managing parks and green spaces and supporting community gardens to enhance urban cooling
	Commissionerate of Revenue Administration (CRA) and Disaster Management	Leading disaster management efforts, coordinating responses to extreme heat events, and integrating urban cooling strategies into disaster preparedness and response plans.
	Commissionerate of Municipal Administration (CMA)	Guiding and supporting municipal corporations across Tamil Nadu in implementing urban cooling measures, standardizing best practices, and monitoring progress at the municipal level.
	Tamil Nadu Green Climate Company (TNGCC)	Overseeing urban cooling projects, coordinating between various departments for climate action, and securing funding for climate resilience projects.
	Housing and Urban Development Department, Tamil Nadu	Integrating urban cooling strategies into urban development projects
	Department of Environment, Climate Change and Forests, Tamil Nadu	Support urban forestry, waterbody restoration, and regulatory compliance.
	Tamil Nadu Urban Habitat Development Board (TNUHDB)	Implement cooling solutions into affordable housing projects
		Highways and Minor Ports Department

Type	Agency/Department	Possible Role of Stakeholder
<b>Government Agencies and Departments</b>	Health & family welfare department	Manage heatwave responses and health advisories particularly for women and children.
	Indian Meteorological Department	Supporting other departments with necessary information for forecasting and early warning systems.
	Directorate of Industrial Safety and Health	Ensuring the safety and well-being of laborers, especially during extreme weather events such as heatwaves, by regulating working hours, ensuring fans and other measures for cooling, providing drinking water, etc.
	State Planning Commission	Planning, coordination, monitoring, and implementation of urban cooling action plans. Align cooling with state development priorities and support cross-sectoral coordination.
	Tamil Nadu Electricity Board (TNEB)	Promote energy-efficient cooling and ensure grid readiness for increased cooling demand.
<b>Urban Local Bodies</b>	Urban Local Bodies 21 Corporations + 138 Municipalities + 490 Town Panchayats	Implementing urban cooling projects at the city/municipality/town panchayats level, maintaining public green spaces, and engaging local communities in cooling initiatives.
	Smart city SPV	Drive urban cooling solutions at the ward level
<b>Research and Academic Institutions</b>	Anna University	Conducting research on urban heat islands and cooling technologies, providing data and insights to inform policy decisions, and developing educational programs to build local capacity.
	Indian Institute of Technology Madras (IIT Madras)	
<b>Private Sector and Industry</b>	CREDAI/Real Estate Developers/ GRIHA/IGBC	Support local and state governments to implement green building and passive design norms within built infrastructure.
	Corporate Social Responsibility (CSR) Divisions of Corporations	Fund urban cooling projects and support community-based cooling initiatives
	Technology and HVAC Companies	Providing energy efficient cooling systems and supporting large-scale deployment of innovative technologies.
<b>Civil Society and Community Organizations</b>	Non-Governmental Organizations (NGOs)	Raising awareness about urban cooling benefits, advocating for policy changes, and mobilizing community participation in urban cooling projects
	Resident Welfare Associations (RWAs)	Collaborating with municipal bodies to implement cooling initiatives at the neighborhood level and maintain green spaces.
	Urban planners	Support governments to design climate-sensitive master plans and land-use policies.
<b>National Agencies/ Ministries/ Departments</b>	National Institute of Urban Affairs (NIUA)	Offer policy guidance, funding support, and inter-state knowledge sharing.
	Ministry of Housing and Urban Affairs (MoHUA)	

## 9.2. Current Schemes and Regulations & Gaps

Existing urban planning frameworks and guidelines were analyzed to understand gaps from a heat resilience perspective and recommendations were provided to address the same.

**Table 48: Overview of existing frameworks at the state level and their gaps with respect to urban heat mitigation**

Framework/Regulation	Gaps	Recommendations
<b>Urban and Regional Development Plans (URDPFI Guidelines, 2014)</b>	Lack of differentiation between green space and open spaces and no urban cooling focus in planning norms.	Clearly differentiate between open and green spaces. Provide benchmarks for per capita green space, number of parks per sq km, etc.
<b>Tamil Nadu Energy Conservation Building Code (TNECBC) 2022</b>	<p><b>Enforcement and Compliance:</b> The TNECBC lacks robust enforcement mechanisms and mandatory compliance checks</p> <p><b>Lack of Emphasis on Urban Cooling:</b> The policy says that roofs that do not have solar panels or solar water heaters, or those that are not fit for solar panels, should be cool roofs or vegetated roofs. This indicates a limited prioritization for the same compared to solar panels.</p> <p><b>Absence of Urban Heat Island (UHI) Considerations:</b> The TNECBC does not address the urban heat island effect explicitly. The code is also limited to commercial buildings</p>	<p><b>Strengthen Enforcement Mechanisms:</b> Implement regular audits and stricter penalties for non-compliance</p> <p><b>Incorporate Urban Cooling Measures:</b> Mandate and enforce the use of cool roofs, green roofs, reflective materials, and green walls</p> <p><b>Address UHI in TNECBC:</b> Include specific guidelines to mitigate the urban heat island effect, such as mandatory green roofing, natural ventilation, glazed windows and increased albedo for building materials.</p>
<b>Tamil Nadu Combined Building Development Rules (TNCBDR)</b>	<p><b>Building Design:</b> The rules do not adequately emphasize climate-responsive design principles.</p> <p><b>Water Bodies and Green Areas:</b> No mandate for inclusion of water bodies or green areas</p> <p><b>Heat Mitigation Measures:</b> The rules lack comprehensive guidelines for implementing heat mitigation measures</p> <p><b>Absence of UHI Focus:</b> The TNCBDR does not address urban heat island mitigation specifically</p>	<p><b>Include Climate Responsive Design principles</b> for building orientation, natural ventilation, and use of cool materials.</p> <p><b>Mandate Water Bodies and Green Areas</b> in new constructions.</p> <p><b>Develop guidelines to integrate heat mitigation</b> in building regulations and include specific measures.</p>

Framework/Regulation	Gaps	Recommendations
<p><b>Directorate of Town and Country Planning (DTCP) Regulations</b></p>	<p><b>Lack of green space allocation:</b> No mandatory green space allocation in urban development projects</p> <p><b>Green Roofs and Reflective Materials:</b> There are no specific mandates for the use of green roofs or reflective materials in building constructions</p>	<p><b>Mandatory Green Space Allocation:</b> Amend regulations to require a minimum percentage of green space in all urban development projects.</p> <p><b>Enforce Use of Green Roofs and Reflective Materials:</b> Introduce mandates for the inclusion of green roofs and reflective materials in building regulations.</p> <p><b>Develop UHI Mitigation Strategies:</b> Create a comprehensive strategy to address the urban heat island effect, integrating various measures into a cohesive plan.</p>
<p><b>TN State Disaster Management Policy 2023</b></p>	<p>No inclusion of heatwave specific measures and no mention of UHI mitigation strategies</p>	<p>Need to include specific measures to address the health-related risk of heatwaves and measures to reduce the UHI effect</p>



## 10. Institutional and Governance Structures for Urban Cooling

A robust and coherent policy and regulatory framework is essential for the successful coordination and implementation of recommendations provided in this guideline. This framework must align with national mandates while being responsive to the state's unique climatic, socio-economic, and urbanization contexts.

### 10.1. State Level Cooling Action Plan

To ensure long-term, climate-resilient urban development, the Government of Tamil Nadu can develop a **State-Level Cooling Action Plan (SCAP)** drawing from this study's findings and aligned with the National Cooling Action Plan (NCAP). The SCAP should act as an integrated framework that guides urban cooling initiatives across departments, municipalities, and sectors. It can be structured around the following key components:

#### 10.1.1. Cooling demand assessment

The plan must begin with a comprehensive evaluation of current and projected cooling demand across all major urban sectors—residential, commercial, municipal, and industrial, in order to.

- Quantify cooling needs based on urban typologies and socioeconomic profiles.
- Understand seasonal and spatial cooling loads at the city and ward level.
- Guide infrastructure planning for sustainable cooling technologies (e.g., district cooling, energy-efficient HVAC, passive cooling in buildings).

#### 10.1.2. Ward level Urban Green cover mapping and monitoring

The SCAP should institutionalize **ward-level assessments of urban green cover** across all 200+ Urban Local Bodies (ULBs) in the state. This is critical because:

- Low NDVI areas identified in this study correlate with high built-up areas and low park density, contributing significantly to urban heat stress.
- Areas with low green cover and high population density, show increased vulnerability and should be prioritized for greening.
- The NDVI-based analysis used in this study provides a replicable method that can be scaled across the state using satellite imagery and GIS tools.

#### 10.1.3. Urban heat island mapping and monitoring

Building on the ward-level UHI hotspot analysis conducted in four cities (Chennai, Coimbatore, Tirunelveli, Tiruchirappalli), the SCAP should establish a **statewide UHI monitoring system** using satellite-derived Land Surface Temperature (LST), NDVI, and NDBI. This should include:

- Annual UHI hotspot updates using standardized classification (e.g., high, medium, low heat zones).
- Identification of "priority wards" where high LST overlaps with vulnerable populations (e.g., slum settlements, elderly populations)
- Integration of UHI mapping into the planning approval process, ensuring high risk zones are avoided for critical infrastructure and residential expansion.

The heat risk index used in this study can also be institutionalized as a decision-making tool to drive urban cooling interventions in ULBs.

#### 10.1.4. Sector specific strategies

Taking recommendations from this guideline as a starting point, the SCAP can include targeted cooling strategies tailored to the specific needs of key urban sectors:

- **Buildings:** Promote energy-efficient and thermally resilient built infrastructure through incentives for cool roofs, green roofs/walls, natural ventilation, building material, glazing, etc, in compliance with ECBC/LEED/IGBC standards.
- **Transport:** Integrate cooling through tree-lined streets, cool pavements, urban greening near transit stations and shaded bus stops
- **Solid waste management:** The study identified dump yards as high heat prone zones, highlighting the need for strong actions focused on biomining and reclamation of dump yards into green spaces, along with a robust waste management and recycling system to reduce waste being sent to landfills.
- **Urban Greening:** Expand urban forestry programs, incentivize community gardens, and develop green buffer zones using OSR lands and vacant public plots.
- **Industry:** Focus on industrial zones like Ambattur (Chennai) and SIDCO (Coimbatore) that show high LSTs; introduce shading, landscaping, and reflective surfaces to reduce heat gain.

## 10.2. Governance & Oversight

### 10.2.1. Dedicated state level governance body

A dedicated governance body, perhaps designated as the Tamil Nadu Urban Cooling Authority (TNUCA), should be established to oversee the implementation of urban cooling strategies under the SCAP. The TNUCA can comprise of stakeholders mapped in Table 42, and can be headed by the Department of Environment, Climate Change and Forests.

This body could be a special task force or an independent regulatory authority with the following roles:

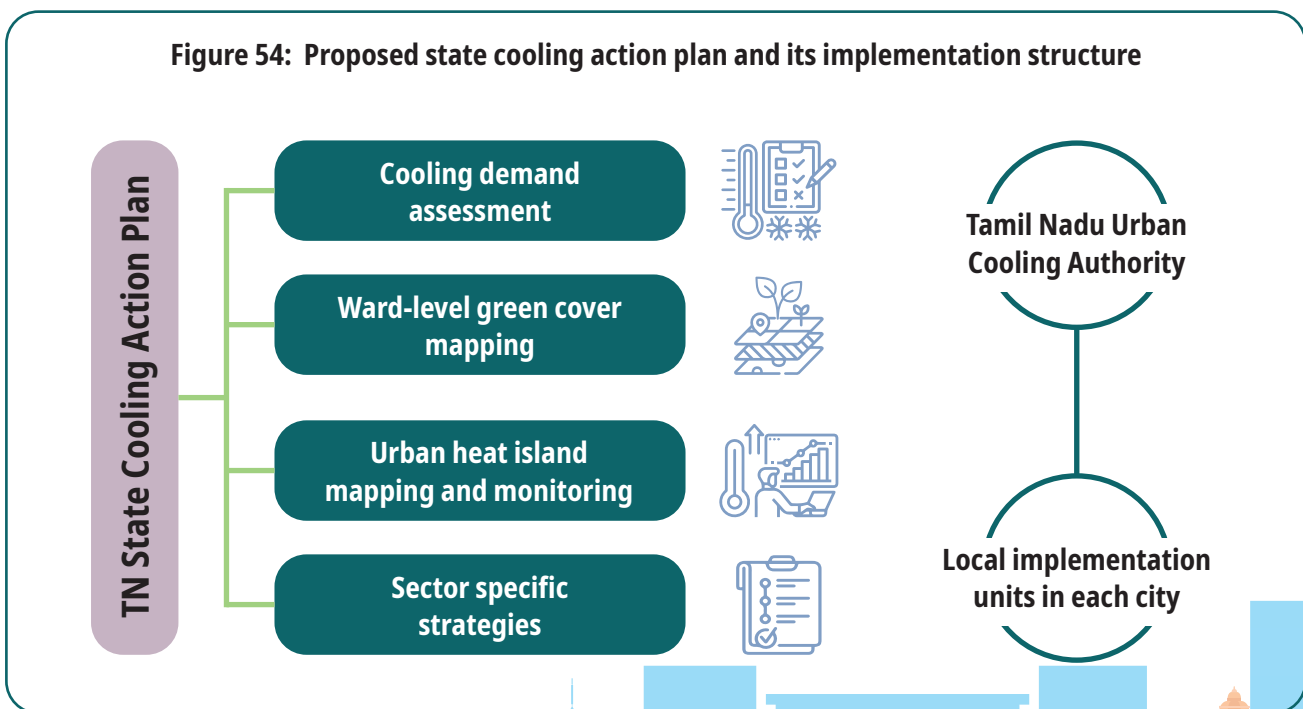
- **Coordination and Integration:** Ensuring that urban cooling strategies are integrated with broader urban planning and development initiatives.
- **Monitoring and Evaluation:** Regularly assessing the progress of cooling initiatives through a robust Monitoring, Reporting and Verification framework, using remote sensing data combined with community level data collection.
- **Stakeholder Engagement:** Facilitating collaboration among government agencies, private sector, and civil society to ensure multistakeholder coordination and effective implementation on ground.
- **Policy Formulation and Implementation:** Developing detailed policies and overseeing their implementation across the state.
- **Inter-Agency Coordination:** Facilitating coordination between various government departments, including the Department of Environment, Department of Energy, and urban local bodies.
- **Funding and Resource Allocation:** Managing the allocation of funds and resources for cooling initiatives, including the administration of incentives and subsidies.
- **Research and Development:** Promoting research and innovation in sustainable cooling technologies and practices.
- **Public-Private Partnerships:** Encouraging collaboration between the government and private sector to leverage expertise and investment.

### 10.2.2. Local Implementation Units (LIUs)

The SCAP can include the institutionalization of Local Implementation Units (LIUs) within urban local bodies to ensure that cooling policies and strategies are effectively implemented at the ground level. These units would be responsible for:

- **Localized Planning and Execution:** Tailoring state-level policies to the specific needs of their respective areas and overseeing their implementation and managing fund allocation and utilization.
- **Community Engagement:** Engaging with local communities to raise awareness and encourage participation in cooling initiatives.
- **Monitoring and Reporting:** Collecting data on cooling demands, energy consumption, and the effectiveness of implemented strategies, and reporting this information to TNUCA.

Figure 54: Proposed state cooling action plan and its implementation structure



## 11. Way Forward

Tamil Nadu is emerging as a frontrunner in addressing urban heat, having officially recognized heatwaves as a state-specific disaster in 2024 and putting in place financial relief mechanisms to support vulnerable communities. Building on the momentum of the State Planning Commission's Urban Heat Island hotspot report, which mapped district-level risks, this study adds a critical new layer by providing high-resolution, ward-level assessments across four key cities.

These insights empower targeted, data-driven action and offer a scalable model for other cities and states. The guidelines developed through this study can serve as a practical and adaptable framework for state and city officials to prioritize critical ward level interventions, particularly in areas that are highly prone to urban heat and its negative impacts and develop robust policy, institutional, financial and governance mechanisms to support urban cooling interventions across Tamil Nadu cities.

Guided by this report as a starting point, Tamil Nadu can adopt a multistakeholder and cross departmental approach towards urban heat mitigation, involving stakeholders such as urban planners, research organizations, NGOs and community representatives, paving the way towards mainstreaming urban cooling into everyday planning, infrastructure, housing, and public open space design and building cooler, heat resilient cities.



## 12. Annexure 1

### 12.1. NDVI Analysis

The equation below is used for calculating the NDVI values (Cetin et al. 2022).

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

Here's a breakdown of what the different NDVI values generally represent:

- +1: Very high vegetation density (e.g., tropical rainforest).
- 0.6 to 0.9: High vegetation density (e.g., temperate forests).
- 0.2 to 0.5: Moderate vegetation density (e.g., shrublands, grasslands).
- 0 to 0.2: Low vegetation density (e.g., sparse vegetation, bare soil).
- < 0: No vegetation (e.g., water bodies, urban areas, barren land).

### 12.2. NDBI Analysis

The difference between the spectral reflectance of the NIR and short-wave infrared (SWIR) band values is then divided by their sum to obtain the NDBI (He et al. 2010).

To calculate the NDBI at the ward level for each city, the below equation is used

$$\text{NDBI} = (\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$$

NDBI values range from -1 to +1:

Here's a summary of what different NDBI values generally represent:

- +1 to 0: Built-up areas, such as cities, industrial zones, and urban infrastructure.
- 0 to -1: non-urban areas, including vegetation and water bodies.
- Values closer to -1 typically represent water bodies or dense vegetation.

### 12.3. LST Analysis

The given equations are used to estimate the LSE and subsequently LST.

$$P_v = [(\text{NDVI} - \text{NDVI}_{\text{min}}) / (\text{NDVI}_{\text{max}} + \text{NDVI}_{\text{min}})]^2$$

Where,  $P_v$  = Proportion of vegetation,  $\text{NDVI}_{\text{min}}$  = Minimum value of NDVI,  $\text{NDVI}_{\text{max}}$  = Maximum value of NDVI

$$\text{LSE} = 0.004P_v$$

Where,  $P_v$  = Proportion of Vegetation

$$\text{LST} = (\text{BT}/1) + W * (\text{BT} / 14380) * \ln(E)$$

Where, BT = At-sensor brightness temperature, W = wavelength of emitted radiance and E = Land Surface Emissivity. The Land Surface Emissivity Value of Landsat 8 OLI is 10.8 W( $\mu\text{m}$ )

### 12.4. UHI Analysis

$$\text{UHI} = \Delta T_i / T_s = (T_i - T_s) / T_s$$

Where,  $T_i$  is the LST of the i-th pixel, and  $T_s$  is the mean LST of the entire study area.



Photo by Priya Singh on Unsplash

