UK Government

BEATING THE HEAT

TAMIL NADU HEAT MITIGATION STRATEGY

ACKNOWLEDGMENTS

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We acknowledge and appreciate the dedication and commitment of all individuals and organizations involved in this collaborative effort. Together, we remain steadfast in our commitment to mitigating the impacts of heat in Tamil Nadu.

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29. Tamil Nadu Agricultural University, Coimbatore
30. Tamil Nadu Climate Change Mission, DoECC
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FOREWORD

In the changing global scenario, heat is emerging as a pre-eminent threat to the health and wellbeing of humans, and biodiversity, apart from impacting agriculture and industrial production.

Heat events directly impact health of humans and animals, causing dehydration, heat exhaustion, mental distress, exacerbating pre-existing diseases, and particularly affecting vulnerable sections like children, elderly and pregnant women. Heat stress on the human body leads to productivity loss due to lowered efficiency and ability to complete tasks. Risks are higher especially in outdoor environments where farm and construction workers are directly exposed or where people reside in ill-designed habitations which trap heat indoors. Furthermore, heat impacts ecosystems by reducing soil moisture and vegetation cover, which when followed by heavy rain leads to high runoff and erosion, further degrading land.

Global reports already indicate that India stands to lose up to 5% of its GDP by 2030 due to rising temperatures. Tamil Nadu, being the southernmost state in India, with its warm tropical weather is projected to be severely impacted by heat. Increased night-time temperatures, intense and prolonged heat wave conditions prevalence of heat waves and increase into the number of hotter days even during 'cooler' months is increasing distress and discomfort across communities, especially among the poor, informal workers and physically vulnerable population.

Heat is a recognized threat in the state of Tamil Nadu and the state's Disaster Management Authority prepared the Heat Wave Action Plan in 2019 to increase preparedness and provide heat treatment and relief. In 2023, the state stepped up formal efforts to promote sustainable cooling solutions. Addressing the complex nature of heat and its compounding effects across sectors needs well-crafted policies, systemic change, collaboration across sectors and departments. Existing measures need to be aligned to reduce duplication and strengthen outcomes and impact on-ground.

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This Heat Mitigation Strategy, developed under the aegis of the State Planning Commission, takes a collaborative approach to devise measures towards sustaining health and wellbeing, productivity and ecology. The interdepartmental engagement brought together key practitioners and decision makers to reflect on the impacts of heat on their sectors. Such focussed discussions delineated the areas of critical concern that need to be addressed on priority.

The Tamil Nadu State Planning Commission has formulated this document as a primer for policymakers, employers, and businesses to identify critical sectoral impacts of heat on communities, workers, economy and biodiversity. Further, using examples from the state, India and the globe, this document lays out heat mitigation practices and/ or opportunities for policy revisions to integrate heat related measures.

There is much work to be done to ensure that increasing prevalence of extreme heat does not erode the developmental gains that the state of Tamil Nadu has accrued over decades of thoughtful policy interventions, rights-based action, and pro-poor schemes. It is only with collaborative efforts across government departments and in partnership with business, industry, and communities that we will be able to effectively mitigate heat impacts in the state and ensure that all citizens in Tamil Nadu continue to thrive in this rapidly warming world.

Vice Chairman,
State Planning Commission

EXECUTIVE SUMMARY

Extreme and prolonged heatwaves diminish human, animal and ecosystem health, and strain their adaptive capacities to endure and thrive in these changing conditions. The temperature range at which humans can thrive is established at **25-30°C** with 60% humidity. However, in many parts of Tamil Nadu this threshold is regularly breached, with high temperatures and humidity disrupting lives and livelihoods.

With nearly 74% of Tamil Nadu's population currently exposed to air temperature above 35°C, there is an urgent need to build heat resilience in the state as climate change-driven heat is only expected to intensify. Extreme heat erodes developmental gains, by impacting economic productivity and increasing vector-borne disease prevalence. Additionally, differential exposure and vulnerabilities across communities are deepening intergenerational inequities and locking the afflicted into long-term distress.

Highlights

- A collaborative and participatory approach complemented by robust evidence will aid in ensuring systemic changes to the complex issue of heat across sectors. The Tamil Nadu State Planning Commission set up the Heat action network to advance efforts for inter-departmental and intersectoral engagement towards heat mitigation.
- Implement cooling solutions to provide effective first-order thermal comfort in indoor and outdoor environments, enhancing liveability across the state.
- Leveraging nature-based solutions can be an effective measure to mitigate heat and provides a range of co-benefits, including increased resilience and climate-proofing of communities while maintaining ecological integrity.
- It is critical to reform practices around habitation, occupation, and ecosystems, to ensure good health and well-being outcomes for all, alongside targeted interventions for differentially impacted groups.
- Polices around productivity and labour safety should integrate heat mitigation measures. Centring heat measures in the planning and operations of various sectors would enable sustained yields in a warming climate. Applying an equity lens to incorporate gender, age, disabilities and other overlooked considerations into policies will ensure balanced outcomes.

Imperatives For Heat Mitigation

The invisible nature of heat as a climate risk, and the insufficient mention it receives in planning governance is shifting. Indian decision-makers, policy makers and local communities are coming forward, across diverse geographies, to discuss, decide and implement heat-related resilience measures.

Exploring the ongoing efforts towards heat mitigation, this strategy document has four components or levers (Communities, Socio-Ecological Systems and Resources, Economy and Livelihood, and Built Environment) that are integral to identifying problems and recommending relevant actions.

This strategy document emerged through a series of stakeholder consultations, including individual informational interviews, focused group discussions and high-level workshops. Through the consultations, key departments were identified and were convened to form the Heat Action Network. The network approach enabled line agencies to identify convergence and alignment across policies and interventions addressing heat related issues. The Heat Action Network has identified three pivotal pathways to ensure long-term preparedness towards heat risks. These include Health and Well-Being, Socio-Ecological Systems and Resources, and Sustained Productivity. While these pathways are universally recognised as important, understanding heat risk from these perspectives was not evident.

This document identifies problems in the context of heat risk and highlights synergies and opportunities for centring heat. This will support the Tamil Nadu Government in converting heat resilience-building actions that have the potential to deliver swift and tangible results. Do note, the scope of this document is not all-inclusive and there is further scope for expansion.

NDBI (Normalised Difference Built-up Index) and LST (Land Surface Temperature) are closely correlated. Increased urbanisation causes urban surface temperature to rise both during the day and at night, indicating a increase in urban heat island impacts. With almost 50% of Tamil Nadu being urbanised, implementing cooling solutions across urban areas is an urgent need.

Evidence from Madurai, Chennai and Thoothukudi indicates that areas affected by extreme heat have increased between 2003 and 2023, with night temperatures almost at par with daytime temperatures. The lack of cooling by night impacts sleep, affects health and well-being, and disrupts productivity.

Source: Inferences derived from data presented in the UNEP report on Identifying Urban Heat Island Hotspots and Mitigation Strategies for Tamil Nadu, 2024)

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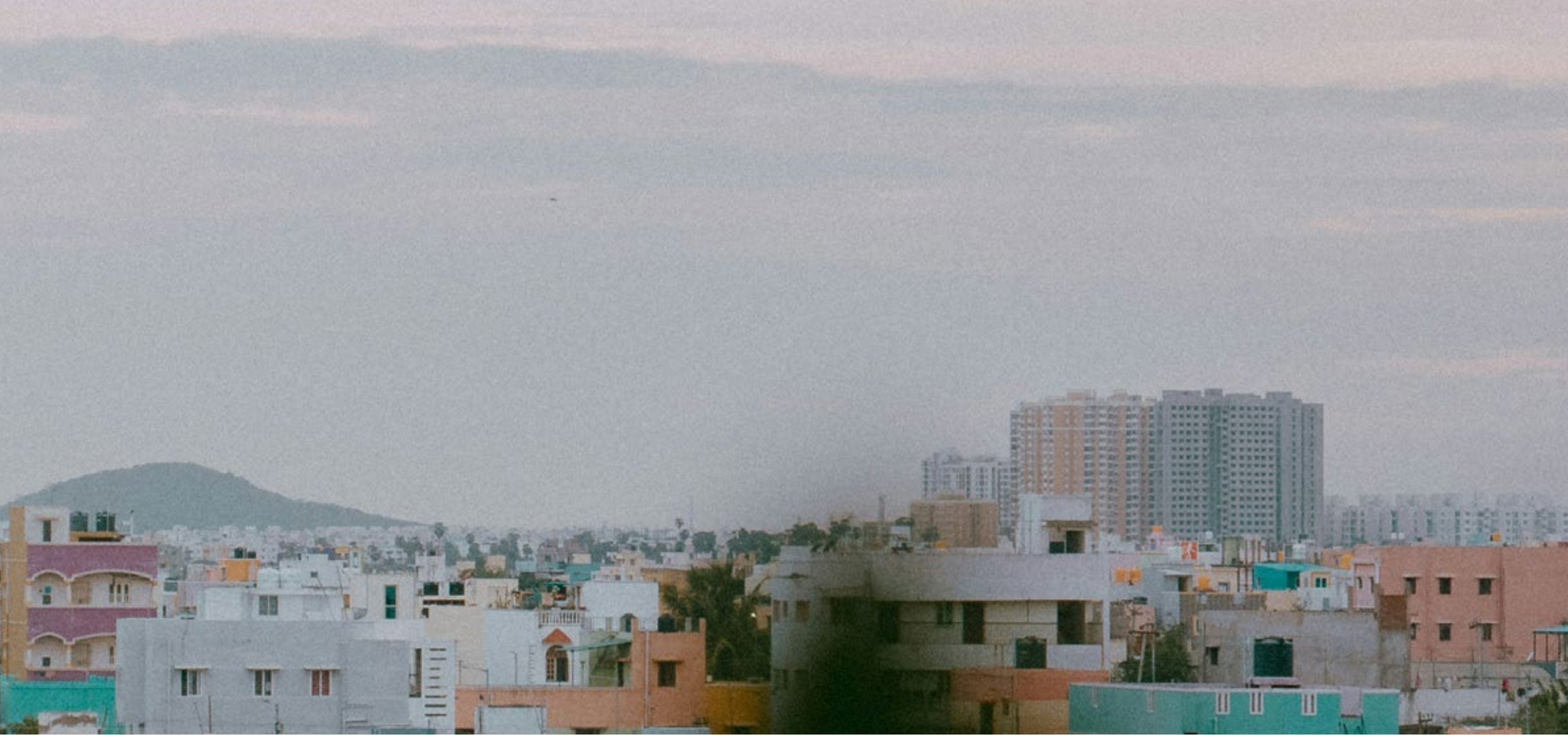

LIST OF ABBREVIATIONS

AMAPPP	Agriculture Marketing and Agribusiness Promotion Project
BEE	Bureau of Energy Efficiency
CBO	Community-based organisation
CGWB	Central Ground Water Board
CMA	Chennai Metropolitan Area
CMDA	Chennai Metropolitan Development Authority
CMIP5	Coupled Model Intercomparison Project Phase 5.
CSO	Civil Society Organisation
DI	Discomfort Index
DISCOMs	Distribution Companies
DMAI	De Martonne Aridity Index
DoE & CC	Department of Environment and Climate Change
DPR	Detailed Project Report
ECMWF	European Centre for Medium-range Weather Forecasts
eNAM	National Agricultural Market
ESCerts	Energy Savings Certificates
EVI	Enhanced Vegetation Index
FSI	Forest Survey of India
GCC	Greater Chennai Corporation
GDP	Gross Domestic Product.
GFW	Global Forest Watch
GHG	Greenhouse Gas
GIS	Geographic Information System
GSDP	Gross State Domestic Product
HAP	Heat Action Plan
HW	Heatwave
ICZM	Integrated Coastal Zone Management
ILO	International Labour Organization
IMD	India Meteorological Department
IPCC AR 6	Intergovernmental Panel on Climate Change Sixth Assessment Report
IYM	International Year of Millets
JFM	Joint Forest Management
KM	Kilometres
LAI	Leaf Area Index
LST	Land Surface Temperature
MAWS	Department of Municipal Administration and Water Supply
MoES	Ministry of Earth Sciences
MPA	Marine Protected Area
MSME	Micro, Small, and Medium Enterprises
MW	Megawatt
NbS	Nature-based Solutions
NDMA	National Disaster Maagement Authority
NDVI	Normalised Difference Vegetation Index
NE	Northeast
NEX-GDDP-CMIP5	NASA Earth Exchange Global Daily Downscaled Projections - Coupled Model Intercomparison Project Phase 5
NGO	Non-Governmental Organisation
NMAET	National Mission on Agricultural Extension and Technology
NMNC	National Mission on Nutri-Cereals
ORS	Oral Rehydration Solution
PAT	Perform, Achieve, and Trade
PHS	Predicted Heat Strain
PM	Particulate Matter
PMKSY	Pradhan Mantri Kisan Sampada Yojana
PWD	Public Works Department
RBI	Reserve Bank of India

RCP 4.5	Representative Concentra tion Pathway 4.5
RCP	Representative Concentration Pathway
ReTV	Residential Envelope Heat Transmittance Value
RKVY	Rashtriya Krishi Vikas Yojana
RWA	Resident Welfare Association
SAVI	Soil-Adjusted Vegetation Index
SHG	Self-Help Group
SLR	Sea Level Rise
SOP	Standard Operating Procedure
SPEI	Standardised Precipitation Evapotranspiration Index
SPV	Special Purpose Vehicle
SST	Sea Surface Temperature
SW	Southwest.
TANGEDCO	Tamil Nadu Generation And Distribution Corporation Limited
TEDA	Tamil Nadu Energy Development Agency
THI	Temperature Humidity Index
TN	Tamil Nadu
TNAU	Tamil Nadu Agricultural University
TNCCM	Tamil Nadu Climate Change Mission
TNECBC	Tamil Nadu Energy Conserva tion Building Code
TNGCC	Tamil Nadu Government Climate Change Department.
TNPCB	Tamil Nadu Pollution Control Board
TNRERA	Tamil Nadu Real Estate Regulatory Authority
TNSAPCC	Tamil Nadu State Action Plan on Climate Change
TNSCB	Tamil Nadu Slum Clearance Board
TNSDMA	Tamil Nadu State Disaster Management Agency
TNSPC	Tamil Nadu State Planning Commission
TWAD	Tamil Nadu Water Supply and Drainage Board
TWIC	Tamil Nadu Water Investment Company
UHI	Urban Heat Island
UN	United Nations
UNEP	United Nations Environment Programme
USD	United States Dollar
UTCI	Universal Thermal Climate Index
VFCs	Village Forest Committees
WBGT	Wet-Bulb Globe Temperature
WHO	World Health Organisation
WRD	Water Resources Department
WUA	Water User Association


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CHAPTER 1

Introduction

The Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR 6) confirms that severe and prolonged heat stress, concurrent with drought and water scarcity, and leading to forest fires and tropical cyclones, are on the rise. Health-related deaths of people over 65 years old are projected to increase by 1,540%, and India alone is expected to record 1 million additional heat-related deaths by 2090, if no action is taken to limit warming (Calvin et al., 2023).

The International Labour Organization (ILO) reports that India lost 4.3% of working hours in 1995 because of heat stress, and that figure is expected to reach 5.8% in 2030, which corresponds to 34 million jobs (Kjellström et al., 2019).

Climate change-driven disruptions of local and global weather patterns are increasing the intensity and duration of extreme events. Extreme and prolonged heat, intensifying due to climate change, has become a key threat to the health, well-being, and productivity of humans and ecosystems. Increased heat enables conditions for disease vectors such as mosquitoes, leads to decrease in yields and nutritive value of food crops, fruits and vegetables, and contributes to water scarcity and water stress, which impact the drinking water supply and water-dependent occupations and industries. Extreme heat causes cascading and multiplying impacts, eroding hard-won development gains, and increasing disease prevalence, food insecurity, health disorders, mental distress, and loss of productivity.

Urgent actions with short- and long-term horizons are needed to mitigate issues related to extreme heat, particularly in developing nations, where income levels, social welfare, energy, and water resources are limited and inequitably distributed. It is in this global context of increasing extreme heat and its multi-sectoral impacts that the Tamil Nadu State Planning Commission is seeking to develop a Heat Mitigation Strategy (HMS).

Climate change-driven heat is making things worse, with the greatest impact on those with the least capacity to respond. Achieving enduring results in heat mitigation requires the fundamental understanding that Tamil Nadu must simultaneosuly tackle three goals: improving human well-being, protecting nature, and addressing climate change impacts. The HMS will enable the identification of convergence opportunities, align priorities across departments, and streamline existing policies and plans to effectively deliver heat actions.

Extreme heat and its impacts in Tamil Nadu

Tamil Nadu, the southernmost state in India, has a tropical climate. Despite being flanked by the sea and the Western Ghats, most of the state is extremely vulnerable to heat stress.

It regularly faces soaring temperatures of more than 40°C for a significant part of the year. Studies indicate that the temperatures and heat stress are likely to increase drastically in the coming years.

Between 2011 and 2021, Tamil Nadu has, on average, witnessed more than eight heatwave (HW) days a year, as reported by India's Ministry of Earth Sciences (MoES) (2022). The state faces an increased number of heat stress days, notably from March to August, with a rising trend in heatwaves observed from 1961 to 2021 (MoES). More recently, from 2021 to 2023, it recorded an annual average of 300 discomfort days, resulting in a daily productivity decline of three to four hours.

In 2023, 12 heatwave-related deaths were reported in Tamil Nadu upto to the end of June (Sansad, 2023). Generally, health-related numbers are hugely under-reported or unreported, as health impacts are often not attributed to heat stress or exposure. Morbidity due to physical and mental stress from prolonged exposure to extreme heat is also not adequately captured. Further, heat has differential impacts affecting the most vulnerable, who lack the access or ability to report heat-related health distress; it also impacts systems and living organisms.

Centring the Heat Mitigation Strategy for Tamil Nadu

Heat exposure poses a great to risk to people in Tamil Nadu. Heat differentially impacts children, senior citizens, pregnant women, persons with disabilities, migrant labourers and outdoor workers, and other vulnerable groups (Table 1, page 15). This report highlights spatio-temporal variations in heat stress and the indicators used to assess heat impacts Tamil Nadu's heat mitigation strategy focuses on critical aspects such as the built environment, socio-ecological systems and resources, the economy, livelihoods, and communities and people. The strategy identifies systems and actions to address the impacts of heat events. The actions presented in this plan include immediate short-term measures as well as long-term strategies that need to be integrated at scale to reduce the impacts of heat.

The strategy builds on the state's ongoing efforts to build heat resilience. It considers existing plans and polices, capacities to drive the actions, the scale of implementation, and other components required to achieve heat resilience in the state. The Tamil Nadu State Planning Commission, recognising the gaps in current heat management and planning, is anchoring the heat mitigation strategy, with support from the British High Commission.

The 'Tamil Nadu Heat Mitigation Strategy' document emerged from consultations and focused group discussions, enabling line agencies to identify convergence (and alignment) across policies and interventions. This has led to the creation of a **Heat Action Network,** convened by the State Planning Commission, to advance efforts in inter-departmental and intersectoral engagement.

The consultations identified three systems – **Natural systems, Vulnerable livelihoods and Built environment -** integral to identifying problems and recommending relevant actions.

The goal of the strategy document is to identify measures and provide enabling mechanisms to reduce heat stress and ensure ecosystem health. To arrive at action areas to address the most urgent issues, this document leverages the learnings from the consultations and uses the multi-sectoral rapid assessments. The strategy also seeks to improve the adaptive capacity of vulnerable groups in the face of increasing heat impacts, and to ensure the sustained productivity of such groups. The three action areas that emerged from this exercise are: Health and well-being, sustained resources and economic productivity, and cooling solutions.

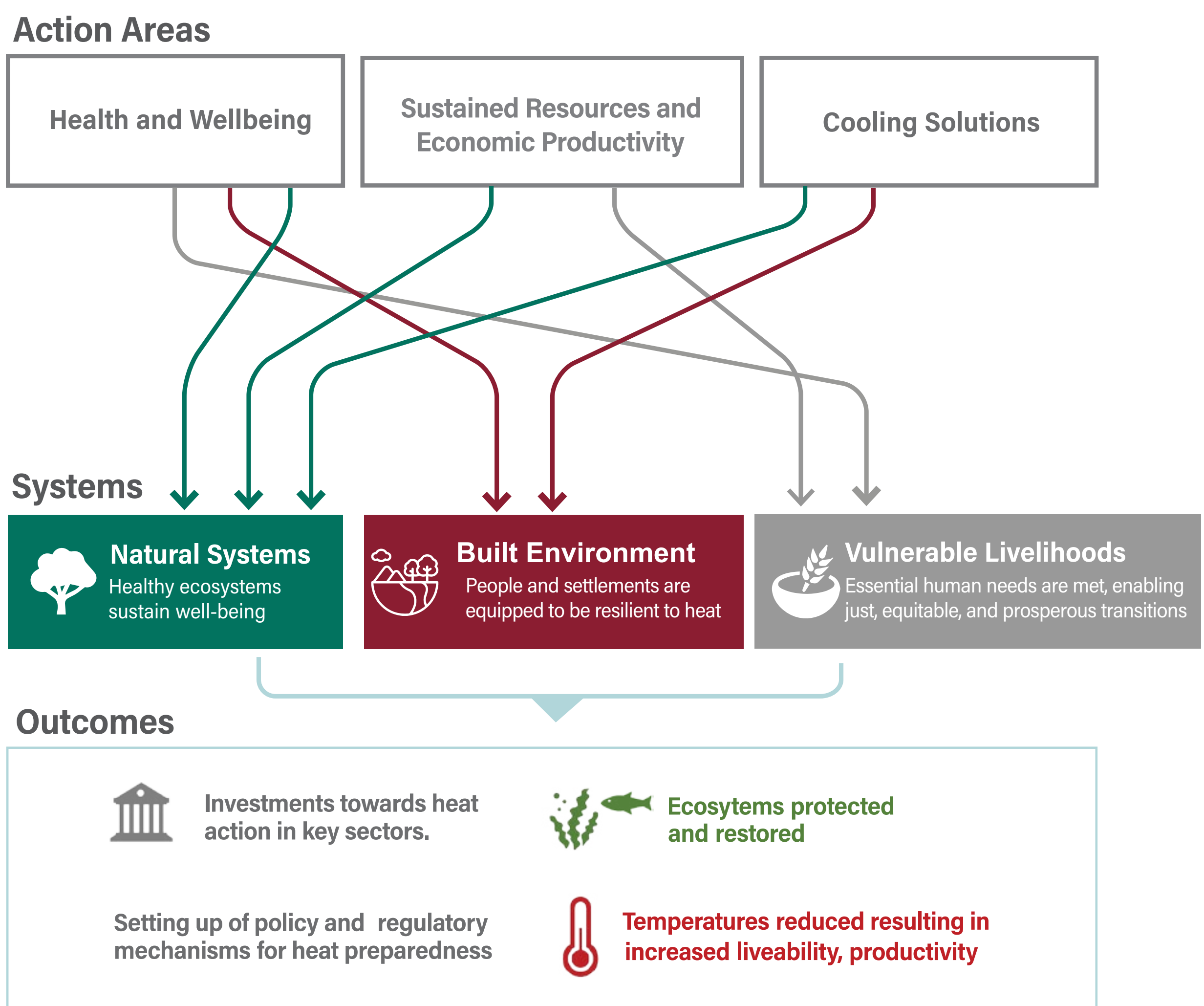
The chapters in this document are as follows:

- Chapter 3: State-level research to **understand and monitor the spatial and temporal trends in temperatures, heat stress,** and its associated indicators, which will help in framing strategies.
- Chapter 4,5, and 6: Identifying the **major issues associated with heat,** based on consultations with all major stakeholders.
- Chapter 4,5, and 6: Listing the recommendations for **heat mitigation and adaptation across sectors and vulnerable populations.**

The actionable items and detailing of the corresponding solutions for the line departments will be carried out in a phased manner over the next few months. This would be steered jointly by the Tamil Nadu State Planning Commission and the Tamil Nadu State Disaster Management Agency (TNSDMA).

The heat mitigation strategy document provides recommendations at scale across three action areas: **health and well-being, sustained resource and economic productivity and cooling solutions.** Addressing the three action areas together promotes greater policy coherence. This approach improves the chances of designing interventions with multiplier effects and co-benefits. The three areas are deeply interconnected and the obstacles to achieving them often have common origins. Although human economic activity has undoubtedly created an array of benefits for people, it is also a disruptor of healthy ecosystems. Furthermore, economic inequality has been exacerbated by a lack of access to essential services and opportunities. Tamil Nadu needs to take action that will redirect trends toward a healthy, more vibrant, and stable future in a warming environment.

FIGURE 1 | Represents the systems and three interconnected action areas



CHAPTER 2

Navigating Heat Mitigation Efforts

Heat is a growing cause for concern across India, driven by the high number of heatwave deaths since the 2010s. Between 2011 and 2018, the reported number of deaths due to heat stress was 6,187, which is likely to be an underestimate (CDKN, 2021). It is only since 2015 that India has begun to apply a disaster management approach to address heat stress, by providing guidance to states, districts and urban local bodies, as well as to health care departments, to ensure preparedness and rapid response (CDKN, 2021). The Indian Meteorological Department, National Disaster Management Authority (NDMA), and state and local bodies have collaboratively drawn up Heat Action Plans (HAPs); so far developed for 23 states including Tamil Nadu. These plans provide a framework for preparedness, preventive aid, and treatment protocols, with a five-day temperature forecast.

There are a few significant gaps in the present conceptualisation and implementation of HAPs, which are detailed in various reports. The primary concerns are a lack of localised and context-specific practices or measures for heat mitigation, limited or no community participation in plans, inability to identify vulnerable groups for targeted action, and the lack of robust finances for implementation. The HAPs also have weak legal foundations, and capacity-building is sectoral targeted, rendering them unable to address the complex and interlinked issues relating to health and productivity that heat stress can cause in human and non-human lives as well as in the ecosystem. Stress due to prolonged and extreme heat also has larger consequences such as food insecurity and increased human-animal conflict, with differential impacts on various vulnerable groups (Centre for Policy Research, 2023).

The Tamil Nadu State Planning Commission recognises the gaps and the silos in existing heat management plans, and the intersectional impacts of heat on health and productivity. Therefore, it has proposed the preparation of this heat mitigation strategy. This high-level document uses a consultative approach to identify and provide guidance to align existing policies and measures for effective heat mitigation outcomes, recommend practices and policies to ensure health and well-being for all, and to promote sustained productivity in a hotter future.

Consultative approach to identify systems

The invisible nature of heat as a climate risk, and the inadequate importance it receives in planning, governance and among communities, are fast changing. Decision-makers, policy makers, and local communities are coming forward across India to discuss, decide and implement heat-related resilience measures. In the following chapters some examples relating to heat preparedness in Tamil Nadu and India are highlighted.

The strategy document emerged through a series of stakeholder consultations, including individual informational interviews, focused group discussions, and high-level workshops. Through the consultations, key line departments were identified and convened, to form the Heat Action Network, including disaster management, health, education, agriculture, environment and forests, and water. The network approach enabled line agencies to identify convergence and alignment across policies and interventions that addressed heat-related issues.

Through consultations three inter-linked systems were identified; **Natural systems, Vulnerable livelihoods and Built environment.** These systems encompass the most impacted sectors which need urgent interventions and policy measures to **advance localised heat action. The systems informed further assessments undertaken to ensure tangible recommendations for targeted action areas.**

TABLE 1 | Systems, components and descriptions identified based on consultations for the heat mitigation strategy

COMPONENT	DESCRIPTION
NATURAL RESOURCES	
Forests, wetlands, and coastal ecosystems	Heatwaves caused by a rapidly changing climate have made drought-like crises more severe across wild habitats. Forest fires, both man-made and natural, cause animals to move, and increase the likelihood of poaching. Changes in water availability and temperatures cause irreversible damage to wetlands and mangroves, including impact on breeding and migration patterns of various species. Frequent and prolonged heat conditions can trigger changes in the composition of flora and fauna, hampering the ecosystem's carbon sequestration potential.
Resources (energy, air quality, water)	Heat stress can strain the existing generation and distribution of crucial resources such as energy and water. Projected demands in high-heat scenarios require immediate investment in low-carbon pathways. Heat and air quality degradation are deeply interconnected. Fire incidents, such as forest fires, industrial fires, and the burning of crop residue, impact the local heat balance and increase pollution.
Animal husbandry and agriculture	Poultry, cattle, and other livestock suffer from illness during conditions of heat stress. This can lead to decrease in feed intake, dehydration, reduced fertility, and death.
VULNERABLE LIVELIHOODS	
Livelihoods dependent on climate/ heat-sensitive activities (agriculture, animal husbandry, fisheries, tourism)	Extreme heat can cause severe changes to ecological systems, altering resource availability, e.g., water scarcity, natural disasters etc. These occurrences hamper the livelihoods of those who are heavily dependent on climate-sensitive activities. Rainfed agriculture (primarily small farms), fishing, and animal husbandry are examples of sectors that are affected both due to worker productivity loss and reduction in yield/ returns. The tourism sector, highly driven by customer preferences, is affected when excessive heat leads to both reduced supply, due to heat wave alerts/ non-operation of activities, and reduced demand for active tourism.
Populations in adverse working conditions (outdoor workers, informal workers, workers exposed to mechanical/ indoor heat)	Workers who spend a substantial part of their workday outside or travelling door to door are the most vulnerable to health impacts related to thermal discomfort and heat stress. This includes professionals who work in in extremely hot indoor conditions, e.g., furnaces, incinerators, and high mechanical heat. Reduced work output, increased fatigue, and absenteeism contribute to economic/livelihood losses and pose challenges in maintaining a healthy and productive workforce.
Vulnerable population	Demographic and socioeconomic factors that are closely tied to living conditions can add to people's vulnerability and capacity to respond to heat stress. According to the ILO, progress towards decent work is greatly threatened by high heat, owing to adverse working conditions and associated health risks that undermine overall labour productivity
BUILT ENVIRONMENT	
Buildings	The built environment can safeguard people from heat but can also add to heat stress. A poorly designed and serviced built environment is a major cause of thermal discomfort, leading to reduced productivity.
Infrastructure and services (food, transport, water supply and distribution, solid waste management, digital communication)	The whole infrastructure sector is under severe threat due to extreme heat. Rising temperatures not only affect the operation of crucial networks but also increase maintenance costs. Food and water security, a major threat to society, is exacerbated by excessive heat due to increased resource demand, and declining yields

CHAPTER 3

Heat Hazard and Vulnerability Profile of the State

Geographical and Climate Context

Tamil Nadu is the southernmost state of India, with a sub-humid to semi-arid climate. The state has diverse physical features, with a coastline of over 1,076 km, the Western Ghats, forests covering 20% of its geographical area, and fertile plains. Between 1989 and 2018, the state received annual average rainfall of 898 mm, with 48% contributed by the Northeast monsoon (October to December), and 35% by the Southwest monsoon (June to September) (TNGCC, 2022). Temperatures range between 18°C and 45°C[1] throughout the year. However, they are not uniform across the state; interior districts such as Tiruchirappalli, Tiruvannamalai, Tiruttani, Kanchipuram, Erode, and Vellore are relatively warmer than the rest of the state (Muthuchami et al., 2021).

Tamil Nadu is the second-largest economy in the country, contributing 9% of the national GDP. In the fiscal year 2020-21, the state generated a Gross State Domestic Product (GSDP) of approximately USD 266 billion. Its economic vitality is due to key sectors, including automobile manufacturing, information technology, textiles, and agriculture. The service sector leads with a 54% contribution to the GSDP, followed by manufacturing at 33%, and agriculture at 13%. Home to more than 16% of India's industries, Tamil Nadu faces both climate and socio-economic challenges. With 48% of its population living in urban areas as per Census 2011, and around 35% of its urban population residing in slums, the state urgently needs to address escalating heat conditions.

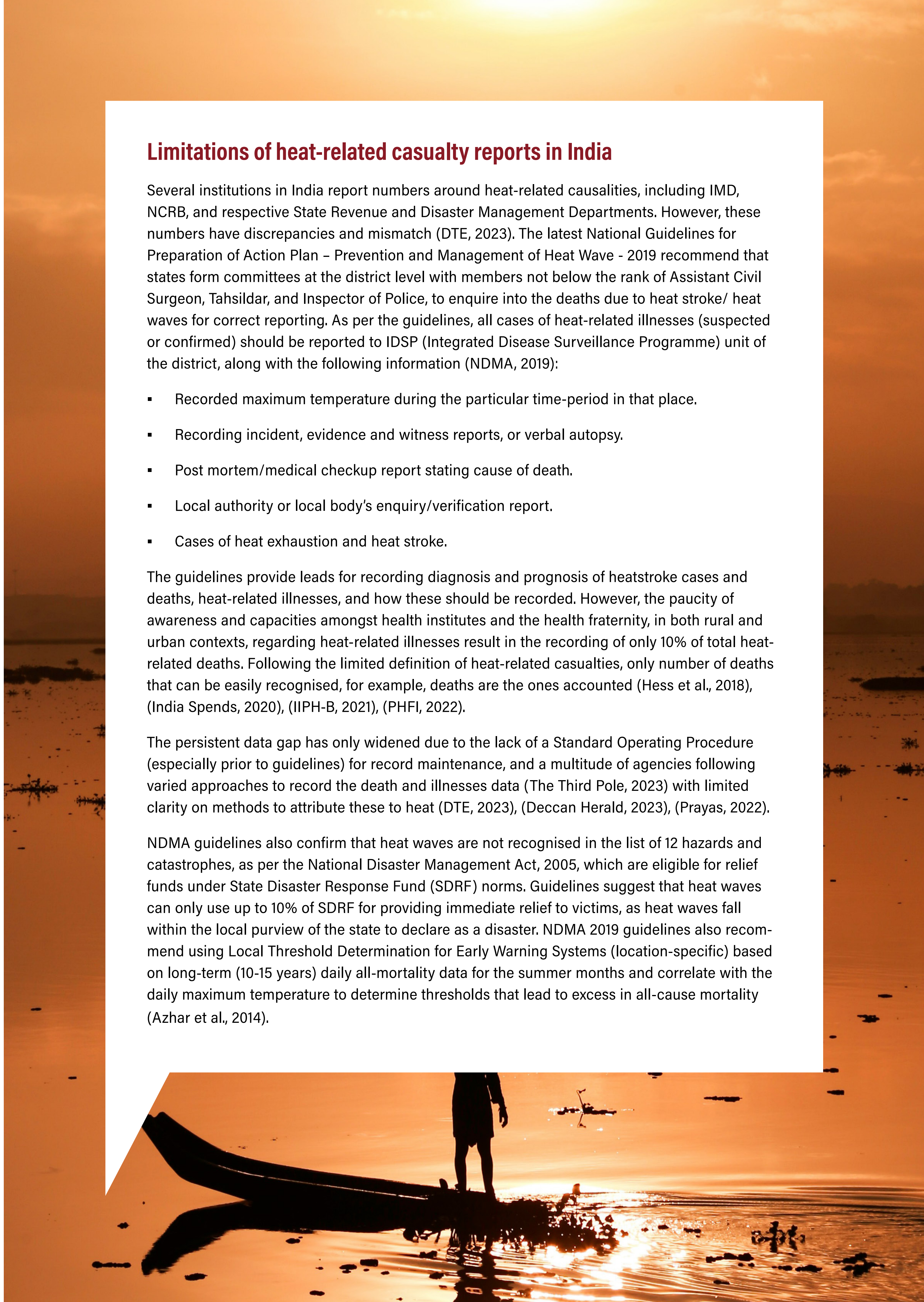
Tamil Nadu's geographical vulnerability to natural disasters, including cyclones, floods, and drought, is compounded by changing climate patterns. This introduces new challenges such as heat waves, longer periods of drought, more frequent floods, and accelerating sea level rise and storm surges.

The state incurs catastrophic economic losses estimated at USD 300-500 million per climate disaster (Appadurai, 2022). Approximately 8% of the state is impacted annually by cyclones[2] , nine out of its 38 districts are drought-prone, 17 districts face the continuous threat of heat waves, and 10 districts experience floods (Jeganathan et al., 2021). Amidst rising temperatures and decreasing moisture levels, the frequency of forest fires has surged. Nearly 11% of the forested area in Tamil Nadu is susceptible to fires (Forest Survey of India, 2019).

According to IMD's Climate Hazard and Vulnerability Atlas of India, between 1969 and 2021, all the districts of Tamil Nadu combined faced a total of 591 disastrous heat wave days[3] . 'Disastrous heat wave days' are defined as days with at least one human fatality per day, reported due to heat wave conditions. While human causality is an extremely critical indicator to assess the loss and damage caused by heat, these numbers are highly underreported in India due to the lack of a clear definition and standard protocol around recording, maintaining and attributing casualties to heat – underscoring the fact that heat is a silent disaster.

Temperatures are only expected to soar further. A study by Anna University's Centre for Climate Change and Disaster Management confirms that thermal discomfort is projected to increase from an average of 107 days per year (observed between 1985 and 2014) to 150 days per year by 2050 (Times of India, 2024). Losses in terms of finances, lives, productivity, and ecological resources, are likely to be dire for vulnerable and marginalised groups. **Therefore, the TN Heat Mitigation Strategy recommends assessing patterns and changes in heat across the state, and includes a focused discussion on vulnerable groups and sectors that need to be supported in heat mitigation efforts.**

[1]Based on TNSAPCC 2.0
[2]State Disaster Management Perspective Plan 2018-2030, TNSDMA, GoTN. 2018.
[3]'Disastrous heat wave days' are defined as days with at least one human fatality per day, reported due to heat wave conditions. Climate Hazards and Vulnerability Atlas of India, IMD, Pune, 1969-2021. https://www.imdpune.gov.in/hazardatlas/heatnew.html



Limitations of heat-related casualty reports in India

Several institutions in India report numbers around heat-related causalities, including IMD, NCRB, and respective State Revenue and Disaster Management Departments. However, these numbers have discrepancies and mismatch (DTE, 2023). The latest National Guidelines for Preparation of Action Plan – Prevention and Management of Heat Wave - 2019 recommend that states form committees at the district level with members not below the rank of Assistant Civil Surgeon, Tahsildar, and Inspector of Police, to enquire into the deaths due to heat stroke/ heat waves for correct reporting. As per the guidelines, all cases of heat-related illnesses (suspected or confirmed) should be reported to IDSP (Integrated Disease Surveillance Programme) unit of the district, along with the following information (NDMA, 2019):

- Recorded maximum temperature during the particular time-period in that place.
- Recording incident, evidence and witness reports, or verbal autopsy.
- Post mortem/medical checkup report stating cause of death.
- Local authority or local body's enquiry/verification report.
- Cases of heat exhaustion and heat stroke.

The guidelines provide leads for recording diagnosis and prognosis of heatstroke cases and deaths, heat-related illnesses, and how these should be recorded. However, the paucity of awareness and capacities amongst health institutes and the health fraternity, in both rural and urban contexts, regarding heat-related illnesses result in the recording of only 10% of total heat-related deaths. Following the limited definition of heat-related casualties, only number of deaths that can be easily recognised, for example, deaths are the ones accounted (Hess et al., 2018), (India Spends, 2020), (IIPH-B, 2021), (PHFI, 2022).

The persistent data gap has only widened due to the lack of a Standard Operating Procedure (especially prior to guidelines) for record maintenance, and a multitude of agencies following varied approaches to record the death and illnesses data (The Third Pole, 2023) with limited clarity on methods to attribute these to heat (DTE, 2023), (Deccan Herald, 2023), (Prayas, 2022).

NDMA guidelines also confirm that heat waves are not recognised in the list of 12 hazards and catastrophes, as per the National Disaster Management Act, 2005, which are eligible for relief funds under State Disaster Response Fund (SDRF) norms. Guidelines suggest that heat waves can only use up to 10% of SDRF for providing immediate relief to victims, as heat waves fall within the local purview of the state to declare as a disaster. NDMA 2019 guidelines also recommend using Local Threshold Determination for Early Warning Systems (location-specific) based on long-term (10-15 years) daily all-mortality data for the summer months and correlate with the daily maximum temperature to determine thresholds that lead to excess in all-cause mortality (Azhar et al., 2014).

How is heat 'hazard' defined?

Many world-renowned institutions, including the U.S. National Weather Service (NWS), World Meteorological Organization (WMO), European Centre for Medium-Range Weather Forecasts (ECMWF), and Health Canada, provide heat-health alerts based on a combination of various meteorological indicators consisting of temperature, humidity, radiation, windspeed, other bio-geographic indicators. However, in India, these health advisories and alerts are severely dependent on the definition of IMD's Heat wave (The Wire, 2018) which is solely based on air temperature thresholds (IMD,2021). Using 'heat wave' criteria alone to define heat related hazard tendencies is highly inadequate (CPR, 2023). Many contributing meteorological and local actors increasing heat 'stress', such as humidity, wind speed, urban heat islands, anthropogenic heat etc. are not acknowledged in the heat hazard assessments.

IMD has also initiated an experimental forecast based on Heat Index (HI) (that provides information on how hot it really feels when relative humidity is taken into account with temperature), however, these numbers are not yet publicly available and validated for India (NDMA, 2024). NDMA in its National Guidelines for Preparation of Action Plan - Prevention and Management of Heat wave 2019, highlights Odisha's efforts in providing early warnings for heat based on a combination of temperature and humidity levels (NDMA, 2019). NDMA's guidelines also encourage states, districts, and cities to conduct locally contextual assessments and define their respective thresholds, so that IMD can issue warning alerts to those states in coordination with state disaster management authorities. As per a recent study on Heat Action Plans in India, only 10 out of 37 HAPs establish local thresholds (CPR, 2023). **TN HMS provides an opportunity to learn from other states' efforts and recommends creating scientifically established and bio-climatically localised thresholds for heat hazard.**

Heat hazard assessment for Tamil Nadu

The heat hazard assessment evaluates existing and potential changes to meteorological indicators that contribute to thermal discomfort or stress. Such an analysis considers factors such as temperature trends, the frequency and intensity of heat events, and the compounding effects of heat and other hydro-meteorological factors, leading to hazards such as drought, fires, and water stress. Indicators used in the analysis and suggested methods are derived from the Climate Hazards Vulnerability Assessment Framework (Rangwala et al., 2024).

The purpose of the heat hazard assessment is to identify the extent, intensity, and likelihood of thermal stress in the state, and to support decision-makers in strategising and prioritising heat action. Refer to Table 2 for the list of indicators studied (highlighted in green), and the indicators suggested for in-depth analysis of heat in the upcoming phases of the TN HMS. Working definitions, thresholds for classification, datasets used, and their sources, along with the rationale and context of each indicator, are documented in Annexure A1.

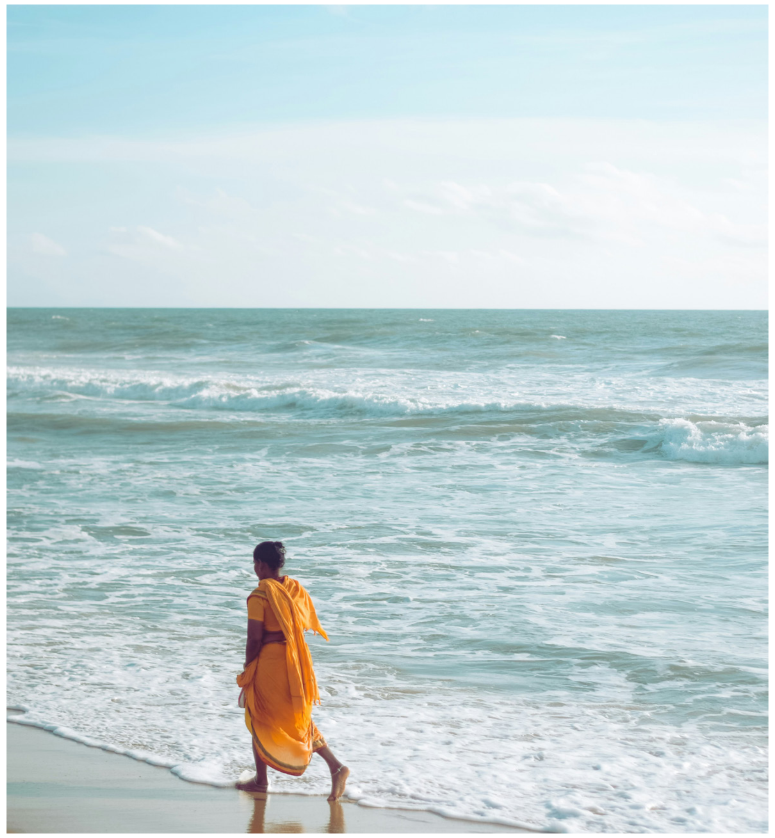


TABLE 2 | Heat Hazard Assessment Indicators

Hazard Category	Indicator for Assessment
Thermal Stress	
Air Temperature	Annual air temperature trend analysis and deviations
	Long-term temperature trends across seasons and time scales
	Frequency of extreme temperature days and nights
	Long-term trend of the frequency of extreme temperature days and nights
	Projected changes in temperature
Land Surface Temperature (LST)	Daytime and nighttime LST trends
	High or low hotspots
Thermal Comfort	Spatiotemporal trend in heat stress
Sea Surface Temperature	Spatiotemporal trends in sea surface temperature close to the coastline
Precipitation Change	
Rainfall	Spatiotemporal trends in rainfall patterns
	Spatiotemporal trends in extreme rainfall events
	Projected changes in rainfall
Weather Events	
Cyclones	Frequency of cyclones
	Temporal trends of cyclone strength and accumulated cyclone energy
Thunderstorms	Spatiotemporal trends in lightning strikes
Hydro-meteorological Hazard	
Meteorological Drought	Spatiotemporal assessment of meteorological drought frequency in the state and the watersheds concerned
Hydrological Drought	Spatiotemporal assessment of baseline water stress in the state and the concerned watersheds
Groundwater Exploitation	Spatiotemporal patterns in groundwater recharge potential
	Spatiotemporal trends in stage of groundwater development
Environmental Degradation	
Forest Fires	Spatiotemporal trends on fire hotspots within forested areas
Other Fires	Spatiotemporal trends in satellite data on thermal anomaly hotspots
Air Quality Degradation	Spatiotemporal trends in the concentration of major/criteria pollutants: physical and gaseous pollutants
Water Quality Degradation	Surface water and groundwater - spatiotemporal assessments for quality criteria based on physical, chemical, and biological parameters
Soil Quality Degradation	Quality criteria based on physical, chemical, and biological parameters
Vegetation Change	Spatiotemporal trends in Normalized Difference Vegetation Index (NDVI)
Built expansion	Spatiotemporal trends in built-up growth

Indicators assessed in the report. Refer to following sections for insights and Annexures for details on methods & datasets.

Additional indicators prescribed for future phases of the Heat Mitigation Strategy

Source: Adopted from Hazard Identification Assessment Framework, Climate-resilient Cities - Assessing Differential Vulnerability to Climate Hazards in Urban India (Rangwala et al., 2024).

Air Temperature

Air temperature trends and anomalies have been derived using daily aggregates from ECMWF ERA5, comparing the averages for recent years (2015-2019) with the long-term average (baseline) for the period of 1981 to 2011. The temperature across the state is observed to be the highest from March to June, i.e., the summer months and partially extending to the monsoon. Some key takeaways from the air temperature analysis are discussed below; refer to Table 3 for details.

- **Maximum temperature patterns:** Since 1981, the average maximum air temperature (March to June) across Tamil Nadu has risen by 1.5°C, reflecting an increase of approximately 0.2°C per decade. About 50% of the state's population experiences temperatures exceeding the state's long-term average. Over the same period, approximately 15% of the state's population has witnessed a notable surge of around 2°C during the summer months. This trend is particularly pronounced in districts such as Tiruchirappalli, Tiruvannamalai, Tiruttani, Kanchipuram, and Vellore (see Figure 5).
- **Minimum temperature patterns:** Like maximum temperature, minimum temperature has also risen in state by 0.75°C. The highest decadal increment, at 0.35°C, has occurred between 2011 and 2019 that can be seen across areas such as Vellore, Erode, Madurai (see Figure 5).
- **Extreme events (heat wave occurrences):** Based on the IMD's criteria of heat waves (refer to Annexure A1 for details), between 2011 and 2019, more than 40% of the state's area faced at least 15 heat wave days every year (see Figure 6).

TABLE 3 | Long-term (spatial) average air temperature and anomalies estimated for Tamil Nadu between the months of March to June

	Baseline* 1981-2011 (°C)	Recent average 2015-19 (°C)	Rise by/ anomaly (°C)**	% population residing above baseline
Minimum temperature	24	25.35	0.75	56%
Maximum temperature	35.2	35.5	1.5	49%

Long-term average, spatially aggregated across all pixels in the state between 1981-2011 is estimated as baselines.

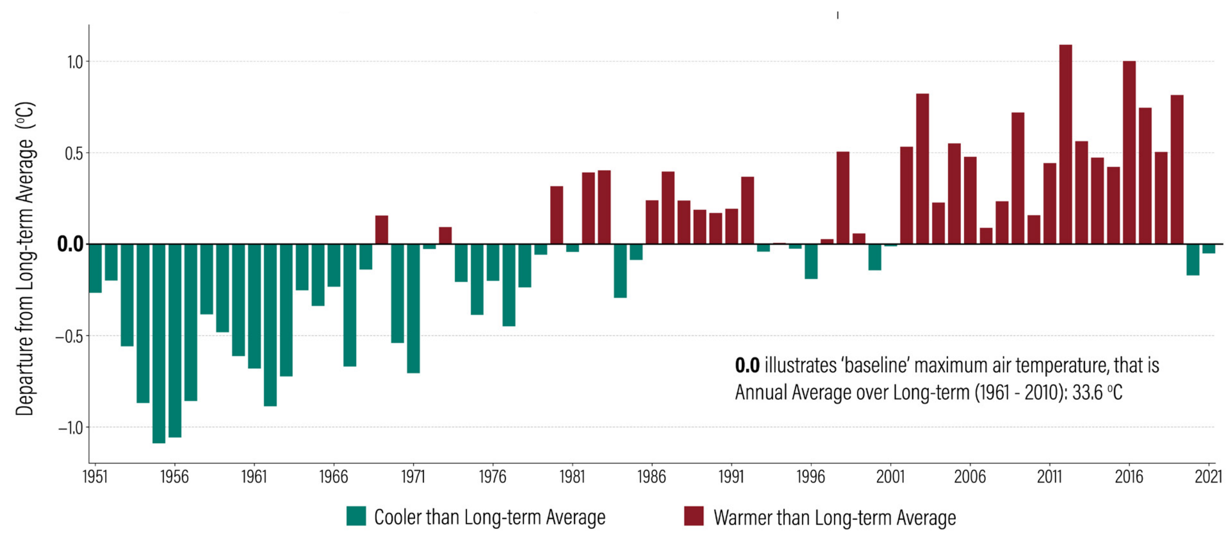
***Spatially aggregated across all pixels, average rise estimated between 1981-2019.*

Source: ERA5 Daily Aggregates, ECMWF/ Produced by Copernicus Climate Change Service, 1981-2019

Deviations in air temperature from long-term average between 1951 and 2021, Chennai

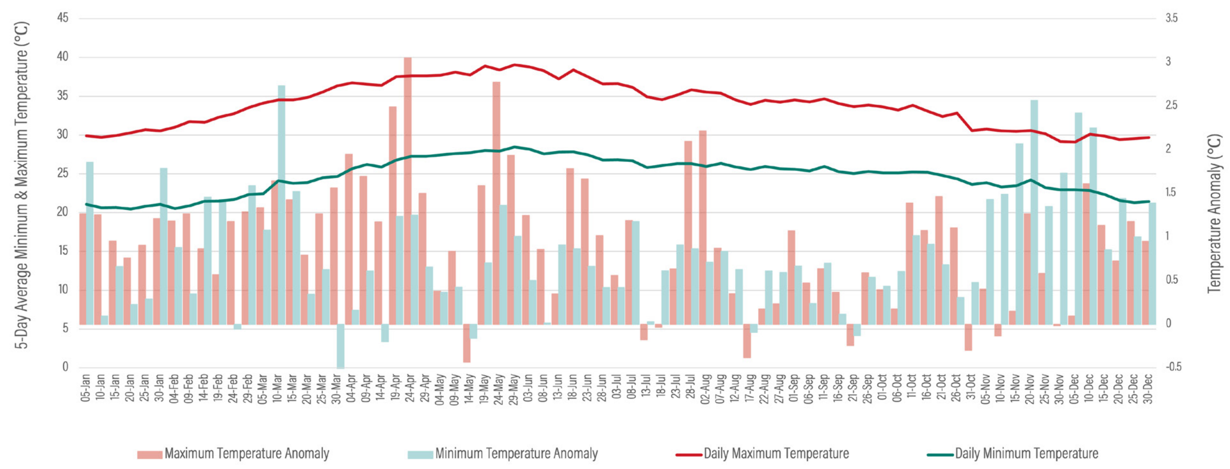
An analysis of data from the IMD weather station at Meenambakkam (Chennai) for the period from 1951 to 2021, shows that since 1980, the temperatures recorded in 31 out of 41 years were above the long-term average. It shows that some years recorded an increase in the maximum air temperature by more than 1°C since 2011 (illustrated in Figure 3). The rise in temperature starts around the middle of March, extending to July, as seen in Figure 4. Minimum temperatures show a noticeable rise as well (Figure 4), leading to an increased number of warmer nights (Rajanpillai et al., 2021).

FIGURE 2 | Anomalies in Annual Average Maximum Air Temperature between 1951 and 2021



Source: Meteorological data from IMD Chennai-Meenambakkam station (1951 - 2021)

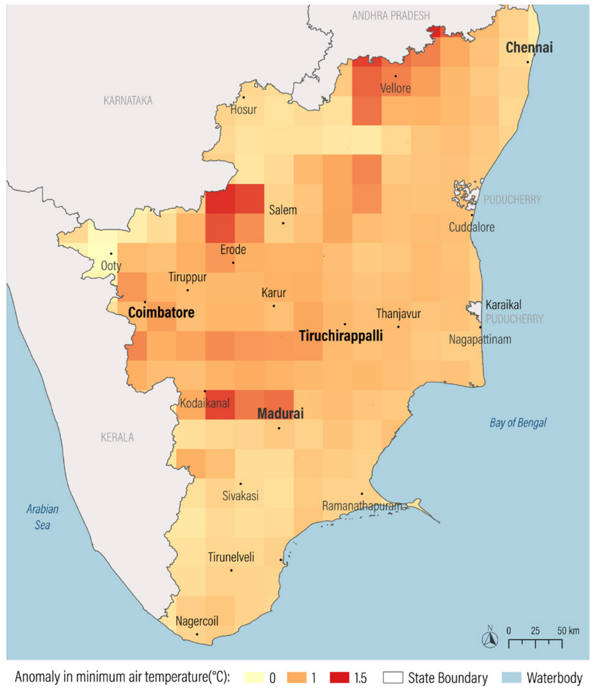
FIGURE 3 | Daily minimum and maximum air temperature (5-day averages and anomalies) from Meenambakkam station between 1951 and 2021



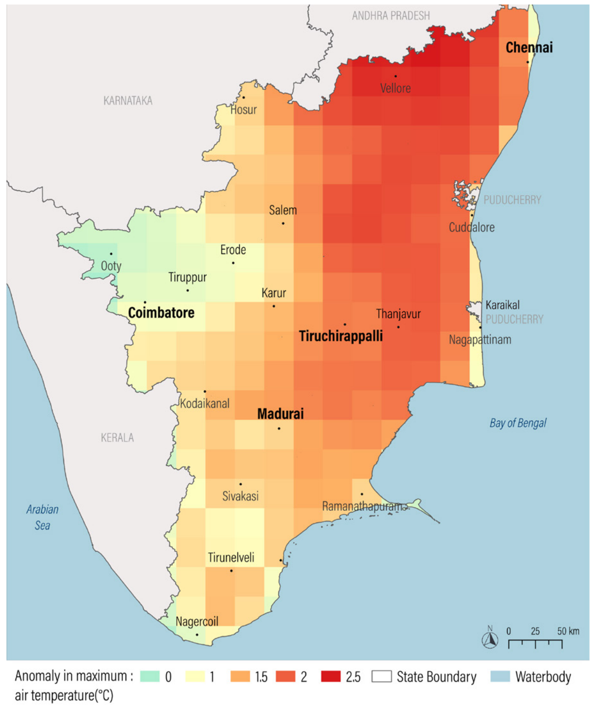
Source: Meteorological data from IMD Chennai-Meenambakkam station (1951 - 2021)

FIGURE 5 | Deviations from baseline in average air temperature from March to June

A) Minimum Air Temperature Deviations



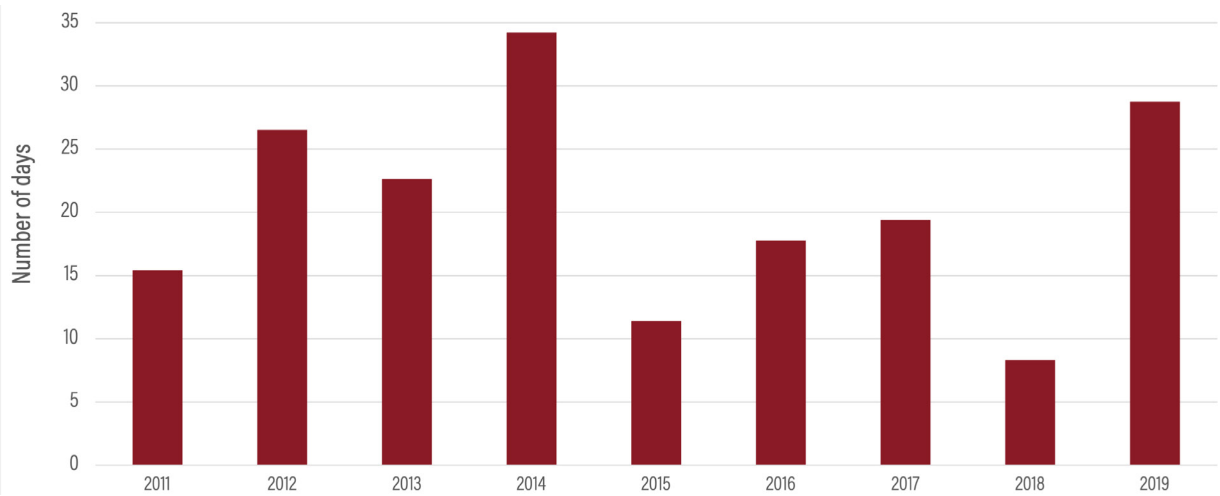
B) Maximum Air Temperature Deviations



Nearly **56% of Tamil Nadu's population lives in areas experiencing minimum temperatures higher than the baseline temperatures.** A relatively higher minimum temperature contributes to warmer nights, leading to various sleep disorders, thereby challenging overall health and well-being.

40% of Tamil Nadu's population lives in areas facing a 1.5°C rise in maximum temperature compared to the baseline. The highest temperatures are observed during the active hours of the day, which can exacerbate challenges related to occupational heat stress.

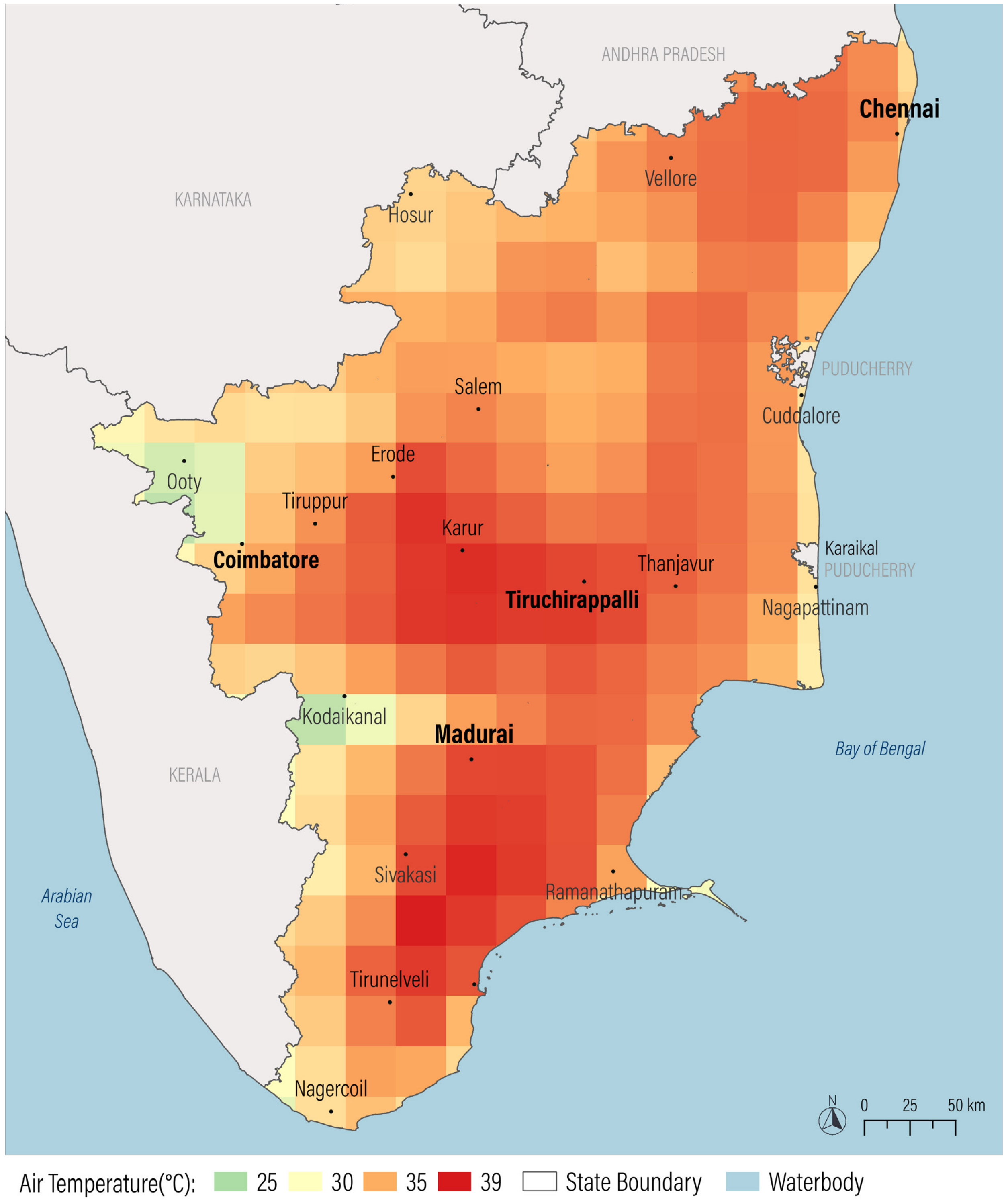
FIGURE 6 | Average number of annual heat wave days observed in Tamil Nadu between 2011-2019



Note: Deviations are estimated based on the recent year averages (2015-2019) for the months of March to June in comparison to baseline (long-term average) for 1981-2011. Refer to annexure A1 for details.

Source: ERA5 Daily Aggregates, ECMWF/ Produced by Copernicus Climate Change Service, 1981-2019. Refer to annexure A1 for details.

FIGURE 7 | Average maximum air temperature from March to June (2015-2019)



Source: ERA5 Daily Aggregates, ECMWF/ Produced by Copernicus Climate Change Service, 2015-2019. Refer to annexure A1 for details.

Thermal Comfort

While the term "heat wave" refers to prolonged high temperatures, the concept of thermal comfort is estimated in terms of heat or cold stress that a human body may feel like in response to meteorological conditions. For assessing thermal comfort, the Universal Thermal Comfort Index (UTCI) has been used, which considers factors such as air temperature, wind speed, radiation, humidity, human thermal physiology, etc. UTCI is defined as the equivalent ambient temperature (°C) that provides an estimate of physiological response of a person in reference to the real surrounding environment (refer to Annexure A1 for details). Thermal comfort is measured in terms of UTCI categories of Strong, Very Strong, and Extreme heat stress, that is ≥32°C.

The annual probability for Strong Heat Stress in Tamil Nadu is estimated based on hourly UTCI data for 1981 – 2022 and is at 81% (refer to Table 4 for details). This is comparable to temperature of ≥32°C experienced for more than nine months per year (see Figure 8). Strong heat stress of around nine hours per day is predominant from March through May (Figure 8), out of which April and May are the most critical months, as they tend to also experience Very Strong to Extreme heat stress (equivalent to ≥38°C). Interior regions see more heat stress days from March to April, while coastal areas have more stress days in May and June (refer to Figure XX, Annexure A2).

Rising Heat Index levels in Tamil Nadu leading to high discomfort

As per an IMD study from 2023, the Heat Index is increasing during summer and monsoon seasons at the rate of +0.56°C and +0.32°C per decade, respectively, averaged over the country with 95% statistical significance levels. The increasing HI indicates a high level of discomfort in both the seasons, which is primarily due to the increase in humidity in the summer, and in the maximum temperature in the monsoon. The spatial distribution of the HI indicates greater chances of heat-related illness in India, especially in the southeast coastal region, i.e., Andhra Pradesh, Odisha, and Tamil Nadu, primarily in the summer (IMD, 2023).

TABLE 4 | Patterns in heat stress across Tamil Nadu (based on data for 1981-2022)

	Average exposure (hours per day, from March to June, 2022)	Average annual probability from 1981 to 2022	% population residing in heat-stressed areas***	Critical months	% population at risk of prolonged exposure
Anything ≥ Strong heat stress	8-9 hours	81%	68% pop; 73.5% area	March-May	62-75%*
≥ Very Strong to Extreme heat stress	4 hours	38.5%	55% pop; 56% area	April-May	21-61%**

*Population at risk of prolonged exposure to ≥ strong heat stress for more than 8 hours per day estimated for 2022 (March-June).

**Population at risk of prolonged exposure to ≥ very strong heat stress for more than 4 hours per day estimated for 2022 (March-June).

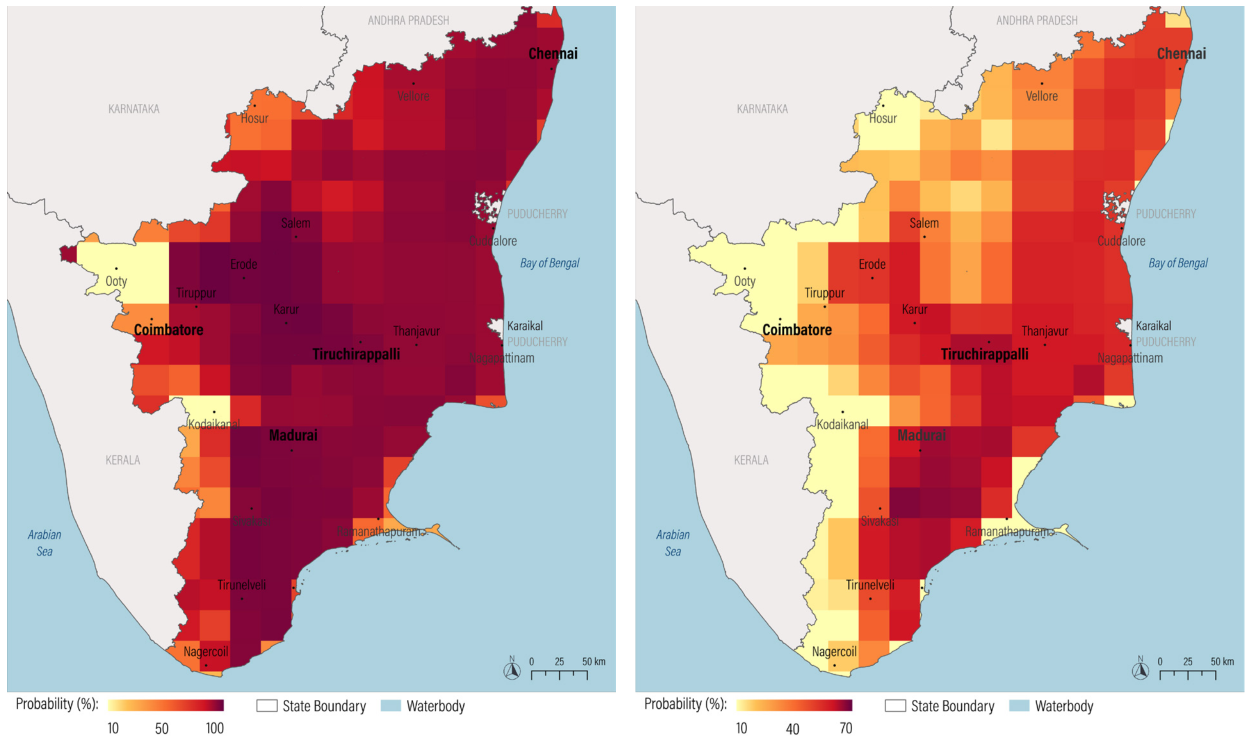
*** Areas with heat stress probability ≥ average annual probability of their respective heat stress category.

Source: Universal Thermal Comfort Index (UTCI), Climate Data Store (CDS), Copernicus EU; 1981-2022. Refer to Annexure A1 for details.

FIGURE 8 | Spatiotemporal patterns in heat stress for Tamil Nadu

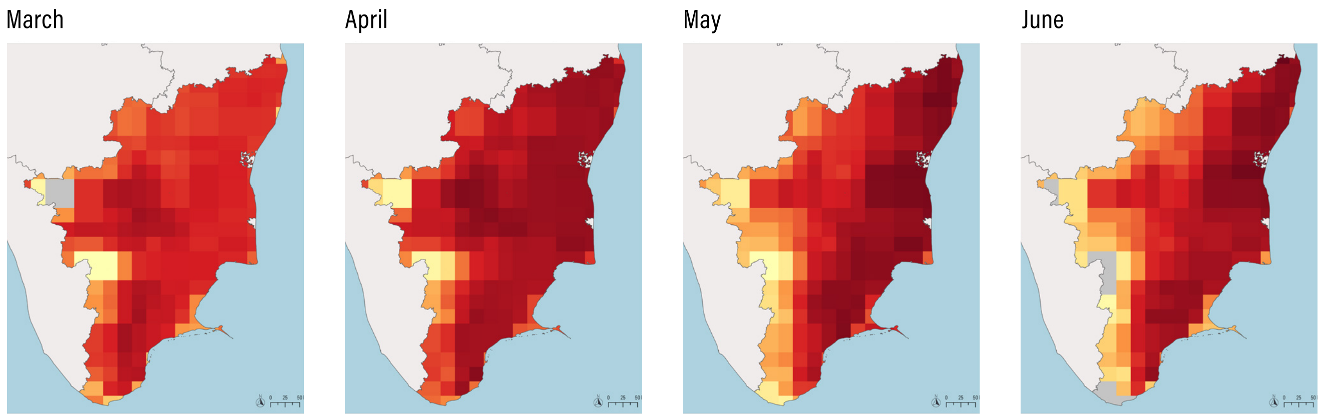
A) Annual probability of strong heat stress

B) Annual probability of very strong to extreme heat stress



- More than half of 'Tamil Nadu's population resides in areas at risk of facing Very Strong heat stress or worse.
- 68% of Tamil Nadu's population is experiences prolonged exposure of 8-9 hours to Strong heat stress from March to June. Strong heat stress is attributed to increased risk of heat-related disorders such as dehydration and sunstroke, and excess morbidity and mortality.

C) Average number of hours spent in strong heat stress and above per day, from March to June, 2022



Note: A and B are derived using hourly UTCI data, categorised as Strong, Very Strong, and Extreme heat stress, between 1981 and 2022.

Source: Universal Thermal Comfort Index (UTCI), Climate Data Store (CDS), Copernicus EU; 1981-2022. Refer to Annexure A1 for details

Urban Heat Island Effects

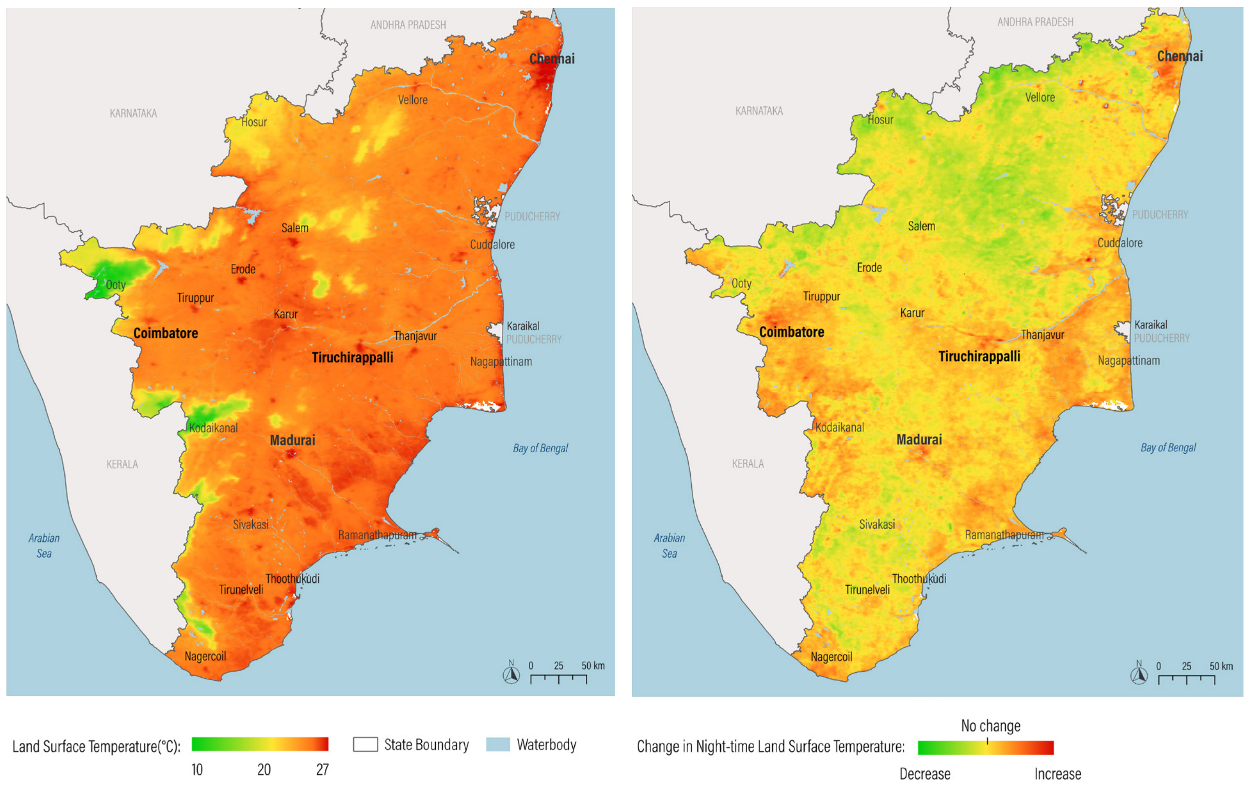
As the name suggests, cities or urban areas are typically observed to be warmer compared to their rural counterparts. The phenomenon of UHI can be spatially understood with the help of Land Surface Temperature (LST) variations. LST is the radiative skin temperature of the land surface that has interrelation with the air temperature, both contributing as factors to thermal comfort. The searing effects of UHI are most prominent while observing nighttime LST trends. Surface temperature variation at night is caused by differences in land cover, built form and density, building materials, vegetation, and soil moisture levels.

Data for recent years' (2019-2023) summer months – March to May, show an average nighttime LST of 24°C (refer to Figure 9) across the state, with 26°C across major built areas including major cities, indicating urban heat island effects. About 27% of the state's population resides in areas with higher nighttime land surface temperature than the state-wide average nighttime LST over built. The map (refer to Figure 9) illustrates the trends in the average nighttime LST from 2019 to 2023, compared to 2001-2005, as the built areas expanded. The linkages between vegetation loss and increasing expanse of relatively higher nighttime LST can be easily seen across all four major cities of Tamil Nadu, namely, Chennai (see Figure 10), Tiruchirappalli, Coimbatore, and Madurai. Refer to Annexure A2, Figure XX-XX for more details on built expansion, vegetation changes and LST.

FIGURE 9 | Nighttime land surface temperature trends in Tamil Nadu

A) LST averaged across summer months for 2019-2023

B) Change in nighttime LST from between 2001-2023

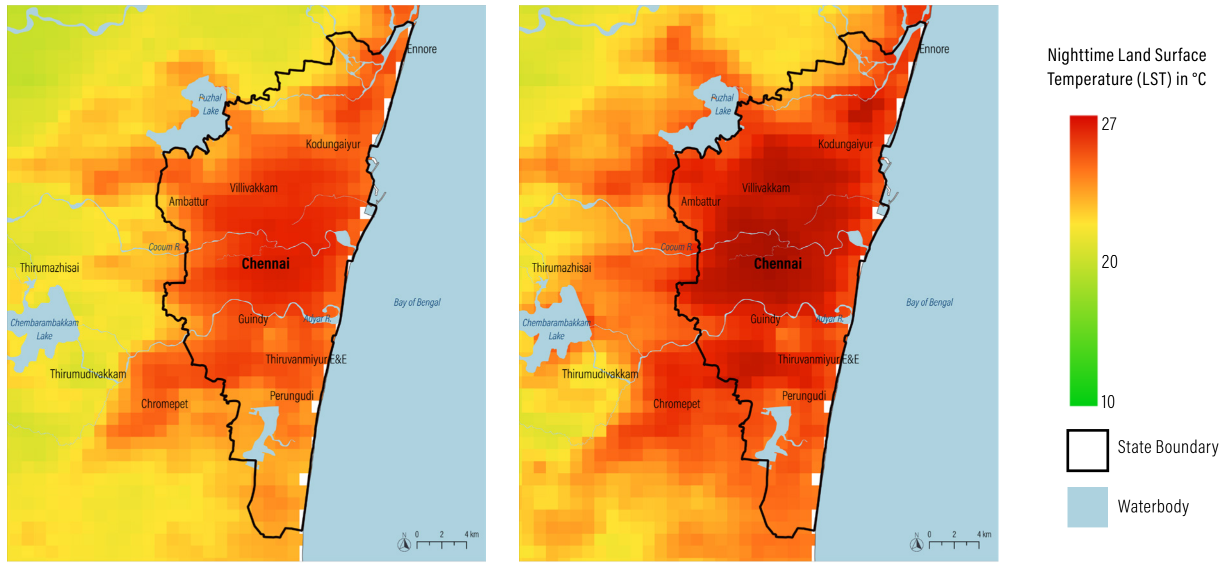


Source: MODIS Terra Land Surface Temperature and Emissivity Daily Global 1km, processed by WRI India.

FIGURE 10 | Deviations from baseline in average air temperature from March to June

A) Nighttime LST averaged for 2001-2005

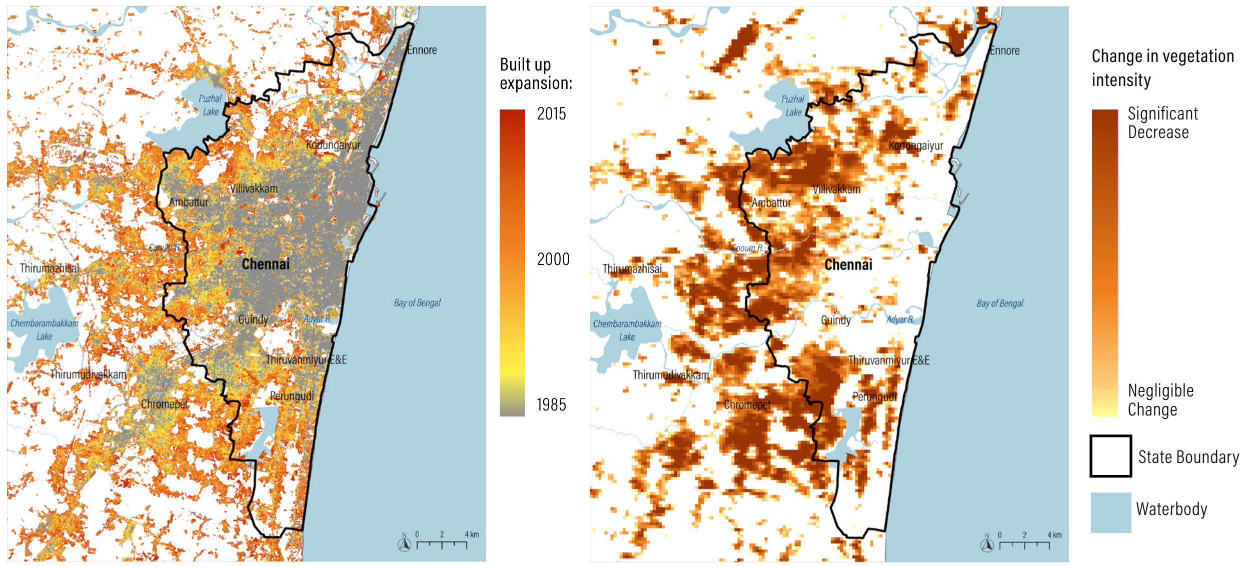
B) Nighttime LST averaged for 2019-2023



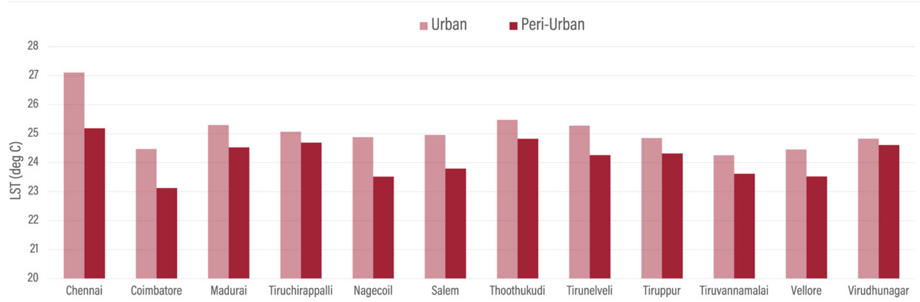
Between 2000-2020, the built area in Chennai more than doubled its size. The average nighttime LST in the city's urban areas, compared to its peri-urban counterparts, is higher by 2°C, putting urban residents at higher risk of heat.

C) Built expansion between 1985-2015

D) Change in Vegetation between 2001-2023



E) Nighttime land surface temperature, urban and peri-urban (2019-2023)



About 27% of the State's population is at greater risk of Urban Heat Island effects as they reside in areas with higher nighttime land surface temperatures.

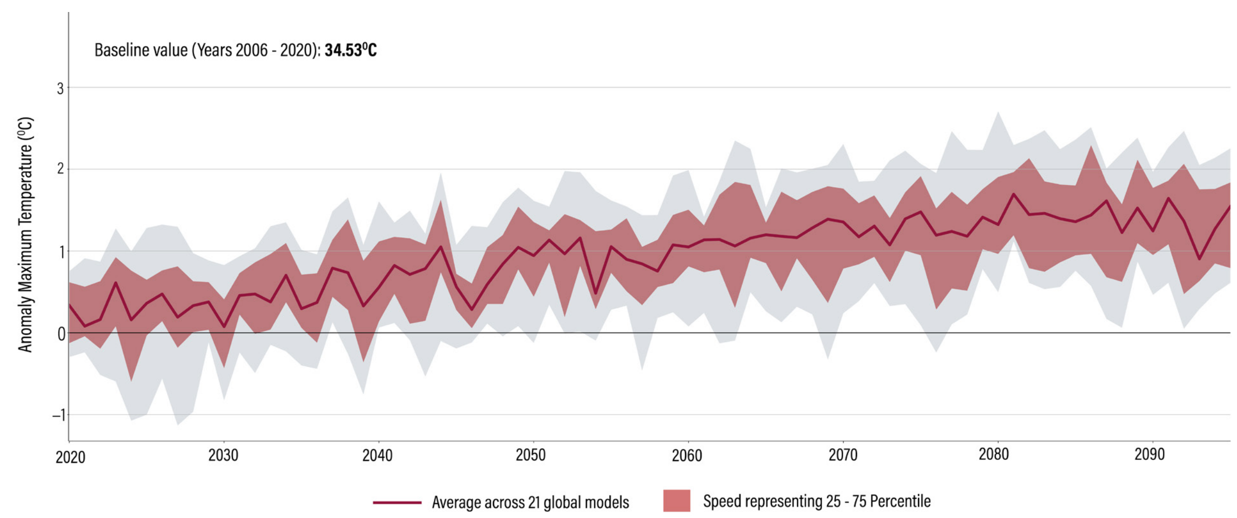
Source: A, B, and E are based on MODIS Terra Land Surface Temperature and Emissivity Daily Global 1 km; B is based on World Settlement Footprint (WSF) Evolution 1985-2015, and WSF 2019 - German Aerospace Center (DLR); and E is based on NDVI (MODIS), NASA/ USGS, processed by WRI India.

Future Heat Risk

Projections for air temperature change up to year 2100 have been analysed based on RCP 4.5 scenario (refer to Annexure A1 for details) using 21 models from NEX GDDP (CMIP5) considering long-term baseline average between 1975-2005 (Figure 11). The analysis of projected maximum air temperature shows an increase of 0.5-1°C by the end of the year 2050. This change is observed to soar up to 2°C from the baseline by the end of 2100 (Refer figure 11). Around 71%, rising to 80% of the population is estimated to be exposed to above average maximum air temperature by the year 2050 and 2100, respectively.

Like maximum air temperature, minimum air temperature is expected to increase by more than 1°C by 2050, and more than 1.5°C by the year 2100. These findings highlight the urgent need for comprehensive strategies to mitigate the adverse impacts of rising temperatures on public health and vulnerable communities.

FIGURE 11 | Projected Maximum Air Temperature for Tamil Nadu according to RCP 4.5



Source: Using 21 models from NEX-GDDP (CMIP5), refer to Annexure A1 for details

Conceptualising vulnerability to heat

Understanding vulnerability to heat involves a multifaceted approach encompassing various dimensions of human health, socio-ecological systems, buildings, animals, forests, agriculture, and environmental balances. Human vulnerability to heat extends beyond physiological responses to include socio-economic factors such as income, access to healthcare, and housing conditions. Vulnerable populations, including the elderly, children, and individuals with pre-existing health conditions, are at increased risk of heat-related illnesses and mortality. Socio-ecological systems face challenges related to water scarcity, food security, and ecosystem disruptions due to rising temperatures, exacerbating vulnerabilities in urban and rural communities. Buildings designed without adequate ventilation, insulation, and cooling systems may contribute to indoor heat stress and discomfort for occupants. Animals and forests experience heat-related impacts on habitat loss, biodiversity decline, and ecosystem degradation, affecting ecological balances and ecosystem services. Agriculture faces challenges such as crop failures, livestock losses, and reduced yields due to heat stress, drought, and pest outbreaks. Environmental balances are disrupted by shifts in precipitation patterns, melting glaciers, and sea-level rise, leading to cascading effects on ecosystems and human well-being.

Conceptualizing vulnerability to heat requires interdisciplinary research, stakeholder engagement, and policy interventions to address systemic risks and enhance resilience across human and natural systems.

FIGURE 12 | Assessment type and components for conceptualizing vulnerability to heat across identified vulnerable/ impacted groups

Source: Learnings from all stakeholder meetings and Heat Action Network Workshop

CHAPTER 4

Health and Well-being

Promoting good health and well-being for all is a crucial component of ensuring sustainable development and is recognised globally under the United Nations Sustainable Development Goals (UN SDGs) framework. The World Health Organization describes a positive vision of health as encompassing the dimensions of physical, mental, psychological, emotional, spiritual, and social well-being. Thus ensuring good health and well-being for all is not limited to providing access to healthcare and medicines, but also ensuring income stability, protection from climate extremes, etc. Across the world, people are facing a plethora of interconnected, complex crises, and heat is emerging as a pre-eminent threat linked to climate change. The state of Tamil Nadu has identified heat as a foundational issue that has immediate and long-term impacts at a multi-sectoral scale (refer to Chapter 2 on the increased incidence of heatwaves and rising average temperatures). The changing global climate is already causing major disruptions, with extreme and prolonged heatwaves becoming more frequent. Increased heat is also likely to spur zoonotic and vector-borne diseases due to increased heat stress and lowered immunity in animal populations. Urgent measures must be deployed for the short and long term, to mitigate on-going effects of heat-related health issues and ensure protections from forecasted diseases and distress.

Under the Heat Mitigation Strategy for Tamil Nadu (HMS TN), recommendations will be included that address the needs and conditions of not just humans but the ecosystem, including plants and animals.

This chapter details issues related to health and well-being, and other interrelated impacts on human and non-human lives that result from increased heat in the state. The chapter also discusses guidance to mitigate and/or prevent health-related impacts of such heat. Guidance and practices that are more relevant to cooling solutions and sustained productivity are detailed in Chapter 5 and 6.

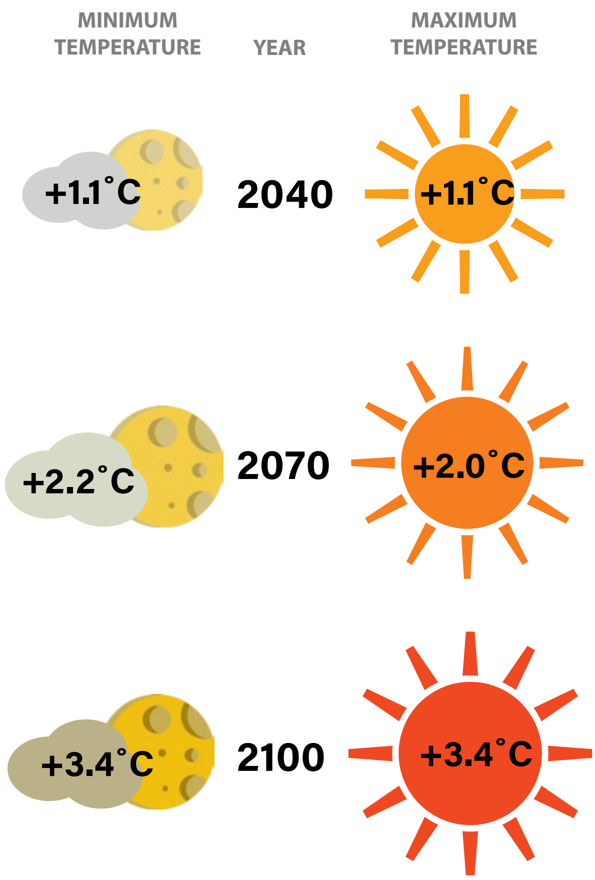
Health and well-being effects of extreme and prolonged heat

Due to its geographic location, Tamil Nadu is generally exposed to high temperatures year-round, with high humidity in the coastal regions as well. Recent data as well as forecasts indicate higher-than-average day and night-time temperatures, and extended heatwave periods, which are straining the adaptive capacities of humans and non-humans.

Figure 9 outlines how extreme and prolonged heat interacts with the health and well-being of humans, non-humans, and ecosystems.

The increase in the prevalence and incidence of diseases emerging in animals, such as avian flu, and the recent COVID-19 global pandemic provides evidence that human health and well-being are closely linked to the health and well-being of ecosystem health (including plant and animal health). There is a growing global consensus to arrive at an integrated approach to maintain human, animal and ecosystem health in balance. This thinking is enshrined in the WHO's One Health framework, which uses a collaborative intersectoral approach to bring together actors in the public health, veterinary and environmental sectors to address concurrent, interacting factors.

FIG 8 | Temperature increase forecast for Tamil Nadu, with reference to the baseline period of 1970-2000.



Heat exposure in humans

74% of the state's population is exposed to air temperature greater than 35°C. Humans face a range of illnesses due to heat exposure, including heat exhaustion and heatstroke. Heat exposure can also aggravate pre-existing conditions such as cardiovascular disorders and respiratory illnesses (National Institute of Environmental Health Sciences, 2022). High heat exposure, especially for prolonged periods, can also cause death, particularly in vulnerable and highly exposed groups, such as the elderly, children, pregnant women, and outdoor workers (WHO,2018).

Populations exposed to high heat often deal with the added burden of poor air quality , as air circulation is poor at high temperatures, and particulate matter and ozone can build up to toxic levels in stagnant air (Global Heat Health Information Network, 2020).

Differential vulnerability to heat stress

There is extensive medical research on how heat exposure, especially over prolonged periods, can lead to physical and mental distress. Depending on a range of factors, certain groups are more vulnerable to heat exposure. Heat mitigation actions must have universal impacts, but it is important to recognise the differential experience of heat stress so that policy and implementation measures can be targeted to reach the most vulnerable in a timely manner.

FIG 9 | Interaction of extreme and prolonged heat with the health and well-being of humans, non-humans, and ecosystems.

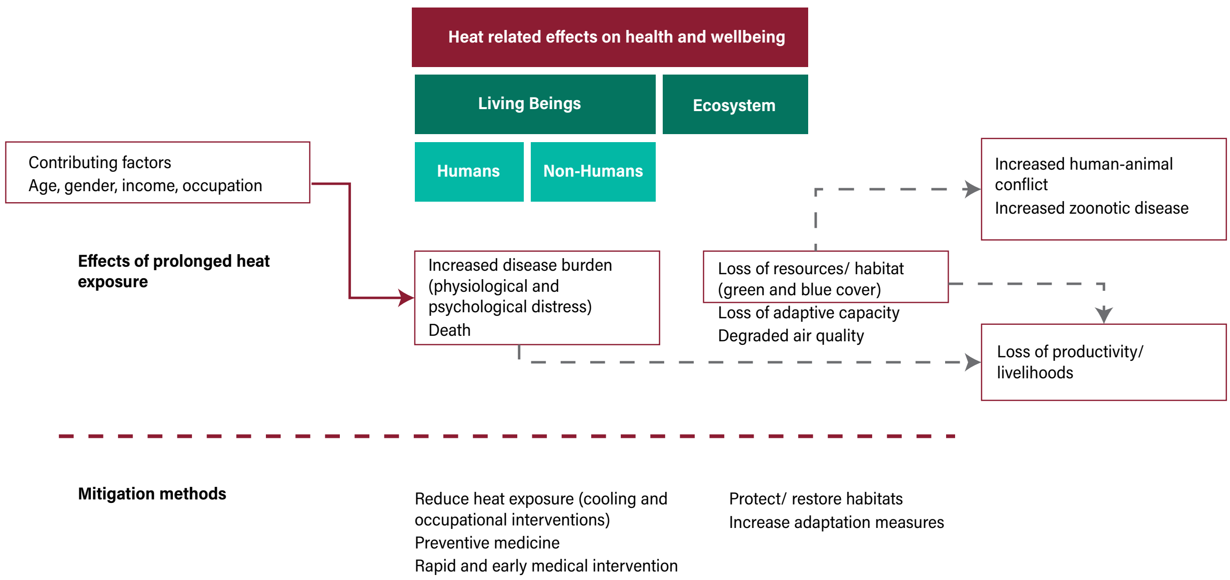
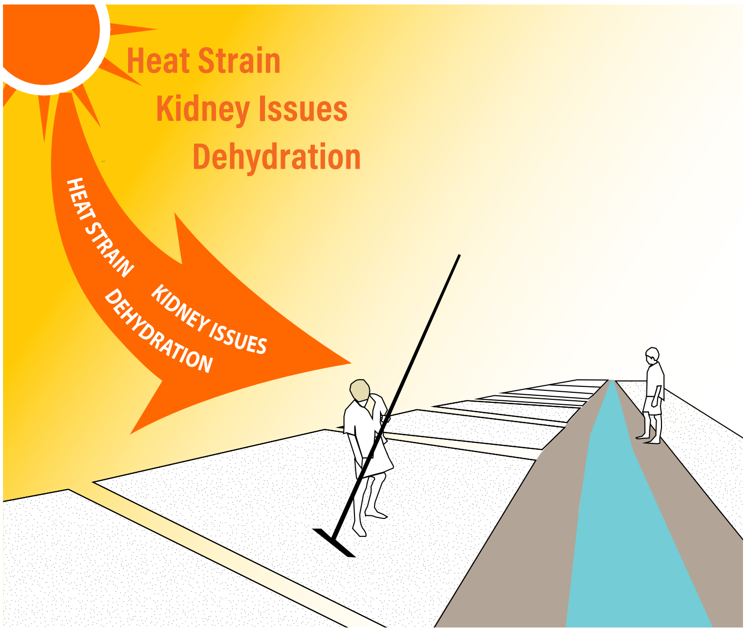


FIG 10 | Rising heat stress poses grave occupational health risk to the salt pan workers in Tamil Nadu



Heat exposure in non-humans

Animal populations also face the risk of dehydration due to heat exposure, which can lead to decreased immunity, higher risk of disease, prevalence of zoonotic diseases, and even death (Gonzalez-Rivas et al., 2020). Aside from the physiological impacts on animal populations, high temperatures also affect local ecosystems in terms of shrinking water bodies and reduced forage areas (Yale Environment 360, 2017). This can drive wild animals to move out of protected forest zones into human-inhabited landscapes, leading to increased human-wildlife conflict.

A study conducted by Sri Ramchandra Institute of Higher Education and Research during 2017 and 2020 in seven salt pans in Tamil Nadu evaluated the impact of heat stress on 352 workers. Key indicators such as pre- and post-shift heart rate, core body temperature, sweat rate, and kidney function parameters were measured. Nearly 90% of the sample people was found to be working above the recommended heat exposure limits (PubMed, 2023).

Another highly vulnerable group to heat stress is pregnant women (Kuehn & McCormick, 2017), whose exposure to heat affects not only their health but also that of the foetus. Pregnant women's capacity to regulate their body temperature is compromised, and they are especially susceptible to dehydration, which releases labour-inducing hormones. (Climate Health Connect, 2016). Extreme heat events correlate to other adverse birth outcomes as well, such as pre-term birth, low birth weight, and infant mortality. Heat-related health challenges and distress in pregnant women also compromise their employability, which affects their livelihood.

Ecosystem health in extreme heat conditions

Extreme and prolonged heat impacts ecosystem health in a variety of ways, and can require long recovery periods. The depletion of water from rivers, lakes, etc., due to evaporation and increased respiration by plants, reduces water levels and soil moisture (Ozewex, 2017). Such drought-like conditions, when followed by rainfall, can lead to high runoff and soil erosion, contributing to further ecosystem degradation. Reduced water levels also change the biochemistry of water bodies, creating conditions for algal blooms, which affect other plant and animal life.

Old-growth and dense forests are better able to withstand extreme heat in comparison to landscapes such as grasslands and woodlands. Ecosystem health depends on the biodiversity available. Extreme heat can cause significant loss of plant and animal life affecting the ecosystem.

Outcomes of high heat prevalence

Increased and uncontrolled forest fires

Fires affect Tamil Nadu's forests, and the frequency is higher in the summer months. Fires are part of the natural process in forests, encouraging regeneration and soil nutrition. But their incidence and intensity have increased in recent years, partly due to more man-made fires and partly due to dry conditions that enable their rapid spread. With more human movement in forested areas due to eco-tourism, the risk to humans is very high.

Increase in zoonotic and vector-borne disease prevalence

Many animals and insects are disease vectors and thrive in hot and humid conditions, e.g., mosquitoes, which spread malaria, dengue, and chikungunya. Higher temperatures over prolonged periods enable the rapid expansion of these vector populations and can cause infection rates to spike (Bush, K.F. et al., 2011).

Loss of productivity and yields

A growing body of research is connecting rising temperatures and atmospheric carbon dioxide (CO_2) to reduced plant yields and lowered nutritive value, which will have long-term impacts on food security and human health (Ebi et al., 2021; Semba et al., 2022). In addition, extreme heat increases competition across sectors for resources such as water, and can lead to crop loss, lowered yields, etc., affecting global supply chains as well as livelihoods of small-holder farmers (Pulitzer Center, 2022).

EXPERIENCE OF HEAT

Humans' experience of heat is due to a combination of high temperatures and exposure to them. Heat risk increases when both these conditions occur simultaneously, leading to the breach of thermal comfort thresholds, especially if this sustains for a prolonged period. Even on a hot day, the availability of and access to shaded areas can provide relief from the heat. Similarly, access to energy to run a fan or air conditioner can also enable a cool environment. Based on their age, gender, pregnancy status, and occupation, people face differential vulnerability to heat. Their adaptive capacity also varies depending on their income, occupation and other factors, which can affect their access to cool spaces, or the energy needed for cooling. Thus, interventions and policy responses must consider the conditions of the most vulnerable to arrive at optimal solutions and provide for targeted solutions to meet the needs of all.

Heat-driven human-wildlife interface

Mitigating heat risk and heat stress in Tamil Nadu will require a multi-pronged approach of increasing cooling measures for indoor and outdoor locations, limiting exposure resulting from occupational practices, increasing availability of and access to healthcare (preventive and curative), and ensuring effective outreach and communication for heat mitigation to affected populations.

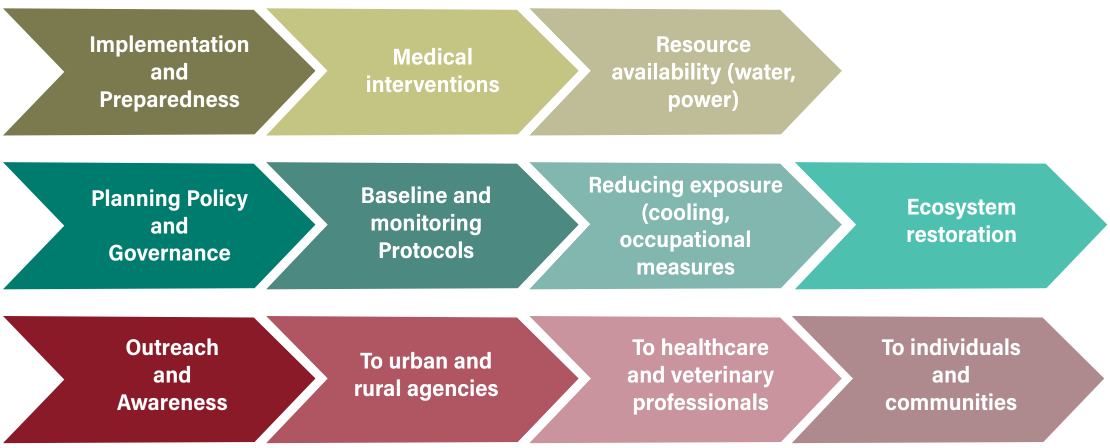
From a health and well-being perspective, the heat-driven increase in human-wildlife interaction and conflict must also be addressed. This will include stepping up the study and monitoring of animal movement, and effective communications to minimise interactions. It will also include the protection of wildlife habitats and corridors, and the provision of resources within forest lands to reduce animal movement into human-dominated landscapes.

A first step towards any policy or implementation action requires detailed baselining across sectors to arrive at optimal solutions.

Baselining and spatial mapping of issues :

- Identification of heat-vulnerable clusters using multi-dimensional analysis to integrate factors such as occupation, age, sex, maternal status, income levels, etc.
- Identification of heat-related physical and mental health concerns, highlighting differential outcomes to identify the specific

FIGURE 10 | Pathways addressing health and well-being concerns in the Tamil Nadu Heat Mitigation Strategy



issues faced by various vulnerable groups in correlation with thresholds such as wet bulb temperatures, etc.

- Identification of outdoor worker categories, and number of workers within each group
- Identification of heat distress and thresholds in livestock and poultry stock
- High-temperature zones (from land surface temperature and other recorded data) identified as heat risk/heat stress zones across the state, correlated with population numbers to arrive at vulnerable areas requiring higher levels of support.

There are three components to addressing health and well-being concerns in the Tamil Nadu Heat Mitigation Strategy to ensure short- and long-term actions and impacts. These are discussed under the heads of implementation and preparedness; planning, policy, and governance; and outreach and awareness.

Implementation and preparedness

This section deals with short-term actions to ensure the health and well-being of humans and non-humans during prolonged and extreme heat conditions. These include medical interventions and adequate resource allocation to prevent or mitigate heat impacts.

Medical Interventions

Practices under this head can be sub-divided into preventive medicine and rapid interventions.

Preventive Medicine

- Preventive healthcare measures, such as access to cool, shaded spaces, drinking water, and rehydration solutions to be provided to vulnerable groups on priority. Specifically targeting population clusters in settings such as schools, hospitals, old-age homes, orphanages, anganwadis, community centres, traffic police, etc.
- Preventive veterinary interventions such as the provision of rehydration solutions to individuals/communities practicing animal husbandry, and to zoos and other animal care centres. Potentially provide measures at subsidised rates or for free.

Rapid and Early Medical Interventions

- Healthcare professionals and veterinarians should be trained in rapid heat treatment management protocols for humans and animals.
- Prioritisation of healthcare to vulnerable groups (by age, maternal status, occupation, etc.)
- Medical treatment for heat-related distress and disorders should be made easily available and accessible to all during heat stress periods, by equitably distributing available resources (water, intravenous solutions, rehydration solutions) across urban locations and district centres.
- Paramedical, rescue and disaster management, and police staff to be trained to provide first aid and early treatment in less severe cases of heat distress.
- Adequate provision of patient-care beds at healthcare facilities across the state. Partnerships with private healthcare providers to ensure adequate availability of beds.

Bring in learnings from epidemiology practices in rapid deployment of solutions and equitable distribution of healthcare services to ensure timely medical treatment for all.

Resource Allocation

- Provide adequate resources such as uninterrupted water and power supply to high-traffic buildings such as schools, hospitals, community, and public buildings, anganwadis, healthcare centres, etc.
- Ensure adequate water availability and uninterrupted power supply to farms with livestock and poultry or other animal care facilities.
- Explore provisioning of renewable energy solutions for remote or off-grid locations.
- Encourage prudent groundwater use in combination with rainwater harvesting, to ensure water availability, especially during high heat periods.

DISTRIBUTED RENEWABLE ENERGY (SOLAR) ON BOAT CLINICS IN ASSAM

Chars, or riverine islands formed by silt deposits, dot the course of the Brahmaputra river in Assam (World Resources Institute India, 2023). These islands are home to small, unelectrified island villages, and their inhabitants depend on the river for food, water, livelihoods, and transportation. Healthcare here is constrained by the limited availability of resources and electricity, and the people face regular floods, which impact their ability to work.

Solar-powered boat clinics are being introduced by the Centre for Northeast Studies and Policy Research and National Health Mission, to serve the health needs of the char population. These boats carry medical professionals and supplies to remote villages for regular check-ups and vaccinations. With the integration of the distributed renewable solution, lighting, and ventilation are now available 24/7. While the boat clinics' hours of service remain limited (as the health camps take place outdoors), it is now possible to handle emergency services better. Although health camp timings are 9 a.m. to 5 p.m., the boat clinic also offers emergency services at night. Boat clinic staff have also assisted in childbirth on an urgent basis. Distributed renewable energy provision can be an effective method to strengthen heat action in health care centres in remote locations and areas which lack grid access or uninterrupted electricity supply.

Planning, policy, and governance

Building guidelines and ecosystem restoration are discussed under planning, policy and regulatory efforts to reduce heat exposure through monitoring measures. Such measures have a longer-term horizon for deployment.

Health and disease monitoring protocols, and targeted delivery

- Improving surveillance, monitoring and forecasting for vector-borne and zoonotic diseases through the use of spatial mapping, AI and other innovative technology tools.
- Ensuring off-grid energy access to health centres to ensure cold storage for vaccines and other medications, as well as working operating suites. This requires the integration of energy providers to be part of health planning efforts. (World Resources Institute, 2023).
- Integrating heat mitigation practices into existing schemes that target the health and well-being of vulnerable populations, such as pregnant women, neonates and children.

INTEGRATING HEAT AWARENESS AND MITIGATION MEASURES INTO EXISTING SCHEMES

The Tamil Nadu Government Pregnancy Scheme (which has existed in various forms since 1987) is an innovative initiative to promote the health and well-being of pregnant women, and to ensure the healthy development of infants. The scheme provides comprehensive healthcare, financial assistance, and awareness programmes, with the aim of reducing maternal and infant mortality rates and improving overall reproductive healthcare.

Under this scheme, the state government has established a network of well-equipped health-care centres, including primary health centres and government hospitals. These facilities offer a wide range of prenatal care services, including regular check-ups, diagnostic tests, nutrition counselling, and immunisations. Pregnant women are encouraged to visit these centres regularly to receive healthcare services, ensuring the early detection and management of potential health risks.

Adding heat risk as a key criterion to screen for during health check-ups and awareness drives can be a simple intervention to improve the adaptive capacity of pregnant women to take care of their health during extreme heat conditions.

Reducing/ preventing heat exposure

A key strategy of ensuring health and well-being in high heat conditions is to reduce heat exposure. This has two components: limiting the time that individuals spend outdoors without shade, and ensuring that indoor environments are maintained at thermal comfort levels. Several policy and regulatory measures are needed to manage indoor and outdoor thermal comfort.

Cooling Measures

The measures discussed below provide an overview of codes and policies that can be updated/ modified to include details of other efforts to mitigate heat through cooling. Targeted locations/populations that need priority are also mentioned (Please see Chapter 6 for more on cooling practices and guidance).

- Maintaining thermal comfort in all built environments through passive and/or active cooling techniques that are integrated into building codes and regulations by urban local bodies (ULBs).
- Increasing green cover to provide shade, especially in public amenities such as community centres, anganwadis, transit stops, and public buildings, as directed by ULBs or the district administration.
- Heat risk zones such as slum settlements and colonies of migrant workers are also areas where increasing the green cover can have beneficial impacts.
- Animal enclosures to be provided with adequate ventilation and active/passive cooling measures, to ensure that extreme temperatures are mitigated.
- Planning for and ensuring uninterrupted power supply (through or off the grid) to high-priority buildings such as hospitals, health centres, and education centres.

Cooling Practices in Vandalur Zoo for Animal Welfare

Arignar Anna Zoological Park, popularly knows as Vandalur Zoo has for many years undertaken a comprehensive summer management plan for its mammals, birds and reptile residents. Adequate shade and water are the primary components that are provided across the zoo. Shade nets and thatched roofs have been introduced at required places to reduce direct sunlight. Water sprinklers and showers inside enclosures especially for larger animals help keep them cool. Many animal and bird enclosures are covered with gunny bags and sprayed with water periodically to keep them cool throughout the day.

Occupational interventions

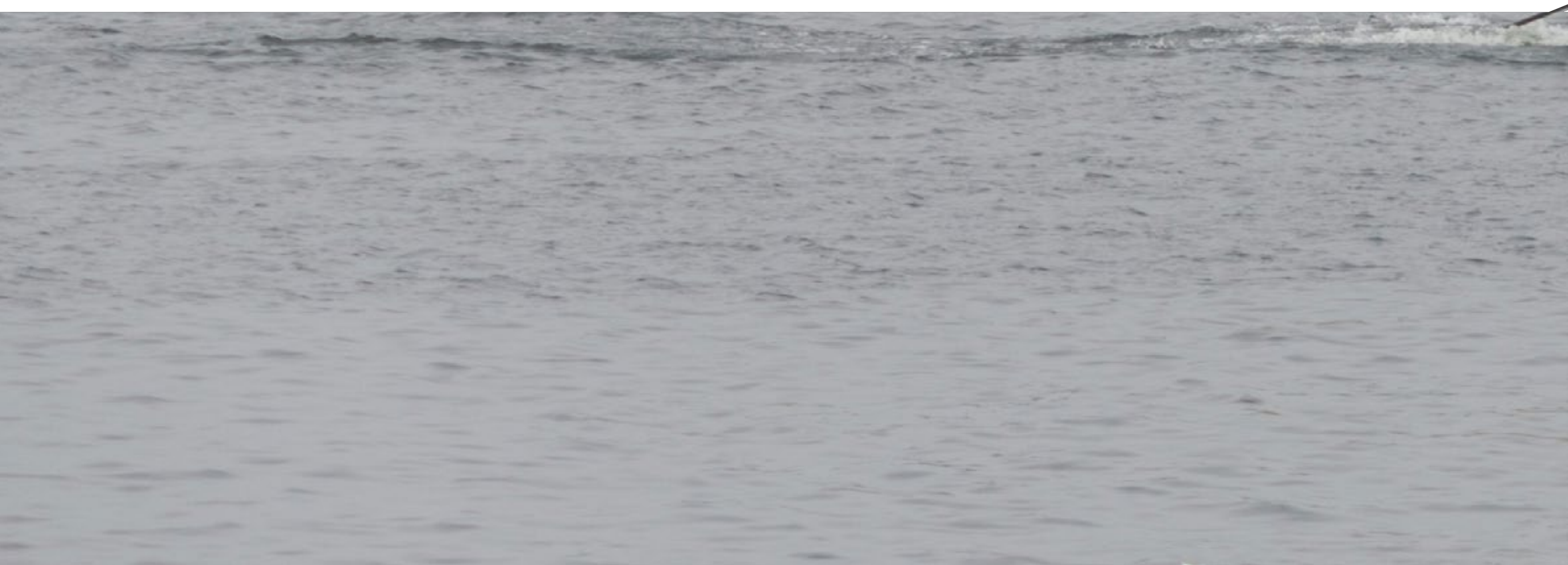
To reduce the time spent in hot indoor or outdoor environments where cooling measures cannot be implemented effectively, occupational interventions are needed to ensure limited heat exposure. The interventions below are suggested for indoor and outdoor spaces, and particularly call out targeted measures to mitigate heat in vulnerable populations.

For outdoor spaces

- Modifying working requirements to ensure that outdoor work is carried out at cooler times of day
- Limiting the direct exposure of outdoor workers to short periods of time, with breaks in shaded spaces
- Providing access to shaded/air-conditioned spaces, with access to water and rehydrating solutions for people in outdoor conditions

For indoor spaces

- Modifying the timings in places where vulnerable populations have heat exposure, to make optimal use of the cooler times of the day, especially for children in schools.
- Ensuring that active/passive cooling measures are integrated in all habitations to provide thermal comfort through building guidelines under ULBs
- Ensuring access to uninterrupted electricity supply so that active cooling measures can be operated at peak temperatures
- Prioritising high-traffic buildings and zones that house vulnerable groups, such as schools, hospitals, public buildings, anganwadis, and health centres



The Ministry of Labour and Employment in 2023 advised all states to develop plans for the effective management of workers and labourers in different sectors during the forecasted heatwave conditions. The guidance included rescheduling of working hours for employees/workers, ensuring adequate drinking water facilities at workplaces, making provisions for emergency ice packs and heat-related illness prevention materials to construction workers, coordinating with health departments to ensure regular health check-ups for the workers, and adherence to health advisories issued by the Ministry of Health and Family Welfare for employers and workers. (Press Information Bureau, 2021)

Tamil Nadu's Labour Welfare and Skill Development Department has notified the Occupational Safety, Health, and Working Conditions (Tamil Nadu) Rules, 2022, which detail various measures that employers must take to ensure workers' health. Specific language to ensure the thermal comfort of workers in indoor and outdoor environments can be integrated into such existing notified rules.

Reducing/ preventing heat exposure

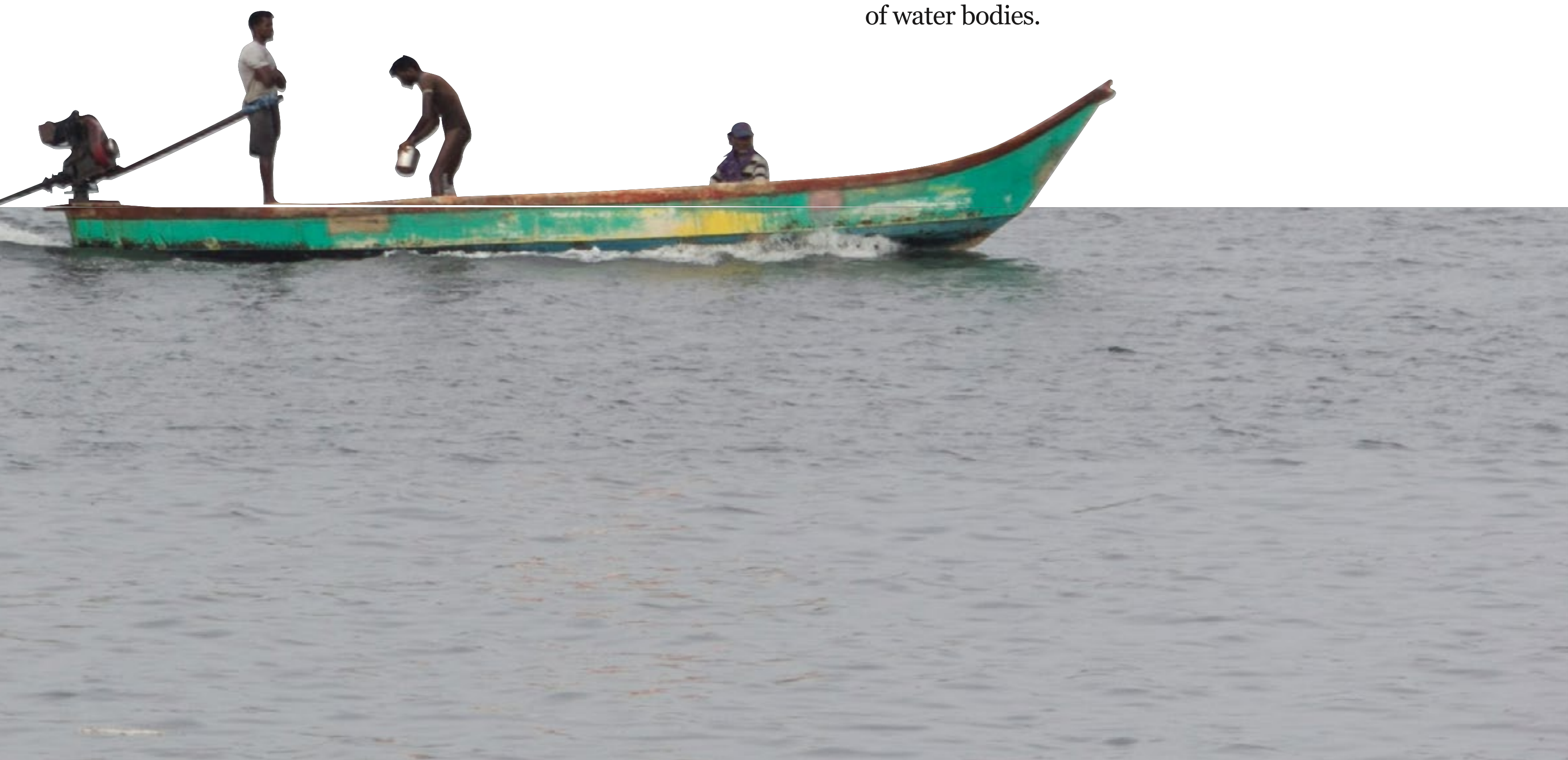
Ecosystem restoration efforts are a long-term measure to ensure a range of beneficial outcomes, these include good health and well-being and sustained productivity. To achieve a restored ecosystem with the adaptive capacity to withstand extreme and prolonged heat conditions requires integrated efforts across departments such as forestry, water resources management, tribal welfare, and health and family welfare.

- Ensuring a healthy and connected ecosystem in urban, rural and forest zones through the protection of existing natural spaces and the restoration of degraded areas, to improve the capacity of ecosystem and inhabitants to tolerate extreme heat.

  - Undertaking strategic greening initiatives specifically to enhance biodiversity health and to reduce soil erosion (many greening initiatives focus on productive landscapes and not necessarily on biodiversity)

  - Incorporating water management practices such as rainwater harvesting, aquifer management, and water body protection for water secure ecosystems.

- Surveillance and monitoring to track biodiversity health and the prevalence of zoonotic diseases, thus enabling pre-emptive or urgent action as needed to stop the spread of disease.
- Work in partnership with local stakeholders, such as forest-dwelling communities, to ensure the long-term stewardship of forest ecosystems, and fisher communities to maintain the health of water bodies.



Human-animal conflict

Large-scale ecosystem restoration, a long-term effort which ensures a healthy habitat for wildlife, should lead to reduced human-wildlife conflict, as competition for resources would diminish. Mitigation measures that can reduce human-wildlife conflicts are:

- Provision of resources and awareness drives to reduce poaching in the summer months, when communities may supplement food resources with wildlife (bush) meat.

  - Reducing poaching can help maintain animal populations which are already stressed in extreme high temperatures, and can reduce the possibility of the spread of zoonotic diseases.

- Protecting and maintaining connected wildlife migratory corridors in the state

- Reducing the crop-raiding behaviour of large animals by:

  - Changing to alternative crops which are not favoured by animals

  - Setting aside a portion of cropland for wildlife to browse on, in order to protect primary fields.

Outreach and awareness

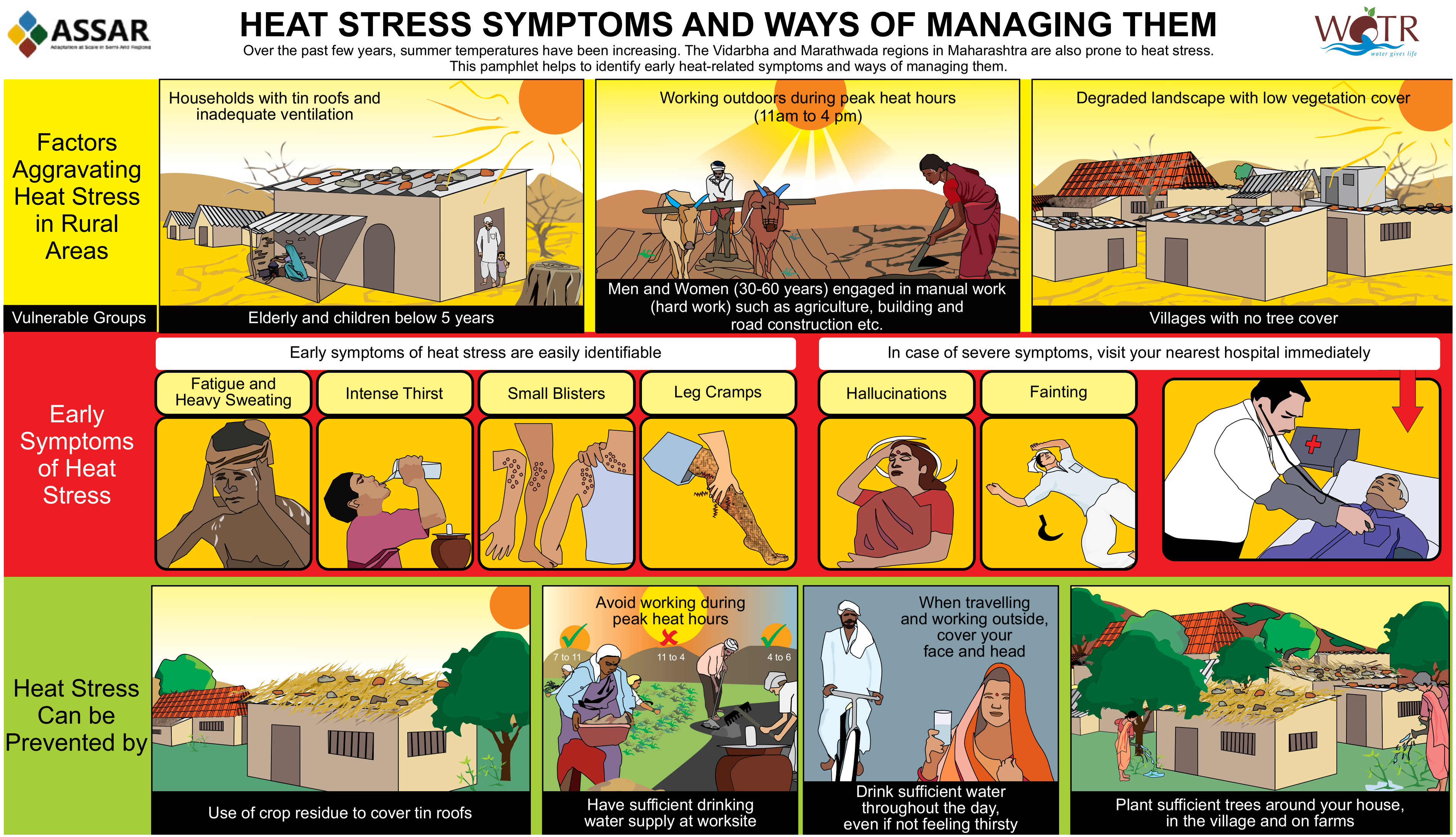
Outreach and awareness form an overarching component that has short- and long-term applications, to increase the visibility of heat impacts across stakeholder groups. Engagement will include state- and local-level agencies (to inform planning and disaster management decisions), healthcare, veterinary and forestry professionals with regard to heat-mitigating medical interventions, and individuals and communities to improve their adaptive capacities.

Targeted awareness campaigns and outreach material must be prepared for especially vulnerable persons, with visual depictions and in regional languages, to ensure dissemination to the affected populations. Health centres, hospitals, and education campuses can serve as nodes to disseminate protective health interventions for heat mitigation. Social media and traditional media can be leveraged for warnings and advisories prior to extreme heat conditions.

ELEPHANT MEAL ZONE IN ASSAM

A cluster of villages in central Assam's Nagaon district is experimenting with ways to keep crop-raiding elephants at bay by setting aside land to create a meal zone for them. Working with a local non-governmental organisation (NGO) called Hati Bondhu, around 60 villagers from two villages donated about 52 hectares (128 acres) of land to grow paddy for elephants. In November 2022, during the harvest season, a team worked on guiding the elephants to these fields. Around 100 elephants were found to be feeding on the paddy over the course of 25 days, while the farmers could safely harvest their own crops. (Mongabay India, 2023).

FIGURE 13 | Example of an outreach material to manage heat stress



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CHAPTER 5

Ensuring Sustained Resources and Productivity

Rising temperatures are heavily altering and straining economies across sectors and supply chains. Heat stress is repeatedly causing disruptions in ecological and economic systems. The increased pressure of demand, the rising consumption of resources such as water and energy, and the declining productivity of agriculture, animal husbandry, forests, labour, and industry, are all becoming increasingly urgent. The previous chapter discussed the impact of heat on people's health and well-being. In addition, heat impacts in terms of occupational and operational risks include the loss of labour supply (shortage of working hours/ human capital), loss of work efficiency (output during working hours) due to heat exhaustion, and fire hazards/machinery failures.

This chapter delves into the critical aspect of the sustainable management and augmentation of resources and productivity to mitigate rising heat-related threats. The following sections detail the challenges and corresponding solutions across various sectors, along with evidence and case studies to support cross-learning.

Heat impacts on livelihood, productivity, and resources

Heat stress can have a significant impact on lives. Health and productivity linkages also hamper the built infrastructure and service provision. As per the International Labour Organization (ILO), by 2030, total working hours globally will be reduced by nearly 2%, due to excessive heat or heat-related work disruptions (ILO, 2019). In India, the lost labour hours due to extreme heat and humidity could cost 4.5% of the national Gross Domestic Product (GDP) by 2030 (RBI, 2023). Based on historical district-level data of temperatures and crop production, the agricultural yield is expected to suffer losses of an estimated 4-5%, according to the RBI.

Different sectors are differently impacted by heat across time and geography. People have differential access to critical infrastructure and services, and communities at the bottom of the social pyramid, due to several socioeconomic reasons, are the worst hit when suffering from productivity losses.

For instance, to reduce heat exposure, educational institutions often reschedule their calendars by extending holidays or learn-from-home measures during extreme temperature days. It emerged during the consultations that schools, especially those that cater to marginalised groups, suffer from extended breaks. Disruption in classes deprives children of benefits such as mid-day meals, and strains curricular and institutional functions, impacting overall child development.

While built infrastructure cooling solutions, and the physiological impact of heat on humans and animals are discussed in Chapters 4 and 6, respectively, this chapter focuses on measures to reduce risk of heat-related losses in terms of income and yield.

Challenges identified are inter-dependent and have differential impacts on vulnerable groups. For instance, for smallholder farmers who depend on rain, the paucity of localised irrigation facilities is exacerbated by drought. Not only do they suffer due to a decrease in the overall yield, but their livelihood is challenged due to inadequate or limited access to post-harvest facilities.

Challenges and recommendations

Assessing productivity and resource depletion are complex tasks that require a comprehensive approach which simultaneously has a local focus and the larger perspective of climate, environment, health, economic concerns. Gauging the impact of heat stress on human productivity requires data and assessment beyond the usual praxis of weather monitoring. Further, to understand heat vulnerability, ILO suggests assessing labour productivity from the perspective of workers' well-being (Sharpe & Fard, 2022) and 'Decent Work' indicators (ILO, 2010).

The first and most important recommendation for improving the state of resources and productivity in Tamil Nadu is to undertake appropriate and detailed scientific research on human, animal, and plant capacities and their response to various meteorological conditions.

Based on consultations with the TN Heat Action Network, the following sectors were identified: agriculture, animal husbandry, fisheries, forests and mangroves, tourism, resources including water, energy, and air quality, and lastly, infrastructure and services. For each sector, we need to explore the challenges and propose recommendations cross-referenced with ongoing efforts across the state.

Agriculture

Challenge 1: Meteorologically induced hazardous drought-like conditions.

- Lack of clear drought risk zoning and forecast measures to support farmers
- Inefficient storage and supply for irrigation facilities
- High seasonal variations in water availability
- Increased dependence on groundwater
- Lack of awareness about heat-resilient agricultural practices

Challenge 2: Decreased crop productivity, economic yield, and loss in nutritional value.

- Increase in root moisture loss
- Reduced fodder production and quality
- Weed infestations, pest attacks
- Increased cost of farm maintenance and
- Limited ability to recover rightful price

Challenge 3: : Poor post-harvesting and marketing infrastructural facilities

- Accelerated deterioration of perishable products such as fruits, vegetables, seafood, and dairy products during storage and transport.
- Increase in product spoilage, reduced market access, and financial losses for stakeholders along the supply chain due to heat-induced disruption in transport networks and logistics operations, making it difficult to transport agricultural products from farms to markets or processing facilities.
- Increase in operational costs for farmers, traders, and facility operators due to higher energy demands for refrigeration, cooling, and ventilation systems used in post-harvest handling and storage facilities.

Challenge 4: Risk to food security at nexus of water, energy, and food production

- Hampering operations of major infrastructural systems of transport, water supply and distribution
- Increased operational costs, risking food affordability

Recommendations

Implementation and preparedness

Creating drought risk profiling across geographical scales (state, districts, villages, blocks) for assisting localised action

Use hydro-meteorological models[4] and climate scenarios[5] to assess effects of heat on water availability and drought across seasons to inform policy makers and aid in localised actions (Gupta A.K, et al., 2021). Encourage community participation in co-creating and implementing drought contingency plans along with institutions, networks of Non-Government Organisations, civil society organisations, self-help groups, community-based organisations, and subject experts.

Implementing climate/heat-resilient agriculture practices

Promoting at scale climate/heat-resilient agriculture practices, such as mulching and cover cropping. Pre-positioning drought-resistant seeds and other inputs for timely distribution during emergencies. Enhancing local weather forecasting and early warning systems and promoting the application of meteorologically recommended farming practices. Ongoing efforts in heat-tolerant crops and techniques by Tamil Nadu Agriculture University and Climate Studio (Anna University) can supplement the recommendations as identified in Tamil Nadu State Action Plan on Climate Change 2.0.

Investing in the design and construction of heat-resilient infrastructure for storage, transportation, and distribution of perishable products

Insulated storage facilities, refrigerated trucks, and cold chain logistics systems that can maintain appropriate temperatures even during periods of extreme heat. (MANAGE, 2019)

Providing training and capacity-building programmes for stakeholders throughout the supply chain, including farmers, traders, transporters, and facility operators, on heat-resilient practices, post-harvest handling techniques, and efficient use of refrigeration and cooling systems.

Planning, policy and governance

Improving water storage and management for irrigation facilities

Promoting water-efficient practices such as drip irrigation and precision agriculture can help ensure water security in heat-stressed conditions. Creating a plan for the routine repair and desilting of irrigation canals and channels across regions. Providing financial assistance to farmers to manage rainwater harvesting structures, tanks, and check dams in suitable locations, and to construct new ones.

Initiatives for effective water management through community participation

Encourage the formation of water user associations (WUAs) for participatory water management and resource allocation. Create zoning regulations and crop husbandry plans to discourage the cultivation of water-intensive crops in drought-prone areas, in accordance with the baseline assessment. Introduce water pricing mechanisms that incentivise efficient water use on farms and discourage over-exploitation of groundwater resources. Leverage the existing network of groundwater observation wells by the Central Ground Water Board (CGWB), State Public Works Department (PWD) (groundwater circle)/ State Ground and Surface Water Resources Data Centre, Water Resource Department (WRD), and Tamil Nadu Water Supply and Drainage Board (TWAD).

[4] Hydro-meteorological models are computer simulations that amalgamate hydrological and meteorological data to comprehend and forecast water system behaviour across diverse geographical scales. These models factor in variables such as precipitation, temperature, soil characteristics, land cover, and topography, offering insights into water availability, drought prediction, flood forecasting, and water resource management. They facilitate spatiotemporal analysis of basin health and the development of early warning systems for informed decision-making, aiding in the identification of vulnerable areas and predicting potential impacts.

[5] Multiple weather forecasts from international meteorological research centres contribute to predicting climate change under various scenarios. When combined with hydrometeorological models, these forecasts generate diverse outcomes, enabling analysis of the potential impacts of climate change on heat stress at various scales. This integrated approach facilitates a comprehensive understanding of the consequences associated with different climate change scenarios and aids in assessing the future implications of heat stress across multiple possibilities.

Facilitate crop diversification and market access for heat-resistant crops

Develop and subsidise programmes for promoting cultivation of heat-resistant crops. Facilitate market linkages and infrastructure for selling heat-resistant and drought-tolerant crops to ensure profitability for farmers. Offer risk insurance schemes to farmers for mitigating losses due to extreme weather events

Regulate standards for the maintenance and operation of refrigeration, cooling, and ventilation systems to ensure energy efficiency and minimise operational costs. Policies that promote the use of renewable energy sources and energy-saving technologies to reduce the carbon footprint of cold storage operations.

Provide financial incentives, subsidies, or grants to encourage investments in heat-resilient infrastructure and technologies. Public-private partnerships and collaborative initiatives can be helpful to improve the efficiency and effectiveness of cold chain logistics.

Case study/ongoing initiative

- Tamil Nadu Irrigated Agriculture Modernization Project (TN IAMP): This project is dedicated to modernising agricultural marketing infrastructure and enhancing market access for farmers across Tamil Nadu. This transformative endeavour encompasses initiatives aimed at upgrading market yards, establishing state-of-the-art cold storage facilities, and fortifying market information systems. Read more about it here: https://www.iamwarm.gov.in/AGMK.asp
- There are centrally funded schemes such as Rashtriya Krishi Vikas Yojana (RKVY) and Pradhan Mantri Kisan Sampada Yojana (PMKSY) which support Tamil Nadu's efforts to revitalise market yards, establish cutting-edge cold storage units, and pioneer the development of innovative packhouses to reduce heat -related losses.

Capacity-building to increase farmers' resilience

Create farmer training with the help of local Non-Government Organisations, civil society organisations, self-help groups, community-based organisations and expert institutions at village/ block level. These training centres can promote information-sharing through mobile apps, advisories, and farmer-to-farmer learning platforms.

Campaign to promote locally grown heat-resistant and drought-tolerant crops

Leveraging social media, creating cultural and traditional knowledge banks to educate consumers about the benefits of consuming locally grown, heat-resistant, and drought-tolerant crops. Tamil Nadu and Government of India have been supporting the Millets Mission, campaigning on the supply and demand sides, locally, nationally, and globally with the National Mission on Nutri-Cereals (NMNC) and International Year of Millets (IYM) 2023.

Educate consumers about the importance of supporting local and regional food systems, purchasing seasonal and locally produced products, and minimising food waste, to reduce the environmental and economic impacts of heat-induced supply chain disruptions.

Research, technology and innovations

Investment, research, and development into heat-resistant and drought-tolerant crop varieties with high yields and nutritional value

Innovative funding mechanisms/monetary support to mitigate risks during extreme heat

Conducting research to devise heat insurance policies, exploring government and external funding mechanisms to cover finances and premiums for farmers and workers affected by heat. The Tamil Nadu government has also floated a Rural Youth Agricultural Skill Development Mission to engage youth in agriculture, as described in TNSAPCC 2.0.

Encouraging the adoption of emerging technologies such as sensor-based monitoring systems, predictive analytics, and blockchain-enabled traceability platforms to improve the efficiency, transparency, and heat resilience of agricultural supply chains.

Investing in and supporting research collaborations between academic institutions, government agencies, and private sector partners, to develop innovative technologies and solutions for the heat-resilient storage, transportation, and distribution of perishable products.

Poultry, cattle and other livestock

Challenge: Increased risk of mortality, and reduced reproduction and productivity losses

- Heat modifies animal behaviour, reducing overall immunity and thereby increasing the risk of zoonotic, non-vector and vector-borne diseases.
- Decreased reproductive efficiency.
- Impact on milk, egg and meat yield, including loss in protein, fat and other nutritional values.
- Reduction in feed intake, altered feed demands.

Recommendations

Implementation and preparedness

Effective management of heat stress

Providing adequate shade and ventilation in livestock housing facilities, along with access to cool and clean drinking water. Use of water-soaked gunny bags, mist fans, reflective paint on shed roofs, and well-ventilated shed design can help ease heat stress faced by the animals. Adjusting feeding schedules to avoid peak heat hours, and implementing cooling technologies such as misters or fans wherever feasible.

Controlling disease outbreaks and advancing corresponding vaccination distribution.

Maintaining strict vaccination schedules to prevent the outbreak of heat-related diseases, along with implementing effective parasite control measures. Technological and logistical advancements for provision and distribution of vaccines at the micro level should receive priority.

Planning, policy and governance

Facilitating livestock breeding

Promoting breeding programmes focused on heat-tolerant breeds with improved resilience, and encouraging the use of artificial insemination with semen from heat-resistant breeds. Alternative insemination timings through day and evening, especially through the summer months, can help improve the success rate.

Improving fodder security

Developing, implementing, and subsidising state-wide programmes for drought-resistant and high-protein fodder crops, along with establishing fodder banks and storage facilities to ensure year-round availability. Implementation of stricter regulations and quality checks for commercially available animal feed. Encouraging the use of locally sourced, high-quality feed ingredients.

Outreach and awareness

Capacity-building and dissemination of information

Organising training programmes and public awareness campaigns on heat stress management, improved animal husbandry practices, and nutritious feed formulation, and information-sharing through mobile apps, advisories, and farmer-to-farmer learning platforms.

Research, technology and innovations

Promotion of heat-resistant livestock genotypes

Investing in research and development of heat-resistant livestock breeds and genetic improvement programmes. Exploring and adopting advanced breeding technologies such as genomics for faster selection of heat-tolerant traits.

Use of precision livestock farming

Promotion of the use of sensors and data analytics to monitor animal health and optimise feed and water management, especially during summer months.

Tourism

Challenge: Adverse effects on the tourism economy, including local businesses, hospitality, and related industries

- Decline in tourist arrivals, and reduction in tourism activity and duration of tour periods during heat events, impacting local businesses.
- Degradation of ecotourism sites and other fragile ecosystems
- Impact on traveller experiences and tourist preferences

Recommendations

Implementation and preparedness

Heat contingency plans

Development and implementation of heatwave contingency plans for tourist destinations, including emergency response measures, heat shelters, water coolers and oral rehydration solution (ORS) booths, shaded walking trails, mist fans/makeshift fountains, and public awareness campaigns. Focusing on creating operations schedules for outdoor tourism destinations and activities during cooler periods. Identifying investment streams for seasonal and year-round attractions, for shaded seating and relief areas with proper sanitation and drinking water facilities, and for immediate medical aid during extreme heat daysareas with proper sanitation and drinking water facilities along with immediate medical aid provisions during extreme heat days.

Case study/ongoing initiative

> Due to scorching weather conditions in Athens, Greece's capital, with temperatures soaring to 41 degrees Celsius, local authorities decided to create a schedule for monuments such as the Acropolis and the Parthenon, which are some of the hottest parts of the city. The monuments were closed from noon to 5:30 p.m., and measures were taken to protect visitors from the intense heat and potential health risks associated with prolonged exposure to extreme temperatures.

Planning, policy and governance

Sustainable tourism planning

Developing and implementing a policy framework that incentivises sustainable tourism practices and integrates heat mitigation, focusing on conservation, responsible visitor access, and climate change resilience. Sustainable tourism plans should address local communities' demands, tourism associations, and global/competitive standards for destination management and for the hospitality industry. Heatwaves are not typically covered by travel insurance companies, hence tourist perception and host perception surveys will play a critical role in planning.

Outreach and awareness

Awareness campaigns to educate tourists about responsible behaviour, heat stress risks, and the importance of sustainable tourism practices.

Case study/ongoing initiative

> Government of South Australia provides tourists with assistance to plan their itineraries by providing web platforms that provide all necessary information for tourist including alerts, weather, destination schedules, advisories on clothing, driving, insurance, fire safety, beach safety, food and drinking, vaccinations, and healthcare, etc. They provide special travel assistance to disabled, recovering from illness or surgery, or travelling with children through Medical Travel Companions. Special tailored experiences for months of extreme heat across South Australian geography is provided by South Australian Tourism Commission.

Providing clear and timely information to tourists about weather conditions, heat stress precautions, forest fires, and available resources during heatwaves.

Engaging with tourism businesses, local communities, and environmental NGOs to develop and implement solutions to mitigate the impacts of heat stress.

Research, technology and innovations

Developing digital platforms that provide tourists with real-time information about weather conditions, heat stress risks, forest fires, and available activities during heatwaves.

Conducting regular assessments to understand the impact of tourism on domestic/international demands, local communities, and ecosystems, informing sustainable planning and management strategies.

Mangrove and coastal regions

Challenge: Disturbed salt-nutrient balances in coastal regions causing habitat degradation of transitional ecosystems and distribution of mangroves.

- Altered biochemical processes that are increasing water salinity; increased risk of water stress
- Changes to composition of biomass and mangrove species, reduced diversity of flora and fauna within coastal ecosystems
- Reduced livelihood opportunities for communities dependent on mangroves and coastal ecosystems

Recommendations

Implementation and preparedness

Mangrove restoration programmes

Implementing and monitoring large-scale mangrove restoration programmes with community participation, focusing on native species and adaptive strategies based on real-time data and scientific evidence. Higher surveillance and monitoring during extreme heat to ensure that mangrove health is maintained.

Planning, policy and governance

Developing and implementing an Integrated coastal zone management (ICZM) plan that balances conservation, development, and the sustainable use of coastal resources in the context of increasing heat and climate change.

Establishing buffer zones around protected mangrove areas to minimise human activity and environmental disturbances.

Designating and effectively managing marine protected areas (MPAs) to protect critical mangrove habitats and biodiversity.

Fostering collaboration with local communities in the management and sustainable use of MPAs.

Outreach and awareness

Raising awareness among coastal communities about the importance of mangrove ecosystems and the threats they face.

Promoting sustainable livelihoods and resource use practices that support the health of mangroves by incentivising communities dependent on mangroves and coastal resources.

Research, technology and innovations

Monitoring and data collection

Investing in long-term monitoring programmes to track changes in salinity, water quality, and mangrove health. Remote sensing and other innovative technologies can be used to improve data collection and analysis.

Climate-resilient mangrove restoration

Researching and developing climate-resilient mangrove restoration techniques to enhance the adaptability of these ecosystems in the face of changing environmental conditions.

Case study/ongoing initiative

The Tamil Nadu Forest Department spearheads robust mangrove conservation and restoration initiatives through the Vedaranyam Mangrove Conservation Programme, Krishnapuram Mangrove Conservation Project, mangrove restoration in Gulf of Mannar Biosphere Reserve, etc., designed to rejuvenate deteriorated mangrove ecosystems, and bolster their resilience to climate change. These initiatives encompass the cultivation of indigenous mangrove species, management of invasive species, and revitalisation of hydrological connectivity within mangrove habitats.

Fisheries

Challenge: Decrease in yields, stock and revenue

- Altered sea and water body temperatures affecting fish migration and breeding patterns.
- Degradation of coastal and other water habitats, impacting the breeding and feeding grounds for fish.
- Loss of yield due to insufficient water availability in lakes and ponds used for aquaculture.
- Decrease in species survival rates

Recommendations

Implementation an preparedness

Monitoring of fish stocks and migration patterns to understand the impacts of temperature changes and habitat degradation.

Implementation of early warning systems to alert fishermen about potential changes in fish migration patterns or environmental risks caused to extreme heat.

Planning, policy and governance

Research into and promotion of climate-resilient aquaculture techniques, such as closed recirculating systems or species diversification.

Implementation of regulatory measures such as establishing marine protected areas, restoring coastal habitats, and developing aquaculture regulations.

Facilitating access to microfinance and insurance schemes which address heat crisis for fishermen to support their income especially during summer months.

Outreach and awareness

Fostering collaboration between fishermen, researchers, and policymakers to develop and implement solutions.

Organising public awareness campaigns and capacity-building.

Case study/ongoing initiative

The mKRISHI Fisheries app is a mobile application for the fishing communities in India that does the following:

- Provides sea temperature data
- Helps identify potential fishing zones using satellite data, sea surface temperature, and phytoplankton presence.
- Provides information on wind speed, wave heights, and unsafe regions.

Research, technology and innovations

Researching and promoting the diversification of aquaculture species to reduce dependence on vulnerable fish populations which are sensitive to heat impacts.

Understanding the long-term impacts of climate change on fish populations and ecosystems.

Developing innovating aquaculture technologies such as Recirculating Aquaculture Systems (RAS), Integrated Multi-Trophic Aquaculture (IMTA), etc.

Forests and forest animals

Challenge: Disturbed carbon cycle, forest structure, species composition, and animal movement negatively impacting forest ecosystem services

- Increased mortality of trees, altering forest composition.
- Reduced availability of water sources within forests, impacting both flora and fauna, causing biodiversity loss
- Proliferation of invasive species favoured by warmer temperatures, leading to ecosystem imbalances.
- Increased risk of frequent and intense forest fires due to prolonged periods of heat
- Reduced capacity of forests to sequester carbon due to stresses on tree health and the prevalence of forest fires.

Recommendations

Implementation and preparedness

Forest management practices

Implementing sustainable forest management practices such as selective logging, prescribed burning, and pest control to maintain forest health and resilience to heat stress, along with regular monitoring of forest ecosystems to detect early signs of stress and intervene promptly to mitigate impacts.

Fire management practices

Developing a comprehensive fire management plan that incorporate early detection systems, rapid response mechanisms, and community involvement in firefighting efforts. Investing in firefighting equipment, training programmes, and resources to enhance the capacity to suppress and manage forest fires effectively.

Strengthening enforcement measures to prevent forest fires and illegal activities such as poaching, habitat destruction, and encroachment within protected areas.

Planning, policy and governance

Strengthen environmental regulations

Promoting sustainable land management through incentives, subsidies and enforcing strict regulations and policies to prevent illegal logging, deforestation, and land degradation, which exacerbate the vulnerability of forests to heat stress and wildfires.

Case study/ongoing initiative

The Joint Forest Management (JFM) approach in Tamil Nadu works to involve local communities in the sustainable management of natural forests. Building on the Interface Forestry Programme initiated in 1988, JFM initiatives have been implemented to elicit people's participation, foster sustainable forest management, and contribute to rural development. Despite numerous advantages, the government acknowledges the challenges and limitations in effectively implementing the JFM approach. Additionally, the formation of Village Forest Committees (VFCs) further demonstrates the commitment of the Tamil Nadu government to sustainable forest management. These committees, established by local communities, play a crucial role in managing village forests and deciding on their sustainable utilisation. The benefits of this approach include fostering a sense of ownership, responsibility, and community involvement in the management of forest resources.

Outreach and awareness

Launching awareness campaigns and educational outreach programmes to inform the public about the impacts of climate change on forests, wildlife, and ecosystems.

Providing training and educational resources to schools, universities, and community groups to promote environmental literacy and encourage citizen participation in conservation efforts.

Case study/ongoing initiative

The Tamil Nadu Government has implemented the Community Fire Watcher Programme as a strategic measure to prevent and manage forest fires. This initiative involving local communities as fire watchers, with responsibilities such as monitoring forests for signs of fire, alerting authorities in case of outbreaks, and actively participating in fire prevention activities, including controlled burning, and creating fire lines. The goals are to enhance the local capacity for forest fire prevention and to promote community involvement in safeguarding forest ecosystems.

Research, technology and innovations

Climate-resilient reforestation and afforestation programmes

Investing in research and development of native heat-resilient tree species and reforestation techniques adapted to warmer temperatures, changing precipitation patterns, and increased wildfire risks, along with deploying innovative technologies such as drone surveillance, remote sensing, and geographic information systems (GIS) to assess forest health, monitor ecosystem dynamics, and prioritise conservation interventions.

Carbon sequestration and climate adaptation strategies

Exploration of nature-based solutions for carbon sequestration, such as agroforestry, rewilding, and forest restoration initiatives, to enhance the capacity of forests to sequester carbon and mitigate climate change impacts. Fostering collaborations between scientists, policymakers, and stakeholders to develop and implement climate adaptation strategies that safeguard forest biodiversity, ecosystem services, and community livelihoods in the face of escalating heat stress and environmental challenges can help further .

Case study/ongoing initiative

Global Forest Watch, a platform developed by WRI, provides open access to satellite data and analytics tools, enabling researchers to identify degraded areas and suitable locations for planting heat-resilient tree species. Government agencies and NGOs can use this data resource when designing and implementing targeted reforestation and afforestation programmes that contribute to climate change mitigation and adaptation.

Populations in adverse working conditions

These could be outdoor workers, informal workers, gig workers, workers exposed to mechanical/indoor heat.

Challenge 1: Reduced work efficiency and productivity due to heat-induced stress, impacting worker welfare

- Risk of reduction in available working hours causing deficit in employment opportunities
- Heat-related illnesses, including heatstroke and heat exhaustion and mental health challenges, causing loss in productive hours
- Limited access to clean drinking water, leading to dehydration
- Limited access to sanitation facilities causing a reduction in fluid intake, leading to dehydration, especially in women
- Lack of access to proper protective gear and cooling measures (access to shade and proper rest areas)

Challenge 2: Increased risk to gig economy due to supply chain disruptions and logistical challenges

- Disruptions in delivery schedules and logistical operations due to extreme weather conditions, leading to wage loss
- Limited to negligible access to health benefits and monetary security

Recommendations

Implementation and preparedness

Workplace safety

Implementing workplace safety protocols that include regular breaks in shaded or cool areas, provision of adequate rest periods, access to potable water, changes in working schedules, optimal clothing guidelines, and rotation of tasks to minimise heat exposure. Establishing mechanisms for monitoring heat stress levels in the workplace through heat stress indices, wearable sensors, or weather monitoring systems, to identify high-risk areas and implement targeted interventions, and developing emergency response plans for heat-related incidents, including protocols for first aid, accessing medical care, and evacuating workers.

Case study/ongoing initiative

The International Labour Organization (ILO) has drawn up guidelines and protocols to safeguard workplace safety amidst heat-related hazards, aiming to shield workers from heat stress and associated health risks. They include:

- Heat stress management by providing shaded rest areas and scheduling demanding tasks during cooler periods.
- Ensuring access to ample drinking water and promoting regular hydration
- Equipping workers with heat safety gear such as breathable clothing, hats, masks etc.
- Implementing health monitoring programmes to detect early signs of heat-related illnesses, with particular attention to vulnerable workers.
- Ensuring swift action during emergencies, through prompt first aid and medical treatment.

Planning, policy and governance

Health insurance

Providing health insurance to workers during extreme heat conditions helps safeguard the worker's interest.

Outreach and awareness

Conducting education campaigns to raise awareness among workers about the risks of heat-related illnesses, the importance of hydration and rest breaks, and how to access assistance if needed.

Engaging with employers, local communities, trade unions, and advocacy groups to advocate for improved working conditions, access to health benefits, and greater protections for vulnerable workers, particularly during periods of extreme heat.

Research, technology and innovations

Monitoring real-time heat stress levels

Developing innovative technologies for real-time monitoring of heat stress levels in the workplace, such as wearable sensors, mobile applications, and predictive modelling systems.

Personal cooling techniques

Investing in research and development of cooling technologies for outdoor work environments, such as personal cooling vests, misting fans, and evaporative cooling systems, to reduce heat exposure.

Case study/ongoing initiative

At the Tata Group's manufacturing plants in Jamshedpur, Jharkhand, workers were equipped with personal cooling vests that feature advanced cooling technology. These vests were provided to employees operating in hot and humid environments. Feedback from workers indicated that they experienced increased comfort and reduced fatigue throughout their shifts, resulting in enhanced productivity and overall well-being.

Resources (energy, air quality, water)

Challenge 1: Increasing electricity demand due to extreme heat

Electricity demand is likely to rise in extreme heat conditions, which will hamper ongoing efforts to decarbonise electricity and shift away from thermal power generation.

- Increase in the electricity demand for cooling and refrigeration will cause additional load on existing production and transmission systems
- The state's dependence on non-renewable energy sources is nearly at 58% (as of 2023), and increased energy demands could be a hurdle for the state to meet its decarbonising goals.
- Reduced power generation capacities, especially in thermal power plants, due to excessive coal demand, water scarcity and compromised infrastructure efficiency.
- Excess heat affects the performance of renewable energy sources such as solar and wind power.
- Increase in downtime, and disruptions in electricity supply due to equipment failure from managing higher loads during heat events.

Recommendations

Implementation and preparedness

Implement energy efficiency programmes

Targeting residential, commercial, and industrial sectors to reduce electricity demand for cooling and refrigeration. This can include incentives for passive cooling solutions such as energy-efficient appliances, building retrofits (BEE rated) and consumer awareness campaigns on energy-saving practices. These measures should also be directed towards vulnerable groups so that they can benefit in terms of energy and cost savings, and have access to energy-efficient cooling.

Case study/ongoing initiative

Tamil Nadu actively engages with the Perform, Achieve, and Trade (PAT) scheme led by the Bureau of Energy Efficiency (BEE). This initiative targets enhancing energy efficiency in energy-intensive industries by setting compulsory energy consumption objectives. Companies exceeding these targets can trade surplus energy savings as Energy Savings Certificates (ESCerts) in the market.

Tamil Nadu Electricity Regulatory Commission (TNERC) and the state electricity distribution companies (DISCOMs) administer Demand Side Management (DSM) initiatives to encourage energy efficiency among consumers. These initiatives encompass activities such as conducting energy audits, raising awareness about energy efficiency through campaigns, and offering incentives for the uptake of energy-efficient appliances and equipment.

Develop load management strategies

Optimising electricity consumption during heat-driven peak demand periods through implementing time-of-use pricing, demand response programmes, smart grid and net metering technologies.

Planning, policy and governance

Diversify the energy mix

Promoting investments in renewable energy projects, energy storage technologies, and grid modernisation initiatives to enhance resilience and flexibility in the electricity system. Integrate low-carbon pathways in planning energy sector transition.

Develop an urban heat island mitigation plan to reduce energy use for cooling.

Plans including green roof innovations, canopy plans, nature-based solutions (NbS), landscape planning, etc., should be integrated into urban planning and building regulations. Refer to Chapter 6 for more detail.

Outreach and awareness

Engage with stakeholders, including utilities, energy companies, regulators, and community groups, to foster collaboration and collective action on energy resilience, demand-side management, and climate adaptation.

Research, technology and innovations

Invest in research and development of advanced and diverse energy technologies, such as energy storage systems, grid integration solutions, and microgrid technologies and distributed renewable energy systems, to enhance reliability and resilience of the electricity system.

Challenge 2 : Shifting rainfall patterns and extreme heat

Shifting rainfall patterns and extreme heat disturbs the overall water balance, intensifying water demand and straining already limited resources.

- Increase in water demand due to high evaporation rates from waterbodies leading to water scarcity and hampering overall water balance.
- Reduction in water quality due to reduced dissolved oxygen levels in water, leading to growth of harmful algae blooms, bacteria, and pathogens; fish kills and other ecological disruptions.
- Increased demand for cooling water in thermal power plants, industrial processes etc. causing additional pressure on water resources and exacerbate competition for water among different users.

Recommendations

Implementation and preparedness

Water conservation measures

Rainwater harvesting, groundwater recharge systems, and efficient irrigation techniques to reduce water demand and enhance water availability during periods of high evaporation.

Develop and implement drought preparedness plans

Include water rationing measures, emergency water supply systems, and contingency plans for water scarcity scenarios. Refer to recommendations in the 'Agriculture' section for detail.

Planning, policy and governance

Reducing high evaporation rates from water bodies by providing shade, floating covers, etc.

Case study/ongoing initiative

Tamil Nadu is considering the implementation of floating solar power projects on water bodies such as lakes and reservoirs. These initiatives serve a dual purpose: generating clean energy while also mitigating evaporation by providing shade to the water surface. Additionally, the state government actively engages in desilting and restoration projects for water bodies. These efforts involve the removal of sediment and debris, enhancing water storage capacity, and minimising the exposed surface area prone to evaporation (Vardhini & Devi, 2024).

Strengthen regulatory frameworks for water quality protection, including standards for wastewater treatment and reuse, pollution control measures, and enforcement mechanisms to prevent contamination and maintain ecological integrity.

Integrate water and energy planning processes

Optimise water use efficiency in thermal power plants, industrial facilities, and other sectors, and minimise conflicts over cooling water requirements.

Challenge 3: Heat-linked air quality degradation

Increased risk for co-exposure due to decline in air quality in extreme heat events

- Increase in ground-level ozone levels, exacerbating respiratory problems and other health issues.
- Increase in heat due to surface-level carbon monoxide (CO) and black carbon presence
- High heat traps leading to increased articulate matter suspension at ground level, leading to health hazards to humans and biodiversity.

Recommendations

Implementation and preparedness

Implement programmes to manage vehicular and industrial emissions during heat events

Planning, policy and governance

- Develop assessment and monitoring methods to establish the relation between high heat events and air quality degradation
- Promote low-emission technologies through enabling measures (incentivisation for non-motorised transport, electric vehicles, etc.) to reduce emissions, particularly during high heat conditions.
- Develop air quality management plans under the National Clean Air Programme (NCAP) 2019, to reduce particulate matter.

Outreach and awareness

- Raise awareness through real-time monitoring around high heat and air quality metrics
- Enabling public access to air quality data and heat interactions

Research, technology and innovations

- New innovation around low-emission technology for transport and industry
- Forecasting methodology using big data, AI/ML tech for heat and air quality interactions.

CHAPTER 6

Cooling Solutions

Cooling is linked with health, well-being, economic growth, and productivity, especially in hot climates. In Tamil Nadu, where hot weather dominates most of the year, cooling measures are more than a luxury. Cooling is now recognised as a cornerstone of various development goals in the state, from food preservation to productivity enhancement, in both rural and urban settings. As Eleni Myrivili, UN-Habitat's first global chief heat officer, puts it, we cannot simply air-condition our way out of the heating problem.

This chapter provides a comprehensive exploration of cooling solutions focused on diverse contexts, both urban and rural. The described solutions extend beyond conventional methods to include innovative strategies that integrate passive cooling techniques, traditional practices, and nature-based solutions into the built environment. The chapter highlights the importance of protecting socio-ecological systems and resources, and of community engagement, to combat the effects of heat.

In Tamil Nadu, 48.45 % of the total population (8.39 crores according to the 2011 census) lives in urban areas. The population stress in urban areas results in an array of environmental problems. For example, in Chennai, the temperature humidity index (THI) shows a rising trend across all months, increasing the discomfort level for the local population. Residents of Tiruvarur, Thanjavur, Nagapattinam, and Tuticorin are experiencing an increased number of days of discomfort each year (Times of India, 2024).

This chapter highlights the cooling needs across three categories to improve thermal comfort for urban and rural contexts at scale:

FIGURE 14 | Cooling strategies at scale

COMMUNITIES/ Individual and Community Scale

- Improved access to shelters
- Awareness building

BUILT ENVIRONMENT/ Neighbourhood Scale

- Passive Cooling
- Integrating traditional practices - Architectural styles
- Integrating Nature-based solutions

SOCIO-ECOLOGICAL SYSTEM & RESOURCES/ Macro Scale

- Protecting and restoring existing ecology and green
- Strengthening water resources and infrastructure

To ensure the effective deployment of cooling solutions, a detailed baselining and spatial mapping of high heat zones is required. This will help identify high-risk zones, vulnerable populations, and prioritisation of actions:

- for identifying outdoor areas with high heat prevalence
- for identifying public buildings and public gathering spaces, both indoors and outdoors, with high risk
- for delineating habitations of vulnerable groups for priority actions, e.g., changing all asbestos roofs to safe and cool roofing materials, especially focusing on low-income housing
- for delineating cool zones that can be leveraged as shelter during heat extremes

Built Environment

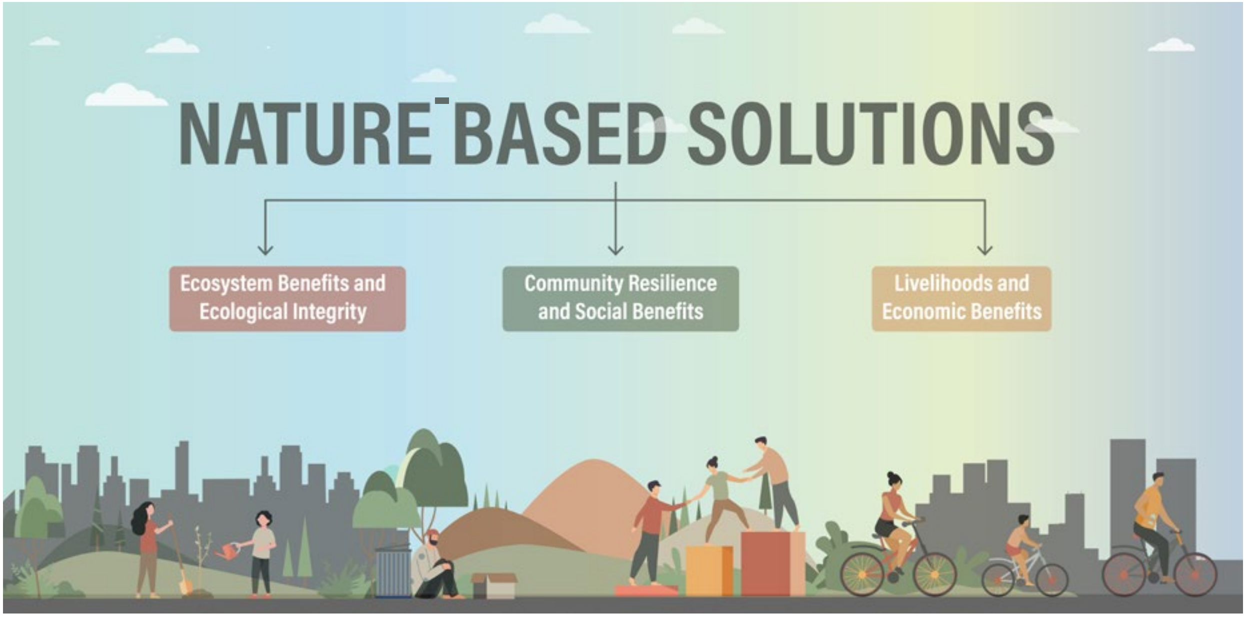
All man-made systems, including physical and social infrastructure networks, service delivery, and buildings that both intensify heat and are at risk due to excessive heat are part of the built environment. By addressing cooling in the built environment, we can deliver comfort for all inhabitants of Tamil Nadu.

- **Integrating traditional practices:** Building materials such as glass and concrete, commonly used in India today, are not suitable for local weather conditions. Rural houses made using locally available resources such as mud, thatch, or any other material, depending on the location are sustainable. They have low environmental impact in terms of production, renewability, and even natural dissolution (Mathi et al., 2014). Additionally, they significantly reduce the energy involved in processing and transport. Traditional Indian architecture used various methods to mitigate heat. Shaded courtyards enabled natural airflow. Verandas buffered heat, while small windows ventilated indoor spaces. Chhajjas provided shade, thick walls insulated the home, domed roofs deterred solar heat. Mud huts with whitewashed exteriors and high thermal mass stone walls utilised the principle of radiant cooling. Thatched, locally sourced roofs and lime-plastered walls insulated and reflected sunlight. Collectively, these traditional methods kept interiors comfortable. (UNDP India, 2024).

- **Integrating nature-based solutions** To address urban sustainability challenges, cities round the world are incorporating nature-based solutions (NbS) to adapt to changes. In the context of heat, nature plays a key role in increasing resilience. For example, trees, parks, and urban forests are essential to cities not just as spaces for community-building, but also because they offer multiple ecological benefits, from building resilience against increasing heat to water security, biodiversity, and residents' health and well-being. It is well established that integrating NbS in the built environment improves the quality of life. In India consensus around nature-based solutions is;

We define Nature-based Solutions as indicated in Figure 15: (www.nbs4india.org/)

FIGURE 15 | Scope, functions and benefits of Nature-based Solutions



Solutions that offer benefits to the urban ecosystem and maintain or restore key ecological processes that are characteristic of or reflect the natural conditions expected in a region.	Solutions that mitigate climate risks and enhance human well-being by promoting social, cultural, recreational, and health co-benefits.	Solutions that help transition towards a nature-positive economy while maintaining resource efficiency and promoting circularity.
Ecosystem benefits and ecological integrity	Community resilience and social benefits	Livelihoods and economic benefits

Socio-ecological systems & resources

Rural and urban landscape systems and resources are socially and ecologically critical, as they are essential to livelihoods and well-being of society, and because of the ecosystem services they provide. Addressing these factors is crucial for maintaining ecological and resource security.

Protecting and restoring existing ecology and green

Ecosystems are the most vital resources for combating climate change and other natural calamities. In both rural and urban contexts, they play a critical role. In rural areas, intense and prolonged heat and drought events can lead to severe socio-economic crises, hence safeguarding ecosystems is extremely important. Chapter 5, which focuses on sustained productivity, highlights the issues in agriculture and animal husbandry.

In the rural context, protecting and restoring ecosystems are imperative to ensure macro level ecological health, combating climate change impacts and for improving lives and livelihoods in local communities.

In the urban context, ecosystems such as urban groves, forests, neighbourhood parks, wetlands etc., provide invaluable benefits (climate-proofing against disaster risks, for example), and their interconnectedness can be leveraged to maximise cooling. Underutilised open spaces and public spaces can be reactivated to create green zones in the city.

- For example, parks, such as Sanjay Gandhi National Park in Mumbai, Lodhi Garden and Sunder Nursery in New Delhi, Cubbon Park in Bengaluru, Guindy National Park in Chennai, Rajaji National Park in Uttara-

FIGURE 16 | The Cubbon park, Bengaluru

khand, and Chandigarh's Capitol Complex and Rock Garden, help modulate extreme heat. These parks have lush greenery and extensive tree canopies providing shade, lowering the surface temperature, and reducing the urban heat Island effect. They also offer recreational activities, besides contributing to climate resilience by preserving biodiversity, absorbing carbon dioxide, and providing cooling through evapotranspiration and water bodies.

Strengthening water resources and infrastructure

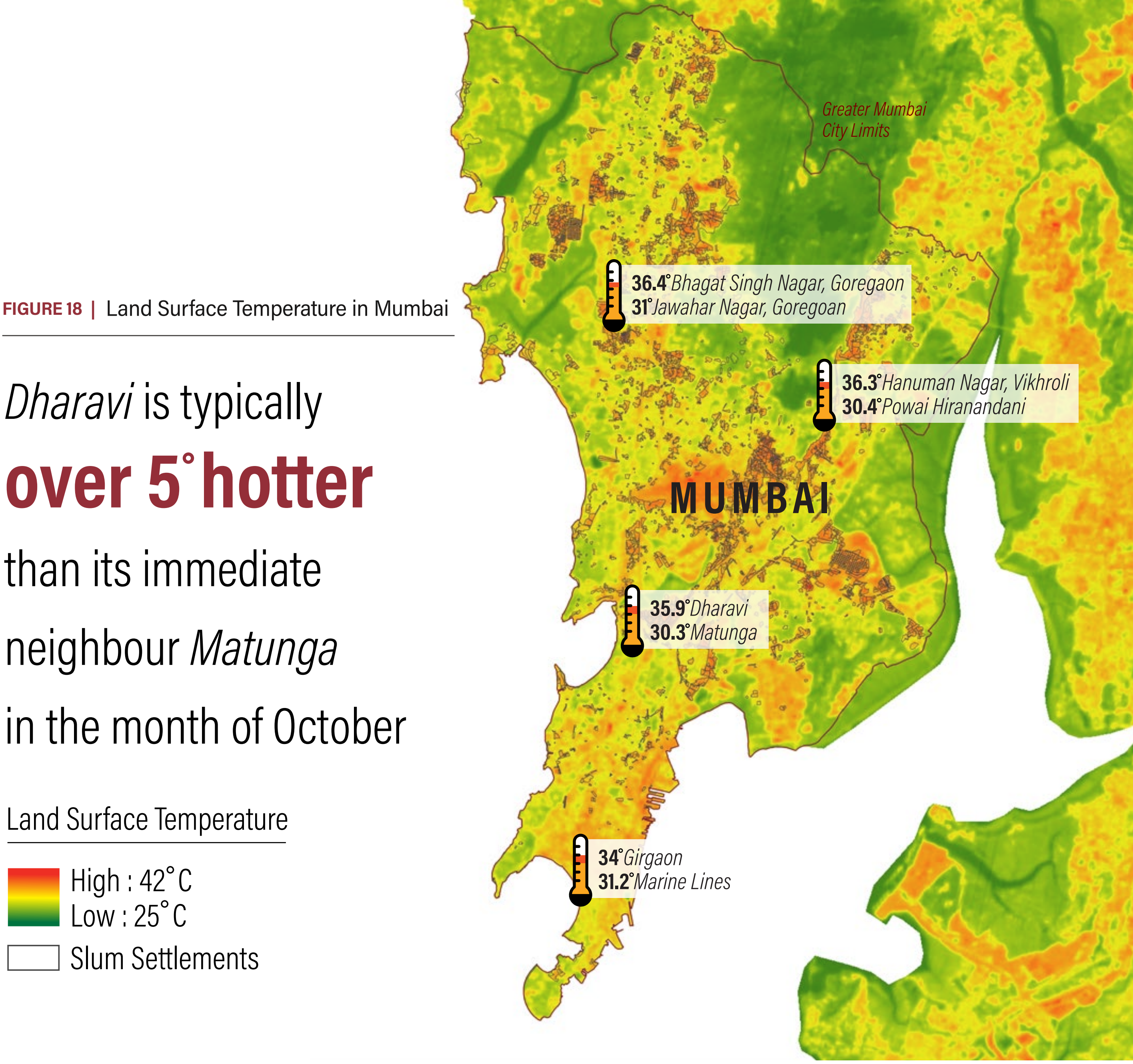
Water bodies and water infrastructure need to be protected and restored to alleviate heat impacts. In both the rural and urban contexts, water is a natural cooling element. Leveraging the natural flow of rivers, location of wetlands, other structures such reservoirs, and tanks, etc., can help alleviate thermal discomfort in a rapidly heating environment.

Water bodies, wetlands and water infrastructure that mitigate heat impacts include the Ganga river, Chilika Lake in Odisha, Suranga Bandha in Karnataka, Hussain Sagar Lake in Telangana, Chembarambakkam Lake and Vaduvur Bird Sanctuary (wetland sanctuary) in Tamil Nadu. These features help reduce thermal discomfort in both rural and urban areas through processes such as evaporation and air movement. Additionally, they promote biodiversity, replenish groundwater, and provide opportunities for recreational activities, all of which enhance community resilience and well-being in the face of rising temperatures.

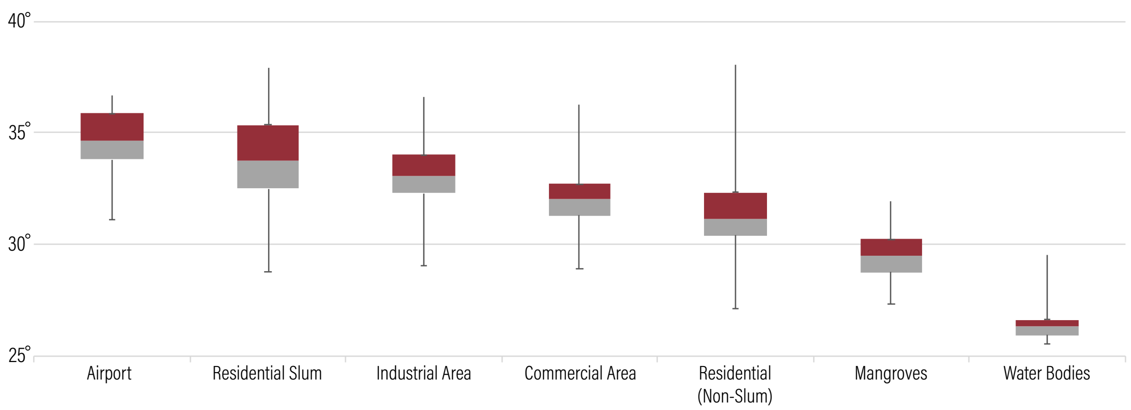
FIGURE 17 | Glimpses of cooling oases: Lake Pichola and vibrant wetlands

FIGURE 18 | Land Surface Temperature in Mumbai

Dharavi is typically **over 5° hotter** than its immediate neighbour *Matunga* in the month of October



Difference in surface temperature by land use in Mumbai



The average surface temperatures for the month of October, in the three years from 2017 to 2019 in Mumbai present a stark difference in heat exposure in poorer communities. This is a function of building material, compromised ventilation and green cover, and limited access to open spaces within these neighbourhoods. Industrial and commercial land use with large built-up footprints like the airport, industrial estates, malls have a significantly higher surface temperature than green and blue areas (forests, lakes, mangroves). The city will need to adopt heat mitigation measures to reduce the ambient temperature and protect people's health, lives and livelihoods.

Source: WRI India using LandSat 8 (USGS), Mean surface temperature at 10:30 am +/- 20 minutes for October (2017-2019)

Communities

Some population groups are disproportionately impacted due to their inherent characteristics, physical and health conditions, socio-cultural and economic conditions, access to services and resources, and rate/type of exposure to heat (Rangwala et al., 2018). Involving local communities and stakeholders in the planning, design and implementation of interventions is key to garnering support, developing stewardship, and ensuring that the benefits of the interventions are well-received. Community engagement also helps deepen the understanding of on-ground conditions and identify challenges and knowledge gaps (refer to Chapter 2 for a list of categories of outdoor workers). Intervention strategies should be designed by first identifying the risk to be addressed, and then evaluating available resources and all aspects of operationalisation, monitoring and maintenance of the intervention. (C-Hed, 2023).

Inefficient housing and energy poverty often restrict access to reliable cooling systems in vulnerable communities, exposing them to high heat. This issue, compounded by inefficient and aged housing, intensifies the impact of extreme heat indoors. Awareness-building, especially among vulnerable groups, is key. Aligning with policies, schemes, building effective collaborations, and dissemination of best practices and learnings will incentivise communities to make the shift to an environment that will protect them from heat. (Nicholas Institute, 2024).

For example, the Telangana Cool Roof Policy 2023-2028, aims to mitigate urban heat islands and reduce energy consumption by promoting cool roof technologies that reflect sunlight and lower the surface temperatures in buildings. By enhancing energy efficiency, improving comfort and health, and fostering economic growth through job creation and sustainable development, the policy seeks to create cooler, more resilient urban environments in Telangana, while contributing to climate change mitigation efforts.

Target-based approach: Government of Telangana to cool roof 300 sq. kms of roof area by 2028. Specific objectives include:

- Driving state-wise adoption of cool roofs to save energy, build heat resilience and increase thermal comfort
- Institutional framework for city-wide cool roof application
- Financing framework – outreach and awareness of building tools for implementing cool roofs
- Workforce development and training for cool roof installation

Recommendations

Mitigating heat risk and associated stress requires an integrated approach. In the context of cooling, the solutions vary based on differential vulnerabilities. However, from a planning perspective, the Tamil Nadu State Government can introduce enforceable regulations. The design for cooling is essentially based on reviving practices and leveraging nature as much as possible. Further, innovation in cooling is an important aspect, and with more focus on sustainability, the state should be onboarding solutions that enable a shift from business as usual to a cleaner greener future. The recommendations here are not inclusive but have emerged as key actionable items during the heat action network consultations.

Implementation and preparedness

Tree planting: In cities, we should encourage scientific greening practices (site-native species match, for instance), and the culture of planting with a plan. The greening efforts should also contribute to strengthening local biodiversity, and potential activation of green public spaces among other benefits.

Mumbai's first-ever greening handbook looks at greening interventions across various scales – small, medium, and large, based on the area available to residents.

In rural areas, there is a need to protect and restore natural blue and green ecosystems, which have a network effect, mitigating heat and providing water during drought years. For example, the Pandalgudi mine restoration in Virudhunagar Tamil Nadu, with native species of trees and shrubs, has enabled the conversion of wasteland into a restored water body, with trees.

The Tamil Nadu government has announced the Green Tamil Nadu Mission, which aims to increase forest and tree cover from 23.8% to 33% of the current geographical area in the state by 2030-2031. The move is part of the government's vision for tackling the effects of warming and climate change. Under the mission, the government plans to plant 265 million crores of economically and ecologically important trees in 10 years. These trees will be planted in public lands in cities, on plantations, around educational institutions, temple lands, sacred forests, industrial areas, tank foreshore, padugai areas, over a total area of almost 13,500 sq km. Particular attention will be paid to the selection of suitable varieties that can grow in different climates and soil conditions, to ensure successful growth. This extensive tree-planting programme aims not only to increase green cover but also to provide shade, reduce urban heat island effects, and mitigate the effects of warming and climate change, enhancing overall environmental resilience in Tamil Nadu.

The Tamil Nadu government's initiative to support native groves through the Kurunthoppu Thittam project, should be leveraged extensively for schools and other institutional and administrative buildings.

FIGURE 19 | Participants planting trees as part of an event of Green Tamil Nadu Mission

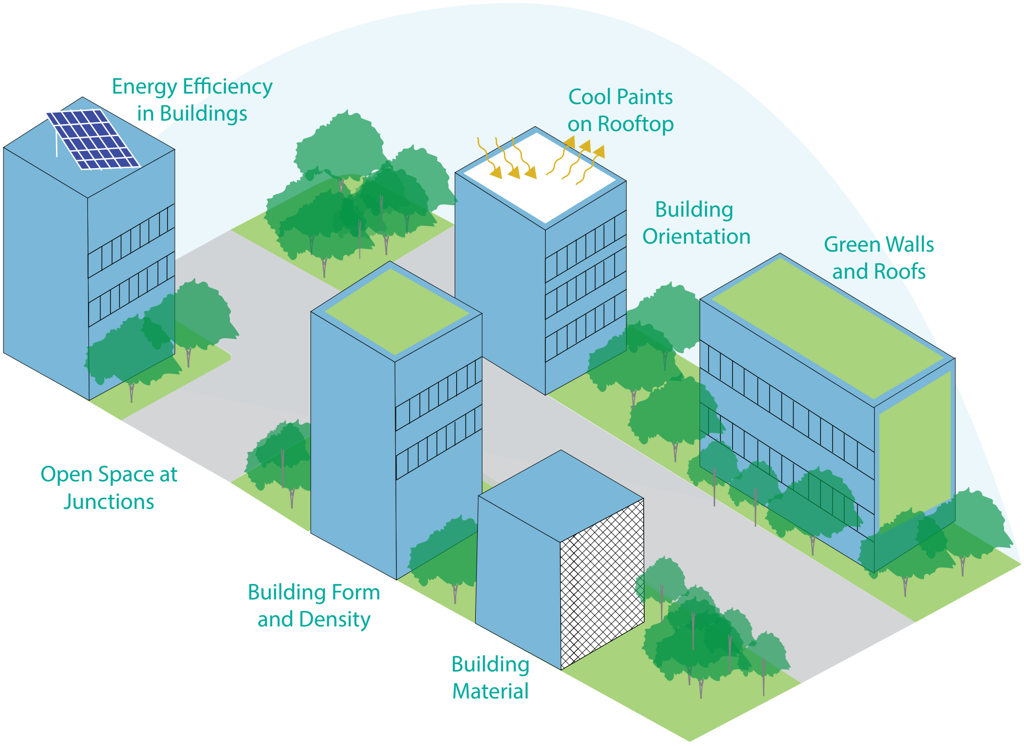
Passive cooling and energy efficiency

Design strategies in the built environment help improve cooling. Mapping the wind flow, optimising a building's location and shape, aligning windows with the sun's direction, all influence how much heat is retained and circulated within the built environment and in the individual building. In hot and dry regions, more compact building shapes can reduce the heat absorbed by a building's walls and roof. Reflective surfaces on the roof also influence the heat in the building, lowering the temperatures by nearly 5 degrees Celsius depending on the geographical location. Passive cooling minimises energy consumption and provides high energy efficiency, while providing enhanced cooling access for those who need it the most (World Economic Forum, 2023).

COOL ROOF FOR INCLUSIVE COMMUNITIES: THE HARIYALI GREEN VILLAGES INITIATIVES

In Rajasthan and Gujarat, the Hariyali Green Villages initiative works to make clean energy more accessible and affordable, especially for poor and vulnerable rural communities. The focus is on using cool roofs to help fight climate change. Cool roofs are painted with solar reflective paint, and can reduce the temperature inside a building by 1.5 to 5°C. This can help reduce heat stress for people who cannot afford air conditioning. It can also lower the amount of energy needed to cool a building, which can reduce air pollution and help fight climate change. The project is working to raise awareness about clean energy technologies, so that people can adopt them and reduce emissions. It also aims to meet the growing need for cooling solutions in India.

FIGURE 20 | Passive cooling techniques



Recommendations

- Including passive cooling techniques such as cool roofs and green roofs. Focusing on building design and layout (as described in Figure 14), which provide multifaceted benefits by addressing heat-related issues and building concerns. Government-led initiatives to showcase passive cooling in public buildings are setting a precedent.
- Reducing the use of glass and promoting designs such as lattices or other locally used designs for windows and other structures in buildings, both residential and commercial.
- Promoting innovative and sustainable technologies that aid in cooling.

Reviving traditional practices

- Traditional materials such as red oxide flooring, mud walls, and other architectural elements to be promoted.
- Use of local materials to be encouraged, which decreases transportation costs and is environmentally more sustainable.

Thannal Natural Homes, a private project in Tiruvannamalai, Tamil Nadu, aims to revive traditional building techniques that promote sustainable living and reduce the need for artificial cooling. Drawing inspiration from ancient Vedic practices, Thannal uses natural materials such as mud, lime, and plant derivatives in their construction methods. Through its 'Revival series of art forms', where old style work is revived, it documents and demonstrates these techniques, proving their feasibility in modern settings. This serves as a sustainable solution to energy-intensive construction practices, providing a natural and environmentally friendly approach to home-building. Thannal facilitates the exchange of knowledge through various initiatives, including workshops, publications, and the 'Respecting an Artisan' interview series. Through these platforms, Thannal encourages people to construct their own environmentally conscious homes, strengthening the bond between occupants and their surroundings.

Resource management

- Enforcing rainwater harvesting measures to mitigate drought. Local geology and topography to be leveraged and directions to local bodies to be given to ensure individual and community-level efforts are in place.
- Using solar panels to be encouraged to reduce the dependence on other energy water-dependent energy sources, especially during summer.
- Wastewater management to be ensured for mitigating drought-like situations during summer months.

In Kancheepuram, the Pattikadu Oorani Improvement Project, guided by the Tamil Nadu Water Supply and Drainage Board, showcases how involving the community can transform a village pond. Collaborating with Anna University's Centre for Environmental Studies, the project introduced clay lining, revetment, and sand filters to guarantee clean water for over 370 villagers in different hamlets. This cooperative effort, funded with Rs. 7.55 lakhs, underscores the effectiveness of comprehensive water management techniques and community participation in solving water scarcity issues in rural Tamil Nadu. (Tamil Nadu Water Supply and Drainage Board ,2018)

Scoping of underutilised spaces

- Incentivising specific departments for the use of underutilised spaces, converting them into shaded zones, sponge parks, gardens, etc.

In Chennai, the city corporation is launching a flood control project called Singara Chennai 2.0. As part of this initiative, they are building "sponge parks" in 10 locations. These parks will have artificial ponds and special gardens that help rainwater soak into the ground instead of flooding the streets. The project is expected to cost Rs. 1.06 crore and will start in February, 2024. The corporation also plans to use empty spaces in existing parks (10% of land) for sponge parks. Sponge parks are not only effective for flood mitigation but will also serve as a way to modulate localised heat (The Hindu, 2023).

Planning, policy, governance and financing

Standard operating procedures for onboarding passive technologies

- Introduce passive cooling technologies across all public buildings to meet set interior cooling targets: Create a model Request for Proposal (RfP), standards and specifications to facilitate the onboarding of passive cooling technologies (wind tunnels, geothermal cooling, etc).

FIGURE 20 | The Pattikadu Oorani Improvement Project in Kancheepuram

Building height regulations

- Advising higher ceiling height in buildings, allowing for better ventilation and reducing the reliance on air-conditioning systems. Additionally, ensure fire safety protocols are redesigned to match the building height regulations. This can be enforced as a mandate in the building by-laws (amendments are already in progress, include the heat sensitivity aspect as key precursor for this enforcement)

Standard operating procedures for tree transplantation

- Establishing a replantation standard operating procedure (SOP) that will help land developers to follow prescribed steps for tree transplantation. Potential opportunities for incentivising tree planting – inclusion in property tax to be explored.

Green public procurement

- Promoting green public procurement, establishing suitable guidelines to ensure sustainable practices. For example, Bureau of Energy Efficiency (BEE) star-rated appliances to be mandatorily installed in large buildings to improve energy efficiency.

Residential envelope heat Transmittance Value (ReTV)

- Ensure that the concept of Residential Envelope Heat Transmittance Value (ReTV) as a metric is introduced to evaluate building design and in construction tenders, specifically for slum redevelopment and for new residential projects, as a solution to address heat gain issues.

Explore district cooling measures

- In high-density urban regions to meet aggregated cooling demand: Map and identify opportunities for district cooling measures, especially targeted towards regions with vulnerable populations such as school zones, hospital zones, slum communities, etc.

The Bureau of Energy Efficiency (BEE) is conducting an energy mapping study focusing on 15 micro, small, and medium enterprise (MSME) clusters, including the textile industry in Tamil Nadu, involving over 150 detailed energy audits for promoting energy efficiency and renewable energy. The study aims to make these clusters more energy-efficient and promote the use of renewable energy, which will also help with passive cooling and heat reduction. BEE wants to find ways to use energy more efficiently and to use more renewable energy sources. This will help MSMEs use less energy, save money on running costs, and be more sustainable (Bureau of Energy Efficiency, 2023).

Aligning with existing policies and schemes

There are multiple efforts in Tamil Nadu to promote cooling. Steering conversations among different stakeholder groups and bringing them into alignment will ensure that Tamil Nadu achieves many of its 2030 and 2050 targets. Climate-proofing Tamil Nadu to protect it from excessive heat is a non-negotiable action. Chapter 2 discusses the need for immediate action.

Viability gap funding model

Opting for a viability gap funding model for integrating heat mitigation strategies technologies, suggesting low-interest loans for developers and others who incorporate heat mitigation strategies.

Outreach and awareness

- Integration of passive cooling concepts, nature-based solutions, etc., into the educational curriculum

- Capacity-building of real estate developers and other private-sector stakeholders on investing in sustainable practices

- Awareness among multiple stakeholders to promote and restore blue and green ecosystems

- Community awareness on harnessing other sources of electricity, especially during summers

Tamil Nadu government has allocated a budget of 1.48 crore for the Climate Smart Villages initiative which aims at demonstrating climate change mitigation technologies to farmers. The initiative raises awareness and helps equip farmers with adaptation measures to cope with changing weather conditions. This can be centred particularly around heat (Business Insider, 2024).

The state has signed an agreement with the United Nations Environment Programme (UNEP) to execute an urban cooling initiative. This initiative is focused on implementing holistic action plans, which include enhancing urban design, increasing green cover in cities, and strategising for extreme heat events. The programme is being undertaken under the framework of the 'Cool Coalition' and the India-Denmark Green Strategic Partnership (The Hindu, 2023).

The Tamil Nadu Green Climate Company (TNGCC) is a Special Purpose Vehicle (SPV), created by the Tamil Nadu government specifically to address the urgent issue of climate change. TNGCC focuses on assisting Tamil Nadu in transitioning to a carbon-neutral future through policy assistance, climate change adaptation and mitigation initiatives, and encouraging technologies that respect the environment. TNGCC support needs to be leveraged to further the action recommendations of the heat mitigation strategy document. On February 28, 2024, TNGCC along with its partners initiated a roadmap for urban cooling in Tamil Nadu.

TABLE 3 | Urban Heat Resilience opportunities - Cooling by design, policies, and planning

DIMENSIONS	RATIONALE	WORKING DEFINITION
Streets	• Implement shaded, vegetated, and cool walks to local destinations and main streets. • Prioritise converting street areas into green spaces and small parks that provide cooling and shade for pedestrians. Under the 'Smart Complete Street Project', the Tamil Nadu government has planned to develop 1,656 km of streets into vibrant public spaces. 'Complete streets' aim to provide safe and inclusive environments that support users of all age groups, genders, and physical dispositions	Directorate of Town & Country Planning, Chennai Metropolitan Development Authority (CMDA) Tamil Nadu Urban Habitat Development Board, Greater Chennai Corporation (GCC), Department of Environment, Forests and Climate Change
Green Spaces and Parks	• Enhance existing parks and create new green spaces with vegetation, trees, and shade to provide cooling and outdoor gathering spaces for communities. • Convert hardscape areas into pocket parks, and prioritise cooling strategies in areas with limited greenery. Tamil Nadu Combined Development and Building Rules have been drafted to create urban areas with more green spaces. The recommendations include changes in open space reservation use, and increasing buffer zones around lakes/water bodies, among others.	Department of Municipal Administration and Water Supply (MAWS), Department of Housing and Urban Development, Department of Environment and Forests, Department of Revenue and Disaster Management, Department of Highways and Minor Ports, Department of Rural Development and Panchayat Raj
Buildings	• Provide resources and incentives for building owners to invest in cool roof technologies and energy-efficient building designs. • Facilitate home cooling resource distribution and support home energy retrofits to improve indoor comfort and reduce energy costs. • Encourage the adoption of cool roofs and energy-efficient methods in commercial buildings to reduce heat absorption and energy consumption. • Promote the use of cool, shaded pavement and surface parking to minimise heat retention in urban areas. Schools • Integrate cool roof technologies, shade structures, and green spaces in school campuses to provide cooler environments for students and staff. • Expand indoor cooling networks, including public cooling centres and community cooling options, to provide relief from extreme heat events. Tamil Nadu Energy Conservation Building Code (TNECBC) 2022 was adopted in the state in 2022 which considers energy-efficient design and construction of commercial buildings to reduce energy consumption. TNECBC-compliant buildings are estimated to consume 50% less energy than conventional buildings.	Department of Housing and Urban Development, Tamil Nadu Energy Development Agency (TEDA), Tamil Nadu Pollution Control Board (TNPCB), Department of Municipal Administration and Water Supply (MAWS), Department of Revenue and Disaster Management, Tamil Nadu Generation and Distribution Corporation) Department of School Education, Tamil Nadu Energy Development Agency (TEDA), Department of Environment and Forests, Department of Revenue and Disaster Management, Department of Health, and Family Welfare
Resilient Design for Planning and Development	• Integrate heat resilience considerations into development review plans, zoning ordinances, and design guidelines to reduce urban heat island effects in new development. • Prioritise affordable housing options with cool design features to ensure equitable access to cooler living environments.	Department of Housing and Urban Development, Tamil Nadu Slum Clearance Board (TNSCB), Department of Municipal Administration and Water Supply (MAWS), Department of Rural Development and Panchayat Raj, Tamil Nadu Town and Country Planning Department, Tamil Nadu Real Estate Regulatory Authority (TNRERA)

CHAPTER 7

Way Forward

The aim of the strategy document is to go beyond the project phase and to inform actions that individual departments can take forward. Locally led heat resilience projects often fail due to a lack of know-how, a lack of finance, and a lack of effective planning, all of which enable the long-term survival of the project. The heat strategy document would enable a few key recommendations that can be taken further to the Detailed Project Report (DPR) stage for pilot implementation and roll-out. Additionally, by highlighting existing practices, the document will enable line departments to leverage ongoing polices, schemes, and plans to sharpen the focus on heat resilience. Further, the key departments involved with the roll-out of recommendations will be invited for review to monitor progress over a period of 6-8 months, to ensure project effectiveness and durability.

For the British High Commission, the strategy document serves as a tool to engage in strategic consultations across different stakeholder groups. The Tamil Nadu State Planning Commission will roll out the heat mitigation strategy document with the support of the Tamil Nadu State Disaster Management Agency.

The two agencies will serve as nodal points for advancing heat mitigation, by providing **technical assistance and capacity-building** from experts on project planning and management, blended finance, regulatory compliance, and stakeholder engagement, monitoring and evaluation, advising on gender, social equity, and other aspects across the different line departments involved.

To enable a system-wide transformation in climate-proofing Tamil Nadu against excess heat, the heat mitigation strategy document provides direction to various stakeholder groups to prioritise action. The document also draws on case examples and identifies opportunities that can enable actions that promote heat resilience. Inclusion of the principles can provide pathways towards sustainable development and the climate-proofing of people, nature, and infrastructure.

I. Design, planning and governance

a. Apply **participatory methods** to develop design strategies that integrate local knowledge and practices.

b. Provide strategies to minimise heat exposure

c. Assessment of existing policies and regulations that enable heat action planning and make necessary amendments to ensure sustainability and create synergy.

II. Interventions at scale

a. Invest in **evidence-driven decision and collaborative approaches** to identify opportunities.

b. Leverage potential across different stakeholder groups ensuring effective communication.

III. Accelerated access to all

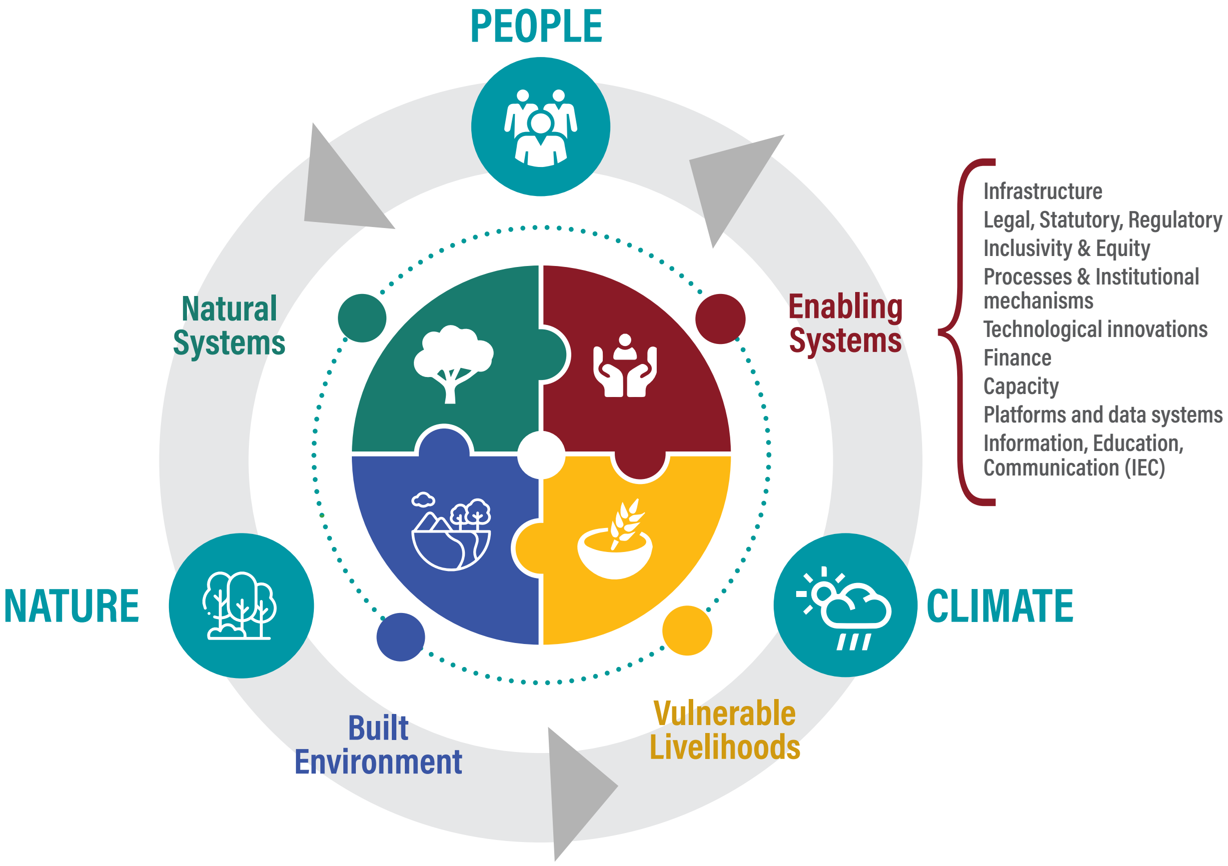
a. Enhanced accessibility to ecological, physical, and social infrastructure to enhance coping capacities (ensuring equity) in communities.

b. **Enabling inclusion** in the decision-making process to maximise co-benefits in mitigation and adaptation.

The guiding principles listed here are based on assessments of the existing structure and operationalisation of heat plans in India. There is scope to expand this in the future.

Tamil Nadu must pursue transitions in the human-centred systems that have most impact on People, Nature, and Climate: food, land, water, energy, and cities. (Figure X: Showing systems transition for heat mitigation) To achieve these transitions, we must also make changes to the underlying enabling systems related to economics, finance, and governance. Changes include fostering economic equality, increasing financial flows, and encouraging inclusive decision-making. We need to make sure that the transitions don't just serve the few but are equitable and help the most vulnerable in Tamil Nadu.

FIGURE X | Key Transitions for Tamil Nadu: People, Nature, and Climate



ANNEXURE

TABLE A1 | Assessment indicators, their definitions, and attributes

DIMENSIONS	RATIONALE	WORKING DEFINITION
THERMAL STRESS		
Indicator: Air Temperature		
Annual air temperature trend analysis and deviations	The comprehensive analysis of annual average air temperatures, long term trends and frequency of extreme temperature days provides a deeper understanding of the temperature dynamics facilitating evidence-based decision-making. Changes in the **mean temperature** provide insights into the long-term warming or cooling trends while examining **minimum temperatures** in case of Tamil Nadu will provide insights into level of heat discomfort at night hours. This poses health risks, especially for individuals vulnerable to heat-related illnesses. **Maximum temperature,** on the other hand, is essential for identifying extreme heat stress conditions leading to heatwaves, affecting human health, agriculture, and energy demand.	Temperature measured at a height of 2 metre above mean sea level, represents the surface air temperature. Air temperature anomalies are calculated for the 2015-2019 from the baseline (1981- 2010).
Long-term trends of temperature across seasons		Trend detection algorithms facilitated determining of the magnitude and direction of the seasonal (summer and winter) air temperature trends.
Frequency of extreme temperature days		IMD defines heat wave as the maximum temperature of a place reaches at least 40°C or more for Plains, 37°C or more for coastal station and at least 30°C or more for Hilly region. The heat wave is then classified when the maximum temperature shows departure of 4.5°C or more from the normal.
		Data sources for above three analysis: Daily data from IMD stations for Chennai and Coimbatore from 1951-2021. Daily aggregates from ERA5 reanalysis data (1980-2019) from ECMWF / Copernicus Climate Change Service available as gridded data at 27 km spatial resolution.
Long-term trend of the frequency of extreme temperature days and nights	Analysing the spatio-temporal patterns of extreme event frequency aids in identifying annual and seasonal variations in the occurrence of such events, facilitating the recognition of changing patterns over time.	
Projected changes in temperature	Climate Projections using diverse climate models is essential for adaptive planning and proactive measures in response to shifting temperature and precipitation patterns. It offers insights for integrated planning, encompassing energy, development, community resilience, and infrastructure. Four Representative Concentration Pathways (RCP) were adopted by IPCC for delineating a possible future, contingent on the levels of greenhouse gases (GHGs) emitted in the years ahead, providing a framework for understanding potential climate outcomes based on different emission scenarios.	Considering RCP 4.5 emission scenario, projection of average minimum and maximum temperatures along with anomalies (using historical baseline from 1975-2005) for each of the three epochs- Early (2006-2020), Mid (2035-2060), and Late (2071-2095) century are calculated.
		Data Sources: NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP5) dataset for corrected daily aggregates of minimum, maximum, and mean temperatures spanning 1975-2095 gridded at 27 km resolution across 20 climatic models.

TABLE A1 | Assessment indicators, their definitions, and attributes

DIMENSIONS	RATIONALE	WORKING DEFINITION
THERMAL STRESS		
Indicator: Land Surface Temperature (LST)		
Day-time and Night-time LST trends	Land Surface Temperature (LST) trends are vital indicators for decision-making in sustainable land management and climate resilience. While the Daytime LST helps assess heat stress in ecosystems and understand the distribution of energy across landscape, Night-time LST aids in identifying areas with inefficient cooling and assessing heat storage in urban environments and Urban Heat Islands (UHI).	LST is the radiative skin temperature of the land, obtained through the measurement of infrared radiation emitted from the Earth's surface. Satellite sensors record it as radiance in the infrared wavelength and converts to LST. Average Daytime and Night-time trends and Average Summer Months Night-time trends are calculated from 2001 to 2023. Data sources: Daily aggregates of Day-time and Night-time LST from MODIS Land Surface Temperature and Emissivity (MOD11) 2001-2023 available as gridded data at 1km spatial resolution
High or low hotspots	Spatial analysis of heat risk studies LST differences between urban areas and rural peripheries and help in identifying local areas that are more exposed to heat stress due to the heat island effect. These data can provide temperature variations from regional averages for specific neighborhoods.	
Indicator: Thermal Comfort		
Spatiotemporal trend in heat stress	The Universal Thermal Climate Index (UTCI) (CDS 2020) is a human biometeorology parameter that is used to assess the linkages between the outdoor environment and human well-being. Thermal comfort indices describe how the human body experiences atmospheric conditions, specifically air temperature, humidity, wind, and radiation	UTCI is calculated from the ERA5 data derived weather variables (Di et al., 2020). Classified into 10 classes as per the intensity, longterm and seasonal (summer) trends and monthly average hours of exposure and number of days for Strong (32 to 38), Very strong (38 to 46) and Extreme heat stress(> 46) categories are calculated. Data sources: Hourly aggregates from ERA5 reanalysis for 2022 from ECMWF / Copernicus Climate Change Service, available as gridded data at 27km spatial resolution
Indicator: Sea Surface Temperature		
Spatiotemporal trends in sea surface temperature close to the coastline	Analysis of the annual average SST demonstrates the varying range (the difference between the observed minimum and maximum) of SST across the ocean surface near the coastline and the macro sea region, which has direct and indirect impacts on the city. The temporal SST trends can be measured using satellite information.	

TABLE A1 | Assessment indicators, their definitions, and attributes

DIMENSIONS	RATIONALE	WORKING DEFINITION
PRECIPITATION CHANGE		
Indicator: Rainfall		
Spatiotemporal trends in rainfall patterns	The spatio-temporal trends of varies across cities - While the inter-annual and intra-annual trends of rainfall give a picture of the city's meteorological situation (IMD n.d.-c), spatial trends help in identifying micro climatic zones. Regional analysis is also critical because cities are dependent on these areas for water availability.	
Spatiotemporal trends in extreme rainfall events	Many studies have projected changes in extreme rainfall events due to climate change. Spatio-temporal trends in the frequency of extreme rainfall days (inter- and intra-annual) are critical for understanding their impacts on different parts of the city, by analyzing meteorological data from ground stations.	
Projected changes in rainfall	Similar to projected change in temperature, understanding projected changes in precipitation is also critical.	
WEATHER EVENTS		
Indicator: Cyclones		
Frequency of cyclones	Coastal cities and states are inherently vulnerable to cyclones. These pose risks to communities and ecosystems, emphasizing the crucial need for continuous monitoring and for effective disaster preparedness, risk reduction, and post-event recovery strategies.	
Temporal trends of cyclone strength and accumulated cyclone energy		
Indicator: Thunderstorms		
Spatiotemporal trends in lightning strikes	Studies indicate that both climate change and the heat island effect increase thunderstorms (Brooks 2013). However, due to data limitations, attributing the increased thunderstorms to climate change can be challenging.	
HYDRO-METEOROLOGICAL HAZARD		
Indicator: Meteorological Drought		
Spatiotemporal assessment of meteorological drought frequency in the state and the concerned watersheds	Droughts lead to prolonged water scarcity, significantly impacting agricultural production and food security. Categorized into meteorological and hydrological droughts, these events vary in intensity and affect vulnerable groups. Understanding the patterns, extent, and severity is crucial for implementing effective preparedness measures.	
Spatiotemporal assessment of baseline water stress in the state and the concerned watersheds		

TABLE A1 | Assessment indicators, their definitions, and attributes

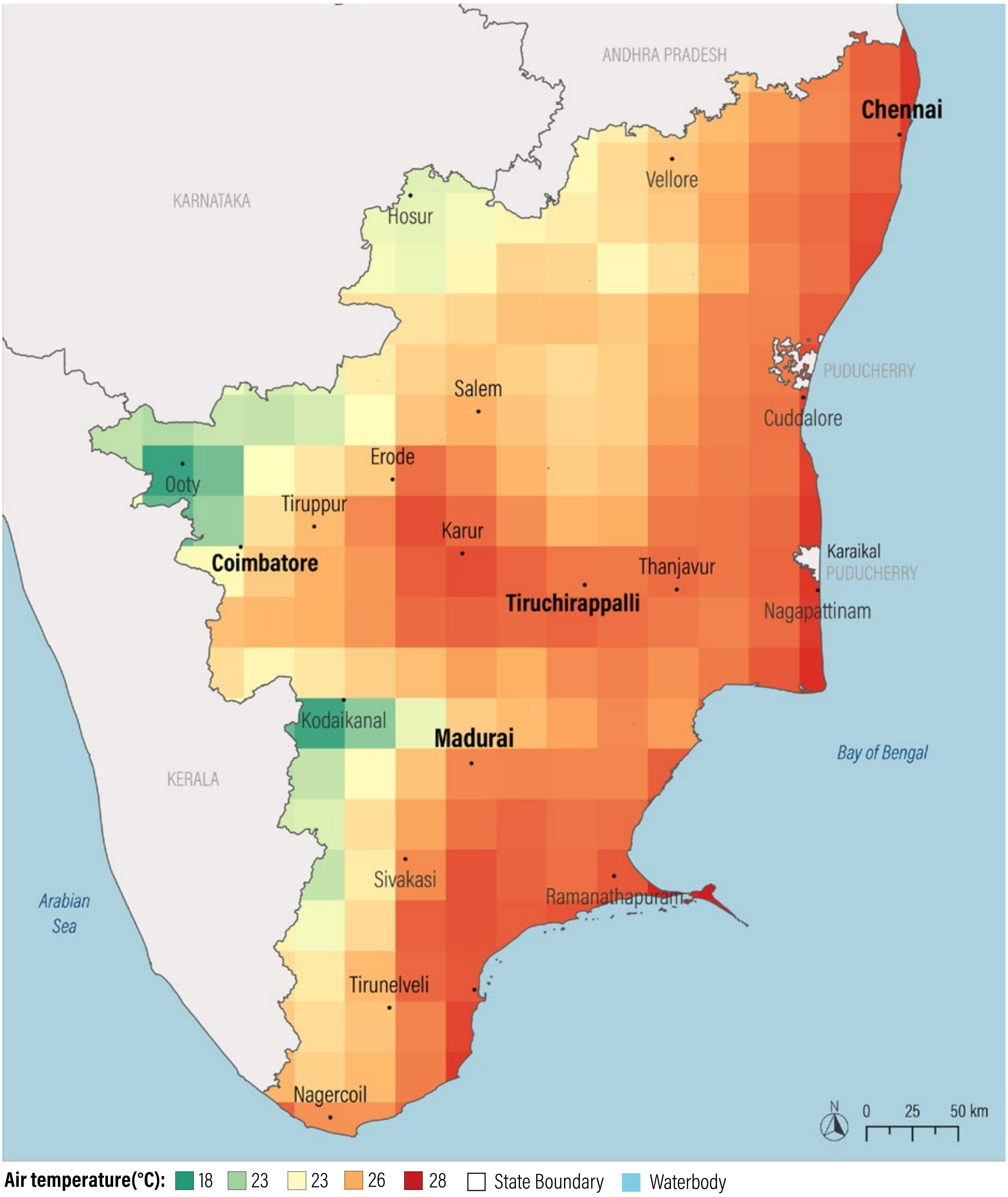
DIMENSIONS	RATIONALE	WORKING DEFINITION
HYDRO-METEOROLOGICAL HAZARD		
Indicator: Groundwater Exploitation		
Spatiotemporal patterns in the groundwater recharge potential	Many Indian cities are greatly dependent on groundwater resources for drinking water and other needs. Hence, monitoring of groundwater is equally important.	
Spatiotemporal trends in stages of groundwater development		
ENVIRONMENTAL DEGRADATION		
Indicator: Forest fires		
Spatiotemporal trends in satellite-observed fire hotspots within forested areas	Forest fires have significant ecological implications, affecting biodiversity and ecosystem resilience. Monitoring the occurrence of wildfires over time helps in early detection, effective firefighting, and understanding the impact on air quality and local ecosystems.	The analysis encompasses the cumulative yearly identification of fire incidents within forested areas spanning from 2013 to 2023 Data Sources: Visible Infrared Imaging Radiometer Suite (VIIRS) (VNP14A1) Version 1 available as 1km gidded data
Indicator: Other fires		
Spatiotemporal trends in satellite-observed thermal anomaly hotspots	Spatial and temporal patterns of these fire observations made in close proximity to the city are useful to understand the pollution and heat faced by the city (NASA n.d.).	
Indicator: Air Quality Degradation		
Spatiotemporal trends in concentration of major/criteria pollutants: physical and gaseous pollutants	The human health challenges and threats posed by air pollution can be aggravated by climate change as the concentration of particulate matter, nitrogen dioxide, and ozone levels in the air increases. Monitoring air pollution helps in assessing its impact on respiratory diseases, air quality, and ecosystem health.	
Indicator: Water Quality Degradation		
Surface water and groundwater - spatiotemporal assessments for quality criteria based on physical, chemical, and biological parameters	Spatiotemporal assessments for the quality of surface and groundwater play a crucial role in ensuring sustainable water management, protecting public health, and promoting the well-being of urban populations. By monitoring and managing water quality effectively, cities can enhance resilience to environmental challenges and support long-term sustainability	
Indicator: Soil Quality Degradation		
Quality criteria based on physical, chemical, and biological parameters	Soil quality is critical for plant and animal productivity and for hazards faced by urban areas and the neighboring regions. Although soil quality is not directly affected by climate change, indirect effects and compounded effects could increase pressure on urban areas.	

TABLE A1 | Assessment indicators, their definitions, and attributes

DIMENSIONS	RATIONALE	WORKING DEFINITION
ENVIRONMENTAL DEGRADATION		
Indicator: Vegetation Change		
Spatiotemporal trends in Normalized Difference Vegetation Index (NDVI)	Vegetation plays a critical role in hazard reduction and resilience, and can be measured by processing satellite images. NDVI (USGS n.d.-a) aids in evaluating and overseeing vegetation health and density across extensive regions over time.	Significant change analysis of NDVI is conducted for the period 2001 - 2023. Data Source: MODIS Terra Vegetation Indices (MOD13Q1.061) available at 250m spatial resolution
Indicator: Built expansion		
Spatiotemporal trends in built up growth	The patterns of urbanization have the potential to impact local climates and ecosystems. Urban sprawl, characterized by the outward expansion of urban areas, necessitates vigilant monitoring. This surveillance is vital for fostering sustainable urban development, effective land-use planning, and the preservation of biodiversity.	Extent of built areas for 1985 and 2019 are analyzed. Data Source: World Settlement Footprint (WSF Evolution) for the year 1985 for 30 metres spatial resolution; and World Settlement Footprint (WSF) for 2019 at 10m spatial resolution

A2. Supporting maps and figures on heat related parameters

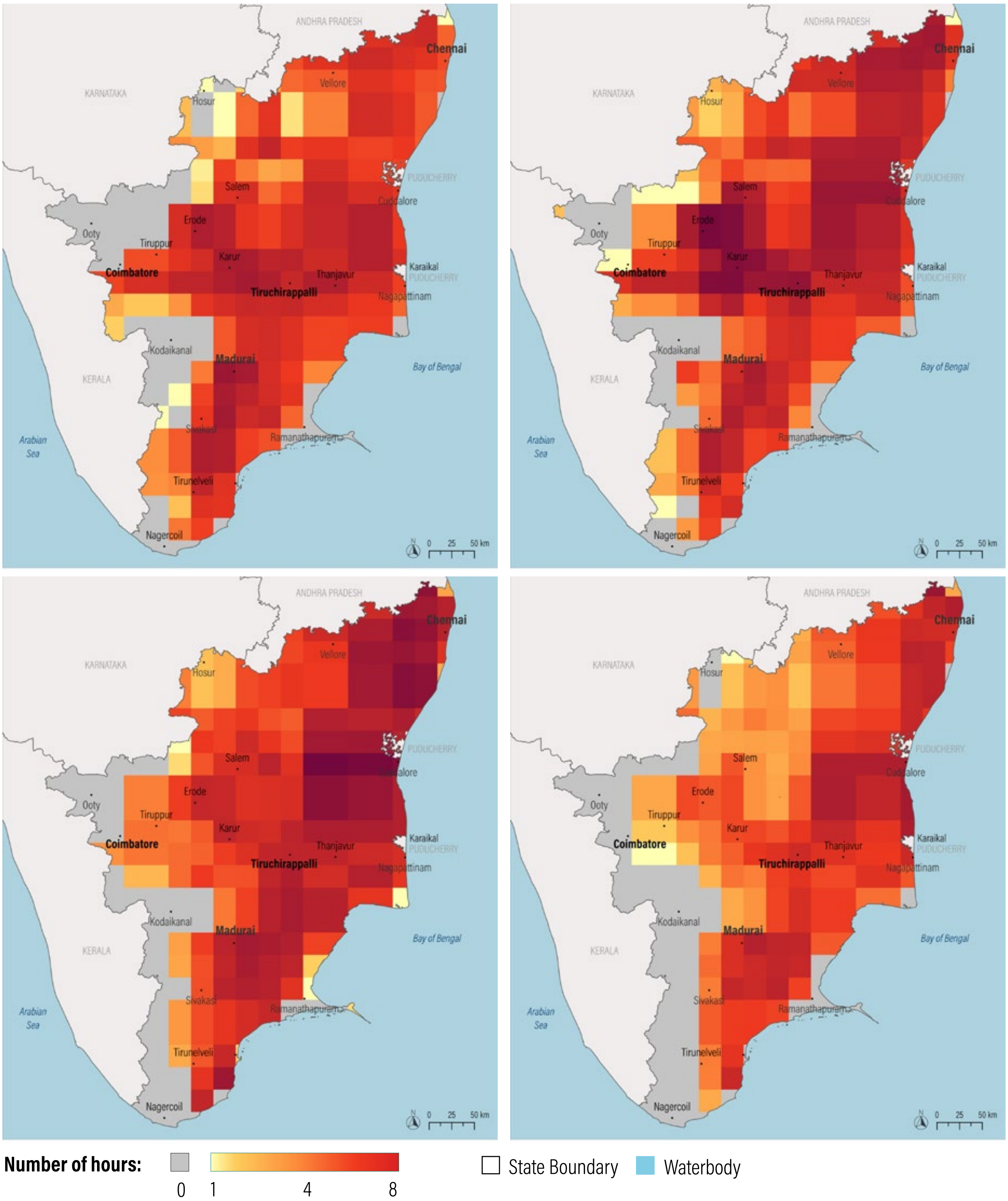
FIGURE 25 | Average Minimum Air Temperature (March to June, 2015-2019)



Source: ERA5 Daily Aggregates, ECMWF/ Produced by Copernicus Climate Change Service, 2015-2019. Refer to Annexure A1 for details.

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

FIGURE 26 | : Average number of hours under Very Strong to Extreme heat stress in Tamil Nadu, (a)March (b) April (c) May (d) June 2022

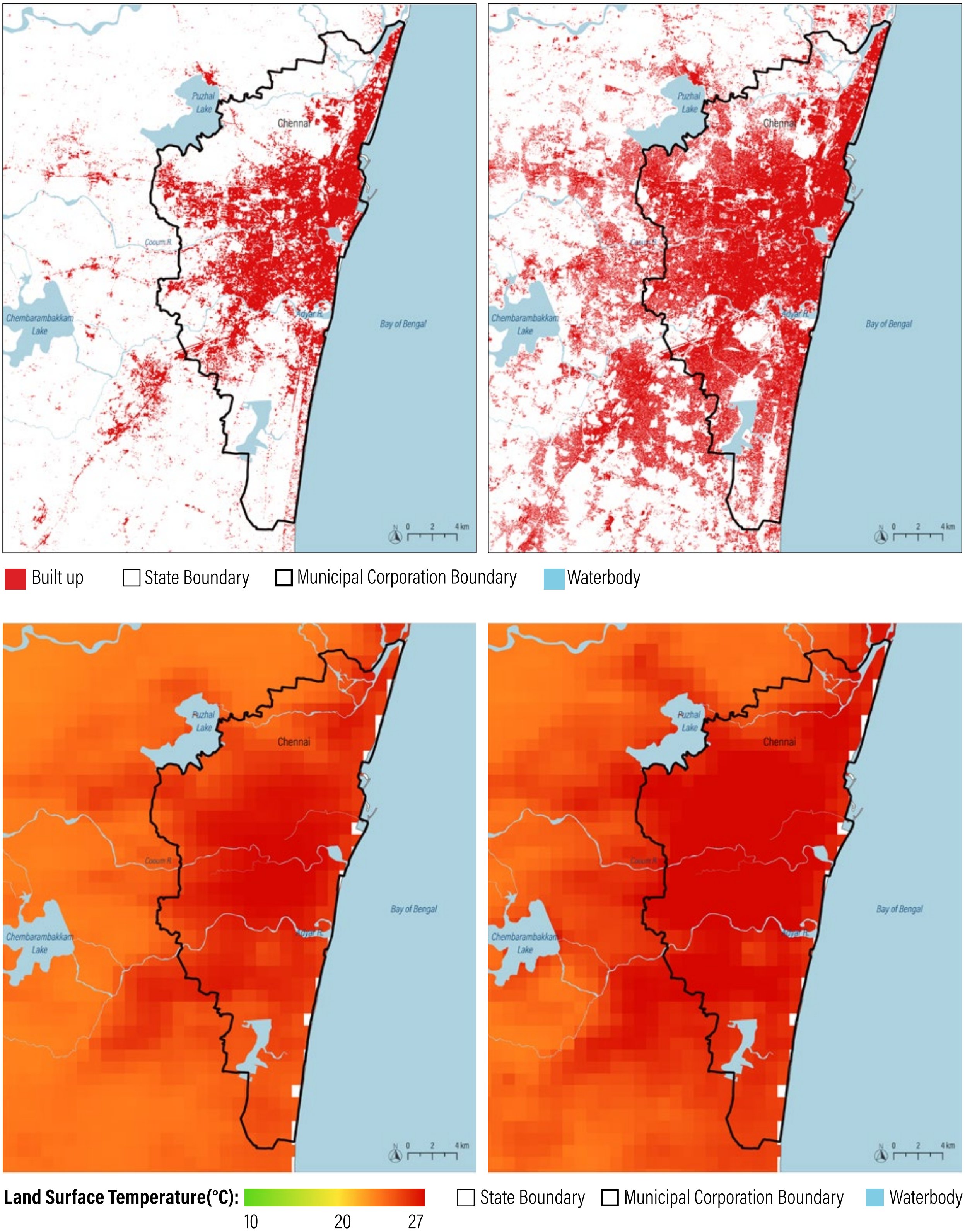


Source: Universal Thermal Comfort Index (UTCI), Climate Data Store (CDS), Copernicus EU; 2022. Refer to Annexure A1 for details.

Note: The average number of hours are derived using hourly UTCI data, categorised as Very Strong and Extreme heat stress for 2022.

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

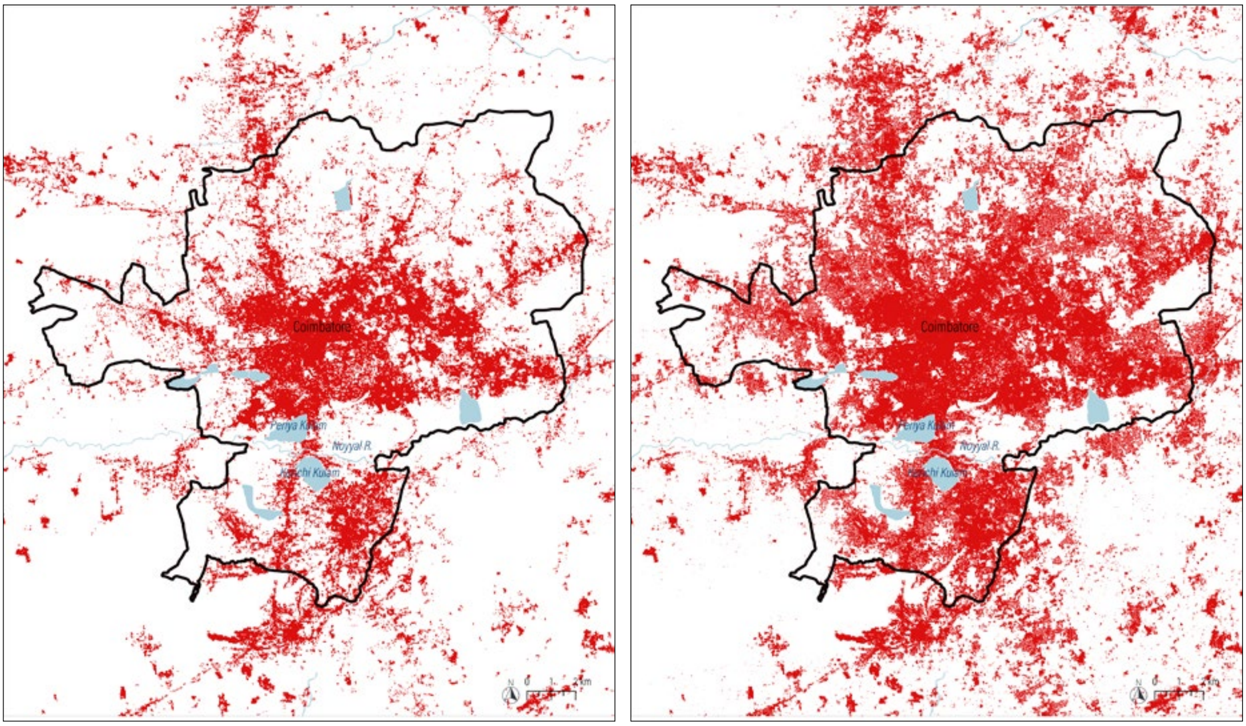
FIGURE 27 | Change in urban growth, 1985 and 2019, Chennai, UHI (LST 2 epochs) map



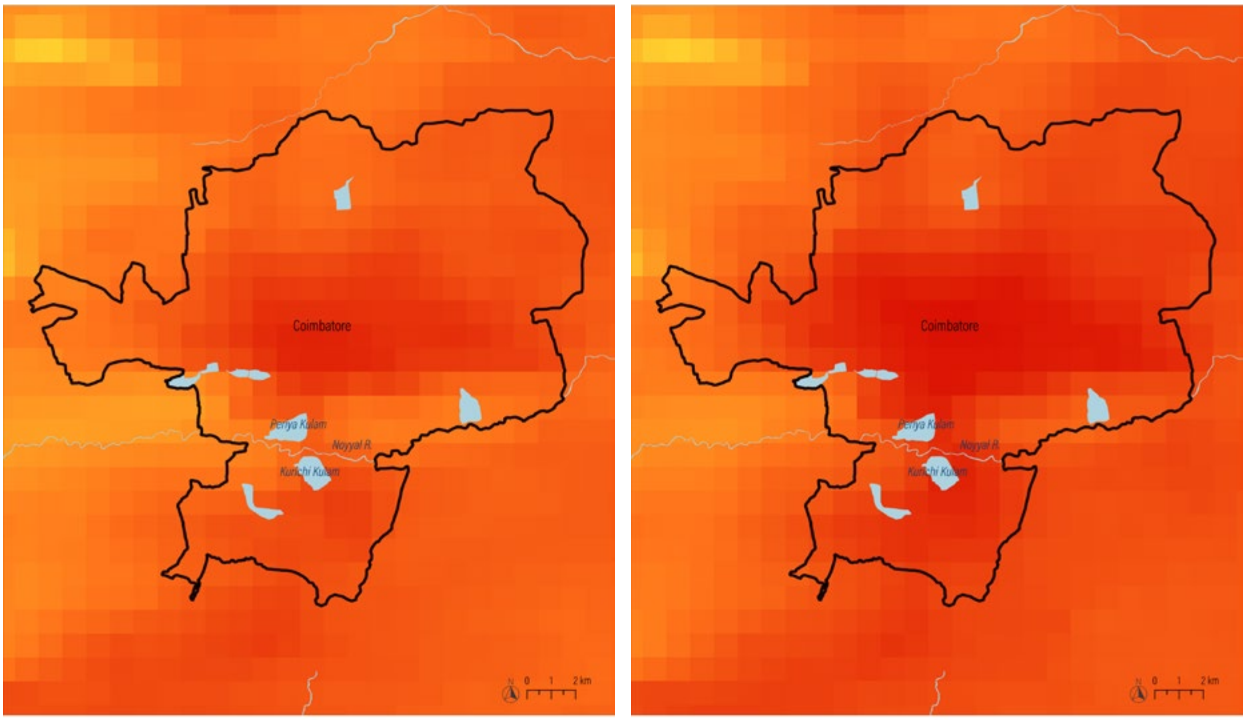
Source: MODIS 2001-2005, CWC

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

FIGURE 28 | Change in urban growth, 1985 and 2019, Coimbatore, UHI (LST 2 epochs) map



Built up   State Boundary   Municipal Corporation Boundary   Waterbody

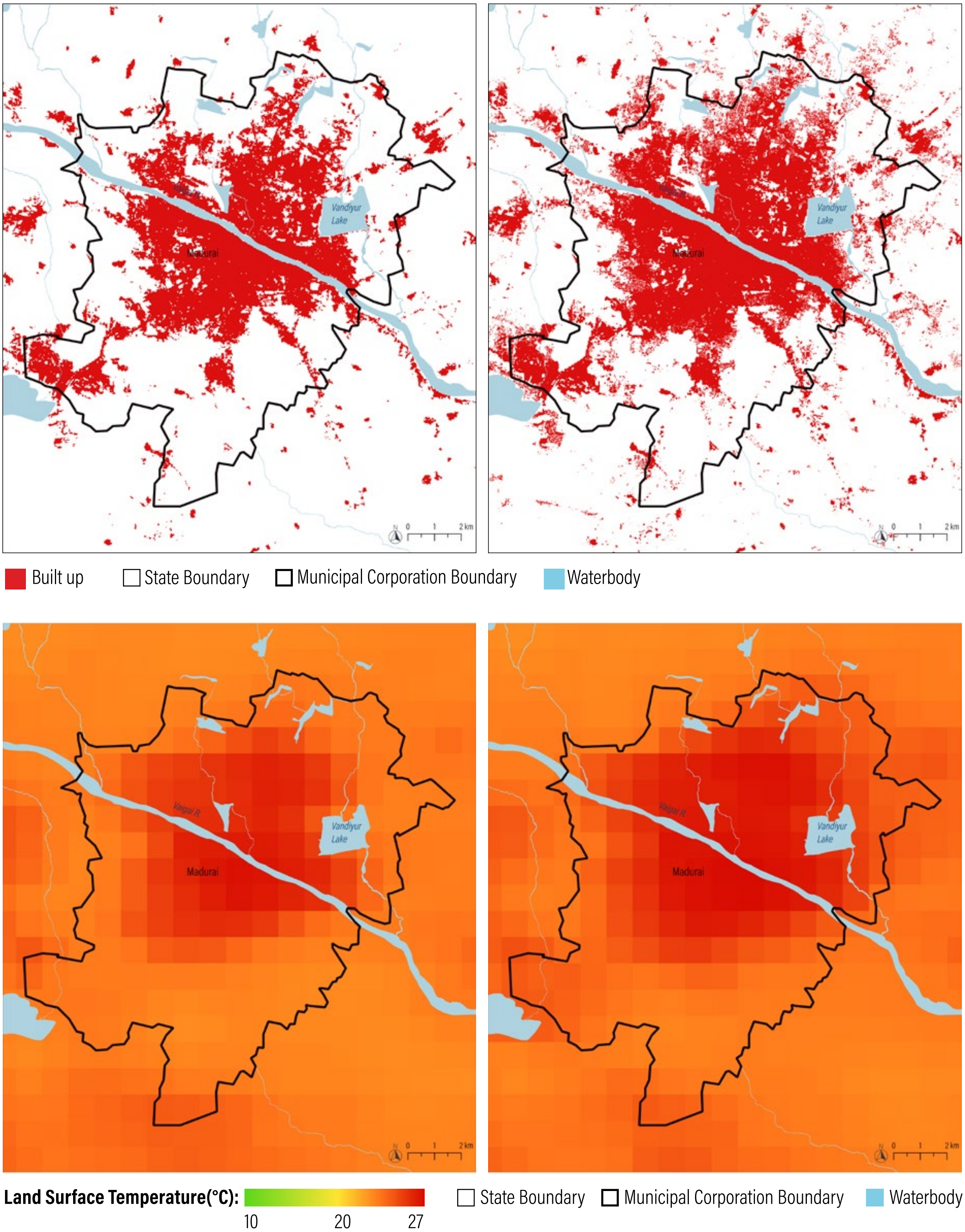


Land Surface Temperature(°C): 10 20 26   State Boundary   Municipal Corporation Boundary   Waterbody

Source: MODIS 2001-2005, CWC

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

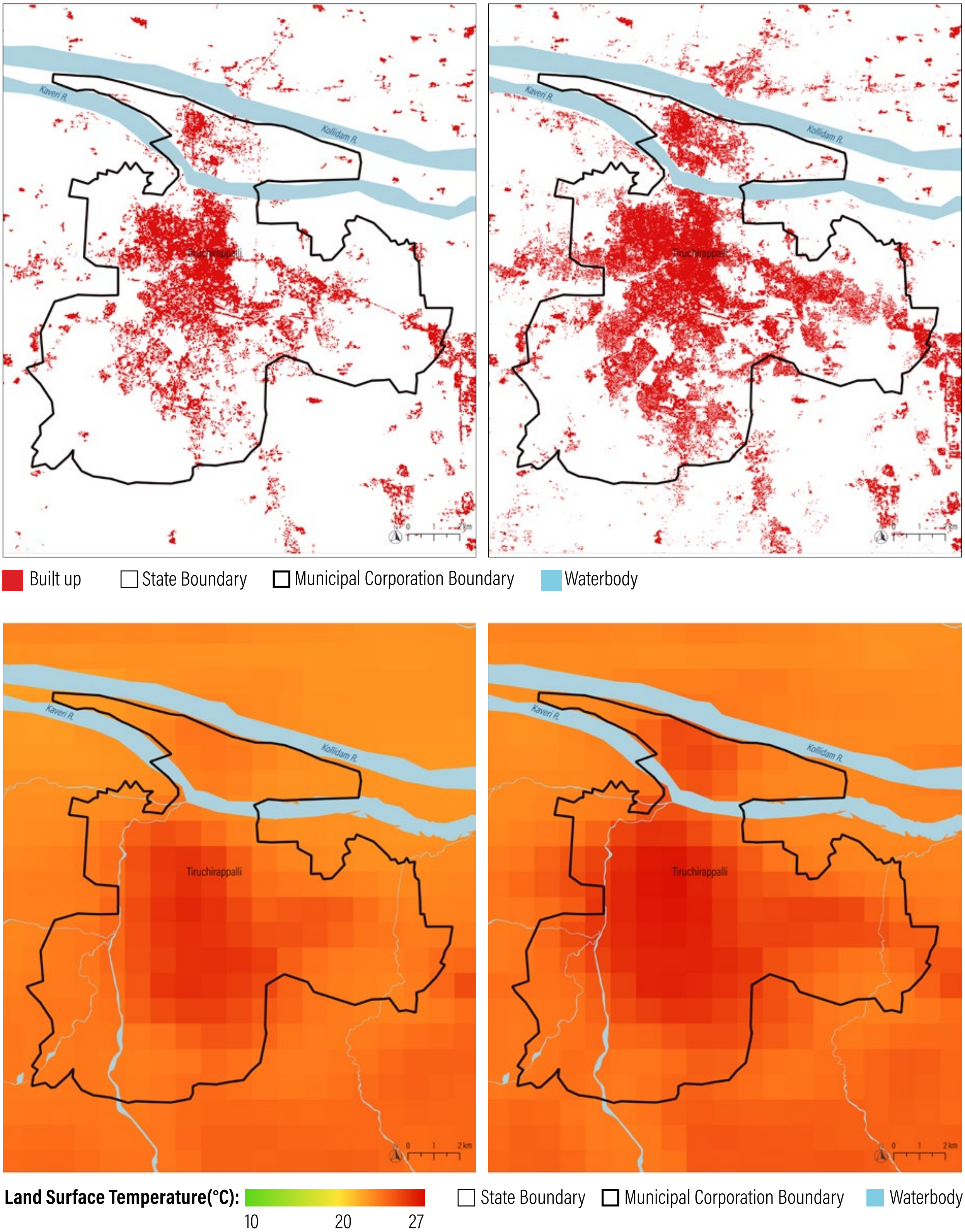
FIGURE 29 | Change in urban growth, 1985 and 2019, Madurai, UHI (LST 2 epochs) map



Source: MODIS 2001-2005, CWC

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

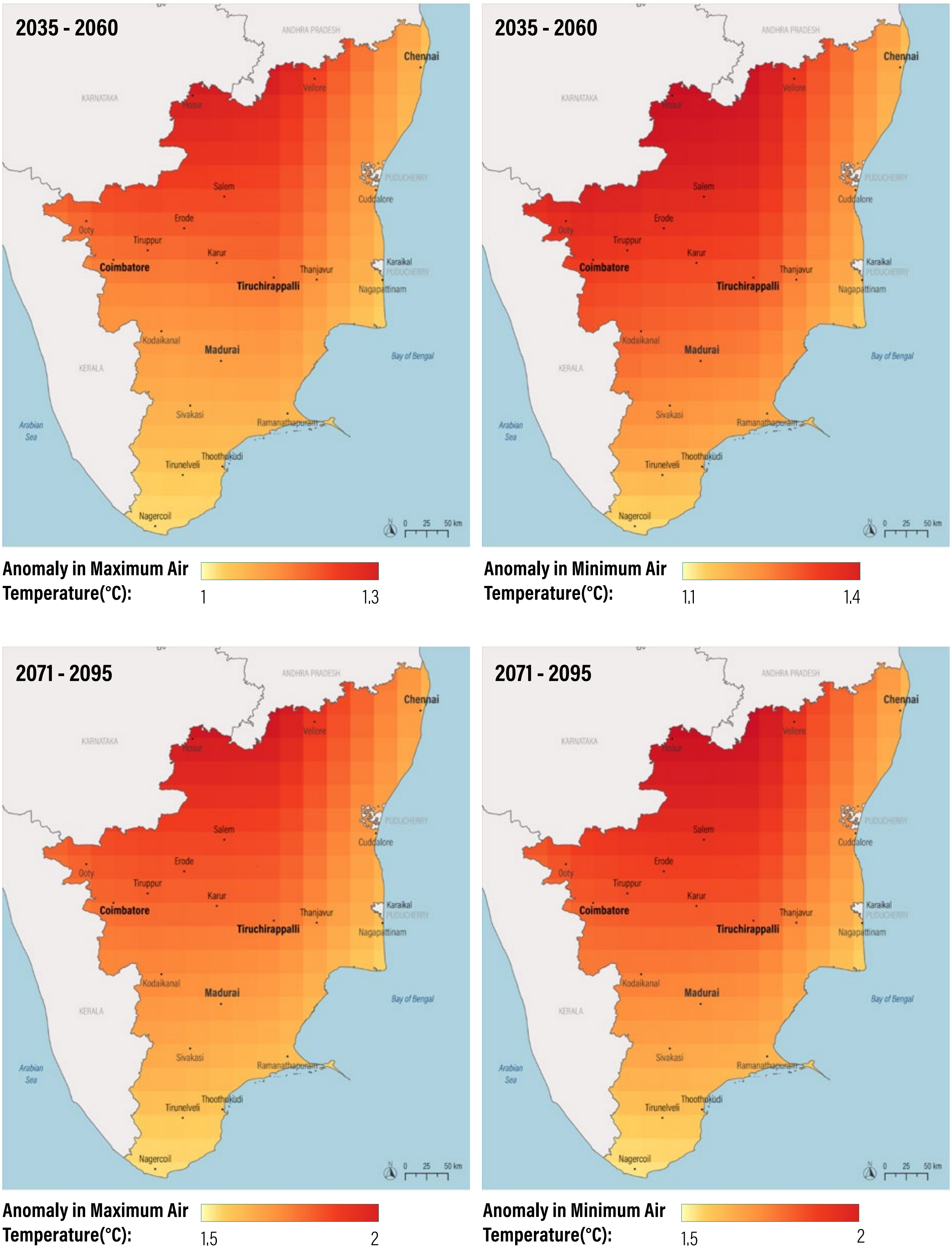
FIGURE 30 | : Change in urban growth, 1985 and 2019, Tiruchirappalli, UHI (LST 2 epochs) map



Source: MODIS 2001-2005, CWC

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

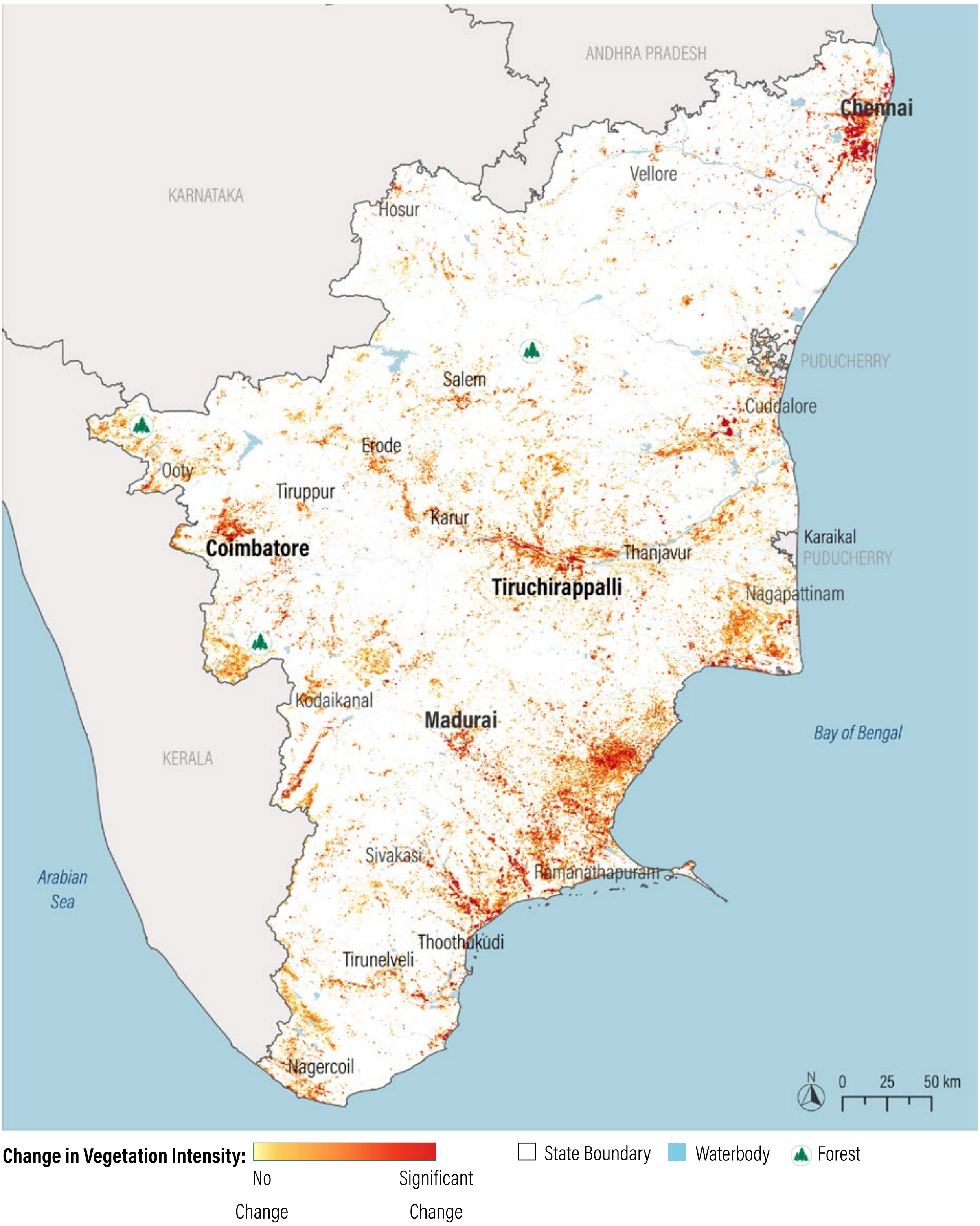
FIGURE 33 | Anomalies in projected air temperature in comparison with baseline



Source: Anomalies derived for time periods 2035-2060 and 2017-2095 using 21 models and baseline for 1975-2005 from NEX-GDDP (CMIP5), refer to Annexure A1 for details.

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

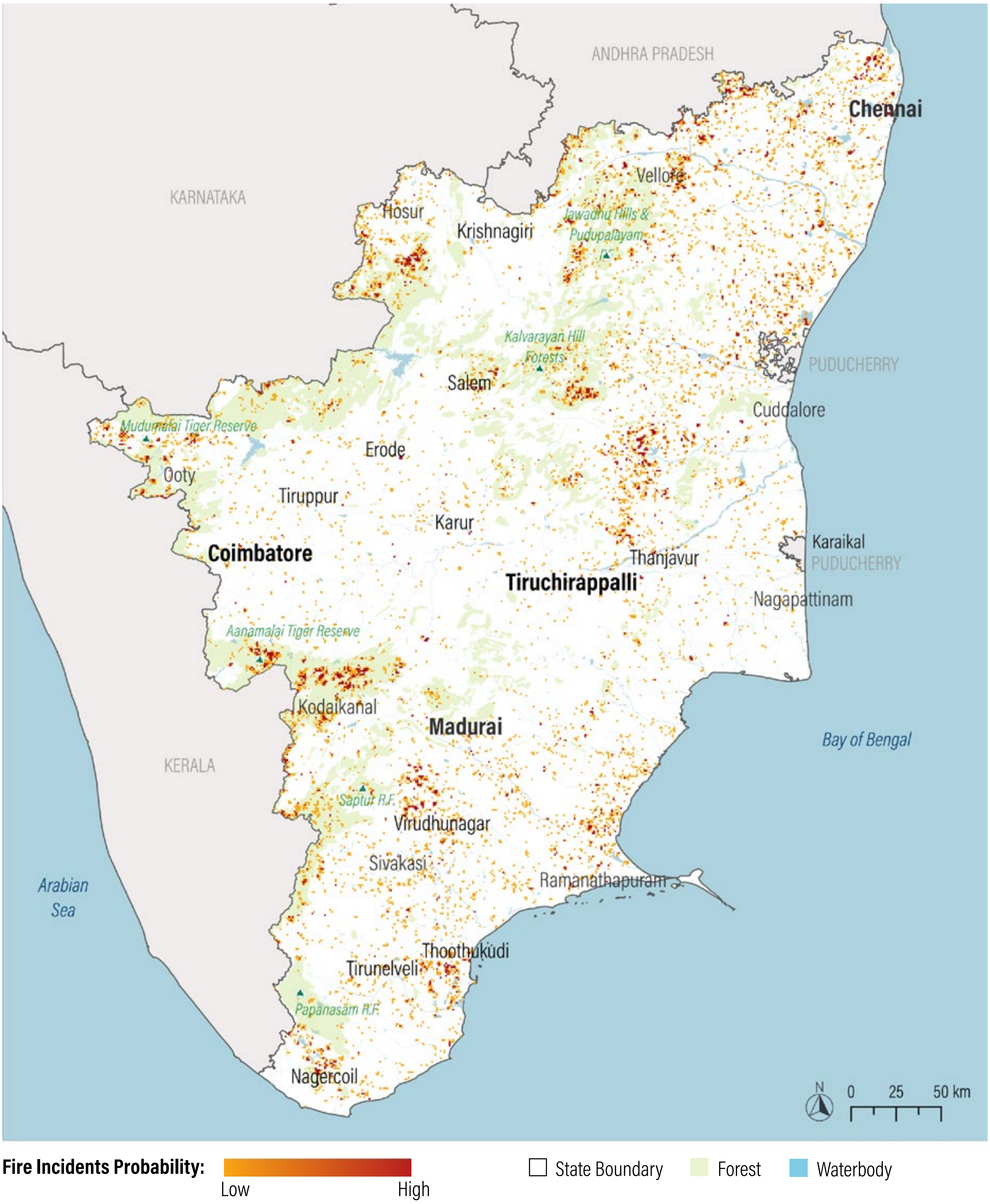
FIGURE 34 | Vegetation change map (2001 - 2023)



Source: Forest fires data based on Active Fires from NOAA VIIRS (2013-2023). Forest boundaries from NRSC 2015 include evergreen and deciduous forests, and scrub land.

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

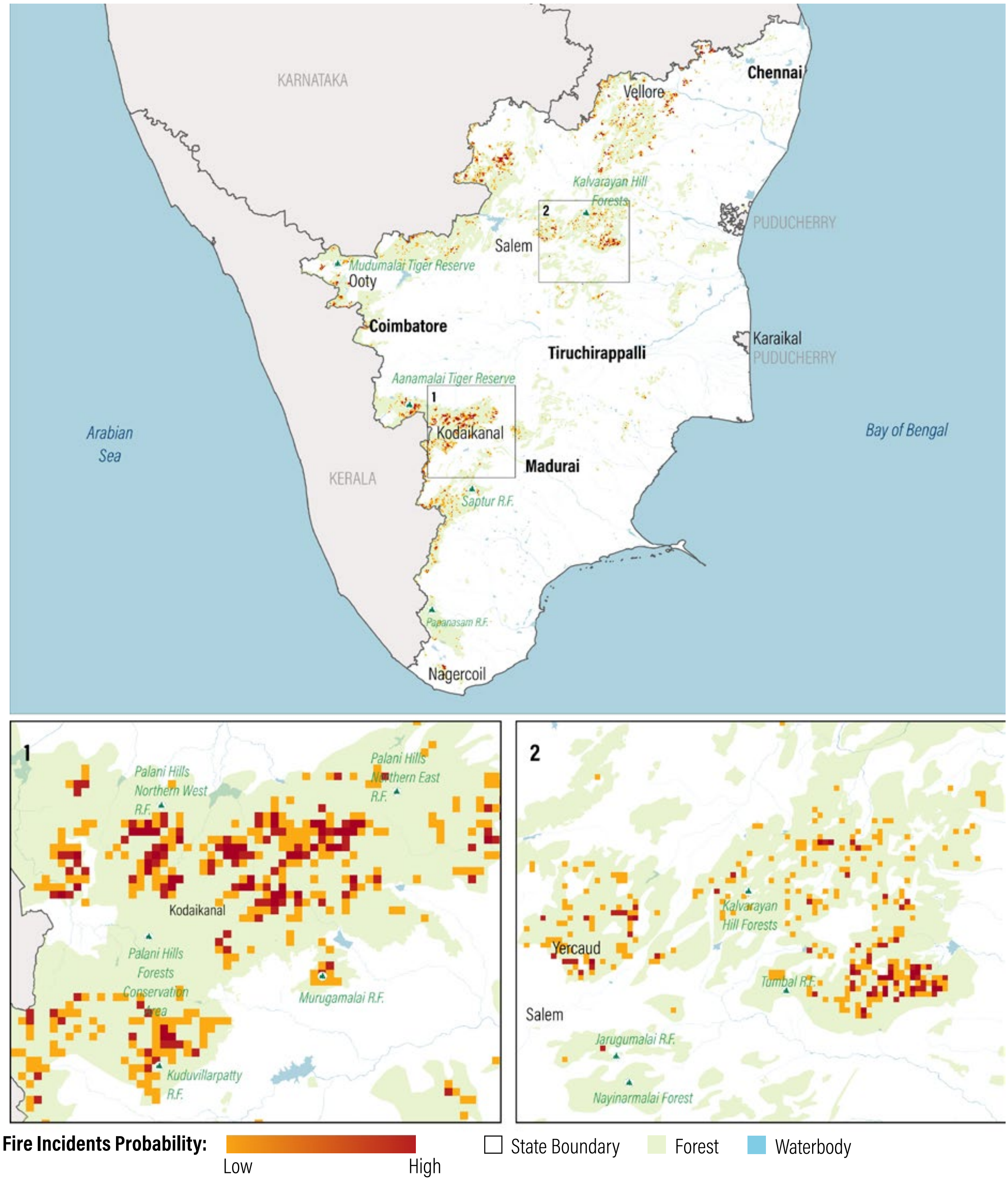
FIGURE 35 | Thermal Anomalies (Whole Tamil Nadu) 2013-2023



Source: Forest fires data based on Active Fires from NOAA VIIRS (2013-2023). Forest boundaries from NRSC 2015 includes evergreen and deciduous forests, and scrub land.

Disclaimer: This map is for illustrative purpose and does not imply the expresssion of any opinion on the part of WRI India, concerning the legal status of any country or territory or concerning the delimiation of frontiers or boundaries

FIGURE 36 | Thermal Anomalies (Forests in Tamil Nadu) 2013-2023



Source: Forest fires data based on Active Fires from NOAA VIIRS (2013-2023). Forest boundaries from NRSC 2015 include evergreen and deciduous forests, and scrub land.

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TABLE A3 | Digital Survey Report

Through focussed group discussions, inputs were collected from multiple stakeholders to identify problems as well as the impacted groups that departments are currently working with and likely to include in the near future. Additionally, participants highlighted ongoing efforts and future opportunities that can be tapped into for more focussed actions for heat mitigation.

VULNERABLE/ IMPACTED GROUPS	OVERALL CHALLENGES/ PROBLEMS	PROPOSED SOLUTIONS/ ONGOING INITIATIVES	SUITABLE CASE STUDIES TO FOLLOW
Groups residing in and around forested and protected areas, and the biodiversity within these regions, are affected.	Wildfires profoundly impact wildlife, vegetation, and local community members. The Muthumaalai Tiger Reserve is an example.	• Fire watchers should be employed throughout the year and not just during the summer months to establish and maintain firelines and controlled burns. • Strengthening their capabilities through advanced fire technology and capacity-building initiatives is essential. • However, it is important not to involve anti-poaching watchers in this endeavor, as their primary responsibility is to patrol the forest for poaching activities.	The initiatives implemented within the Muthumaalai Tiger Reserve
Participants of state and district level sporting events	During sporting events, shade facilities for participants are scarce.	• Shade facilities should be organized in accordance with the anticipated number of participants, along with provisions for hydration.	A preliminary case study could be prepared on the organization of state-level junior or senior athletics championships.
Prisoners in State and Central prisons	There is limited green space within the prison premises. As the inmates are housed in concrete buildings, they are susceptible to heat-related discomfort.	• The implementation of cool roofing systems in jails and prisons must be expanded across Tamil Nadu. • The green cover must be enhanced by planting tree saplings and ensuring their growth.	
The general public, particularly marginalized populations and the elderly, is disproportionately affected.	Frequent power cuts, worsened by climate change and rising temperatures, make reliable power supply a constant challenge.	• Real-time outage alerts must be implemented. • Electricity transmission lines must be improved to prevent wastage amidst constantly rising electricity demand.	
Low Income Group	The sick building syndrome is exacerbated by factors such as asbestos roofs, inadequate ventilation, poor water availability, and limited cross ventilation in poorly planned houses as well as the high cost of solar energy.	• Solutions include the implementation of cool roofs, green roofs, traditional methods such as using pots, white-painted terraces, passive energy conservation techniques, reconstruction of buildings for low-income groups, incentives for adopting cool roofs, and the use of sustainable bricks.	

VULNERABLE/ IMPACTED GROUPS	OVERALL CHALLENGES/ PROBLEMS	PROPOSED SOLUTIONS/ ONGOING INITIATIVES	SUITABLE CASE STUDIES TO FOLLOW
		• Solar appliances, such as solar fans and portable panels, can be subsidized or incentivized, will benefit small-scale vendors and individuals who work outdoors and those who work in heat-exposed environments, including fishermen, women vendors, and conservancy workers. • Additionally, incentivizing or subsidizing solar adoption for residential use can decrease costs, making solar energy more accessible to low income groups.	
The general public	Limited awareness and accessibility to information.	• Capacity building for stakeholders, government authorities, and officials within the community, can be undertaken along with the provision of clear and concise information.	
Construction workers, conservancy workers, small-scale roadside vendors		• Aerated and cool rest areas can be established to enhance people's well-being and productivity. • Additionally, green and cool rest areas equipped with electricity supply for fans and lighting can be created to provide relief from the heat. • Green and cool bus stops and railway stations can offer respite to commuters. • Furthermore, employing AI or IoT technology to automatically switch off amenities when not in use can help conserve energy and reduce heat buildup in these areas.	The shady area between central metro station and central station
The elderly population	The elderly population with pre-existing health conditions experience heightened challenges during the summer months, exacerbated by social isolation that restricts access to assistance and limited mobility.	• Social support to conduct regular check-ins on the elderly must be organized. • There must be scheduled health check-ups for monitoring their well-being. • Environments must be temperature-controlled to mitigate health risks.	'Beat the Heat Arizona' initiative

VULNERABLE/ IMPACTED GROUPS	OVERALL CHALLENGES/ PROBLEMS	PROPOSED SOLUTIONS/ ONGOING INITIATIVES	SUITABLE CASE STUDIES TO FOLLOW
Gig workers	Continuous outdoor exposure increases the risk of heat stress due to limited access to shelter and hydration, compounded by financial constraints. Additionally, lack of awareness and no paid sick leave offered by employer exacerbate these issues. Peak hours present health hazards for those delivering food and other services. Moreover, institutional support to address these challenges effectively are lacking.	• Mobile hydration stations must be established. • Heat awareness campaigns must be conducted. • Financial assistance programs must be implemented. • Technology solutions must be integrated. • A new policy aimed at regulating gig companies and safeguarding gig workers must be introduced	
People engaged in agriculture and animal husbandry	High temperatures lead to heat injury in crops, causing scorching, flower abortion, and stunted growth due to water stress, ultimately resulting in crop failure, yield losses, and poor produce quality. Livestock and poultry management suffer from increased food and water requirements amidst limited feed materials, leading to lower meat and milk yields. Grass burning is utilized to promote the growth of grass used for grazing. Fluctuating temperatures, inadequate rainfall, and prolonged droughts disrupt the metabolism of short-day plants, contributing to poor crop performance, yield losses, and adverse impacts on farming communities' livelihoods.	• Breeding programs to develop high-temperature tolerant crop varieties must be implemented, and there must be timely distribution of seed materials to regions prone to heat stress. • Low-cost or no-cost advanced drought mitigation measures must be implemented. • Mixed farming, multi-tier cropping, and hydroponics-based fodder production must be encouraged. • Effective recycling of crop residues through composting must be promoted to reduce emissions from animal manures. • Mulching practices must be encouraged in fields. • Farmers must be encouraged to reduce the frequency of ploughing. • Drip fertigation and micro-irrigation techniques must be adopted. • Land-use based cropping strategies must be implemented. • Green manuring must be promoted as an alternative to fallowing. • The cultivation of millets and pulses must be encouraged. • The use of biomass must be increased through the erection of border trees, bund crops, trap crops, and rainwater catch crops.	• Utilizing the resources available on the Tamil Nadu Agricultural University (TNAU) website in both Tamil and English languages: www.tnauagriportal.co.in and www.tauagritech.comco.in • Accessing agricultural advisory services provided by TNAU for medium- and long-term weather forecasts across all blocks and districts of Tamil Nadu

VULNERABLE/ IMPACTED GROUPS	OVERALL CHALLENGES/ PROBLEMS	PROPOSED SOLUTIONS/ ONGOING INITIATIVES	SUITABLE CASE STUDIES TO FOLLOW
Residential and housing initiatives	High GHG emissions, coupled with insufficient attention to indoor environmental quality and temperature control	Efforts to raise awareness and provide readily accessible knowledge to builders and Resident Welfare Associations (RWAs) are underway.	A workshop organized by TNCCM, Department of Environment and Climate Change (DoE & CC), focusing on green building practices for both builders and RWAs is in progress.
Schoolchildren	The absence of greenery contributes to a dull appearance and compromises air quality. Buildings require a fresh coat of white paint to enhance their aesthetic appeal. Inadequate access to clean drinking water and proper toilet facilities poses health risks.	• The Green School program by Tamil Nadu Climate Change Mission (TNCCM) must be implemente. • White paint must be applied on roofs to reflect heat. • Solar panels must be installed for electricity generation. • Dedicated staff must be appointed to ensure clean and well-maintained toilet facilities. • More trees must be planted within school premises for natural cooling. • Water filtration systems must be installed for access to clean drinking water.	Name: ELA Green Schools Location: Maraimalai Nagar, Chengalpattu district Specialty: Environmental focus on sustainability and green practices
Street Vendors	Heat exhaustion, stroke, decreased productivity, and income loss. High temperatures also contribute to food spoilage, while limited access to resources further exacerbates these challenges.	• Implementation of heat shelters and cooling centres for relief from high temperatures • Provision of subsidised ice boxes to help prevent food spoilage • Public awareness campaigns to educate communities about heat-related risks and preventive measures • Ensuring access to safe drinking water to mitigate heat-related health concerns	Ahmedabad's Heat Action Plan, executed by the Municipal Corporation, includes the establishment of cooling centres, distribution of ice boxes, and implementation of awareness campaigns.

TABLE A4 | : Questionnaire Template

The set of questions given below is designed to aid in conducting a thorough investigation and collecting data required to develop the document. In-person interviews and discussions, focussed group discussions, and board exercises are the research methods for collecting data.

The assessing agency should delineate the scope, scale, and institutional framework of the city as well as identify pertinent stakeholders for interviews and discussions corresponding to the areas of enquiry. These stakeholders may include Central, state, and local institutions. The questionnaire serves as a flexible guiding tool rather than a checklist and can be adapted to suit the relevance of the subject and stakeholders involved.

INFORMATION NEEDS	QUESTIONS
Details of specific initiatives or programs that the department is currently implementing to address heat and climate risk	
Initiatives are being undertaken currently in your department to address heat and climate risk	
Objectives and goals of these initiatives in relation to mitigating heat- and climate-related impacts	
Target audience and geography that are the focus of these initiatives	
Strategies or measures being employed to address heat and climate risk, such as infrastructure upgrades, community education campaigns, or policy development	
Information on any partnerships or collaborations with other agencies, organizations, or stakeholders involved in these initiatives	
Data on the progress or outcomes of these initiatives, including any challenges or successes encountered during implementation	
Identification of specific challenges or barriers hindering the implementation of initiatives aimed at addressing heat and climate risk	
	What are the primary challenges faced by your department in implementing these actions?
Details of the nature and extent of each challenge, including whether they are related to technical, financial, institutional, or social factors	
Information on how these challenges are impacting the progress or effectiveness of the department's actions	
Any efforts or strategies being employed to overcome these challenges	
Input on potential solutions or resources needed to address these challenges effectively	
Insights into any external factors or constraints contributing to the challenges faced by the department	
Perspectives on the long-term implications of these challenges for the department's ability to achieve its goals related to heat and climate risk mitigation	
Insights into the budgetary allocations or funding sources supporting these alignments, including details on allocated funds, expenditure, and any plans for future budget allocations	
	Which existing policies and programs is your department aligning with or seeking to align with in order to address heat and climate risk? Additionally, what are budgetary allocations in place or being sought for these alignments?
Data on how the allocated funds are being utilized to implement activities related to heat and climate risk mitigation, and any expected outcomes or impacts	
Specific recommendations or suggestions from the department for enhancing the existing heat mitigation strategy document	
	What recommendations does your department have for the development or enhancement of the heat mitigation strategy document?
Proposed revisions or additions to the strategy document to address these gaps and enhance its effectiveness	
Insights into the department's priorities and focus areas for heat mitigation, and how these can be reflected in the strategy document	
Input on strategies or measures that should be included in the document to address emerging challenges or new developments related to heat mitigation	

INFORMATION NEEDS	QUESTIONS
Perspectives on the stakeholder engagement process and coordination mechanisms that should be incorporated into the strategy document	
Information on any resources or support needed from other agencies or stakeholders to develop or enhance the heat mitigation strategy document effectively	
Data on regional variations in heat stress levels across different areas within the state, including temperature patterns, heatwave occurrences, and duration and intensity of hot weather events	
	Can you provide examples of how different regions within the state are impacted differently by heat stress and which groups are particularly vulnerable?
Identification of vulnerable groups within each region, such as the elderly, children, outdoor workers, or low-income communities, who may be disproportionately impacted by heat stress	
Insights into the factors contributing to differential vulnerability among different regions, including socio-economic disparities, urbanization levels, access to cooling infrastructure, and environmental conditions	
Examples or case studies illustrating how heat stress affects various regions differently, including impacts on public health, infrastructure, agriculture, and ecosystems	
Information on the existing adaptation measures or interventions implemented in different regions to address heat stress and protect vulnerable populations	
Perspectives on future projections or anticipated changes in heat stress patterns across different regions, considering factors such as climate change, urban development, and demographic shifts	
Data on the effectiveness of interventions or policies aimed at reducing heat stress impacts in specific regions and among vulnerable groups, including any challenges or limitations encountered in implementation	
Identification of ongoing initiatives or research projects focused on addressing heat stress, including their objectives, scope, and target populations	
	Are there any ongoing initiatives or research projects aimed at addressing the multifaceted nature of heat stress, and if so, what are the key findings or outcomes so far?
Details on the methodologies and approaches being used in these initiatives or research projects to study the multifaceted nature of heat stress, including data collection methods, analysis techniques, and collaboration with other stakeholders	
Key findings or preliminary outcomes from the ongoing initiatives or research projects, including insights into the factors contributing to heat stress, vulnerable populations, and potential adaptation strategies	
Information on any innovative solutions or interventions being developed or tested to mitigate the impacts of heat stress, including their effectiveness and scalability	
Perspectives on the significance and implications of the findings or outcomes from these initiatives or research projects for policy development, planning, and decision-making related to heat stress management	
Insights into the challenges, limitations, or gaps encountered in ongoing initiatives or research projects aimed at addressing heat stress, and any recommendations for future research directions or interventions	
Understanding the objectives and goals of the Carbon Neutral Cities program under the Tamil Nadu Climate Mission, including its rationale and overarching vision	
	What was the thinking behind the carbon neutral cities program that is being implementing under the Tamil Nadu Climate Mission?
Details of the specific strategies, interventions, and initiatives being implemented as part of the program to achieve carbon neutrality in cities	

INFORMATION NEEDS	QUESTIONS
Insights into the planning and implementation processes involved in launching the Carbon Neutral Cities program, including stakeholder engagement, policy development, and coordination mechanisms	
	What kind of insights have been generated so far from the Carbon Neutral Cities program? How do we address these to make cities more resilient to heat impacts?
Information on the criteria and selection process for identifying cities to participate in the program, as well as the timeline for implementation and expected outcomes	
Perspectives on the challenges, opportunities, and potential impacts associated with implementing the Carbon Neutral Cities program, including considerations related to technology, financing, governance, and community engagement	
Data on the progress, achievements, and lessons learned from cities that have already embarked on the journey towards carbon neutrality under the program	
Insights into the long-term vision and sustainability of the Carbon Neutral Cities program, including plans for monitoring, evaluation, and continuous improvement	
Details of the existing mechanisms and frameworks within the TN Disaster Risk Management Agency (TNDRMA) relevant to addressing heat-related risks and emergencies	
	How do we leverage the existing mechanisms within TNDRMA to develop a sound heat mitigation strategy?
Insights into the roles, responsibilities, and capacities of TNDRMA in coordinating and managing disaster risk reduction efforts, including its mandate, organizational structure, and key stakeholders	
Information on the specific policies, guidelines, and protocols established by TNDRMA for addressing heat-related hazards and emergencies, including any existing heat mitigation strategies or action plans	
Perspectives on the challenges, gaps, and opportunities for leveraging TNDRMA's existing mechanisms to develop a comprehensive heat mitigation strategy, including considerations related to coordination with other agencies, resource mobilization, and community engagement	
Data on the current state of heat-related risks and vulnerabilities in Tamil Nadu, including historical trends, hotspots, and vulnerable populations, to inform the development of targeted interventions and strategies	
Insights into best practices, lessons learned, and case studies from other jurisdictions or organizations that have successfully integrated heat mitigation into their disaster risk management frameworks	
Perspectives on the integration of climate change adaptation considerations in TNDRMA's mandate and operations, including strategies for mainstreaming heat resilience into disaster risk reduction efforts	
Information on the stakeholder engagement process and mechanisms for collaboration between TNDRMA, relevant government agencies, civil society organizations, academia, and other stakeholders in developing and implementing the heat mitigation strategy	
Details of the current monitoring and early warning systems in place for heat-related events and risks in Tamil Nadu, including the data sources, technologies, and methodologies utilized	
	Close monitoring and early warning is an important component of heat mitigation strategy. How can it be ensured that the heat concerns are integrated in the planning and budgeting processes?
Insights into the gaps, challenges, and limitations of existing monitoring and early warning systems for heat-related hazards, including issues related to data availability, accuracy, and timeliness	
Perspectives on the key stakeholders involved in monitoring and early warning efforts for heat-related risks, including government agencies, research institutions, civil society organizations, and community-based networks	

INFORMATION NEEDS	QUESTIONS
Information on the specific indicators, thresholds, and triggers used to activate heat-related warnings, advisories, and response measures, as well as the communication channels and dissemination strategies employed	
Data on the historical trends and patterns of heat-related events in Tamil Nadu, including temperature extremes, heatwaves, and associated impacts on human health, infrastructure, and ecosystems	
Insights into the potential impacts of climate change on heat-related risks and vulnerabilities in Tamil Nadu, including projections for future temperature trends, changes in heatwave frequency and intensity, and shifts in spatial patterns	
Perspectives on the integration of heat concerns in the planning and budgeting processes at the state and local levels, including strategies for mainstreaming heat resilience considerations into development plans, infrastructure projects, and public investments	
Information on the resource requirements, funding mechanisms, and budget allocations needed to strengthen monitoring and early warning systems for heat-related hazards, including investments in technology, capacity-building, and community engagement initiatives	
Data on the current status of heat-induced health risks in Tamil Nadu, including statistics on heat-related illnesses, hospitalizations, and mortality rates	
	Extreme heat has tremendous adverse effects on human health. Urbanization leads to higher proportions of people exposed to heat and air pollution. It is a major public health issue today across the globe, and Tamil Nadu is no different. What are your priorities for managing the heat-induced health risks. What has been done so far, and what are the future plans?
Insights into the specific populations and communities most vulnerable to heat-induced health risks in Tamil Nadu, including demography, geography, and socioeconomic factors	
Information on the existing public health initiatives and interventions aimed at mitigating heat-induced health risks in Tamil Nadu, including heatwave early warning systems, heat health action plans, and public awareness campaigns	
Perspectives on the effectiveness and impact of past interventions and programs in reducing heat-related morbidity and mortality in Tamil Nadu, including lessons learned, best practices, and areas for improvement	
Strategies for enhancing heat resilience and public health preparedness in Tamil Nadu, including recommendations for strengthening healthcare infrastructure, improving access to healthcare services, and enhancing community resilience	
Insights into the integration of heat health considerations in the broader public health policies and programs in Tamil Nadu, including coordination mechanisms, partnerships, and collaborations between government agencies, healthcare providers, and community organizations	
Data on the projected future trends and scenarios of heat-induced health risks in Tamil Nadu, including anticipated changes in temperature extremes, heatwave frequency, and associated health impacts due to climate change	
Perspectives on the resource requirements, funding needs, and policy priorities for addressing heat-induced health risks in Tamil Nadu, including budget allocations, capacity-building initiatives, and research investments	
Identification of specific areas within the understanding of heat impacts, vulnerability of the population, and assessments of impacts on health and well-being where research is lacking or insufficient	
	There is a significant research gap with regard to the science of heat impacts, vulnerability of the population, and more holistic assessments of impacts on health and well-being. There is a need for more comprehensive and integrated quantitative investigations of physical, behavioral, environmental, and social risk factors. How can the research community contribute to this?
Insights into the key research questions and priorities identified by stakeholders, policymakers, and experts in the field related to heat impacts and vulnerability	

INFORMATION NEEDS	QUESTIONS
Data on existing research efforts and studies conducted in Tamil Nadu or similar contexts that address heat-related issues, including their methodologies, findings, and limitations	
Perspectives on the potential contributions of interdisciplinary research approaches and collaboration between different sectors (e.g., public health, environmental science, social sciences) to fill the research gap	
Information on the capacity and resources available within the research community in Tamil Nadu, including academic institutions, research organizations, and funding opportunities for heat-related research	
Recommendations for enhancing research capacity, infrastructure, and funding support to facilitate more comprehensive and integrated investigations of heat impacts and vulnerability in Tamil Nadu	
Insights into the role of community engagement, stakeholder involvement, and participatory research approaches in addressing research gaps and generating actionable knowledge to inform policy and practice	
Perspectives on the translation of research findings into actionable recommendations, policies, and interventions to mitigate heat impacts and improve resilience at the local, regional, and state levels in Tamil Nadu	
Data on the current level of community resilience to heat stress in Chennai, including an assessment of existing strengths, weaknesses, and vulnerabilities within local communities	
	Locally led actions are important to manage any risks or threats arising in a specific geography, be it floods, droughts, or crimes. The onus is as much with the local communities as it is with the government. Building community resilience is key in managing climate-induced risks, and heat risks are no exception. Nature-based solutions are considered to be a key component of managing heat risks at the city level. What are the initiatives that need to be taken to build community resilience to heat stress in the context of a city like Chennai?
Insights into the specific climate-induced risks and heat-related challenges faced by communities in different areas of Chennai, considering factors such as socioeconomic status, infrastructure, urbanization, and environmental conditions	
Identification of nature-based solutions and community-driven initiatives that have been implemented or proposed to address heat stress and enhance resilience in Chennai, along with their effectiveness and scalability	
Perspectives from local community leaders, residents, and stakeholders on their priorities, needs, and preferences for building resilience to heat stress, including their knowledge, attitudes, and practices related to climate adaptation and mitigation	
Information on existing policies, programs, and governance structures that support or hinder community-led actions and nature-based solutions for heat resilience in Chennai, including any barriers or gaps in implementation	
Insights into successful case studies, best practices, and lessons learned from other cities or regions with similar climatic conditions and urban challenges, which could inform strategies for building community resilience in Chennai	
Data on resources, funding opportunities, and capacity-building efforts to support community-led initiatives and nature-based solutions for heat resilience in Chennai, including collaborations with government agencies, NGOs, academic institutions, and the private sector	
Perspectives on the role of local government, civil society organizations, community-based organizations, and other stakeholders in facilitating community engagement, empowerment, and ownership of heat resilience initiatives in Chennai	
Data on the specific vulnerabilities of marginalized populations, including the poor and women, to heat-related impacts in urban areas, such as exposure to extreme heat, limited access to cooling resources, and increased health risks	

INFORMATION NEEDS	QUESTIONS
There is ample evidence that proves that the poor and the marginal, especially women, are disproportionately impacted by climate impacts. The difference between men and women can also be seen in their differential roles, responsibilities, decision-making, access to land and other resources, opportunities and needs. The intersection of increased heat island conditions and demographic inequities amplifies additional heat-related risk factors. What are the steps that need to be taken to address this discrepancy, and how can we make the urban heat resilience plans more gender-sensitive?	
Insights into the differential roles, responsibilities, and decision-making power of men and women in urban settings, including their access to land, employment opportunities, social services, and infrastructure	
Analysis of the intersectional factors that contribute to gender disparities in urban heat resilience, such as socioeconomic status, education level, household dynamics, and cultural norms	
Examples of existing urban heat resilience plans and initiatives that have successfully integrated gender-sensitive approaches, including strategies for identifying and addressing the specific needs and priorities of women, marginalized groups, and vulnerable communities	
Perspectives from women's organizations, community leaders, and gender experts on their experiences, challenges, and recommendations for promoting gender equality and social inclusion in urban heat resilience planning and policymaking	
Information on policy frameworks, guidelines, and best practices for mainstreaming gender considerations into urban planning, infrastructure development, disaster risk reduction, and climate adaptation strategies	
Data on the impacts of gender-responsive interventions and investments in urban heat resilience, including their effectiveness in reducing vulnerability, enhancing adaptive capacity, and promoting social equity and empowerment	
Insights into the role of the local government, civil society organizations, academic institutions, and other stakeholders in championing gender-sensitive approaches to urban heat resilience, including capacity-building efforts, advocacy campaigns, and partnerships for change	

GLOSSARY

Adaptation gap: The difference between implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts and reflecting resource limitations and competing priorities (UNEP, 2014; UNEP, 2018).

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.(IPCC 2022)

Afforestation: Conversion to forest of land that historically has not contained forests. (IPCC 2022)

Agroforestry: Collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economical interactions between the different components. Agroforestry can also be defined as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (FAO, 2015a)

Air pollution: Degradation of air quality with negative effects on human health or the natural or built environment due to the introduction, by natural processes or human activity, into the atmosphere of substances (gases, aerosols) which have a direct (primary pollutants) or indirect (secondary pollutants) harmful effect.(IPCC 2022)

Air Quality Degradation: The deterioration of air quality due to pollutants emitted from various sources such as vehicles, industries, and agricultural activities.

Air Quality: The measure of the cleanliness and purity of the air, which can be affected by pollutants such as particulate matter, ozone, and other harmful substances.

Air Temperature: The temperature of the air, usually measured using thermometers at various heights above the ground.

Anganwadi: Anganwadi is a type of rural child care centre in India. It was started by the Indian government in 1975 as part of the Integrated Child Development Services program to combat child hunger and malnutrition. Anganwadi in Hindi means "courtyard shelter" in English.

Anomaly: Deviations from the long-term average, typically calculated over a period of 30 years or more.

Anthropogenic: Resulting from or produced by human activities. (IPCC 2022)

Attribution: The process of determining the causes of observed changes in climate or weather patterns.

Baseline: The long-term average of an indicator calculated over a period of 30 years or more, serving as a reference point for comparison and analysis.

Biodiversity: Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UN, 1992).

Blockchain-Enabled Traceability Platforms: Systems utilizing blockchain technology to enhance transparency and traceability in the agricultural supply chain, allowing stakeholders to track the journey of products from farm to consumer.

Blue infrastructure: Blue infrastructure includes bodies of water, watercourses, ponds, lakes and storm drainage, that provide ecological and hydrological functions including evaporation, transpiration, drainage, infiltration and temporarily storage of runoff and discharge.(IPCC 2022)

Built Environment: Human-made structures and infrastructure, including buildings, roads, and utilities.

Capacity building: The practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society or organisation to respond to change.(IPCC 2022)

Carbon footprint: Measure of the exclusive total amount of emissions of carbon dioxide (CO2) that is directly and indirectly caused by an activity or accumulated over the life stages of a product .(IPCC 2022)

Carbon Sequestration: The process of capturing and storing atmospheric carbon dioxide (IPCC 2022)

Cardiovascular Disorders: Medical conditions affecting the heart and blood vessels, such as heart disease, hypertension, and stroke.

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. (IPCC 2022)

Climate extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., high temperature, drought or heavy rainfall over a season). For simplicity, both extreme weather events and extreme climate events are referred to collectively as climate extremes.(IPCC 2022)

Climate Hazards Vulnerability Assessment Framework: A framework used to assess vulnerability to climate-related hazards, including heat, by considering various factors such as exposure, sensitivity, and adaptive capacity.

Climate projection: Simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases (GHGs) and aerosols and changes in land use, generally derived using climate models. Climate projections depend on an emission/concentration/radiative forcing scenario, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised.(IPCC 2022)

Climate resilient development: In the WGII report, climate resilient development refers to the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all.

Climate: In a narrow sense, climate is usually defined as the average weather -or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities- over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (IPCC 2022)

Climate-Smart Villages: Tamil Nadu's Climate-Smart Villages are rural communities actively tackling climate change threats. The initiative, part of the state's Climate Change Mission, focuses on understanding each village's unique vulnerabilities and developing solutions. This includes studying existing adaptation strategies and using them to build future resilience through targeted adaptation and mitigation measures. With a budget allocation of Rs 77 crore, the mission emphasizes coastal habitat rehabilitation and pilot projects for climate-proofed temples, all aiming to empower communities to become more resilient to climate change.

Closed Recirculating Systems: Aquaculture systems designed to recycle and reuse water within a closed environment, reducing environmental impact and resource usage.

CMIP5: Coupled Model Intercomparison Project Phase 5. It is a collaborative climate modeling project that provides a framework for coordinated climate model experiments.

Coastal erosion: Coastal erosion, sometimes referred to as shoreline retreat, occurs when a net loss of sediment or bedrock from the shoreline results in landward movement of the high-tide mark.(IPCC 2022)

Community-based adaptation: Local, community-driven adaptation. Community-based adaptation focuses attention on empowering and promoting the adaptive capacity of communities. It is an approach that takes context, culture, knowledge, agency and preferences of communities as strengths.(IPCC 2022)

Conservation Tillage: Agricultural practices that involve minimal soil disturbance, promoting water retention and reducing the need for crop residue burning.

Cool Coalition: A collaborative effort among governments, organizations, and businesses aimed at promoting cooling solutions to mitigate climate change and improve resilience to extreme heat.

Cool Roofs: Roofing materials and techniques designed to reflect sunlight and reduce heat absorption, thereby lowering indoor temperatures and energy consumption.

Cooling Solutions: Strategies and technologies aimed at reducing heat and improving thermal comfort in various contexts, including urban and rural areas, through passive cooling techniques, nature-based solutions, and innovative practices.

Criteria Pollutants: Criteria pollutants, as defined by the National Clean Air Programme (NCAP), refer to a set of common air pollutants identified for regulation due to their adverse effects on human health and the environment. The criteria pollutants typically include Particulate Matter (PM10 and PM2.5), Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), Carbon Monoxide(CO) , Ozone (O3), Lead (Pb).

Critical infrastructure: Urban infrastructure, such as public transport, roads and highways, water distribution, sanitation, solid waste management, healthcare, and other essential aspects of urban infrastructure that are often publicly provided or supported.

Cyclones: Large-scale rotating storms characterised by low pressure centres and strong winds, typically forming over warm ocean waters.

Daytime and Nighttime Temperatures: Refers to the temperature levels experienced during the day and night, respectively, which can vary significantly and impact human comfort and health.

Decent work indicators: Decent Work, as defined by the ILO, encompasses employment opportunities, fair income, social protection, and social dialogue, forming a comprehensive framework to assess and promote equitable and inclusive working conditions. Basically answering 'What makes work decent? And how to measure it?'

Decent Work: Employment that is productive and delivers a fair income, security in the workplace, social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives, and equality of opportunity and treatment for all women and men.

Decision-making: The process of selecting a course of action from among various alternatives, often based on careful consideration of available information and potential outcomes.

Differential Vulnerability: The concept that different groups or individuals may experience varying levels of susceptibility or resilience to the impacts of heat exposure based on factors such as age, gender, socioeconomic status, and health status.

Disaster Management Approach: A systematic approach to managing and reducing the risks associated with disasters, including preparedness, response, recovery, and mitigation activities.

Disaster risk management (DRM): Processes for designing, implementing and evaluating strategies, policies and measures to improve the understanding of current and future disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, prevention and protection, response and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life and sustainable development (SD).(IPCC 2022)

Disaster risk reduction (DRR): The strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard or vulnerability; and improving resilience (IPCC 2022). In practice, it is often an incremental rather than transformational policy or set of policies that focuses on coping with and recovering from disasters. DRR rarely focuses on fundamentally changing social or economic systems, addressing the root social causes of vulnerability to disasters, or considering slower-onset climate hazards.

Disaster: A 'serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts' (UNGA, 2016).

Discomfort Days: Days characterized by conditions that cause discomfort or reduced productivity due to heat stress.

Drainage: Artificial lowering of the soil water table (IPCC, 2013).

Drought: An exceptional period of water shortage for existing ecosystems and the human population (due to low rainfall, high temperature and/or wind).(IPCC 2022)

Early warning systems (EWS): The set of technical and institutional capacities to forecast, predict and communicate timely and meaningful warning information to enable individuals, communities, managed ecosystems and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss.(IPCC 2022)

Economy & Livelihood: The financial and occupational activities that sustain individuals and communities, including agriculture, animal husbandry, fisheries, and tourism.

Ecosystem Health: The overall condition and resilience of ecosystems, including their ability to support biodiversity and provide ecosystem services.

Ecosystem Restoration: Activities aimed at returning degraded ecosystems to a more natural or functional state, often involving habitat restoration and conservation efforts.

Ecosystem services: Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or carbon sequestration and (4) cultural services such as tourism or spiritual and aesthetic appreciation. See also Ecosystem and Ecosystem health.(IPCC 2022)

Ecosystem: A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases, they are relatively sharp, while in others they are diffuse. (IPCC 2022)

Ecosystem-based adaptation (EBA): The use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change.(IPCC 2022)

Energy efficiency: The ratio of output or useful energy or energy services or other useful physical outputs obtained from a system, conversion process, transmission or storage activity to the input of energy (measured as kWh kWh−1, tonnes kWh−1 or any other physical measure of useful output like tonne-km transported). Energy efficiency is often described by energy intensity.(IPCC 2022)

Energy Mapping Study: An assessment to identify energy consumption patterns and opportunities for improving energy efficiency and renewable energy utilization in specific sectors or regions.

Energy system: The energy system comprises all components related to the production, conversion, delivery and use of energy.(IPCC 2022)

Epidemiology: The study of the distribution and determinants of health-related states or events in populations, often used to inform public health interventions.

Equitable Access: Ensuring fair and inclusive distribution of resources, opportunities, and benefits across different social groups and communities

ERA5: Fifth generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis dataset. It provides global meteorological data covering various atmospheric parameters.

Evapotranspiration: The combined processes through which water is transferred to the atmosphere from open water and ice surfaces, bare soil and vegetation that make up the Earth's surface.(IPCC 2022)

Extreme Heat: Abnormally high temperatures that persist over a prolonged period, often resulting in adverse impacts on human health, ecosystems, and infrastructure.

Food Security: The condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Forest degradation: A reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes.(IPCC 2022)

Forest Fires: Uncontrolled fires occurring in forested areas, often leading to ecological damage and loss of biodiversity.

Gaseous Pollutants: Gaseous pollutants refer to harmful substances present in the atmosphere in the form of gases. These pollutants include gases such as Sulfur Dioxide (SO2), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Ozone (O3), Volatile Organic Compounds (VOCs), and other hazardous gases emitted from industrial processes, vehicle emissions, and various combustion activities. Gaseous pollutants can have adverse effects on human health, ecosystems, and the environment, contributing to respiratory illnesses, smog formation, acid rain, and global climate change.

Gig Workers: Gig workers are independent contractors who engage in temporary or project-based work, often facilitated through digital platforms, allowing them flexibility in their work arrangements.

Global warming: Global warming refers to the increase in global surface temperature relative to a baseline reference period, averaging over a period sufficient to remove interannual variations (e.g., 20 or 30 years). A common choice for the baseline is 1850–1900 (the earliest period of reliable observations with sufficient geographic coverage), with more modern baselines used depending upon the application.(IPCC 2022)

Green Index: A ranking system used to assess cities based on their environmental performance and sustainability efforts, guiding policy-making and urban planning decisions.

Green infrastructure: The strategically planned interconnected set of natural and constructed ecological systems, green spaces and other landscape features that can provide functions and services including air and water purification, temperature management, floodwater management and coastal defence often with co-benefits for human and ecological well-being. Green infrastructure includes planted and remnant native vegetation, soils, wetlands, parks and green open spaces, as well as building and street-level design interventions that incorporate vegetation. (IPCC 2022)

Greenhouse gases (GHG): Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's ocean and land surface, by the atmosphere itself and by clouds. This property causes the greenhouse effect.(IPCC 2022)

Ground Level Ozone: ground level ozone, is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC). This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight.

Groundwater Exploitation: The extraction of groundwater from underground aquifers for various purposes such as irrigation, drinking water, and industrial use.

Groundwater recharge: The process by which external water is added to the zone of saturation of an aquifer, either directly into a geologic formation that traps the water or indirectly by way of another formation.(IPCC 2022)

GSDP: Gross State Domestic Product. It is a measure of the economic performance of a state, similar to Gross Domestic Product (GDP) but at the state level.

Heat Action Plans (HAPs): Strategic plans developed to mitigate the impacts of heat waves, including preparedness, prevention, and response measures, often issued by government agencies or disaster management authorities.

Heat Exhaustion: A condition characterized by heavy sweating, weakness, dizziness, nausea, and often accompanied by dehydration, resulting from exposure to high temperatures.

Heat Exposure Reduction: Measures focused on reducing heat exposure, including building guidelines, ecosystem restoration, and occupational interventions.

Heat Index: Heat index is the combination of air temperature and relative humidity & is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature.

Heat Mitigation Strategy (HMS): A comprehensive plan aimed at reducing the adverse impacts of extreme heat events through various measures and interventions.

Heat Resilience: The ability of individuals, communities, and ecosystems to withstand and recover from the impacts of extreme heat.

Heat Shelters: Designated areas or structures providing shade and relief for public during extreme heat conditions, contributing to their safety and well-being.

Heat stress: A range of conditions in, for example, terrestrial or aquatic organisms when the body absorbs excess heat during overexposure to high air or water temperatures or thermal radiation. In aquatic water-breathing animals, hypoxia and acidification can exacerbate vulnerability to heat.(IPCC 2022)

Heat-preparedness: Measures and actions taken to anticipate, prevent, and mitigate the impacts of extreme heat events.

Heatstroke: A severe condition resulting from prolonged exposure to high temperatures, characterized by an elevated body temperature, altered mental state, and often accompanied by dehydration and organ dysfunction, which can be life-threatening if not treated promptly.

Heat-Tolerant Crops: Plant varieties specifically bred or modified to withstand high temperatures, addressing the challenges posed by heat stress on agricultural productivity.

Heatwave Contingency Plans: Comprehensive plans outlining emergency response measures, infrastructure, and operational strategies for governments and non-governmental organizations to manage adverse effects during heatwaves.

Heatwave Days: Days where temperatures reach or exceed levels considered dangerous or uncomfortable for prolonged periods.

Heatwave: A period of abnormally hot weather, often defined with reference to a relative temperature threshold, lasting from two days to months.(IPCC 2022)

Human-wildlife Conflict: Conflicts arising from interactions between humans and wildlife, often related to competition for resources or habitat encroachment.

Hydrological Drought: A drought affecting water resources such as rivers, lakes, and reservoirs, resulting from prolonged deficits in precipitation and increased evaporation.

Hyperthermia: Hyperthermia is an abnormally high body temperature. It occurs when your body absorbs or generates more heat than it can release. A human's normal body temperature is about 98.6 degrees Fahrenheit. Any body temperature above 99 or 100 degrees Fahrenheit is too warm. Hyperthermia isn't the same as a fever. When you have hyperthermia, your body temperature rises above a certain "set-point" that's controlled by your hypothalamus (a part of your brain that controls many body functions). But when you have a fever, your hypothalamus actually increases your body's set-point temperature. This intentional rise in body temperature is your body's attempt to fight off an illness or infection.

IMD: India Meteorological Department. The national meteorological service of the Government of India, responsible for meteorological observations, weather forecasting, and seismology.

Implementation and Preparedness: Immediate actions and readiness measures undertaken in the short term to address health and well-being concerns during extreme heat conditions, including medical interventions and resource allocation.

Infant Mortality: The death of an infant before their first birthday, often used as an indicator of the overall health and well-being of a population.

Informal settlement: A term given to settlements or residential areas that, by at least one criterion, fall outside official rules and regulations. Most informal settlements have poor housing (with widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads and basic services is inadequate or lacking. The term 'slum' is often used for informal settlements, although it is misleading as many informal settlements develop into good-quality residential areas, especially where governments support such development.(IPCC 2022)

Infrastructure and Services: Essential facilities and systems necessary for the functioning of a society, such as food distribution, transportation, water supply, waste management, and communication networks.

Institutional capacity: Building and strengthening individual organisations and providing technical and management training to support integrated planning and decision-making processes between organisations and people, as well as empowerment, social capital and an enabling environment, including culture, values and power relations. (IPCC 2022)

Integrated Coastal Zone Management (ICZM): Integrated Coastal Zone Management (ICZM) is a comprehensive approach aimed at enhancing the resilience of India's coastal communities, as outlined in the draft Environmental and Social Management Framework (ESMF) by the Ministry of Environment, Forest and Climate Change (MoEFCC), involving guidelines for assessing infrastructure projects and adopting sustainable practices to achieve sustainability, biodiversity conservation, disaster vulnerability reduction, and livelihood security, with the Society of Integrated Coastal Management (SICOM) serving as the national project management unit for successful ICZMP implementation.

Intersectoral Collaboration: Collaboration between different sectors or disciplines, such as public health, veterinary medicine, environmental science, etc., to address complex health challenges and promote holistic solutions.

Land cover change: Change from one land cover class to another, due to change in land use or change in natural conditions. (IPCC 2022)

Land cover: The biophysical coverage of land (e.g., bare soil, rocks, forests, buildings and roads, or lakes).(IPCC 2022)

Line Departments: Government agencies or ministries responsible for implementing policies and programs within specific sectors or areas of expertise.

Livelihoods: The means of securing the necessities of life, including employment, income, and access to resources.

Low Birth Weight: A birth weight of less than 2,500 grams (5.5 pounds), which can be a result of premature birth or restricted fetal growth and is associated with increased health risks for the infant.

LST: Land Surface Temperature. It refers to the temperature of the land surface, which can be measured using satellite imagery or ground-based instruments.

LST Trend: Statistical linear slope of change in LST average between two units of time.

Marine Protected Areas (MPAs): MPAs are designated areas of the ocean that are set aside for the protection and conservation of marine ecosystems and their biodiversity.Within the region, certain activities are limited, or entirely prohibited, to meet specific conservation, habitat protection, ecosystem monitoring or fisheries management objectives. There are total of 31 MPAs in India.

Maximum Temperature: The highest temperature recorded in a specific location over a certain period, typically within a day or month.

Mean sea level : The surface level of the ocean at a particular point averaged over an extended period of time such as a month or year. Mean sea level is often used as a national datum to which heights on land are referred. (IPCC 2022)

Medical Interventions: Measures aimed at preventing and treating heat-related health issues, including preventive medicine and rapid medical interventions.

Mental health: The state of well-being in which an individual realises his or her own abilities, can cope with the normal stresses of life, can work productively and is able to contribute to his or her community.(IPCC 2022)

Meteorological Drought: A prolonged period of below-average precipitation leading to water shortages, especially in terms of agricultural needs.

Meteorologically Induced Droughts: Droughts that occurs when dry weather patterns dominate an area. It is defined usually on the basis of the degree of dryness and the duration of the dry period.

Microfinance and Insurance Schemes: Financial programs providing small-scale loans and insurance coverage for low-income people against climate risks, promoting economic stability and resilience in the face of climate-related challenges.

Minimum Temperature: The lowest temperature recorded in a specific location over a certain period, typically within a day or month.

Mitigation (of climate change): A human intervention to reduce emissions or enhance the sinks of greenhouse gases.(IPCC 2022)

Mitigation measures: In climate policy, mitigation measures are technologies, processes or practices that contribute to mitigation, for example renewable energy technologies, waste minimisation processes and public transport commuting practices.(IPCC 2022)

Morbidity: The incidence or prevalence of disease or illness within a population.

Mulching and cover cropping: The application of a layer of organic or synthetic material to the soil surface to improve soil conditions and plant growth. Mulch acts as a physical barrier, minimizing water loss from the soil due to evaporation, which is crucial during hot and dry periods.

Multi-sectoral Scale: Refers to involving or affecting multiple sectors or areas of society, such as health, environment, economy, etc.

Multi-sectoral: Involving or affecting multiple sectors or areas of activity.

National Disaster Management Authority (NDMA): The apex body responsible for disaster management in India, tasked with formulating policies, plans, and guidelines for disaster management at various levels

Natural systems: The dynamic physical, physicochemical and biological components of the Earth system that would operate independently of human activities.(IPCC 2022)

Nature-based solution (NBS): Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. (IUCN, 2016).

NDVI: Normalized Difference Vegetation Index. It is a measure of the amount and health of vegetation in an area based on satellite imagery, calculated using the difference between near-infrared and red light reflectance.

Net Metering: A billing arrangement that allows consumers with renewable energy systems to receive credit for excess electricity they generate and feed back into the grid.

Non-humans: Refers to all living organisms other than humans, including plants, animals, and microorganisms.

Northeast Monsoon: Also known as the winter monsoon or retreating monsoon, it is a seasonal prevailing wind that blows from the northeast in the northern hemisphere, bringing heavy rainfall to southern India during the months of October to December.

Occupational Exposure: The exposure of workers to environmental factors, such as heat, noise, chemicals, and physical hazards, in the workplace, which can impact their health and safety.

Occupational Interventions: Measures to reduce heat exposure for workers in both indoor and outdoor settings, including modifying working hours and ensuring access to shaded spaces and water.

Occupational Safety and Health: Measures aimed at ensuring the safety, health, and welfare of workers in the workplace

Off-grid: Not connected to the main electricity grid, often relying on decentralized renewable energy sources.

One Health Framework: An approach that recognizes the interconnectedness of human health, animal health, and environmental health, emphasizing collaboration across multiple sectors to achieve optimal health outcomes for all.

Outreach and Awareness: Efforts to raise awareness and disseminate information about heat-related risks and protective measures to stakeholders and vulnerable populations through targeted campaigns and outreach materials.

Passive Cooling Solutions: Techniques and design strategies that utilize natural means, such as shading and ventilation, to cool indoor spaces without the need for active energy consumption.

Phased Approach: A methodical approach to implementing a plan or project in stages, with each phase building upon the previous one.

Physical Pollutants: Physical pollutants are contaminants present in the environment that affect air, water, or soil quality through their physical properties. These pollutants may include particulate matter (such as dust, smoke, and soot), which are solid particles suspended in the air, as well as visible pollutants like litter and debris. Physical pollutants can impair visibility, create respiratory problems, and contribute to environmental degradation.

Planning, Policy, and Governance: Long-term efforts aimed at reducing heat exposure through planning, policy development, and regulatory measures.

Poaching: Illegal hunting or capturing of wild animals, often for commercial gain.

Precision Agriculture: Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual plant and animal data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.

Prescribed Burning: Controlled fires intentionally set under specific conditions to reduce forest undergrowth, prevent wildfires, and promote ecosystem health.

Preterm Birth: The birth of a baby before 37 weeks of pregnancy are completed, which can be associated with various health risks and complications.

Preventive Medicine: Healthcare practices focused on preventing heat-related illnesses, such as providing access to cool spaces, drinking water, and rehydration solutions for vulnerable populations.

Projection: A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.(IPCC 2022)

Rainfall: The amount of precipitation (rain) received over a certain area and time period, typically measured in millimeters or inches.

Rainwater Harvesting: The collection and storage of rainwater for various uses, such as irrigation and domestic purposes.

Rapid and Early Medical Interventions: Prompt medical responses to treat heat-related distress and disorders, including training healthcare professionals and ensuring the availability of necessary resources for treatment.

Relative humidity: The relative humidity specifies the ratio of actual water vapour pressure to that at saturation with respect to liquid water or ice at the same temperature.(IPCC 2022)

Residential Envelope Heat Transmittance Value (ReTV): A metric used to evaluate the ability of a building's envelope (walls, roof, windows) to resist heat transfer, thus impacting indoor temperatures.

Resilience: The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure.(IPCC 2022)

Resilient Design: Design principles and strategies that enhance the ability of communities and infrastructure to withstand and recover from various environmental stresses and shocks, including extreme heat events.

Resolution: In climate models, this term refers to the physical distance (metres or degrees) between each point on the grid used to compute the equations. Temporal resolution refers to the time step or time elapsed between each model computation of the equations.(IPCC 2022)

Resource Allocation: Allocation of resources, such as water and power supply, to ensure the well-being of both humans and animals during extreme heat conditions.

Respiratory Illnesses: Diseases affecting the lungs and airways, such as asthma, chronic obstructive pulmonary disease (COPD), and pneumonia.

Restoration: In environmental context, restoration involves human interventions to assist the recovery of an ecosystem that has been previously degraded, damaged or destroyed.(IPCC 2022)

Risk assessment: The qualitative and/or quantitative scientific estimation of risks. (IPCC 2022)

Risk: The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. (IPCC 2022)

Runoff: The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ ice melt that does not evaporate, transpire or refreeze, and returns to water bodies.(IPCC 2022)

Sea level change (sea level rise/sea level fall): Change to the height of sea level, both globally and locally (relative sea level change) (at seasonal, annual or longer time scales) due to (1) a change in ocean volume as a result of a change in the mass of water in the ocean (e.g., due to melt of glaciers and ice sheets), (2) changes in ocean volume as a result of changes in ocean water density (e.g., expansion under warmer conditions), (3) changes in the shape of the ocean basins and changes in the Earth's gravitational and rotational fields and (4) local subsidence or uplift of the land. Global mean sea level change resulting from change in the mass of the ocean is called barystatic.(IPCC 2022)

Sea Surface temperature (SST): The subsurface bulk temperature in the top few metres of the ocean, measured by ships, buoys and drifters. From ships, measurements of water samples in buckets were mostly switched in the 1940s to samples from engine intake water. (IPCC 2022)

Sea Surface Temperature: The temperature of the ocean surface, which influences weather patterns and oceanic ecosystems.

Sensor-Based Monitoring Systems: Technologies incorporating sensors to monitor and gather data on various aspects of the supply chain, contributing to efficiency, transparency, and resilience.

Settlements: Places of concentrated human habitation. Settlements can range from isolated rural villages to urban regions with significant global influence. They can include formally planned and informal or illegal habitation and related infrastructure.(IPCC 2022)

Sink: Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.(IPCC 2022)

Smart Complete Street Project: An initiative aimed at transforming streets into vibrant public spaces that prioritize safety, inclusivity, and sustainability, often incorporating green infrastructure and pedestrian-friendly features.

Smart Grid: An advanced electricity grid that uses digital technology for two-way communication between utilities and consumers, enabling better management of electricity demand. They can be incorporated with renewable energy sources alongside conventional generation.

Socio-ecological Systems: Complex systems involving interactions between social and ecological components, often studied in the context of sustainability.

Soil Quality Degradation: The deterioration of soil health and fertility due to factors such as erosion, pollution, and loss of organic matter.

Southwest Monsoon: Also known as the summer monsoon, it is a seasonal prevailing wind that blows from the southwest across the Indian subcontinent, bringing heavy rainfall to much of the region during the months of June to September.

Spatial Data: Information that is referenced to specific geographical locations, often used to analyze patterns and trends across different areas.

Stakeholders: Individuals, organizations, or groups with a vested interest or concern in a particular issue or outcome.

Standard Operating Procedures (SOP): Established protocols and guidelines outlining the step-by-step processes for carrying out specific tasks or operations.

Strong Heat Stress: A condition characterized by elevated levels of thermal discomfort and heat stress, typically defined as temperatures exceeding 32 degrees Celsius equivalent temperature. This measure accounts for factors such as air temperature, humidity, wind speed, and radiation to assess the level of discomfort experienced by individuals due to heat exposure. Strong heat stress can pose health risks, particularly to vulnerable populations, and may lead to heat-related illnesses such as heat exhaustion or heat stroke.

Sustainability: Involves ensuring the persistence of natural and human systems, implying the continuous functioning of ecosystems, the conservation of high biodiversity, the recycling of natural resources and, in the human sector, successful application of justice and equity.(IPCC 2022)

Sustainable Development Goals (SDGs): The 17 global goals for development for all countries established by the United Nations through a participatory process and elaborated in the 2030 Agenda for Sustainable Development, including ending poverty and hunger; ensuring health and well-being, education, gender equality, clean water and energy, and decent work; building and ensuring resilient and sustainable infrastructure, cities and consumption; reducing inequalities; protecting land and water ecosystems; promoting peace, justice and partnerships; and taking urgent action on climate change. (IPCC 2022)

Temperature Humidity Index (THI): A measure used to quantify discomfort levels by considering both temperature and humidity in a given environment.

Thermal Comfort: The condition of mind that expresses satisfaction with the thermal environment, influenced by factors such as air temperature, humidity, air speed, and personal clothing.

Thermal Discomfort or Stress: A condition where individuals experience discomfort or stress due to high temperatures, often resulting in health issues such as heat exhaustion or heat stroke.

Thermoregulatory Systems: Physiological mechanisms that maintain a constant body temperature (homeostasis) within a narrow range despite fluctuations in environmental temperature or metabolic heat production.

Thunderstorms: Atmospheric disturbances characterized by lightning and thunder, often accompanied by heavy rain, strong winds, and sometimes hail.

Time-of-Use Pricing: A pricing strategy where electricity rates vary based on the time of day, encouraging consumers to shift their usage to off-peak hours.

Tropical Cyclones: Intense rotating storms that form over warm ocean waters and can cause destructive winds, heavy rainfall, and storm surges when they make landfall.

Urban heat island (UHI): The relative warmth of a city compared with surrounding rural areas, associated with heat trapping due to land use, the configuration and design of the built environment, including street layout and building size, the heat-absorbing properties of urban building materials, reduced ventilation, reduced greenery and water features, and domestic and industrial heat emissions generated directly from human activities. (IPCC 2022)

Urbanisation: Urbanisation is a multi-dimensional process that involves at least three simultaneous changes: (1) land-use change: transformation of formerly rural settlements or natural land into urban settlements, (2) demographic change: a shift in the spatial distribution of a population from rural to urban areas and (3) infrastructure change: an increase in provision of infrastructure services including electricity, sanitation, etc. Urbanisation often includes changes in lifestyle, culture and behaviour, and thus alters the demographic, economic and social structure of both urban and rural areas. (IPCC 2022)

UTCI: Universal Thermal Climate Index. It is a measure used to assess the thermal comfort or stress experienced by individuals based on environmental factors such as air temperature, wind speed, humidity, and radiation.

Vector-borne Diseases: Diseases caused by pathogens such as viruses, bacteria, or parasites that are transmitted to humans through vectors such as mosquitoes, ticks, and fleas.

Vegetation Change: Alterations in the type, density, and distribution of plant species over time, often influenced by environmental factors such as climate change and human activities.

Vulnerability index: A metric characterising the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability.(IPCC 2022)

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.(IPCC 2022)

Vulnerable Groups: Populations that are particularly susceptible to the impacts of extreme heat, including children, the elderly, pregnant women, and outdoor workers.

Warm Night: A meteorological phenomenon characterized by nighttime temperatures that are notably higher than the seasonal or historical average, typically occurring when the minimum temperature departure from the normal range is between 4.5°C to 6.4°C.(IMD, 2024)

Water Quality Degradation: The decline in the quality of surface water and groundwater due to contamination by pollutants, chemicals, or biological agents.

Water security: The capacity of a population to safeguard sustainable access to adequate quantities of acceptable-quality water for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against waterborne pollution and water-related disasters and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013).

Well-being: A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive and to feel satisfied with one's life. Ecosystem well-being refers to the ability of ecosystems to maintain their diversity and quality.(IPCC 2022)

Wet bulb temperature: The Wet Bulb Globe Temperature (WBGT) is an indicator of heat related stress on the human body at work (or play) in direct sunlight. It takes into account multiple atmospheric variables, including: temperature, humidity, wind speed, sun angle, and cloud cover. This is usually considered to be 35C, approximately equivalent to an air temperature of 40C with a relative humidity of 75%

Wetland: Land that is covered or saturated by water for all or part of the year (e.g., peatland).(IPCC 2022)

Yields: The amount of agricultural or horticultural product harvested per unit area of land, such as crop yields or livestock yields.

Zero-Burning Policies: Regulations prohibiting the burning of crop residues and incentivizing alternative methods for managing agricultural waste.

Zoonotic Diseases: Diseases that can be transmitted from animals to humans.

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