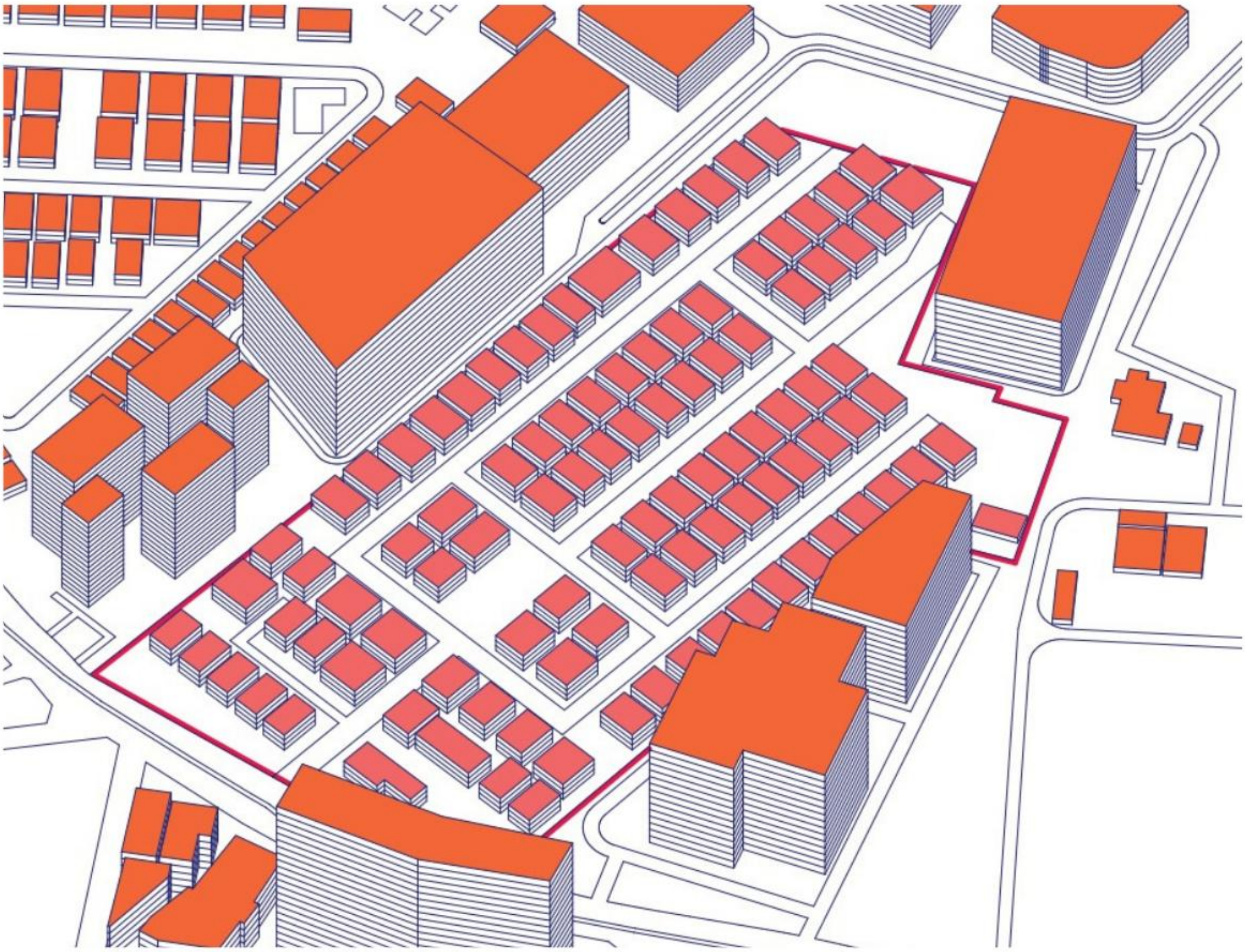
TUR_24_01 | AMRUT Funded Centres of Urban Planning for Capacity Building | SPAV

INTERIM REPORT



COOLING STRATEGIES FOR HYDERABAD

Canopy Layer Mitigation Measures Local Climate Zone Approach

Atal Mission for Rejuvenation and Urban Transformation

AMRUT Centre of Urban Planning for Capacity Building

A-CUPCB-SPAV

School of Planning and Architecture Vijayawada

Project Team

Dr. Faiz Ahmed Chundeli (PI)

Email: faizahmed@spav.ac.in ; Ph: +91 94455 45513

Ar. Vijesh Kumar V (Co-PI)

Ar. Kapil Natawadkar (Member)

Nakka Sunny (Project Officer)

Ar. Jyoti Kushwaha (Student Member)

Ar. Fathima Shouheen (Student Member)

Ar. Sakshi Agarwal (Student Member)

TABLE OF CONTENTS

LIST OF MAPS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Global warming is a critical challenge for humanity in the coming decades, while rapid urbanization exacerbates Urban Heat Islands (UHI). Rising temperatures and the UHI effect led to increased extreme weather events such as heatwaves, especially in core cities. In this context, climate-responsive urban planning and design strategies have gained traction globally. The need for developing Canopy Layer UHI mitigation strategies in Hyderabad also arises from the city's rapid urbanization, which has led to significant temperature increases in specific areas, intensifying the effect. This phenomenon impacts public health, increases energy consumption, and challenges urban sustainability. By using the Local Climate Zones (LCZs) approach and mapping indices such as NDVI, NDWI, NDBI, and LST, the research identifies hotspots and assesses the impact of urban development on temperature variations. Tools like ENVI-met and Urban Weather Generator (UWG), Cliamtestudio will be used to process the data obtained through field measurements and modified weather files of the identified hotspots. Analyzing these relationships facilitates the creation of targeted zoning regulations and the developing of practical solutions for mitigating heat effects, thereby enhancing climate resilience and improving living conditions in Hyderabad.

Chapter 1: INTRODUCTION

1.1 Background

1.1.1 Urban Heat Island (UHI)

Urban Heat Islands (UHIs) refer to the phenomenon in which cities and urban areas experience higher temperatures compared to their surrounding rural areas. This temperature gap comes from the interplay of various factors within the urban environment and the atmosphere, leading to distinct types of UHIs operating at different scales. The three primary types of UHIs include the surface layer UHI, the canopy layer UHI, and the boundary layer UHI. Each type is characterized by specific spatial scales and particular heat dynamics, contributing to the overall temperature variations observed within urban landscapes.

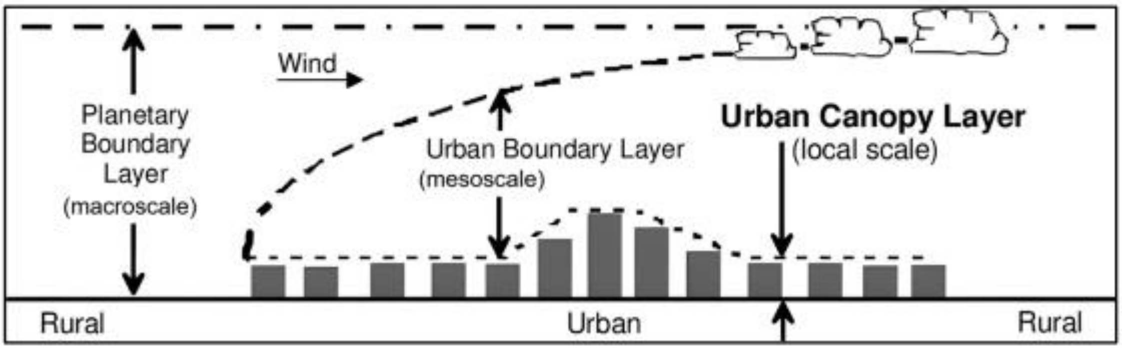


Figure 1.1: Layers of the urban atmosphere

1.1.2 Scales of UHI

Urban Heat Island (UHI) effects can be observed at different spatial scales, each with distinct characteristics and contributing factors. The main scales of UHI are Surface Layer UHI (Micro Scale to Local Scale), Canopy Layer UHI (Local Scale to Meso Scale), Boundary Layer UHI (Mesoscale to macroscale).

UHI Layer	Scale of Study	Description
Surface layer UHI	Microscale to Local Scale	The surface layer is the layer closest to the ground and typically extends up to a height of a few meters. The surface layer is influenced mainly by the thermal properties of urban materials. It is often characterized by an increase in temperature due to the absorption and re-radiation of heat by materials.
Canopy layer UHI	Local Scale to Mesoscale	The urban canopy layer is the layer above the surface layer and it extends from the ground up to the roof of buildings. This layer is influenced by the urban form, which affects sun exposure and airflow

		and can therefore create trapped "heat pockets" between buildings. At this layer, Urban Heat Islands are typically measured using ground-based methods. This includes mobile measurement throughout cities and their surroundings, or fixed networks of sensors distributed within and around cities.
Boundary Layer UHI	Mesoscale to Macroscale	The urban boundary layer UHI sits above the urban canopy layer and varies in thickness, from hundreds of meters at night to over a kilometer during the day. This layer is influenced by anthropogenic heat as well as meteorological conditions; it can trap heat and pollutants, resulting in negative impacts on air quality and public health.

The scope of this study is limited to Canopy Layer UHI. Canopy Layer UHI, exists from the ground up to the height of trees and buildings. This is the most relevant to human activities.

The Canopy Urban Heat Island (CUHI) effect represents the temperature difference between an urban area and a rural area at the air temperature level (typically measured at 1.5–2 meters above ground).

$$\mathbf{CUHIs = ATs - ATr}$$

Were,
ATs = Air Temperature in the Urban Area
ATr = Air Temperature in the Rural Area
CUHIs = Urban Air Temperature – Rural Air Temperature

1.1.3 Factors affecting UHI

Urban overheating is caused by an imbalance in heat gains, storage, and losses in cities. Urban areas absorb more heat and lose less compared to rural surroundings, leading to higher temperatures. This effect, known as the urban heat island (UHI) phenomenon, is one of the most documented climate change impacts.

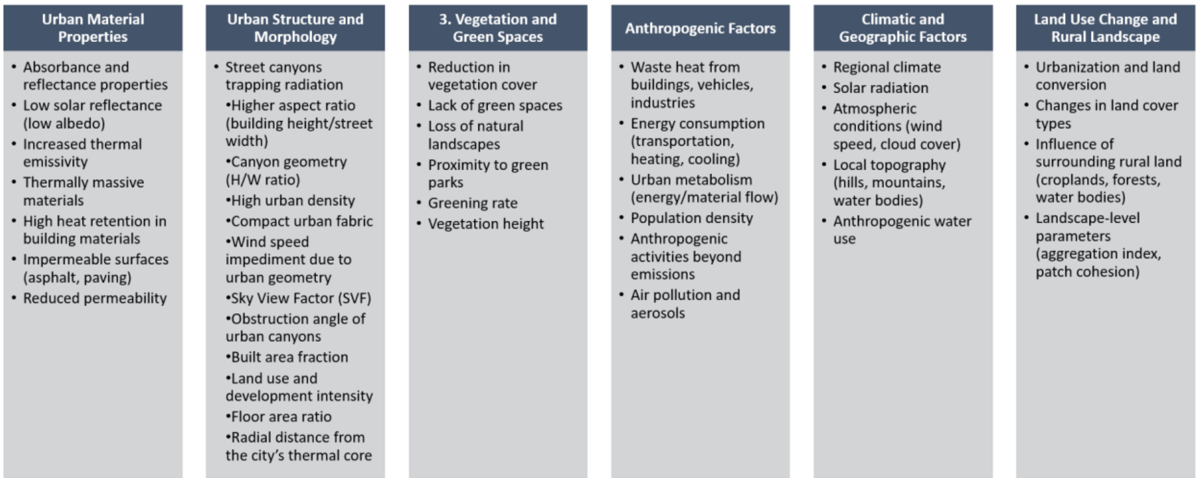
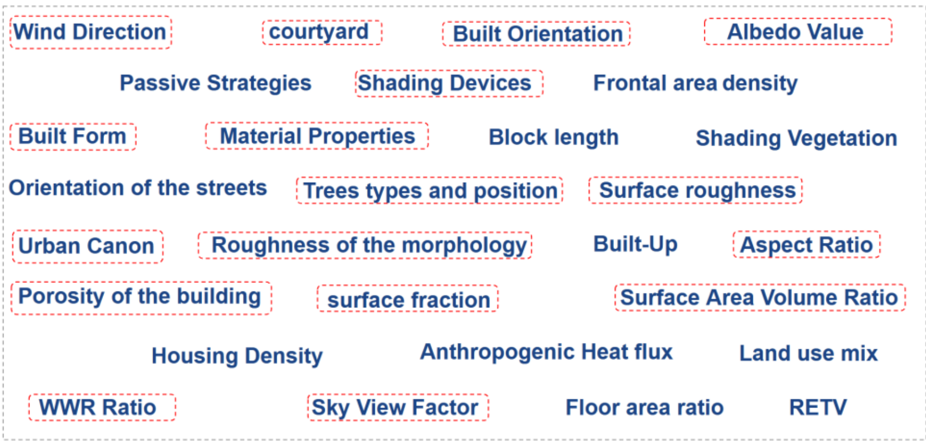


Figure 1.2 Factors affecting UHI form Literature review

Numerous factors and parameters are used to describe and analyse urban morphology that contributes to UHI and energy consumption. Some examples include:

- Building density (Wang et al., 2022) (Zhou et al., 2017)
- Floor area ratio (Oh et al., 2021)
- Building height distribution (Wang et al., 2022)
- Canyon aspect ratio (Wang et al., 2022)
- Frontal area density (Wang et al., 2022)
- Land use mix (Shi et al., 2017)
- Street density (Shi et al., 2017)
- Block length (Shi et al., 2017)
- Sky view factor (Shi et al., 2017)
- Surface to volume ratio (Wang et al., 2022)
- Street orientation (GRIHA)

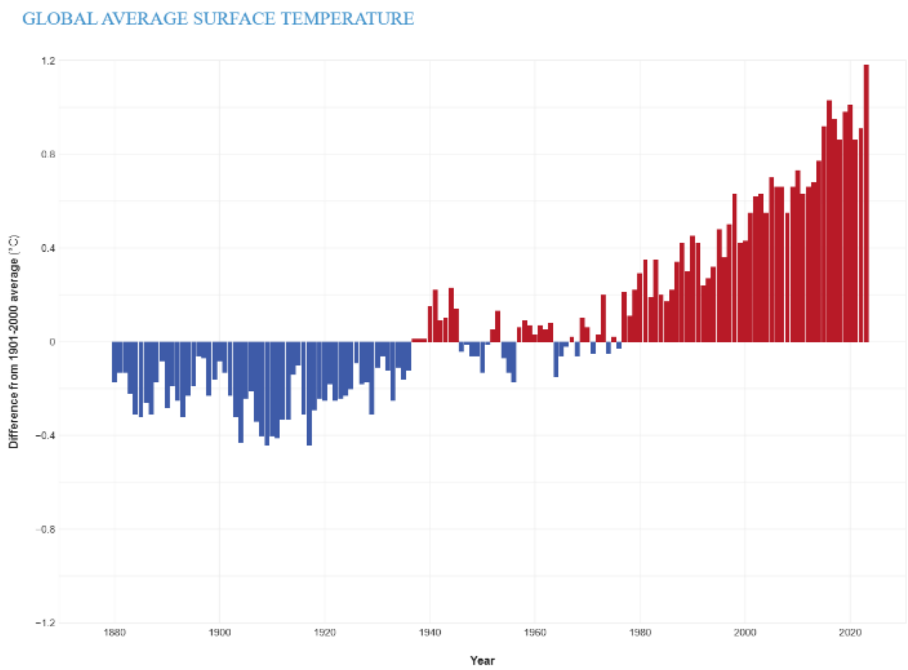


1.1.4 Urban Climate Scenario

Given the tremendous size and heat capacity of the global oceans, it takes a massive amount of added heat energy to raise Earth's average yearly surface temperature even a small amount. The roughly 2-degree Fahrenheit (1 degrees Celsius) increase in global average surface temperature that has occurred since the pre-industrial era (1850-1900 in NOAA's record) might seem small, but it means a significant increase in accumulated heat (Urban Climates, n.d.).

Adaptation to climate change, as defined by the **IPCC (2007)**, can be categorized into **anticipatory, autonomous, and planned adaptation**. These strategies have influenced territorial management and urban planning discussions. While **sustainability** has been a core focus in recent decades, **adaptation** aims to ensure long-term resilience through targeted strategies and actions. Given the complexity of predicting climate changes across different scales and environments, adaptation must not only maintain system functionality but also leverage emerging opportunities. (Matzarakis et al., 2016)

Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020 (*NOAA*, 2025).



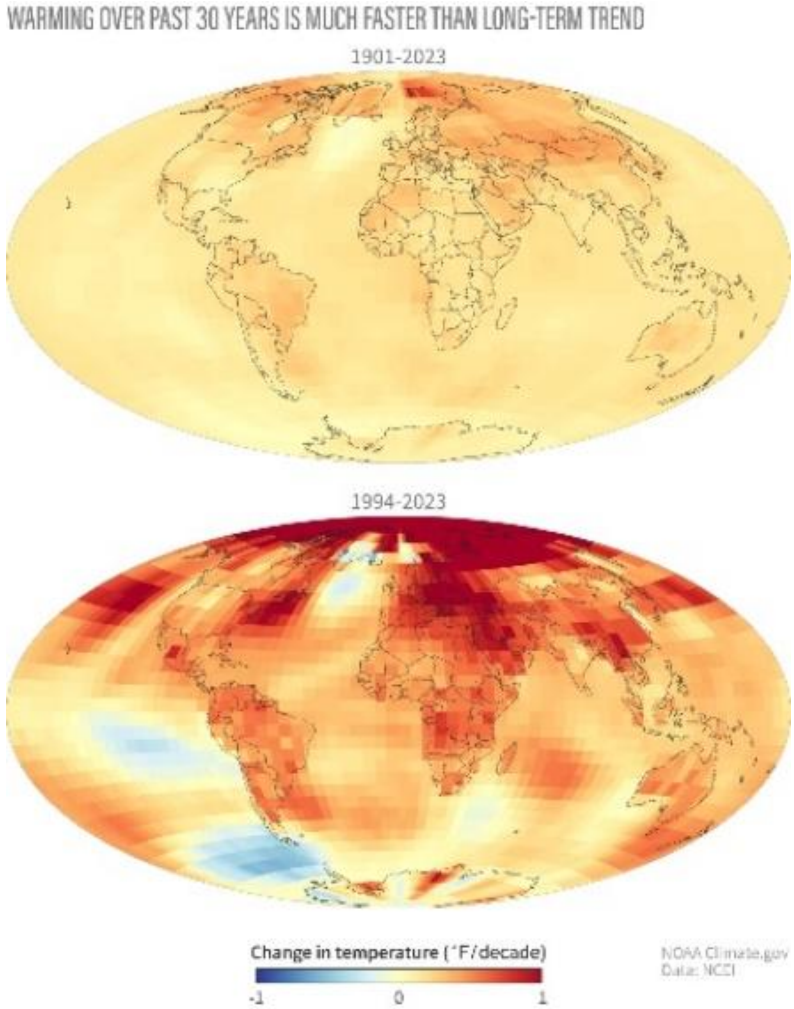
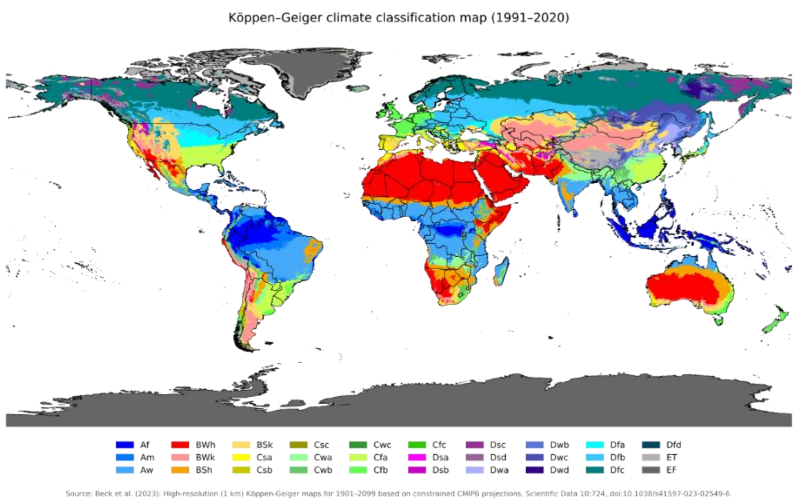


Figure 1.3 Global surface temperature and change in temperature trend

The Köppen climate classification scheme divides climates into five main climate groups: A (tropical), B (arid), C (temperate), D (continental), and E (polar). The second letter indicates the seasonal precipitation type, while the third letter indicates the level of heat.



The Köppen climate classification is the most widely used system for categorizing global climates. Originally developed by German-Russian climatologist Wladimir Köppen in 1884, it underwent several modifications, notably in 1918 and 1936. Later, German climatologist Rudolf Geiger introduced further refinements in 1954 and 1961, leading to the system being referred to as the Köppen–Geiger climate classification.

The study done by (Raymond et al., 2020) examines the rising frequency of extreme humid heat events worldwide, particularly those **surpassing human physiological limits**. The authors find that such extreme conditions, approaching or exceeding human tolerance, have already occurred in certain regions and are intensifying at a rapid pace.

India, with a population of approximately 1.35 billion (as of 2018), is the second most populous country, characterized by high built-up density. It is highly disaster-prone, with most regions vulnerable to extreme events. Urbanization is accelerating, with 33.6% of the population living in cities, a trend expected to continue due to migration. This rapid growth, coupled with challenges like the Urban Heat Island (UHI) effect, will intensify heatwave impacts across the country. (NDMA, 2019)

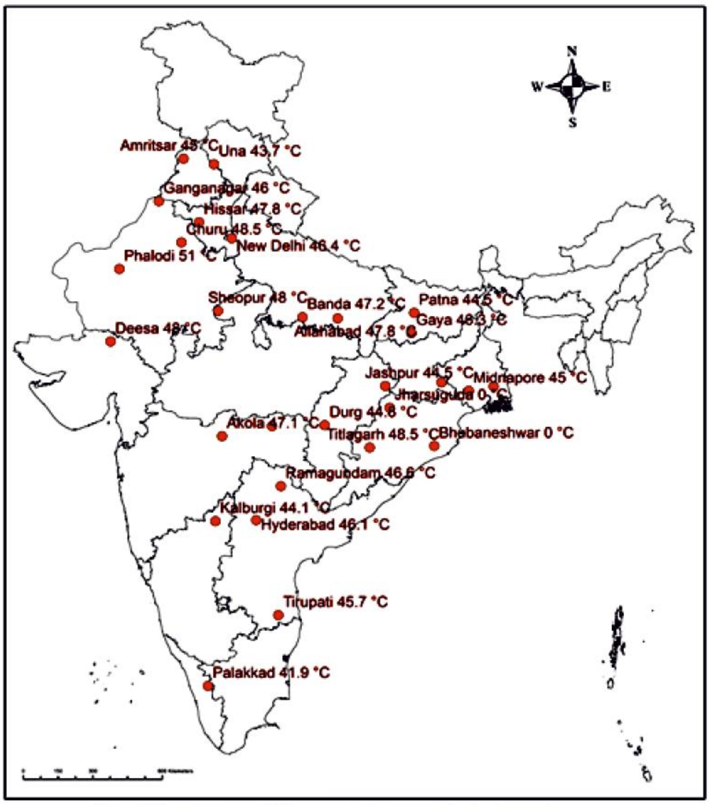


Figure 1: Higest ever recorded temperature at some station in the country

Figure 1.4 Highest Temperature record, Source: NDMA, 2019

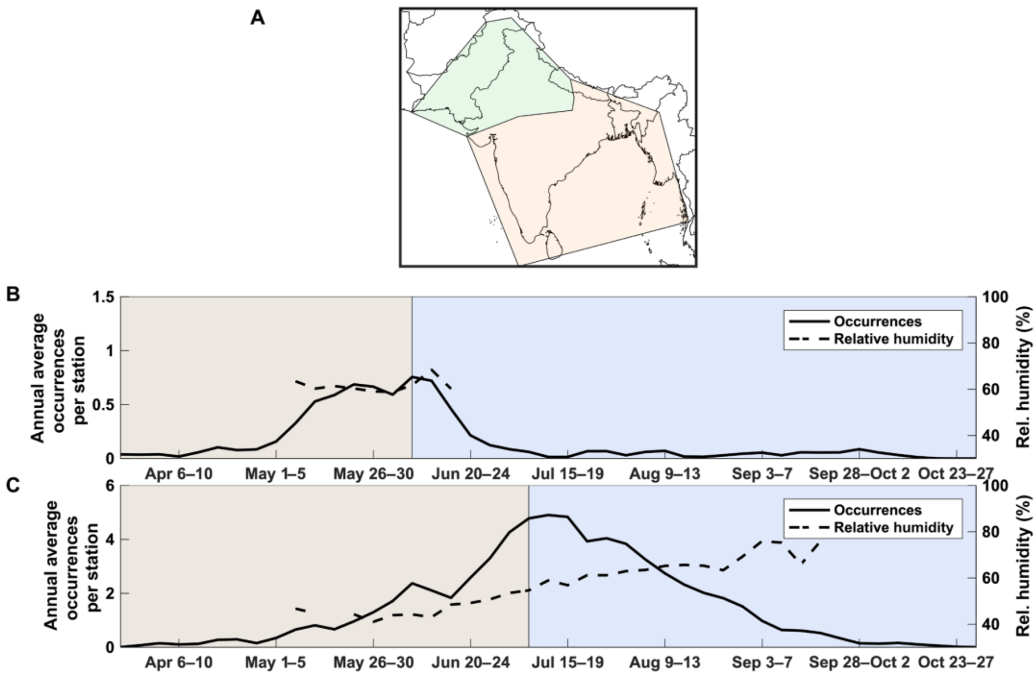


Figure 1.5 modulated seasonality of extreme humid heat.

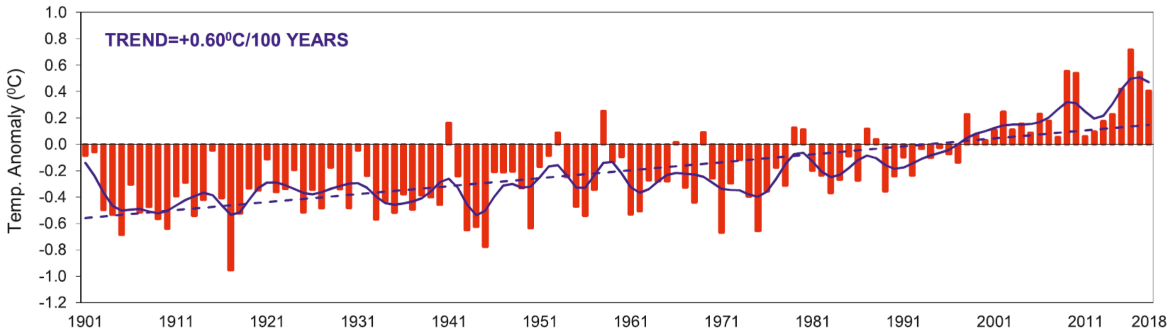


Figure 1.6 Annual mean land surface air temperatures anomalies

1.1.5 Properties of the Urban Surface

An urban system is composed of an almost limitless number of climatically-active surfaces. They consist of a range of fabrics each of which has different climatic properties including the following:

Property Type	Key Characteristics
Radiative	Geometry, absorptivity, reflectivity, transmissivity, emissivity.
Thermal	Specific heat, heat capacity, thermal conductivity, thermal diffusivity, thermal admittance.
Moisture	Interception and storage capacity, permeability, stomatal characteristics, chemical nature.

Aerodynamic	Roughness, zero-plane displacement, porosity.

1.1.6 Urban Environment

As urban populations grow, settlements expand, altering both the atmosphere and natural ecosystems. Urban ecology examines the interactions between living organisms and their environment in cities. Urban ecosystems consist of biological populations and abiotic factors shaped by human activity. The cultural environment includes built structures, while the biophysical environment encompasses natural elements. Urban climatology can help to make informed decisions during this transformation, for example, to efficiently use energy and water in cities, mitigate and adapt to global climate change and combat air pollution (Oke et al., 2017).

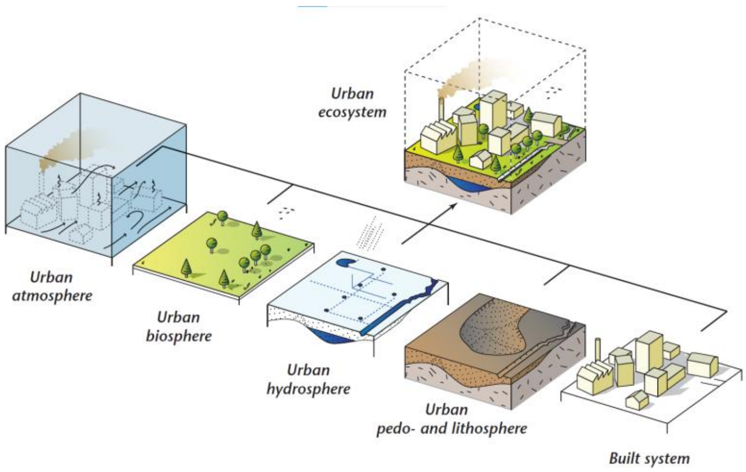


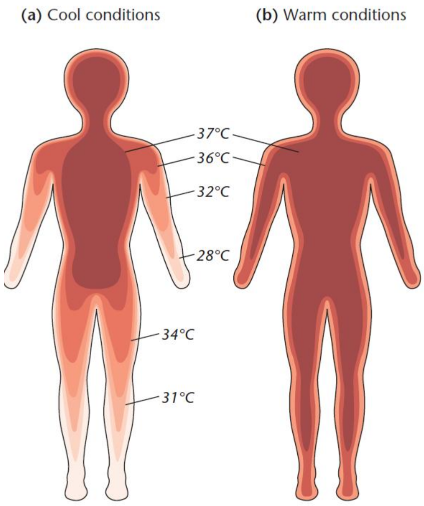
Figure 1.7 Urban ecosystems

Urban systems can be broadly characterized by their urban form (**fabric, land cover, geometric structure)** and urban function **(land uses, industrial and other processes, transport, etc.)**. Both affect the atmosphere through either physical (e.g. roughness) or chemical influences (e.g. air pollutant emissions). (Oke et al., 2017).

1.1.7 Thermal Comfort in Urban environment

The variation in the urban morphology of a city impacts its thermal comfort, and this phenomenon has been studied using the thermal comfort index in numerous research, UTCI is a proven tool for urban planning an landscape-related research, so it is used in this study to evaluate OTC. (Madhavan & Kannamma, 2024a).

Thermal stress and body strain result from the body's continuous adjustment to environmental changes to maintain thermal equilibrium ($\Delta QS \approx 0$). Six key variables regulate these exchanges: radiation, air temperature, humidity, and wind speed, which define the exposure environment, while metabolism and clothing represent individual responses. When environmental conditions impose thermal stress, the body reacts with physiological responses such as sweating to regulate heat



PMV	PET	Thermal perception	Grade of physiological stress	Universal Thermal Climate Index (UTCI) (°C) range	Physiological responses
		Very cold	Extreme cold stress	< 40	Decrease in core temperature
−3.5	4			−27 to −40	Shivering, average skin temperature will fall below 0°C if exposure is sustained
−2.5	8	Cold	Strong cold stress	−13 to −27	Face temperature < 7°C (numbness), core to skin temperature gradient increases
		Cool	Moderate cold stress	0 to −13	Vasoconstriction, exposed skin temperature < 15°C
−1.5	13	Slightly cool	Slight cold stress	+9 to 0	Localized cooling, need for gloves
−0.5	18				
		Comfortable	No thermal stress	+9 to +26	Comfortable, sweat rate < 100 g h^{-1}
0.5	23				
1.5	29	Slightly warm	Slight heat stress	+26 to +32	Slight heat stress
		Warm	Moderate heat stress	+32 to +38	Positive change in rate of sweating, and of skin temperature
2.5	35	Hot	Strong heat stress	+32 to +38	Sweat rate > 200 g h^{-1}
3.5	41			+38 to +46	Small core to skin temperature gradient (< 1 K). Sweat rate increase (> 650 g h^{-1} at limit)
		Very hot	Extreme heat stress	> 46	Increase in core temperature

Figure 1.8 a) The temperature distribution and the ranges

1.1.8 Local Climatic Zones

Urban surfaces are classified based on four key climate controls: **fabric, land cover, structure, and metabolism**. These factors tend to cluster within cities, influencing their local climate. City centers often feature dense, tall buildings with impervious surfaces that store heat and emit pollutants, while suburban and rural areas have lower-density housing with more greenery, leading to lower heat emissions but higher water use through irrigation. This spatial clustering forms the basis of the **Local Climate Zone (LCZ) scheme**, which categorizes urban and natural environments based on their climatic impact. LCZs are determined by measurable physical properties like **impermeability, roughness, thermal behavior, and energy and water usage**. Unlike traditional land use classifications (e.g., residential, commercial), which focus on function, LCZs emphasize physical characteristics that directly affect climate, making them valuable for urban climate studies.

LCZs are likely to be more meaningful ways to classify urban districts at the local (neighbourhood) scale for urban climate purposes (Oke et al., 2017).

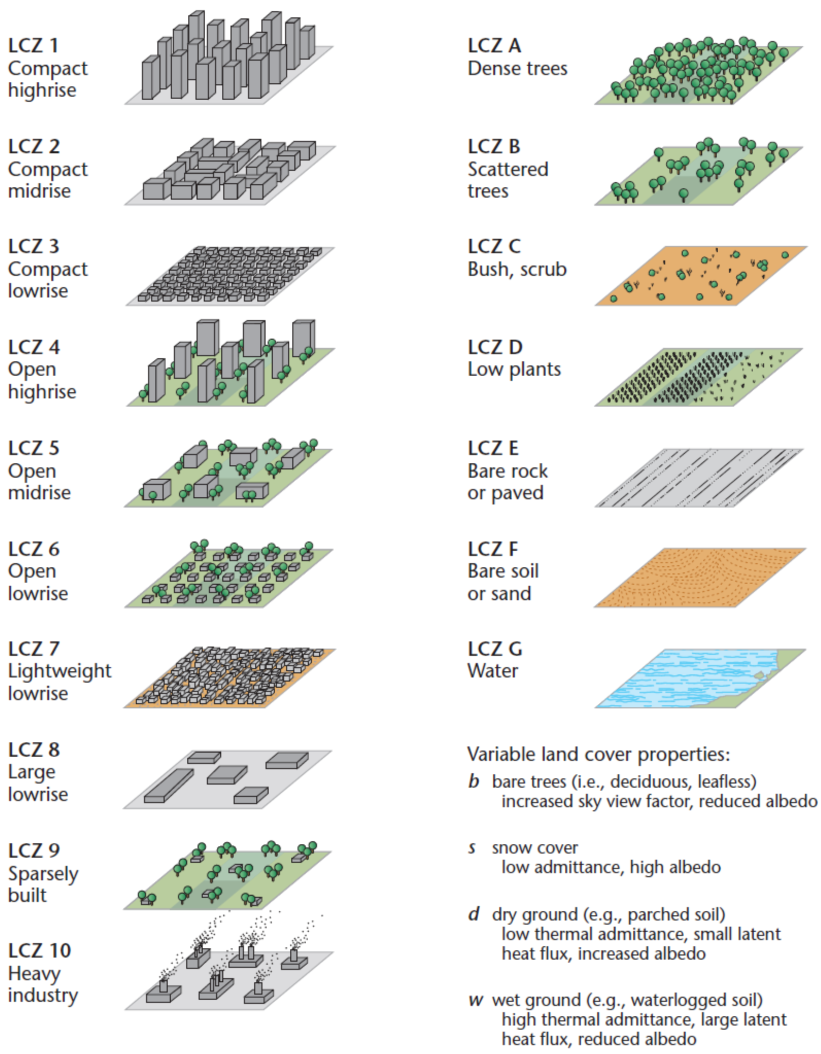
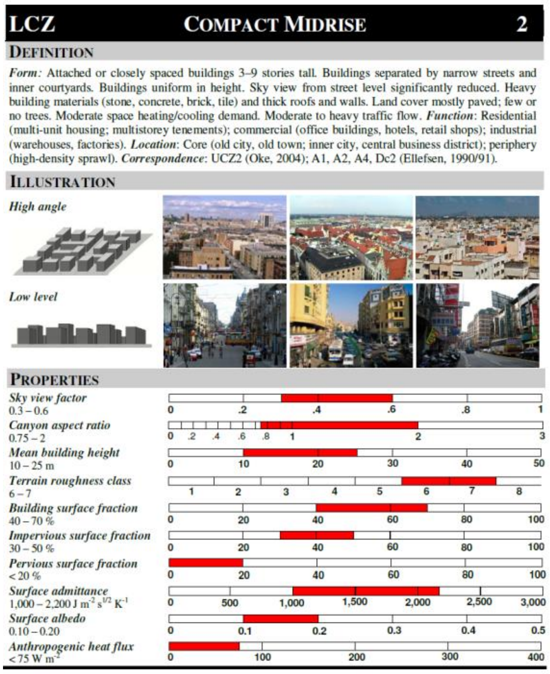
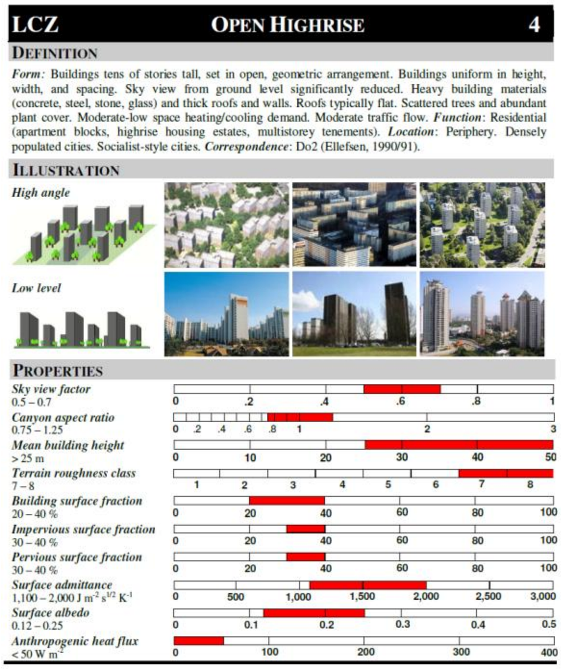
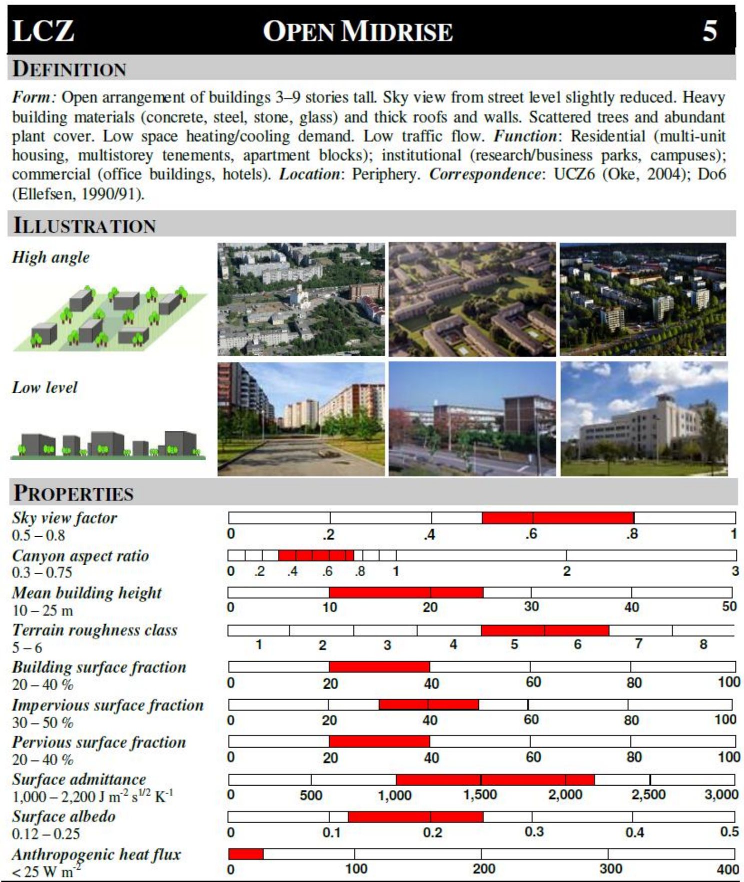


Figure 1.9 Classification of Local Climate Zones (LCZ)







1.1.9 LCZ explored for UHI mitigation strategies

Urban agglomeration is a serious concern due to its high energy usage and impact on the local climate. Developing countries strive to determine the development path to optimize energy usage. The problem we face due to urbanization is caused by poor planning strategies and unemployment n the towns and nearby villages, which cause a massive population to move towards the cities. The current issues raised by the urban population are related to energy consumption and heat waves. Additionally, the land surface temperature (LST) is increased by urbanization, which also negatively impacts the net primary productivity (NPP) of the Indian Ecosystem (Madhavan & Kannamma, 2024a) .

The local climatic zone is defined as a **“region of uniform surface cover, structure, material and human activity that span hundreds of meters to several kilometres in horizontal scale”.** In intra-urban climate studies, LCZ enables the researchers to divide the city into distinct zones. To effectively differentiate the city into different regions for climatic studies, developed a scheme called UCZ (urban climatic zone), which was later replaced by LCZ due to lower accuracy. The LCZ framework has been helpful in climate-based studies related to outdoor thermal comfort (OTC) and energy consumption. LCZ was created to construct urban climate studies that quantify the relationship between urban morphology and urban heat islands (UHIs) (Oke et al., 2017).

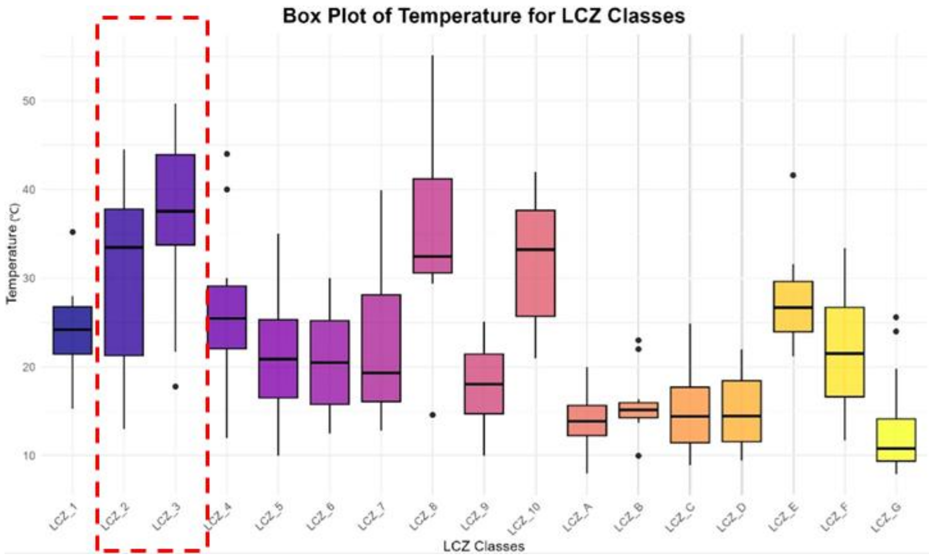


Figure 1.10 Box plot of Temperature for LCZ Classes

The UHII data reveals notable variations in heat island intensity among different LCZs, highlighting the influence of urban morphology, land use patterns, and other environmental factors on heat accumulation within urban areas(Rahmani & Sharifi, 2025).

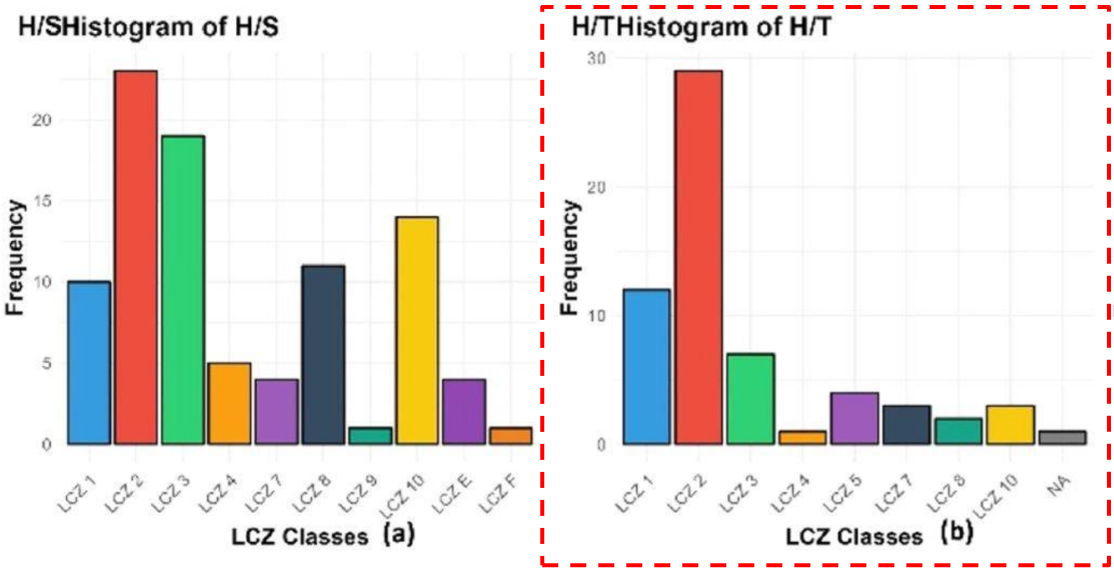


Figure 1.11 (a) illustrating the hottest LCZs in CUHI (h/t)

Figure 1.12 (b) depicting hottest LCZs based on SUHI measurements (h/s)

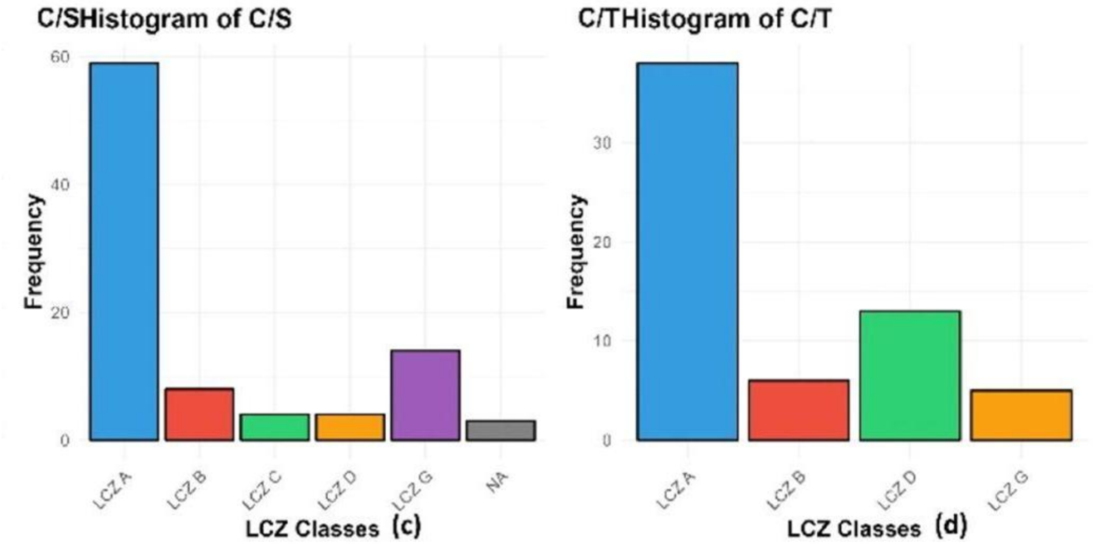


Figure 1.13 (c) showcasing the coolest LCZs in SUHI (c/s)

Figure 1.14 (d) presenting the coolest LCZs in CUHI (c/t)

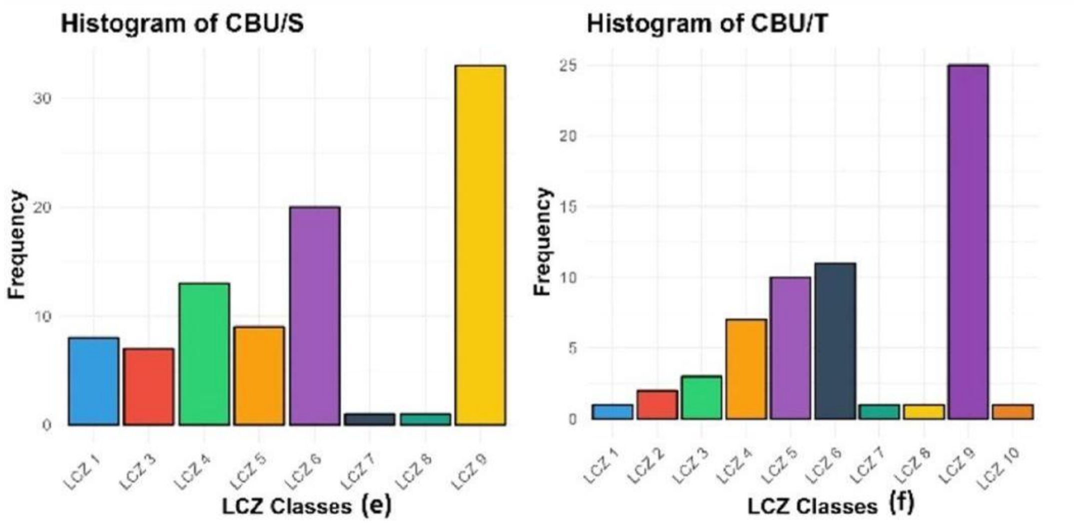


Figure 1.15 (e) displaying the coolest built-up (cbu/s) LCZs in SUHI

Figure 1.16 (f) delineating the coolest built-up (cbu/t) LCZs in CUHI

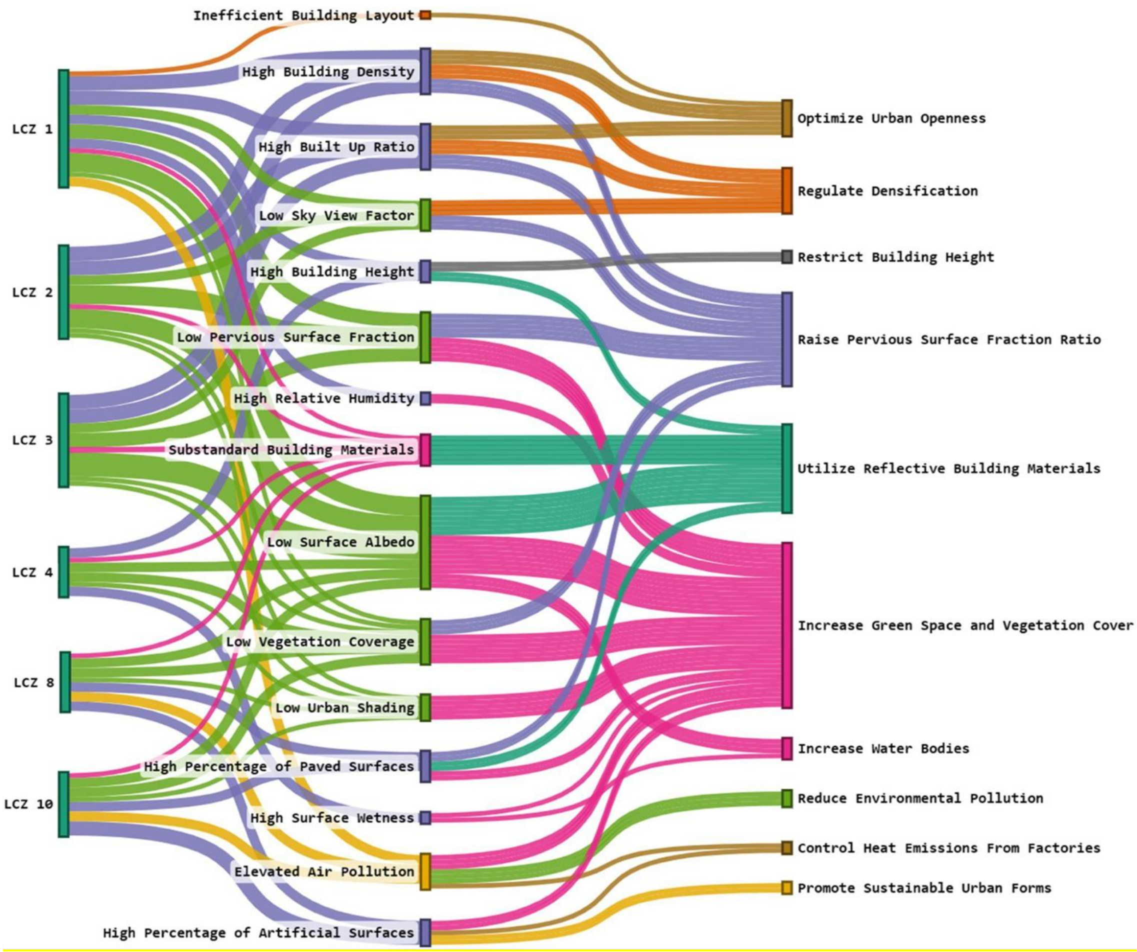


Figure 1.17 Major contributing factors to the UHI

Local climate zone (LCZ) land cover classification system has been effective in investigating the urban heat island (UHI) phenomenon. In mid-latitude tropical cities, temporal variation and composite type climate prove it difficult to evaluate critical LCZs. It is important to address which LCZ is most critical in terms of UHI and air temperature exposure and how to approach mitigation strategies for the same (Kotharkar et al., 2020a). Increasing green area ration is found to be a more effective strategy for the sparsely built (LCZ 9) and planned settlement with open spaces (LCZ 3F) while application of cool roof shows significant reductions in air temperature in the older unplanned settlement with dense urban agglomeration (LCZ 3).

The study concludes that LCZ 2_3 (compact mid-rise with open low-rise) and LCZ 6_B (open low-rise with scattered trees) perform better for 80% and 50% of total hours in warm and humid climate. It also proves the presence of significant performance differences between mid-rise and low-rise zones. The intra-zonal differences between the climatic variables are higher than the inter-zonal differences due to the impact of land surface temperature (LST). The high aspect ratio and low sky view factor of LCZ 2_3 help the residents in that morphology in enhancing better thermal comfort and reducing cooling load consumption (Madhavan & Kannamma, 2024a)

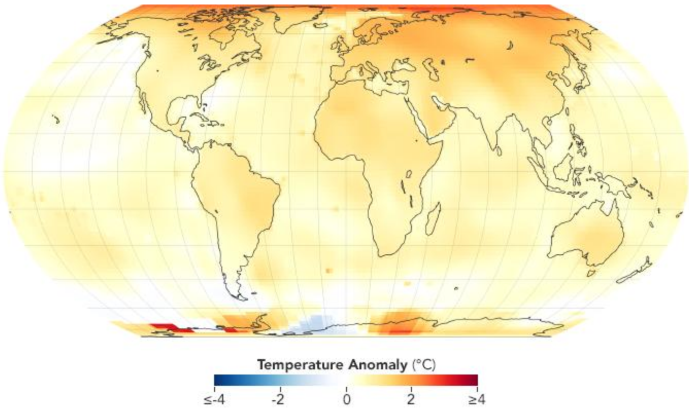
. By analyzing and comparing a large number of representative LCZ sites and multi-year remotely-sensed LST data, the aim of this work is twofold. Firstly, to study the suitability of the LCZ scheme, with a focus on the built types, for surface temperature studies in four distinct macroclimate regions, namely, the tropical, the arid, the temperate and the cold. Secondly, to understand the influence of the macroclimate region on the LST and SUHI characteristics of the standard LCZ built types. Results show that the urban LCZ standard scheme is applicable, with varying degrees, to all macroclimate regions other than the arid, where a LCZ subclassification might be essential. Also, it has been demonstrated that most LCZ built types exhibit significantly different LST and SUHI characteristics across the remaining macroclimate regions (Eldesoky et al., 2021a).

For tropical megacity Dhaka, open low-rise, mid-rise and high-rise morphology emerges as more favourable built environment benefiting both people and the local biodiversity. Conversely, areas comprising compact mid-rise, large low-rise and heavy industry buildings that are becoming increasingly densely populated, are the least suitable options. Given the increasing need for high-density living, our results indicate that the most suitable approach to planning would be to substitute compact low-rise housing, typically prevalent in developing country megacities as slums, with a combination of open high-rise and open mid-rise housing. This study demonstrates that increasing SUHI and LSTs can be mitigated in densely populated tropical megacities by appropriate planning using urban morphology as demonstrated by LCZ classification (Sharmin & Chappell, 2025a).

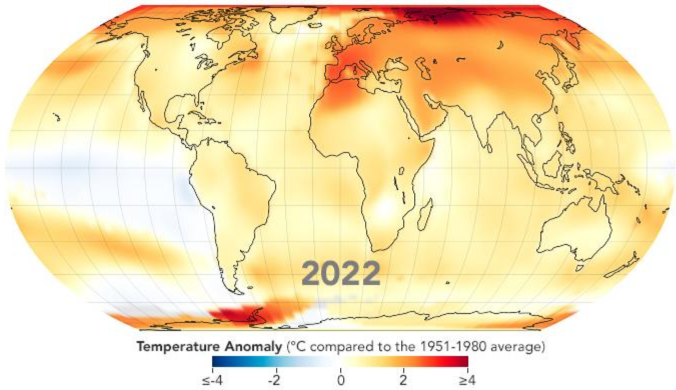
1.2 Need for the study:

Since the Industrial Revolution, Earth's air temperatures have been increasing. The overwhelming body of data suggests that human actions, especially the release of heat-trapping greenhouse gases, are mostly to blame for the warming of our world, even though natural variability plays a role.

The average global temperature has risen by at least 1.1° Celsius (1.9° Fahrenheit) since 1880, according to a current temperature analysis conducted by researchers at NASA's Goddard Institute for Space Studies (GISS). Since 1975, most of the warming has taken place, with an approximate yearly pace of 0.15 to 0.20°C.

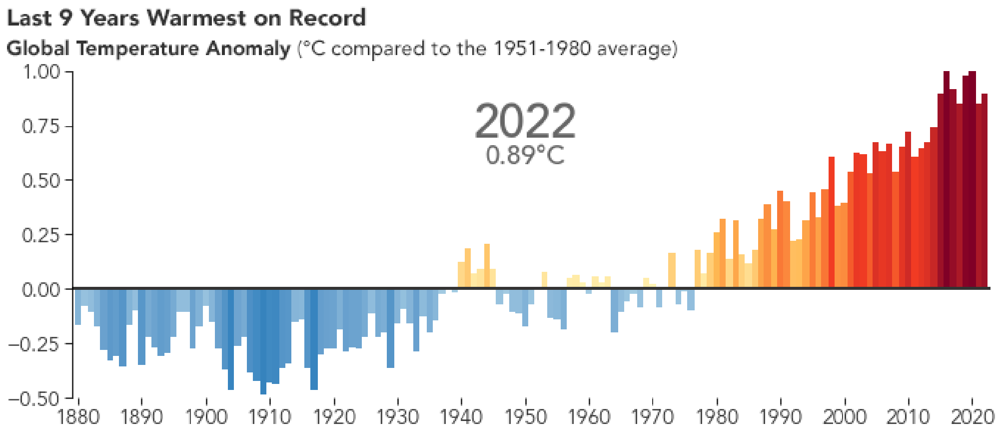


Map 1.1 Global Temperature Anomaly for 2009



Map 1.2 Global Temperature Anomaly for 2022

The map shows global temperature anomalies in 2022, which tied for the fifth warmest year on record. The past nine years have been the warmest years since modern recordkeeping began in 1880.



The temperatures we experience locally and in short periods can fluctuate significantly due to predictable, cyclical events (night and day, summer and winter) and hard-to-predict wind and precipitation patterns. But the global temperature mainly depends on how much energy the planet receives from the Sun and how much it radiates back into space. The energy coming from the Sun fluctuates very little by year, while the amount of energy radiated by Earth is closely tied to the chemical composition of the atmosphere—particularly the amount of heat-trapping greenhouse gases.

A one-degree global change is significant because it takes a vast amount of heat to warm all of the oceans, the atmosphere, and the land masses by that much. In the past, a one- to two-degree drop was all it took to plunge the Earth into the Little Ice Age. A five-degree drop was enough to bury a large part of North America under a towering mass of ice 20,000 years ago.

Source: NASA Earth Observatory

Recent climatic data for Hyderabad reveals a discernible warming trend in the city's mean annual temperatures over the past four decades, as shown in the graph depicting temperature anomalies from 1979 to 2024. While interannual variability is evident, the long-term pattern demonstrates a steady increase in average temperatures, with several years post-2000 consistently registering above the historical mean. The anomaly stripes—shifting from blue to progressively warmer shades of red—indicate an intensifying deviation from baseline climatic conditions, signaling prolonged exposure to elevated urban temperatures.

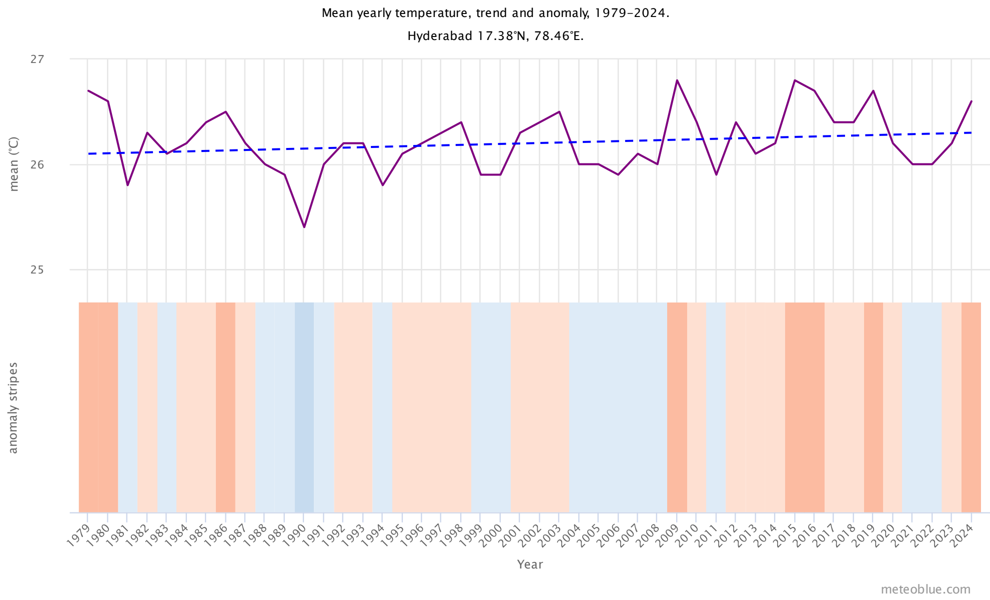


Chart 1.1 showing mean yearly temperature and anomaly, 1979-2024

This rise coincides with rapid urbanization, loss of green cover, and increased impervious surface areas in the city. Such warming patterns reinforce the urgency for comprehensive Urban Heat Island (UHI) studies in Hyderabad, as localized temperature spikes have direct implications on public health, energy demand, and thermal comfort. Understanding UHI dynamics is essential to formulate adaptive cooling strategies and inform resilient urban planning that mitigates heat stress for vulnerable populations.

Temperature and Humidity for Hyderabad – typical year

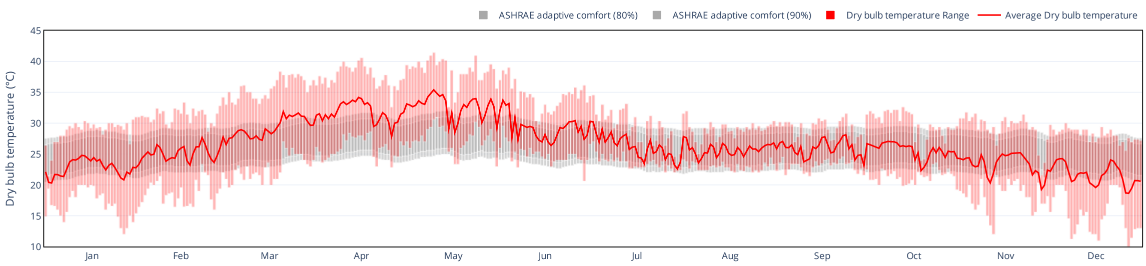


Chart 1.2 showing dry bulb temperatures for Hyderabad

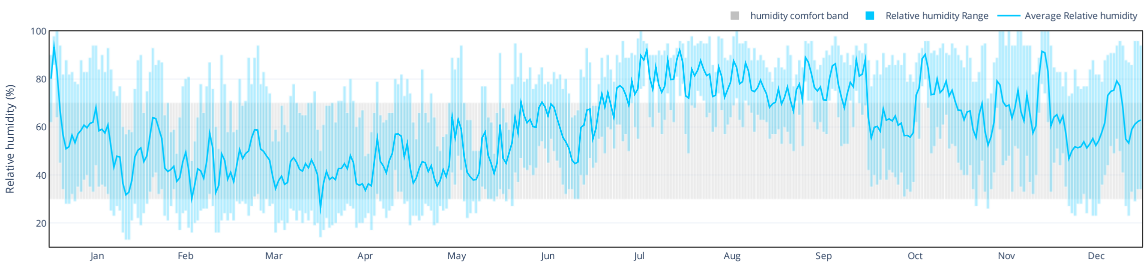


Chart 1.3 Showing Relative Humidity

The annual climate profile of Hyderabad demonstrates a clear inverse relationship between dry bulb temperature and relative humidity throughout the year. From March to May, the city experiences its peak temperatures, with average daily highs frequently exceeding 35°C, pushing well beyond the ASHRAE adaptive thermal comfort thresholds. During this same period, relative humidity levels drop significantly, often dipping below 30%, creating hot and arid conditions typical of pre-monsoon summer. Conversely, during the monsoon and post-monsoon months (June to September), temperatures moderate to around 30–32°C, while relative humidity surges above 70%, due to increased atmospheric moisture. This climatic pattern highlights the dual discomfort challenge for Hyderabad: intense heat with low humidity in summer and thermal stress due to high humidity in monsoon, both of which reduce outdoor thermal comfort and elevate Urban Heat Island (UHI) intensity. Understanding this interplay is essential for designing climate-responsive cooling strategies such as canopy cover enhancement, ventilation corridors, and reflective surfaces that can buffer both heat and humidity extremes.

1.3 Outcomes

Development of tailored Canopy Layer UHI mitigation strategies for Hyderabad's hotspots, based on Singapore's best practices in urban cooling. Strategies include increased tree cover, reflective surfaces, optimized urban ventilation, and water-based cooling solutions.

Reduction of extreme heat impacts, leading to improved thermal comfort and livability for hotspots identified in Hyderabad. Support for sustainable urban development through climate-responsive planning and nature-based solutions.

Creation of a scalable cooling strategy model that can be adapted to other Indian cities facing similar UHI challenges. Knowledge transfer from Singapore's successful cooling strategies to Hyderabad's urban planning framework.

A comprehensive suite of cooling strategies has been adapted from Singapore's acclaimed urban climate resilience model and integrated into the Project. These strategies address both spatial and architectural dimensions of urban design, aiming to mitigate the Urban Heat Island (UHI) effect while enhancing thermal comfort across the city. The framework includes green infrastructure interventions such as planting green roofs, vertical gardens, and infrastructure greenery, alongside the creation of parks, open spaces, and green corridors to restore ecological continuity. Additionally, blue features like wetlands, water catchment areas, and cool sinks are proposed to enhance evaporative cooling. The strategies also emphasize the optimization of urban form and canyon geometry, breezeways, and surface coverage to facilitate passive cooling and air circulation.

Furthermore, advanced material and building innovations—including cool pavements, retro-reflective surfaces, dynamic façades, and water-cooling envelope systems—have been considered to reduce thermal gain. Lastly, shading solutions and orientation-based building geometry are promoted to improve microclimate responsiveness. Collectively, these multi-scalar, integrated approaches are tailored to Hyderabad's context, offering a resilient roadmap for mitigating heat stress and enhancing urban livability.

1.3.1 Building Geometry

GEOMETRY OF URBAN CANYON

Sky view factor
Aspect ratio
Mean building/tree height
Building form
Variation between building heights
Wider streets

BREEZEWAY

Avoid obstruction
Open spaces along sea shore
Building porosity
Street axes orientation
Well-ventilated sidewalks
Building arrangement
Open spaces at road junctions
Guide wind flows with urban elements
Passive cooling systems

SURFACE COVERAGE

Urban density by Local Climate Zones
Building Surface Fraction
Green Plot Ratio
Topography

1.3.2 Material & Surfaces

STREETS AND OPEN SPACES

Cool pavements
Permeable surfaces
Photocatalytic cool pavements

BUILDINGS

Cool roofs
Cool façades
Photocatalytic cool building envelope
Retro-reflective materials
Phase Change Materials
Desiccant systems
Water cooling façade system
Thermochromic/selective materials
Dynamic and active roofs
Dynamic and active façades or building components
Building envelop performance

1.3.3 Shading

BUILDING GEOMETRY

Building orientation
Shading on buildings

SHELTER DESIGN

Permanent shading devices
Moveable shading devices
Smart shading devices
Shaded pedestrian spaces
Shaded bicycle lanes

1.3.4 Vegetation & Waterbodies

PLANTING GREENERIES

Green roofs
Vertical greeneries
Green walls/facades
Vegetation around buildings
Selective Planting
Green pavements
Infrastructure greenery

PARKS AND OPEN SPACES

Macroscale urban greening
Local scale urban greening
Microscale urban greening
Green parking lots
Tree species
Urban farming

GREEN CORRIDORS

Transport corridors

BODIES

Cool sinks
Blue and green spaces
Wetlands
Water catchment areas

FEATURES

Ponds on roofs/ground floor
Evaporative cooling
Fountains

Chapter 2: LITERATURE REVIEW

2.1 Consolidated Literature Review

Paper Name	Methodology	Tools Used	Conclusions/ Mitigation Strategies Suggested
Multi-objective method of selecting performance-based local climatic zones using binomial logistic regression in warm and humid climate (Madhavan & Kannamma, 2024b)	LCZ mapping using WUDAPT Level 0 data. - Urban morphology modeling. - Energy simulations using URBANopt. - OTC assessment via UTCI simulated in Rhino (LBT 1.6.0). - LST analysis from Landsat 8 images. - Binomial logistic regression for model selection.	WUDAPT, ArcGIS, Landsat 8, UWG, EPW files, URBANopt, Rhino (LBT 1.6.0).	Promote high aspect ratio, low SVF designs (LCZ 23). - Increase urban vegetation (LCZ 6B). - Implement targeted interventions based on LST.
A systematic approach for urban heat island mitigation strategies in critical local climate zones of an Indian city (Kotharkar et al., 2020b)	LCZ assessment in Nagpur, India. - TOPSIS analysis on summer air temperature data. - ENVI-met simulations for mitigation strategies.	TOPSIS, ENVI-met 4.0.	Increase GAR for LCZ 9 & 3F. - Apply cool roofs in LCZ 3. - Use cool pavements and trees for solar-exposed streets.
Modeling UHI on LCZs using Sentinel 3 images: Urban determining factors (Hidalgo	Granada divided into LCZs. - Data panel statistical analysis. -	Sentinel 3, QGIS, data panel analysis.	Optimize urban planning for vegetation, density, and energy use. - Research efficient

García & Arco Díaz, 2021)	Sentinel 3 imaging for LST and UHI study.		heating/cooling strategies.
Detecting UHI impact using LCZs in a tropical megacity (Sharmin & Chappell, 2025b)	Integrated urban morphology-based UHI estimates. - LST & NDVI analysis from satellite data.	Satellite data, LCZ mapping.	Increase greenery, use pervious & low-albedo materials, reduce high-density development.
Urban heat dynamics in LCZs: A systematic review (Rahmani & Sharifi, 2025)	Systematic literature review of 154 studies. - Content analysis.	Literature review, content analysis.	Increase green spaces, use reflective materials, optimize urban openness.
The suitability of LCZ classification for surface temperature studies in different macroclimate regions (Eldesoky et al., 2021b)	Analysed LCZ sites from different macroclimate regions. - Multi-year LST analysis from Landsat data. - Statistical tests (Kruskal–Wallis, Welch's, Dunn's).	Landsat 7 & 8, Google Earth Engine, SC algorithm, NDVI, GIS, R.	Use LCZ classification to guide urban planning. - Implement soil moisture management in arid regions.
UHI mitigation strategy based on LCZ classification using Landsat 8 (Yunita et al., 2022a)	LCZ classification of Jakarta using Landsat 8 & random forest. - LST analysis (2018–2020).	Landsat 8, random forest, GIS.	Implement urban forests, green roofs, shading, and cool materials. - Strengthen institutional frameworks for UHI mitigation.
An Application of the LCZ Approach in Surface Urban Heat Island Mapping in Sofia, Bulgaria (Dimitrov et al., 2021)		Statistical Analysis, Spatial Interpolation techniques, Heat load estimation.	Impact of Urban Morphology: The research confirms that areas with a higher proportion of green spaces tend to have lower surface temperatures, while built-up and impervious areas

			exhibit higher temperatures.
Assessment of green space cooling effects in dense urban landscape: a case study of Delhi, India		Statistical Analyses: Various statistical methods were used, including: Ordinary least square regression, Multiple linear regression, Spatial autoregression (SAR) to understand the relationships between urban greenery and cooling effects	The study concludes that urban green spaces play a crucial role in mitigating UHI effects, which is essential for the sustainable management of cities. The findings suggest that larger patches of green space with simple shapes (like circles or squares) are more beneficial than smaller, fragmented areas.
Local Climate Zones for Urban Temperature Studies (Stewart & Oke, 2012)		Tools used in the study comprise unmanned aerial systems (UAS) equipped with thermal radiometric infrared sensors and photogrammetric cameras, which enhance the resolution of thermal data collection.	The conclusions drawn indicate that the research approach is applicable to other urban studies, and the developed geoinformation model serves as a foundation for future assessments of UHI effects, emphasizing the need for urban adaptation strategies in light of climate change.
Urban Heat Island Mitigation Strategy based on Local Climate Zone Classification using Landsat 8 satellite imagery (Yunita et al., 2022b)	Classification of Landscape: To classify the landscape of Jakarta using the Local Climate Zone (LCZ) method, which takes into account urban morphology. Analysis of Land Surface Temperature	Landsat 8 Satellite Imagery: The study utilizes Landsat 8 satellite data to classify Jakarta's local climate zones into 17 classes. Random Forest Algorithm: This algorithm is employed to identify the spatial distribution of LCZ in Jakarta.	The study concludes that the spatial distribution of LCZ in Jakarta can be effectively identified using Landsat 8 satellite imagery and the random forest algorithm, which aids in understanding urban structure and characteristics to mitigate the negative impacts of urbanization.

	(LST): To analyze the land surface temperature range of each LCZ class and calculate the UHI intensity. Propose Mitigation Strategies: To propose possible strategies for mitigation and adaptation based on the actual conditions observed in Jakarta	Analysis of Thermal Characteristics: The study examines the thermal characteristics of different urban structures to understand their impact on UHI intensity	The addition of green spaces and cool roof materials is likely to be beneficial in reducing daytime temperatures in the area. UHI mitigation efforts should focus on densely populated areas that exhibit higher temperatures due to poor spatial layout and building material choices.

Table 2.1 showing consolidated literature review.

2.2 <u>Selection Criteria of Case studies referred</u>

Space Type	City	Strategies Implemented	Impact on Urban Quality of Life
Urban Rooftops	Basel, Switzerland	Mandating green roofs on all new and renovated flat-roofed buildings.	Enhanced urban biodiversity, improved air quality, reduced temperatures, increased green spaces.
Urban Neighborhoods	Houston, USA	Comprehensive heat mapping to guide targeted tree-planting efforts.	Reduction in surface temperatures, improved public health, equitable green infrastructure.
Urban Infrastructure	Paris, France	Planting trees, installing mist fountains, transforming rooftops.	Mitigated UHI, improved resilience, increased public comfort during heatwaves.

Public Walkways	San Antonio, USA	Shaded walkways, green roofs, misting systems.	Increased walkability, reduced auto-dependence, improved public comfort.
Urban Planning	Singapore	Urban forests, green roofs, integrated green infrastructure.	Mitigated UHI, improved urban livability, enhanced sustainability.
High-Rise Buildings	Mumbai, India	Traditional architectural elements (verandas, courtyards) for ventilation.	Enhanced thermal comfort, reduced energy use, improved connection with nature.
Urban Streets	Detroit, USA	Large-scale tree-planting and creation of green spaces.	Improved air quality, reduced urban heat, enhanced public health.
Urban Rooftops	London, UK	White roofs to reflect solar energy.	Lowered street temperatures, significant reduction in heat-related mortality.
Urban Green Belts	Ouagadougou, Burkina Faso	2,000-hectare green belt with trees, vegetable plots, water tanks.	Cooled urban areas, promoted urban agriculture, improved food security.
Urban Parks	New York City, USA	Expansion of green spaces (High Line, Brooklyn Bridge Park).	Increased recreational areas, improved mental health, reduced urban temperatures.
Urban Rooftops	Tokyo, Japan	Rooftop gardens and green walls.	Enhanced aesthetics, improved air quality, reduced building energy use.
Urban Streets	Melbourne, Australia	Urban forest strategy to double tree canopy cover by 2040.	Improved microclimate, enhanced biodiversity, increased public well-being.
Urban Infrastructure	Los Angeles, USA	Cool pavements and reflective coatings.	Reduced surface temperatures, decreased energy use, extended infrastructure lifespan.

Urban Rooftops	Toronto, Canada	Green Roof Bylaw requiring green roofs on new buildings.	Increased green space, improved stormwater management, reduced urban heat.
Urban Planning	Copenhagen, Denmark	Climate-resilient neighborhoods (green roofs, permeable pavements, urban waterways).	Enhanced flood management, reduced temperatures, improved quality of life.
Urban Streets	Seoul, South Korea	Urban green corridors, restoration of Cheonggyecheon Stream.	Improved urban aesthetics, increased biodiversity, provided cooling effects.
Urban Infrastructure	Athens, Greece	Cool roofs and reflective materials in public spaces.	Lowered ambient temperatures, reduced energy costs, improved comfort for residents and tourists.
Urban Rooftops	Chicago, USA	Green roof programs (City Hall Rooftop Garden).	Reduced heat, improved stormwater management, enhanced urban biodiversity.
Urban Planning	Rotterdam, Netherlands	Water plazas and green roofs for heat and flood management.	Improved climate resilience, enhanced urban aesthetics, provided recreational spaces.
Urban Streets	Barcelona, Spain	Superblocks to reduce traffic, increase green spaces, and promote pedestrian-friendly environments.	Decreased air and noise pollution, improved public health, enhanced social cohesion.

Type of Space	Type of Intervention	Criteria for Site Selection
Cities and Urban Centers	Urban design and greening, urban forestry, ecological infrastructure, cool materials,	Areas with high land surface temperature variations

	increased solar reflectance, evapotranspiration of urban surfaces	
Buildings and Houses	Green roofs, green facades, cool roofs, reflective materials, optimized radiation and air fluxes, street geometry modification	High energy demand and heat exposure
School Buildings and Hospitals	Vulnerability assessment and thermal comfort interventions	Areas with high vulnerability to overheating
Urban Parks	Tree planting, water-sensitive design, permeable surfaces, biophilic urbanism	Need for cooling and heat stress reduction
Street Canyons	Optimized urban morphology, ventilation corridors, shading strategies	High-density urban areas with limited airflow
Roads, Streets, Sidewalks, Parking Lots	High-albedo pavements, permeable materials, cool pavements	Areas with extensive impervious surfaces
Building Roofs and Walls	Cool roofs, green roofs, green walls, reflective coatings	Large heat-absorbing surfaces in dense urban areas
Coastal Megacities	Green corridors for airflow regulation, urban greening	Proximity to coastal waters with high heat absorption
Individual Lots and Buildings	3D modeling, UHI evaluation, green infrastructure integration	Urban areas with potential for customized solutions
Parking Lots	Shaded parking areas, solar canopies, permeable pavements	Large impervious spaces contributing to UHI
Disused Industrial Buildings	Adaptive reuse, green retrofits	Underutilized areas suitable for transformation
Urban Residential Blocks	Green buffers, optimized morphology for airflow	High-density peri-urban areas with microclimate variations
Areas within City Limits	Green, blue, or gray infrastructure (trees, lakes, parks, green roofs)	High urban heat stress with potential for green intervention

Public Spaces & Transit Corridors	Shaded bus stops, permeable surfaces, reflective coatings	Areas with high pedestrian footfall and transit congestion
Industrial Zones & Warehouses	Cool roofing materials, reflective walls, green buffer zones	Heat-prone industrial districts with large heat-absorbing surfaces
Urban Waterfronts & Riverfronts	Blue-green infrastructure, wetlands, tree-lined pathways	Sites near water bodies with potential for evaporative cooling
Informal Settlements & Slums	Community-led tree planting, low-cost cool roofs, passive ventilation	Areas with high population density and limited infrastructure
Mixed-Use Developments	Integrated green infrastructure, rooftop farming, climate-responsive designs	Urban zones with diverse land use needing holistic mitigation approaches

Chapter 3: PROJECT OUTLINE

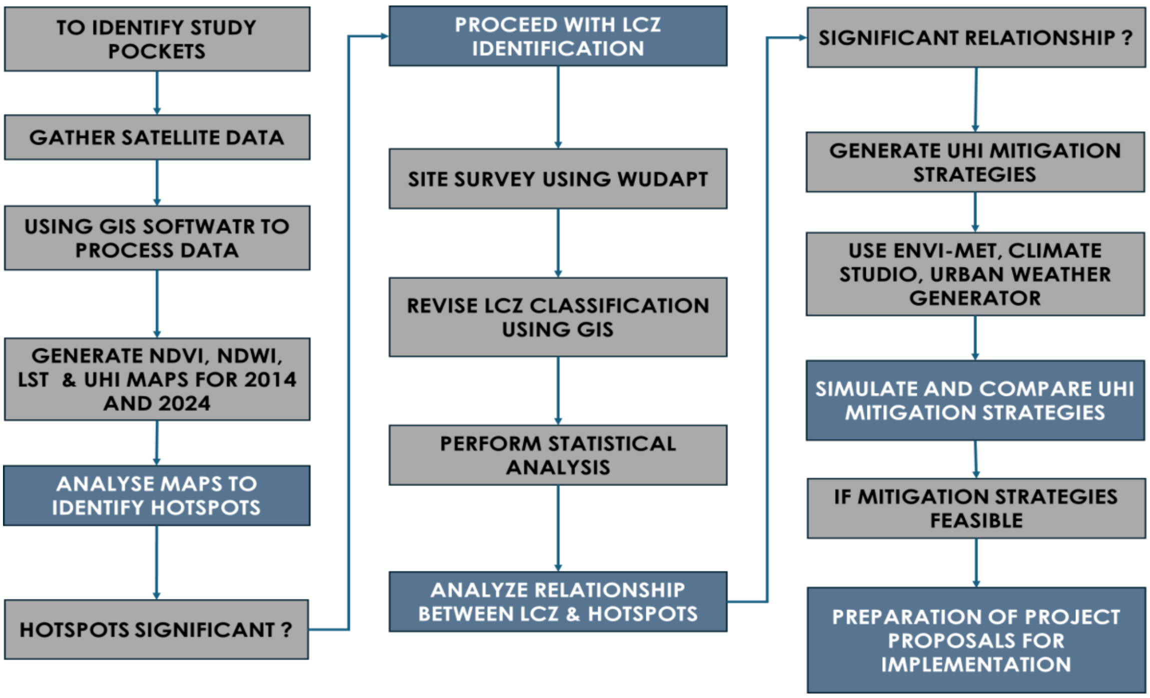
3.1 Aim of the study:

3.2 Objectives:

The project aims to develop evidence-based, implementable Canopy Layer UHI mitigation strategies for Hyderabad's hotspots using the Local Climatic Zones approach.

3.3 Framework and Methodology:

The entire project begins with the identification of study pockets and the gathering of satellite data. GIS software is then used to process this data, generating NDBI, LST, and UHI maps for 2004, 2014 and 2024. These maps are analyzed to identify UHI hotspots, after which LCZ identification is performed, incorporating site surveys using WUDAPT and GIS-based revisions of LCZ classifications. Statistical analysis is conducted, and the relationship between LCZs and UHI hotspots is analyzed. If a significant relationship is found between LCZ types and UHI hotspots, UHI mitigation strategies are generated and simulated using tools like ENVI-met, Climate Studio, and Urban Weather Generator, and then compared. Finally, if the mitigation strategies are deemed feasible, the project proceeds to the preparation of project proposals for implementation.



3.4 Scope and limitations:

The study aims to identify, simulate, and compare UHI mitigation strategies, providing a basis for project proposals.

The study relies on the accuracy and availability of satellite data, WUDAPT data, and GIS software.

The accuracy of UHI mitigation strategy simulations depends on the reliability of the ENVI-met, Climate Studio, and Urban Weather Generator.

Chapter 4: INTRODUCTION TO THE CASE AREA

Now that the research framework has been finalised, it is imperative that we choose a study area so that we can continue with our study. For this project we have considered Hyderabad City as the suitable case area based on the literature review.

Hyderabad is the capital of Telangana state. The city, founded in the year 1591 by Mohammed Quli Qutub Shah, the fifth sultan of Qutb Shahi dynasty, offers a fascinating panorama of the past, with richly mixed cultural and historical tradition spanning over 400 years. It is one of the fastest growing cities of India and has emerged as a strong industrial, commercial, technology center, gives a picture of glimpses of past splenders and the legacy of its old history.

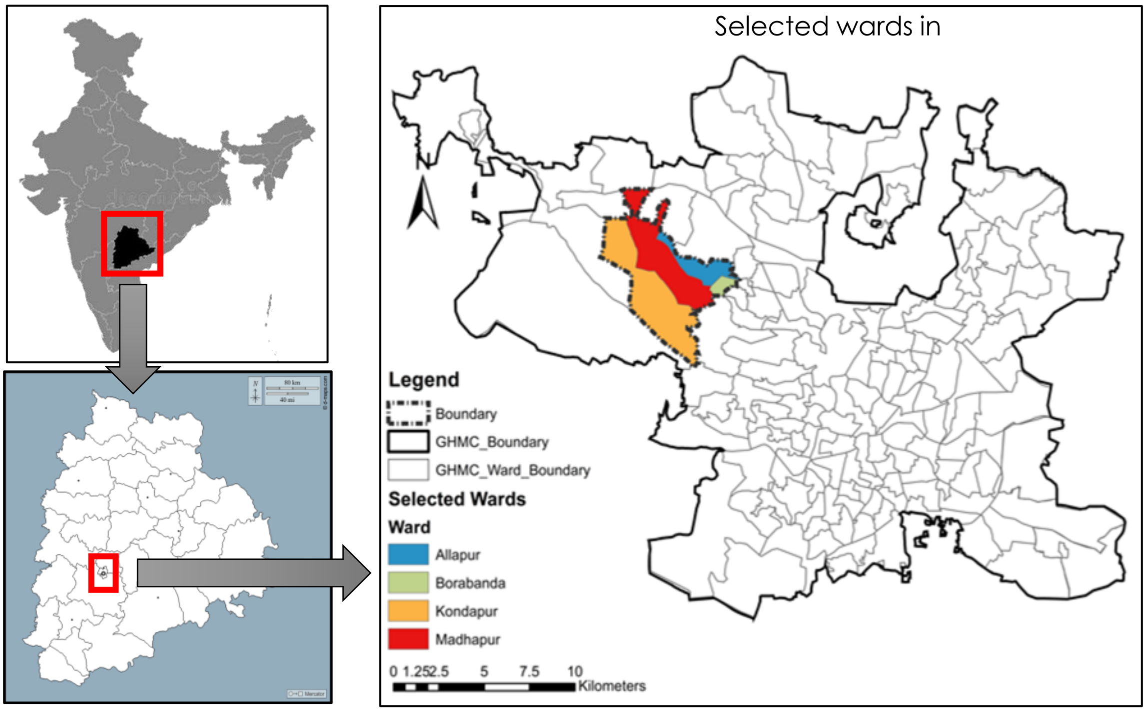


Figure 4.1: Showing selected wards in the GHMC area

4.1 <u>Why Hyderabad?</u>

Telangana government mentioned in it's report after the 'Urban Heat Stress Tracker-Hyderabad' Document published by the Centre for Science and Environment (CSE), highlighted the growing intensity of UHI effects in Hyderabad and other urban areas of Telangana.

The report states a 1°C increase in temperature for March-April 2024 compared to the 2014-23 average, with humidity levels rising by 10 percent over the last two decades. This added moisture in the air, has led to an increase in the city's heat index, making it feel

1.5°C hotter on average. The report states that Hyderabad is not cooling down at night as effectively as it used to, with the gap between daytime and night time temperatures shrinking by 13 percent.

“In the last ten summers (2014-23) the night time cooling has reduced to 11.5°C. But between 2001-10, the temperature used to decrease by average 13.2°C,” reads the report.

“Hot nights are as dangerous as midday peak temperatures. People get little chance to recover from daytime heat slaughter if temperatures remain high overnight, exerting prolonged stress on the body. A study published in the Lancet Planetary Health by a group from Japan, Germany and the U.S., noted that the risk of death from excessively hot nights would increase nearly six-fold. This prediction is much higher than the mortality risk from daily average warming suggested by climate change models,” points the report.

It also points that Hyderabad’s core is 0.7°C cooler than its outskirts during the day, it becomes 1.9°C hotter at night, trapping heat within concrete structures.

(Source: News Article, South First, 2025)

4.1.1 Location Selection Criteria

As per the study done by Centre for Science and Environment Hyderabad is one of the major contributor for emission which ultimately leads to increase in heat index.

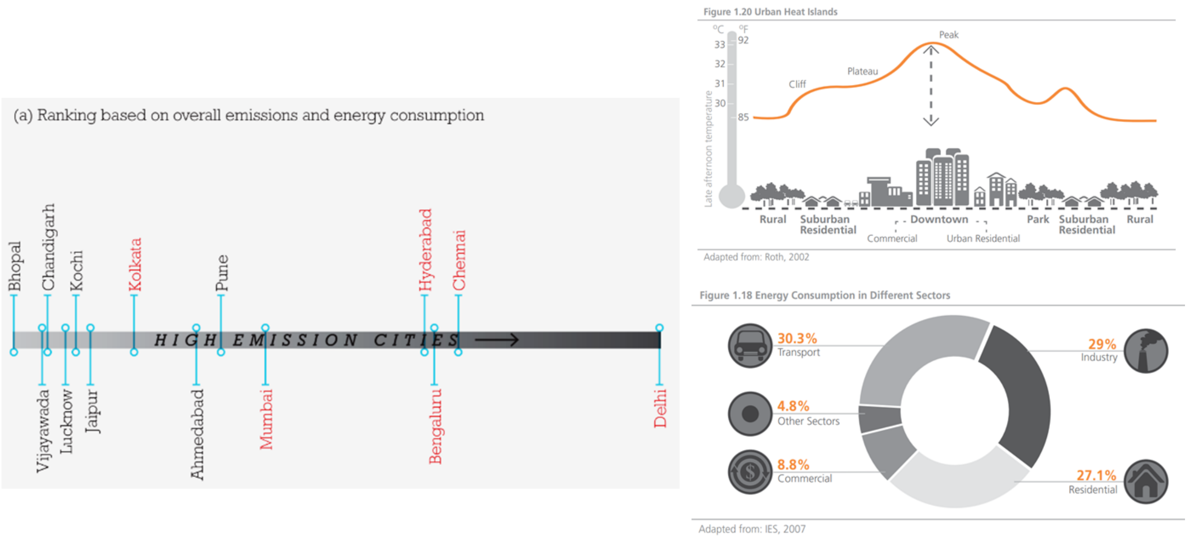


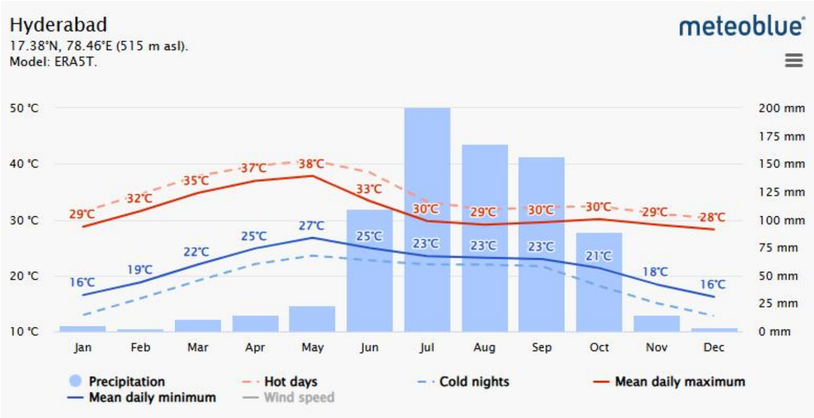
Figure 4.2 ranking based on overall emissions and energy consumption

Source: Centre for Science and Environment

4.2 Climate

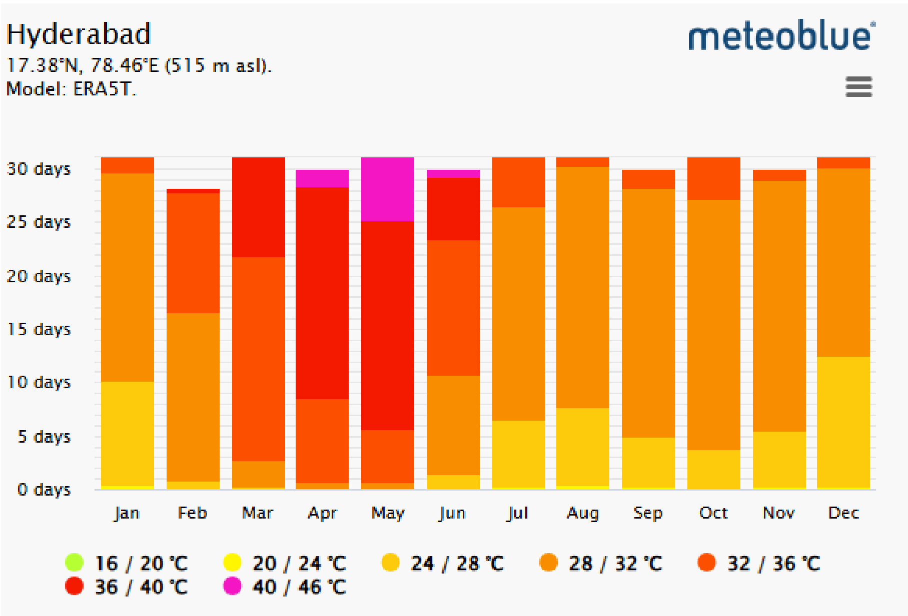
4.2.1 Average temperatures and precipitation

The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Hyderabad. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years.



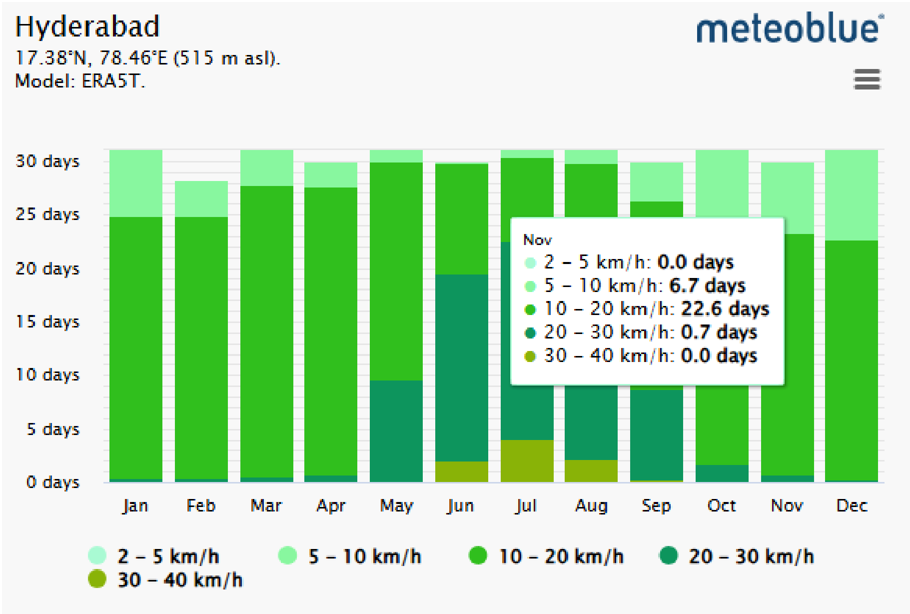
4.2.2 Maximum temperatures

The maximum temperature diagram for Hyderabad displays how many days per month reach certain temperatures



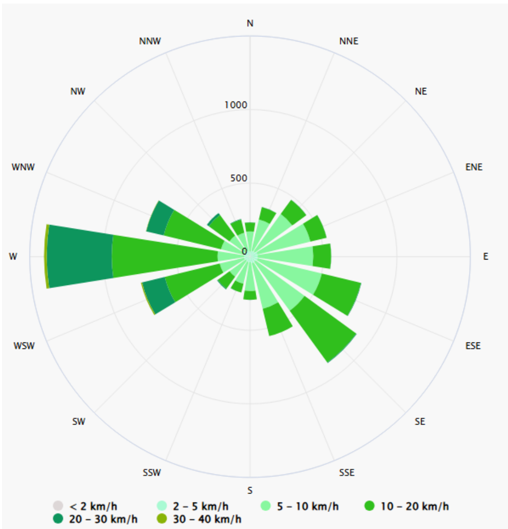
4.2.3 Wind Speed

The diagram for Hyderabad shows the days per month, during which the wind reaches a certain speed.



4.2.4 Wind Rose

The wind rose for Hyderabad shows how many hours per year the wind blows from the indicated direction



Chapter 5: Field Visit Description

As part of the data collection process for this project, several key offices were visited. A visit to RCEUS, Hyderabad, was undertaken to gather information regarding previous environmental studies related to the Urban Heat Island effect in the region. Furthermore, a visit to the Telangana State Development Planning Society was conducted to acquire relevant weather data, which is essential for validating and calibrating the UHI models used in this study. These visits provided valuable insights and data resources that contribute to a comprehensive understanding of the UHI phenomenon in the GHMC area.

5.1 <u>Meeting with RCUES</u>

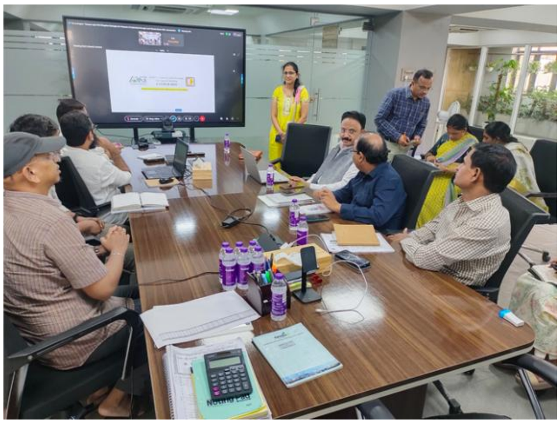
Figure 5.1 Meeting with Director of RCUES

Figure 5.2 submitting project description to director RCUES

5.2 Stakeholder meeting with HMDA

As part of the ongoing research on Urban Heat Island (UHI) mitigation strategies, the project team presented the study titled “Cooling Strategies for Hyderabad: Canopy Layer UHI Mitigation through Local Climate Zones (LCZ)” at a stakeholder meeting organized by the Hyderabad Metropolitan Development Authority (HMDA). The session was attended by key officials including Director-1 and Director-2 (HMDA), the Director of Urban Forestry, a Senior Landscape Architect, the Chief Planning Officer (CPO), HMDA, and the Director of NCPE, Hyderabad. Notably, Sarfaraz Ahmad, IAS, the Metropolitan Commissioner of HMDA, was also present, highlighting the strategic importance of the initiative. The presentation was delivered by Dr. Faiz Ahmed Chundeli (PI) on behalf of the School of Planning and Architecture, Vijayawada, supported by team members Ar. Vijesh Kumar (Co-PI), Ar. Kapil Natawadkar, Nakka Sunny (Project Officer), and Ar. Fathima Shouheen (Student Member). The meeting facilitated critical feedback and fostered cross-departmental dialogue, reinforcing the relevance of climate-responsive urban planning for Hyderabad’s sustainable growth.

Figure 5.3 Stakeholder meeting with HMDA



5.3 NCPE Infrastructure

As part of the field outreach and stakeholder engagement process, the project team presented the study titled "Cooling Strategies for Hyderabad: Canopy Layer UHI Mitigation Using Local Climate Zones (LCZ)" at NCPE Infrastructure, Hyderabad. The presentation was delivered by Dr. Faiz Ahmed Chundeli (PI) on behalf of the School of Planning and Architecture, Vijayawada. The session was attended by the Director of NCPE, who also presented the parallel Blue-Green Infrastructure (BGI) initiative being developed for the HMDA region. The discussion emphasized the integration of micro-climate planning, thermal comfort strategies, and land-based zoning tools such as LCZs. The project team comprised Ar. Vijesh Kumar (Co-PI), Ar. Kapil Natawadkar (Member), Nakka Sunny (Project Officer), and Ar. Fathima Shouheen (Student Member). The session offered valuable insights into inter-agency alignment and reinforced the potential for climate-adaptive urban strategies in Hyderabad's planning framework.

Figure 5.4 showing cooling strategies proposal to NCPE

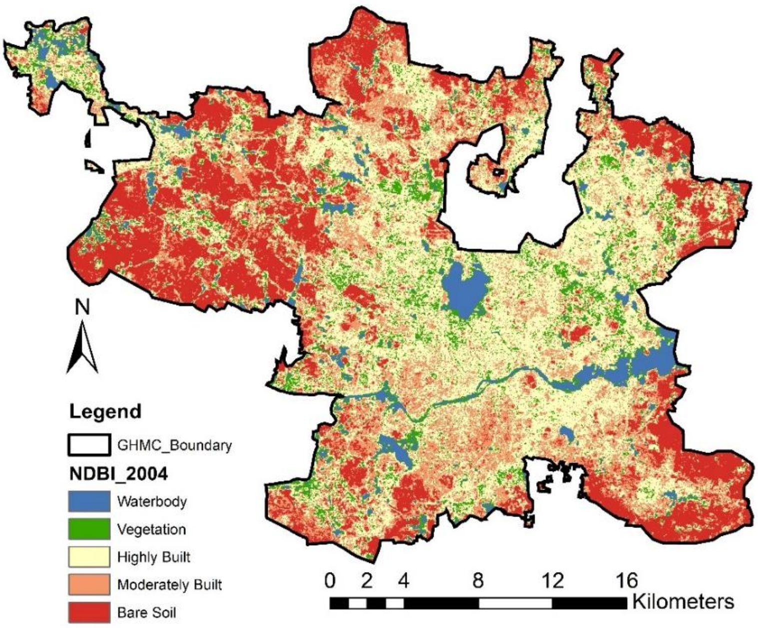
Figure 5.5 showing project team of SPAV & NCPE

Chapter 6: Preliminary Analysis

This chapter presents a preliminary analysis of the Urban Heat Island (UHI) effect within the Greater Hyderabad Municipal Corporation (GHMC) area. As a first step, we processed satellite imagery to generate Normalized Difference Built-up Index (NDBI) maps to analyze the built-up density, Land Surface Temperature (LST) maps to understand the surface heat distribution, and UHI maps to identify areas with significant temperature differences. By overlaying these maps and integrating them with Local Climate Zone (LCZ) classifications, we aim to pinpoint specific UHI hotspots across the GHMC, providing a foundation for targeted mitigation strategies.Normalized Difference in Built-up Index

6.1.1 NDBI 2004

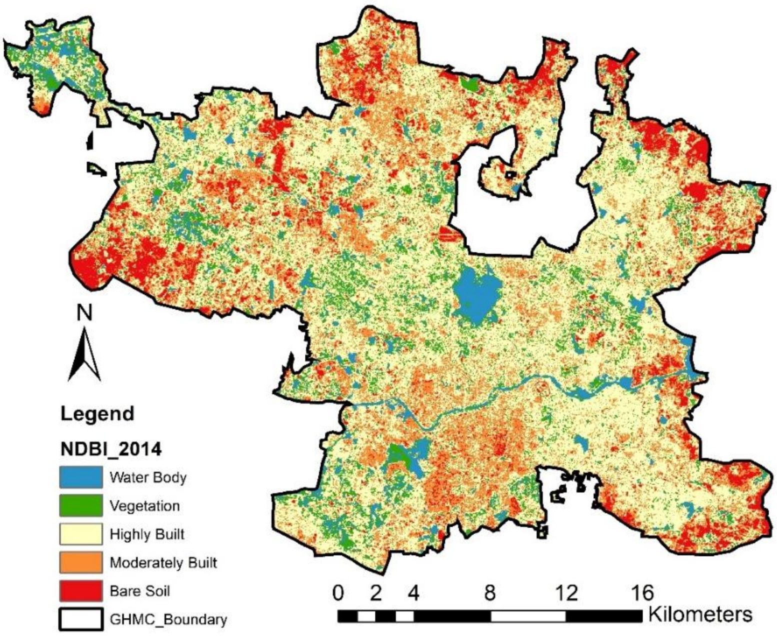
In 2004, the peripheral areas of Hyderabad began to emerge as significant zones of less built-up land, driven by rapid urbanization and the city's expanding infrastructure. As a result, the demand for residential properties surged, with projections indicating significant growth potential in these areas. By 2004, the trend towards less built-up environments was evident, reflecting a broader movement towards sustainable urban development in response to Hyderabad's burgeoning IT sector and industrial corridors.



Map 6.1 showing NDBI map 2004

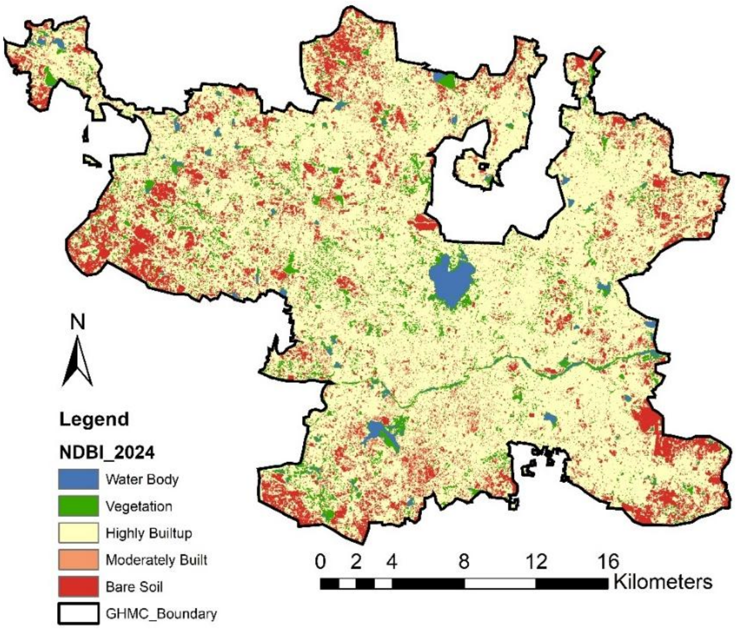
6.1.2 NDBI 2014

Between 2004 and 2014, Hyderabad witnessed significant growth in built-up areas in its peripheral regions, driven by rapid urbanization and infrastructure development. The expansion was fueled by the establishment of IT hubs like Cyberabad, the development of the Outer Ring Road (ORR), and increased industrialization, which attracted migrants and reshaped the city's economic geography.



Map 6.2 showing NDBI map 2014

6.1.3 NDBI 2024

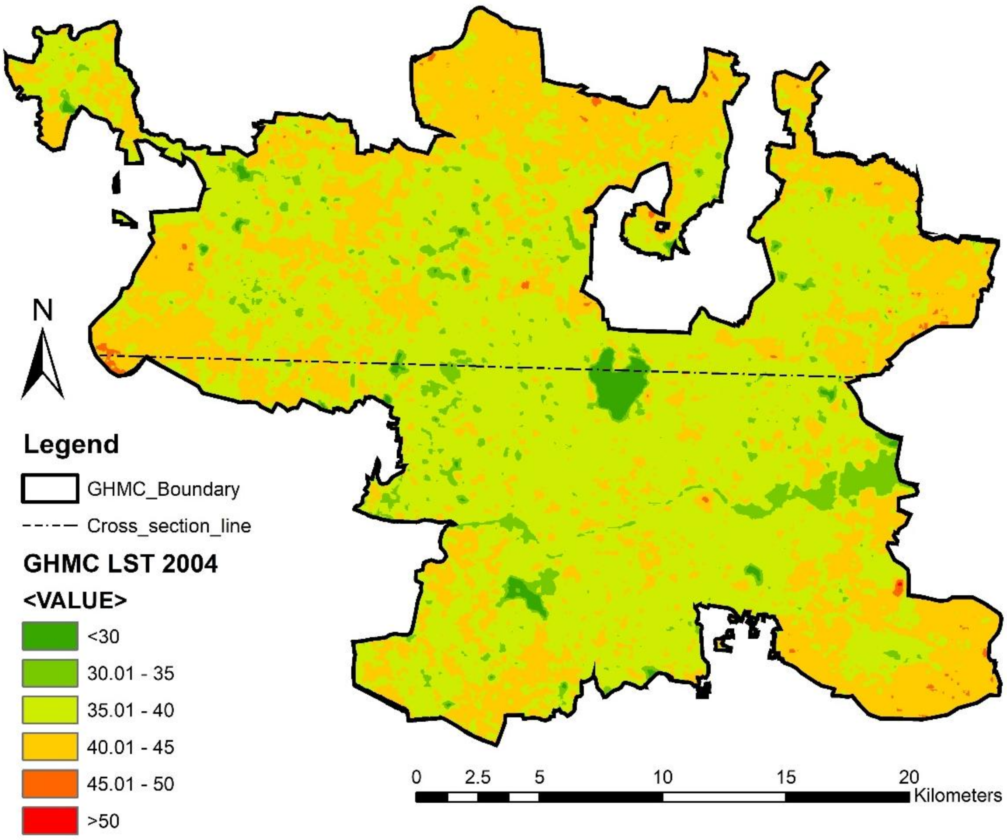


Map 6.3 showing NDBI map 2024

Between 2014 and 2024, Hyderabad's peripheral areas, including Madhapur and its surroundings, experienced significant urban expansion due to the city's rapid growth as an IT and real estate hub. The built-up area in these outskirts increased substantially, driven by infrastructure projects such as the Hyderabad Metro Phase II, the Regional Ring Road (RRR), and the development of IT corridors extending from HITEC City to Kokapet. Madhapur, already a key IT hub, saw further densification with new office spaces, residential complexes, and commercial establishments catering to professionals working in HITEC City and Gachibowli.

6.2 <u>Land Surface Temperature</u>

6.2.1 GHMC Land Surface Temperature 2004



Map 6.4 GHMC LST Map 2004

This was the LST map of GHMC area generated using Landsat 5 image in GIS Application (March -May),

- The peripheral areas of GHMC consisted largely of barren lands, rocky surfaces, and dry agricultural fields.
- These surfaces have low moisture content and higher heat absorption and retention capacity, leading to increased LST.

The below is the cross section of the LST map where it shows the temperature values at an interval of 50 meters in the GHMC area.

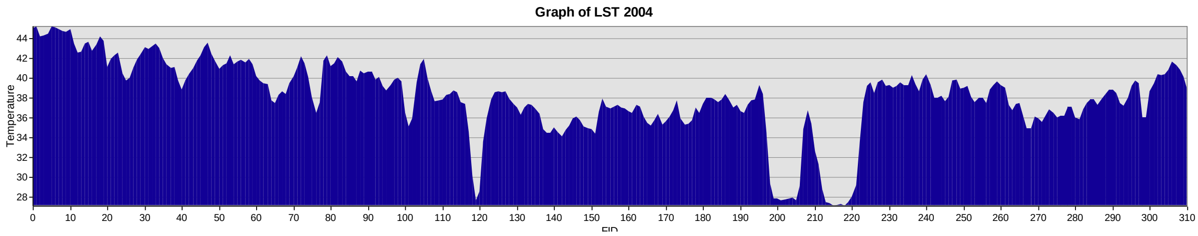
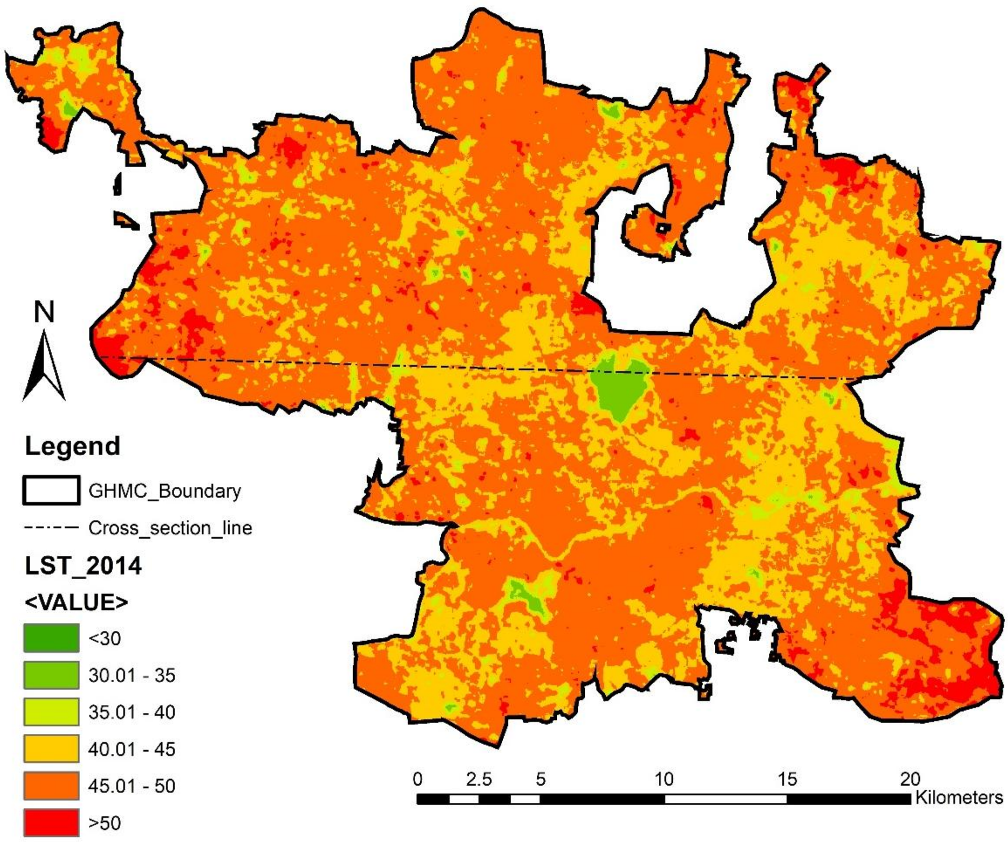


Figure 6.1 Cross section of the LST Map 2004

6.2.2 GHMC Land Surface Temperature 2014



Map 6.5 GHMC LST Map 2014

This was the LST map of GHMC area generated using Landsat 8 image in GIS Application for 2014 (March -May),

- The mean LST in the study area was 47.45 degrees.
- Due to urban expansion, loss of vegetation, and increased built-up areas the LST was higher in the study area.

The below is the cross section of the LST map where it shows the temperature values at an interval of 50 meters in the GHMC area.

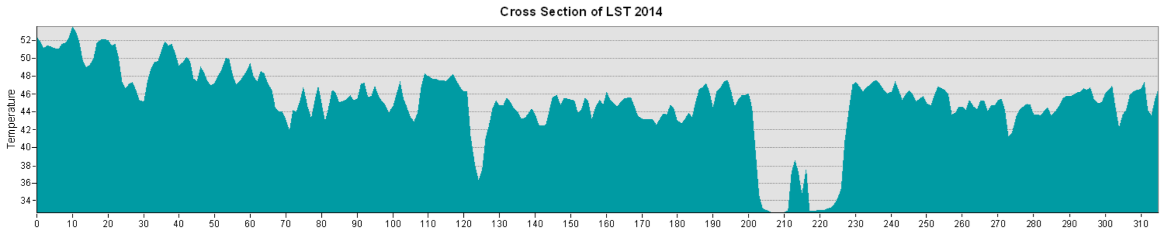
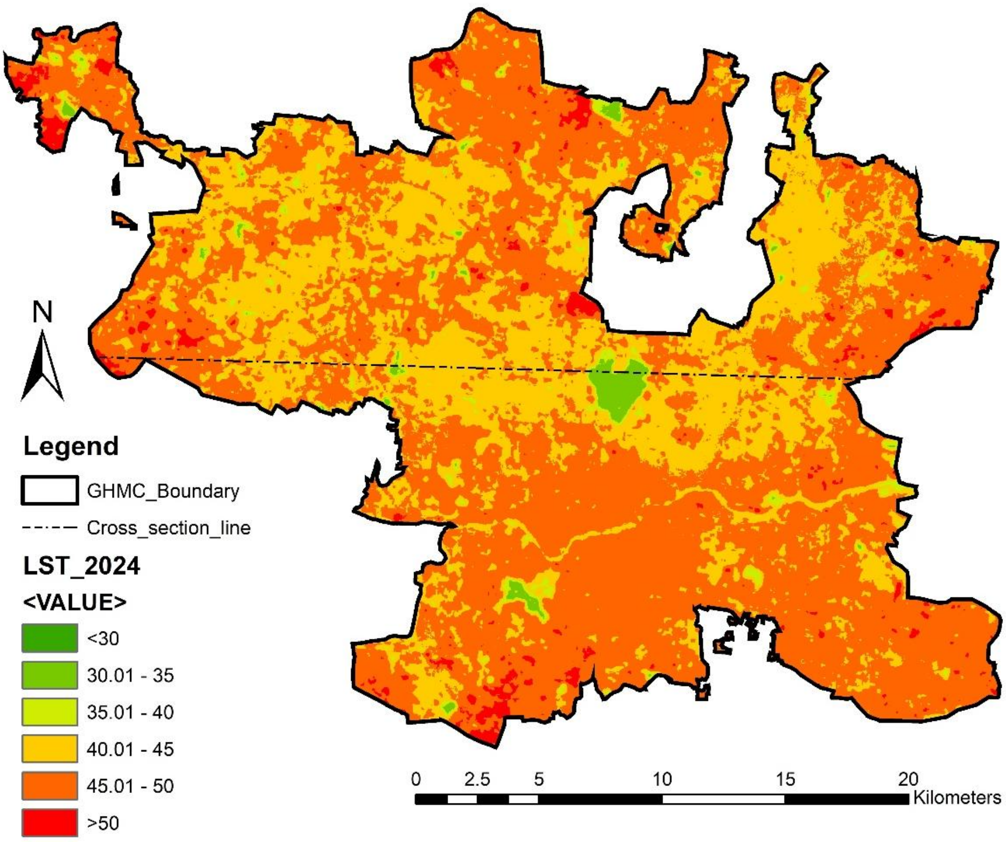


Figure 6.2 Cross section of the LST Map 2014

6.2.3 GHMC Land Surface Temperature 2024



Map 6.6 GHMC LST Map 2024

This was the LST map of GHMC area generated using Landsat 8 image in GIS Application for 2024 (March -May),

- The mean LST in the study area was 47.79 degrees.
- The Highest LST obtained in the study area was 52 degrees.

The below is the cross section of the LST map where it shows the temperature values at an interval of 50 meters in the GHMC area.

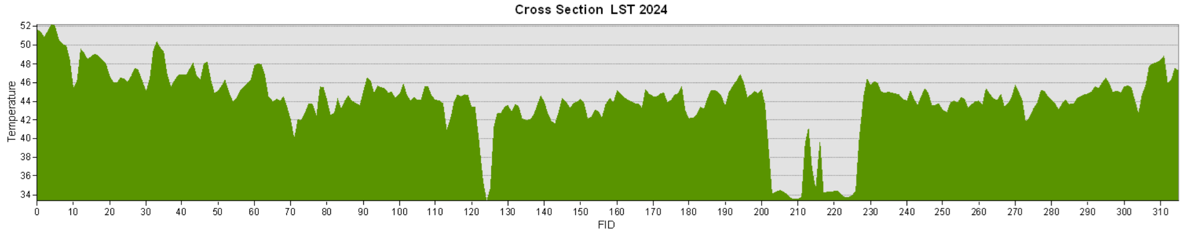
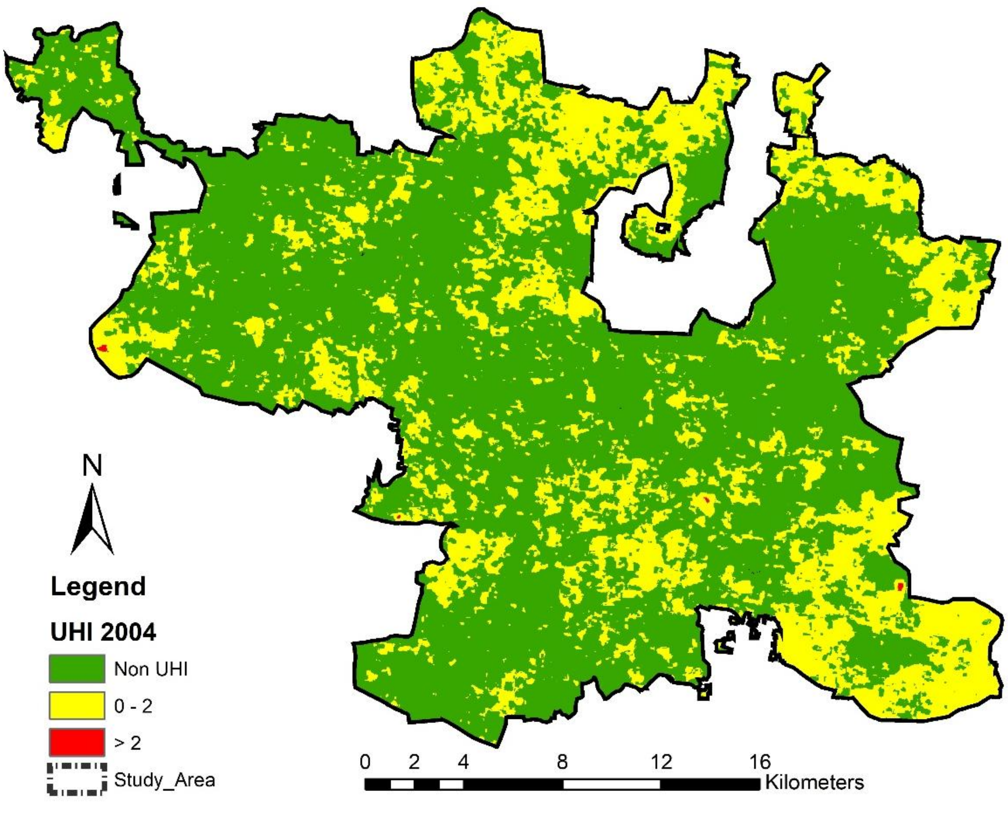


Figure 6.3 Cross section of the LST Map 2014

6.3 Urban Heat Island

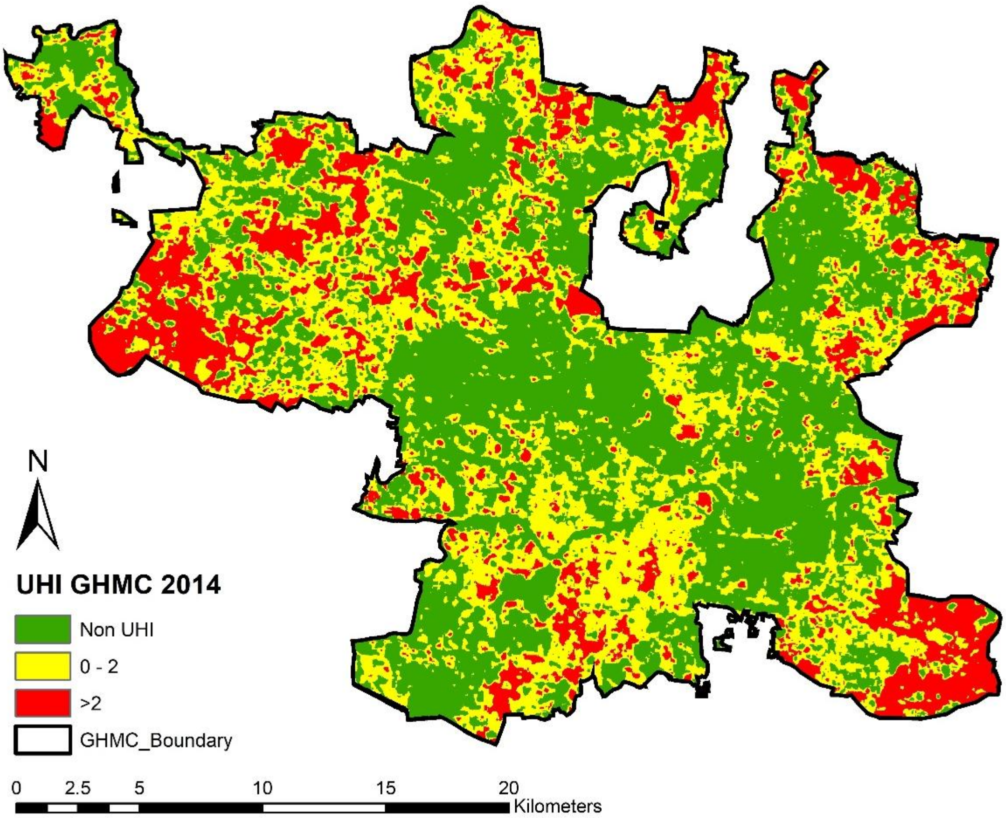
6.4 GHMC UHI 2004



Map 6.7 GHMC UHI areas 2004

From the map, it is evident that non-UHI zones (green) dominate the landscape, especially in the southern, western, and peripheral parts of the GHMC region. Moderate UHI zones (yellow) are scattered across the inner and mid-urban zones, while high UHI zones (red) are sparse, mostly concentrated in isolated pockets—likely corresponding to early built-up or industrial clusters such as parts of Secunderabad, Kukatpally, and commercial hubs.

6.4.1 GHMC UHI 2014



Map 6.8 GHMC UHI areas 2014

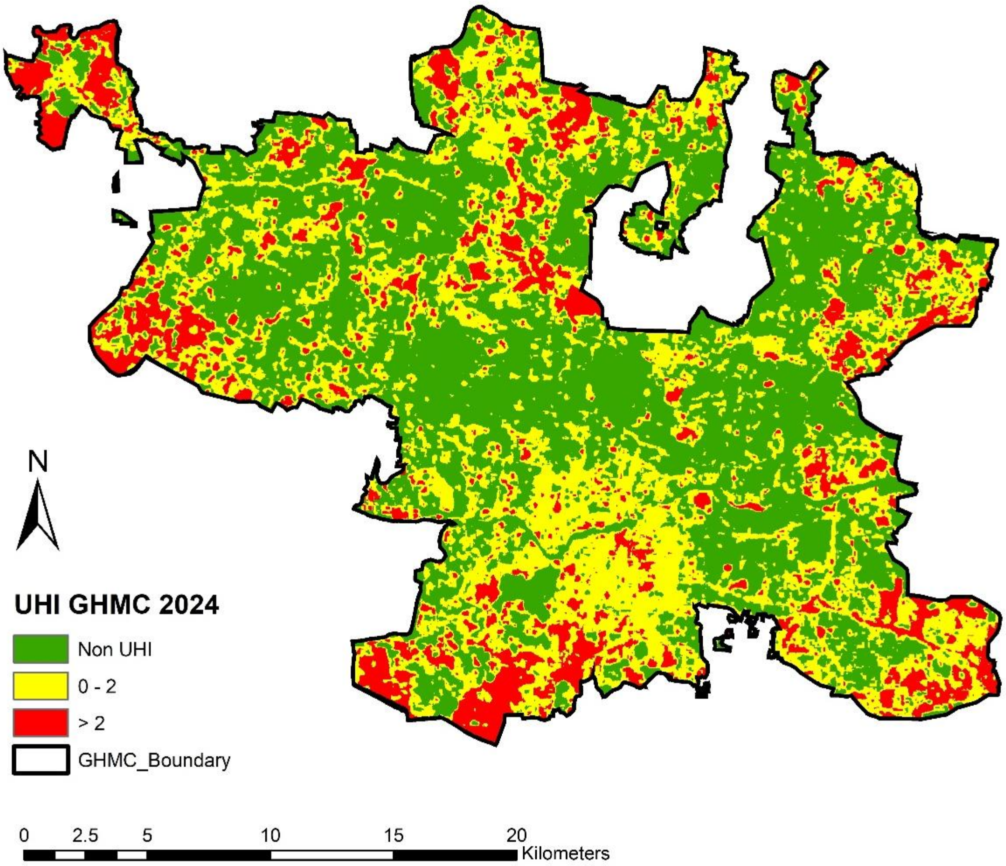
Based on the UHI map of Hyderabad for 2014, Madhapur is marked in red, indicates a UHI of >2 degrees Celsius. This signifies a significantly higher temperature compared to the surrounding non-urbanized areas. Due to Dense Construction, Less Green Cover and Anthropogenic Heat.

Madhapur is a major IT and commercial hub. The area has a high density of buildings and paved surfaces. These materials absorb and retain more heat compared to natural surfaces. Urban development in Madhapur likely replaced green spaces with concrete, reducing the cooling effect of vegetation. High traffic volume, air conditioning systems, and industrial activities release substantial amounts of heat into the environment.

6.4.2 GHMC UHI 2024

Based on the UHI map 2024, the overall UHI area in the Hyderabad is less compared to UHI areas in 2014, due to implementation of city-wide initiatives to reduce UHI, such as increasing green cover through afforestation programs, promoting cool roofs, or improving urban planning to enhance ventilation. These measures could have lowered the overall UHI across the city, but their impact might not have been sufficient to offset the factors driving high UHI in intensely developed areas like Madhapur.

Madhapur has continued to experience rapid development with more construction, increased traffic, and higher energy consumption. These factors exacerbate the UHI effect. Specific UHI mitigation strategies might not have been implemented effectively or extensively enough in Madhapur to counteract the increasing urbanization. Madhapur already had a high UHI in 2014. Even if some mitigation measures were taken, they might only have been enough to prevent it from getting worse, not necessarily to reduce it significantly.



Map 6.9 GHMC UHI areas 2024

UHI effects are not uniform. Factors like land use, building density, vegetation cover, and human activity patterns vary significantly across the city, leading to spatial variations in UHI intensity. Effective mitigation strategies are required to comprehensively addressing the specific drivers of UHI in different areas.

Chapter 7: LCZ Classification

For this study, Local Climate Zone (LCZ) classification was performed using two distinct tools: WUDAPT and ArcGIS. The WUDAPT method utilized freely available satellite imagery and training samples to generate LCZ maps, offering a standardized approach to urban morphology classification. To enhance classification precision, a supervised classification approach was implemented in ArcGIS using composite Landsat 8 imagery from 2024. The classification results from both methods were compared, and the tool providing better accuracy will be adopted for further analysis and integration into UHI mitigation strategies.

7.1 LCZ Classification Using WUDAPT

As part of this study, Local Climate Zone (LCZ) classification was performed across the GHMC area using the WUDAPT. This involved collecting training samples representative of the different LCZ types present in the study area, followed by a supervised classification process to generate an LCZ map. This LCZ map serves as a crucial input for analyzing the relationship between urban morphology and UHI intensity. The initial LCZ classification was then revised using GIS techniques to improve its accuracy and spatial representation.

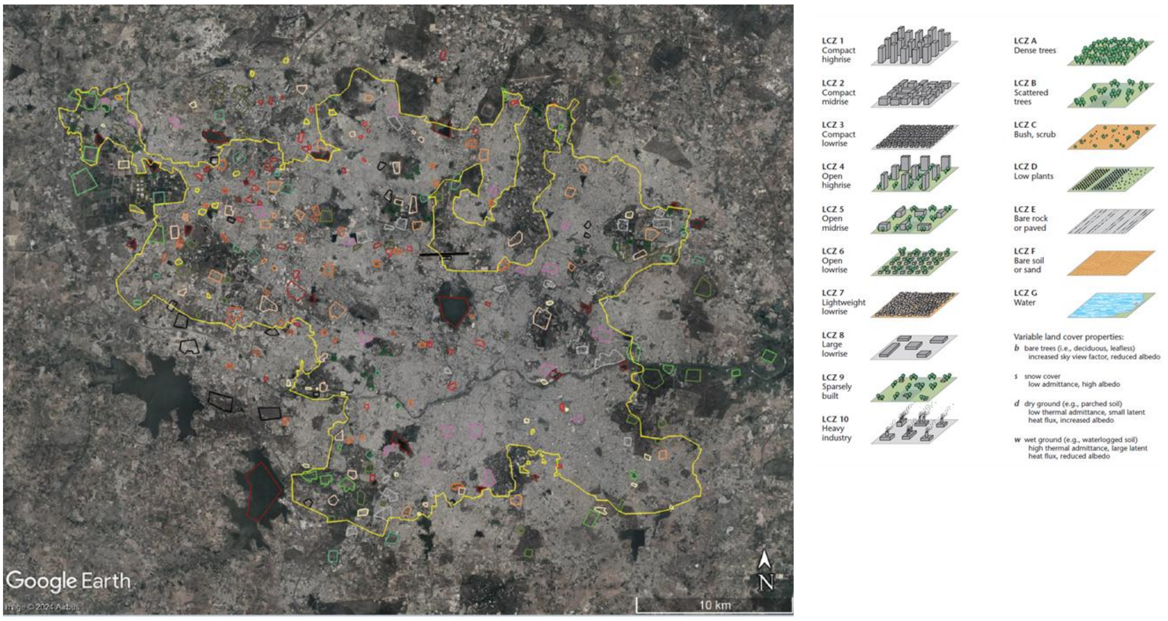


Figure 7.1 showing training samples used for the LCZ classification

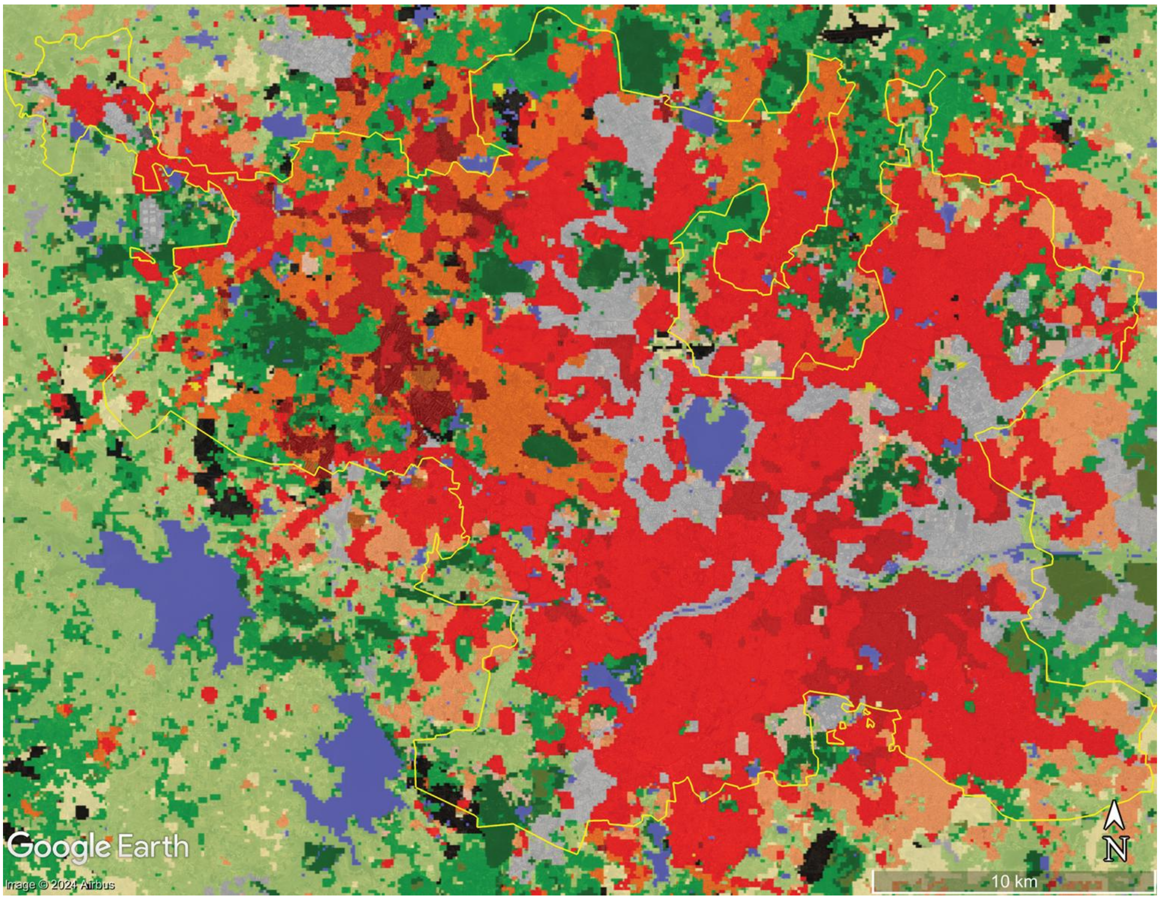
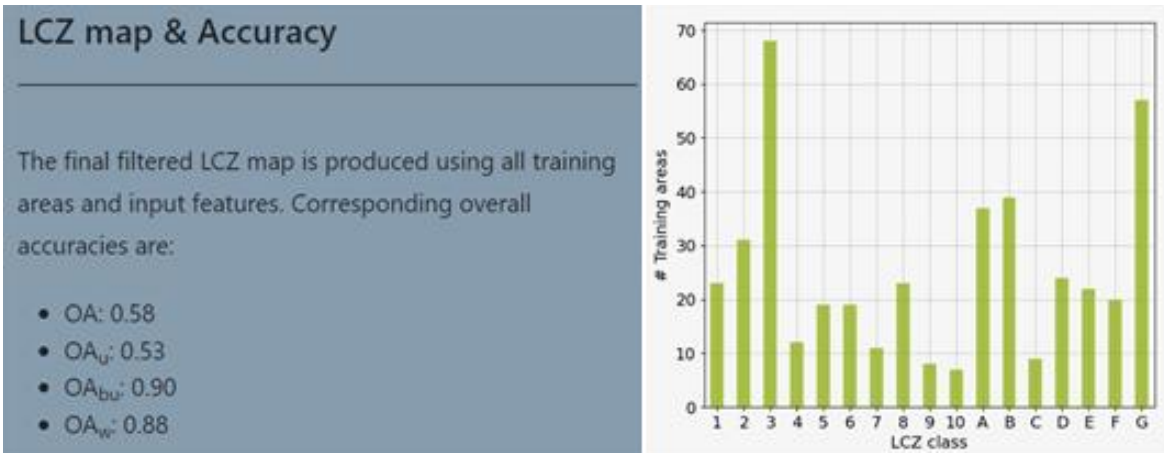


Figure 7.2 WUDAPT LCZ Classification for GHMC area

LCZ Map & Accuracy



7.1.1 LCZ Classification Using GIS Supervised Classification

The initial LCZ classification for the GHMC area was conducted using the WUDAPT framework, yielding an accuracy of 0.58. While this provided a foundational understanding of urban morphology, the relatively low accuracy highlighted limitations in capturing detailed LCZ variations, particularly in densely built-up areas. To improve classification results and enhance spatial resolution, we adopted a supervised classification approach using composite Landsat 8 imagery from 2024. This method allowed for a more precise delineation of LCZs by leveraging high-resolution spectral data and incorporating site-specific characteristics. The refined LCZ map generated through this approach serves as a robust tool for identifying UHI hotspots and analyzing their relationship with urban morphology.

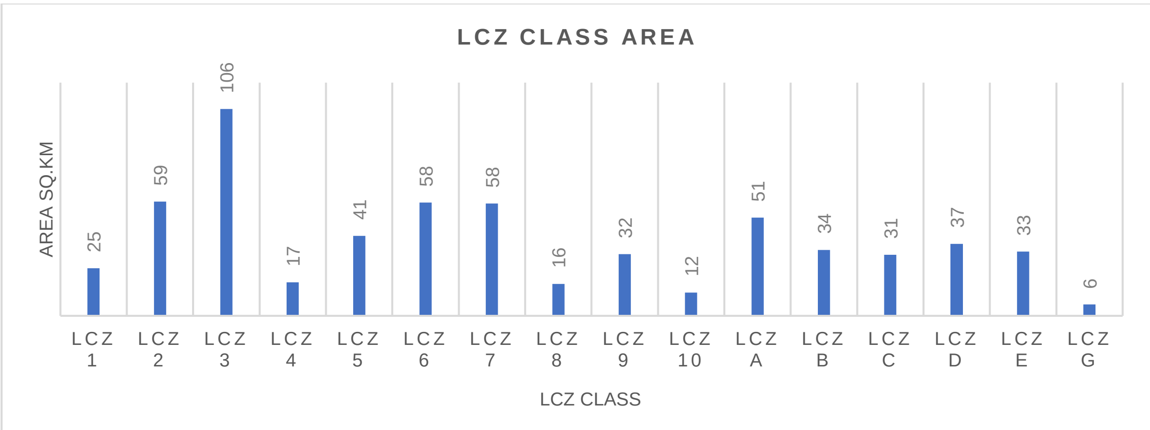
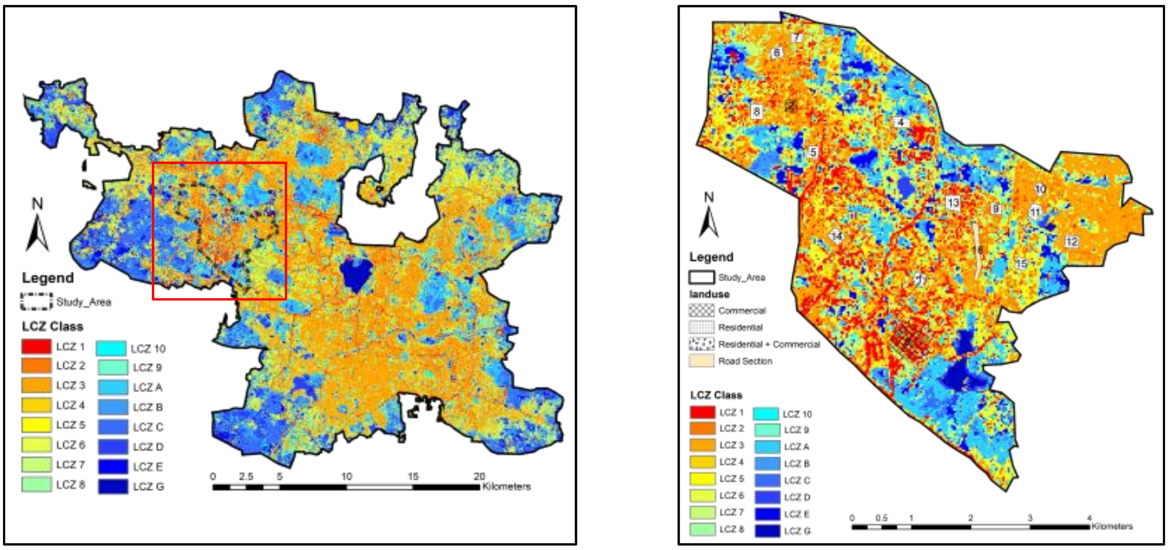


Chart 7.1 Showing LCZ Class areas in GHMC

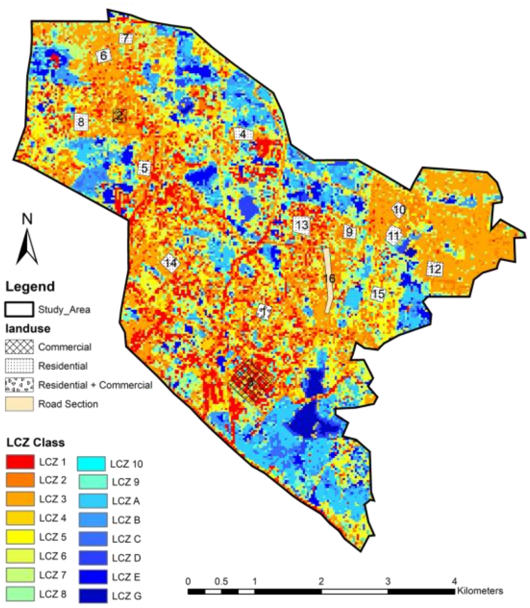


Map 7.1 LCZ Classification using GIS

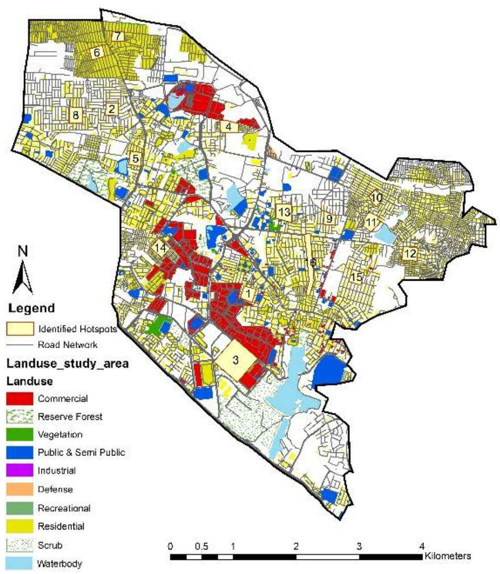
From the literature review, it was observed that LCZ 2 (compact midrise) and LCZ 3 (compact low-rise) are most prone to Urban Heat Island (UHI) effects due to their high building density and reduced vegetation cover. Based on this understanding, hotspots within the GHMC area were identified using a combination of criteria. These included LCZ 2 and LCZ 3 classifications, areas with high residential and built-up densities derived from Normalized Difference Built-up Index (NDBI) maps, elevated Land Surface Temperature (LST) values, and significant UHI intensity. This integrated approach allowed for a targeted identification of UHI-prone zones, providing a foundation for subsequent analysis and mitigation strategies tailored to these hotspots. The Map 7.1 shows the LCZ Classification in the GHMC area, and the hotspots identified.

7.1.1.1 <u>Identified Hotspots using LCZ</u>

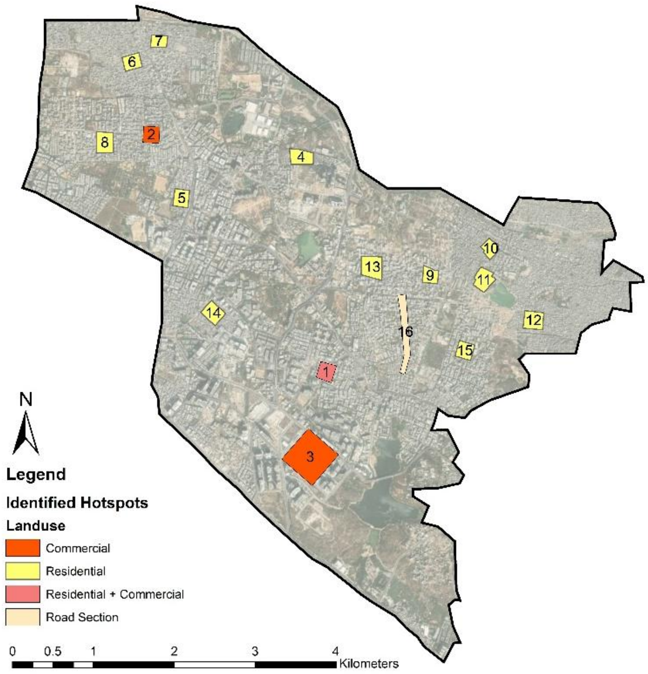
The suitable hotspots were identified using LCZ, LST, NDBI and UHI maps, the primary landuse that we consider for identifying hotspots was residential landuse, then also we considered the commercial landuse for two sites, and one mixed landuse to understand the UHI effect in different landuses. A total of 16 sites were identified, out of those 15 were hotspots and 1 road stretch was there.



Map 7.2 Identified hotspots using LCZ



Map 7.3 Land use in the study area



Map 7.4 Land use of each hotspot

Table 7.1 Showing details of the identified hotspots

S. No	Name	Description	Land use
1	HUDA Techno Enclave 1	Open High-Rise + Low-Rise	Residential + Commercial
2	Seshadri Marg	Open Mid-Rise	Commercial
3	Navi Hub	Open High-Rise	Commercial
4	Izzathnagar	Compact Mid-Rise + Less Low-Rise	Residential
5	Prashanth Nagar Colony	Compact Low Rise + Compact Mid-Rise	Residential
6	New Hafeezpet	Compact Low Rise + Compact Mid-Rise	Residential
7	Vishal P	Open Low Rise	Residential
8	Esperanza Schol Ln	Open Mid Rise	Residential
9	Rd Number 37	Open Mid Rise	Residential
10	Parvathi Nagar	Compact Low Rise	Residential
11	Gayathri Nagar	Compact Mid Rise	Residential
12	Shree Haripriya Provision	Mid-Rise and less Low-Rise Building	Residential
13	SBI Officers Colony	Mid Rise Building	Residential
14	1260, Madhapur	Compact Mid Rise Few Low-Rise Buildings	Residential
15	310	Open Mid Rise	Residential
16	Road Section	Road Section	

7.2 <u>Profile of Each Hotspot</u>

7.2.1 HUDA Techno Enclave

This site features a mix of open high-rise and low-rise buildings, with a land use classification of both residential and commercial. The LCZ classification can be described as a mix of LCZ 1 (Compact High-rise) and LCZ 6 (Open Low-rise).

Figure 7.3 HUDA Techno Enclave

7.2.2 Seshadri Marg

Classified as an open mid-rise area with commercial land use, this site would likely fall under LCZ 5 (Open Mid-rise).

Figure 7.4 Showing Seshadri Marg site

7.2.3 Navi Hub

This site is characterized by open high-rise buildings and commercial land use, corresponding to LCZ 4 (Open High-rise).

Figure 7.5 showing Navi Hub

7.2.4 Izzathnagar

Featuring compact mid-rise buildings with some low-rise elements and residential land use, Izzathnagar can be classified as a mix of LCZ 2 (Compact Mid-rise) and LCZ 3 (Compact Low-rise).

Figure 7.6 showing Izzathnagar site

7.2.5 Prashanth Nagar Colony

This residential area consists of a mix of compact low-rise and compact mid-rise buildings, aligning with LCZ 3 (Compact Low-rise) and LCZ 2 (Compact Mid-rise).

Figure 7.7 showing Prashanth Nagar Colony

7.2.6 New Hafeezpet

Similar to Prashanth Nagar Colony, New Hafeezpet is a residential area with both compact low-rise and compact mid-rise buildings, falling under LCZ 3 (Compact Low-rise) and LCZ 2 (Compact Mid-rise).

Figure 7.8 showing New Hafeezpet

7.2.7 Vishal P

Classified as an open low-rise residential area, Vishal P corresponds to LCZ 6 (Open Low-rise).

Figure 7.9 showing Vishal P site

7.2.8 Esperanza Schol Ln

This residential area with open mid-rise buildings is classified as LCZ 5 (Open Mid-rise).

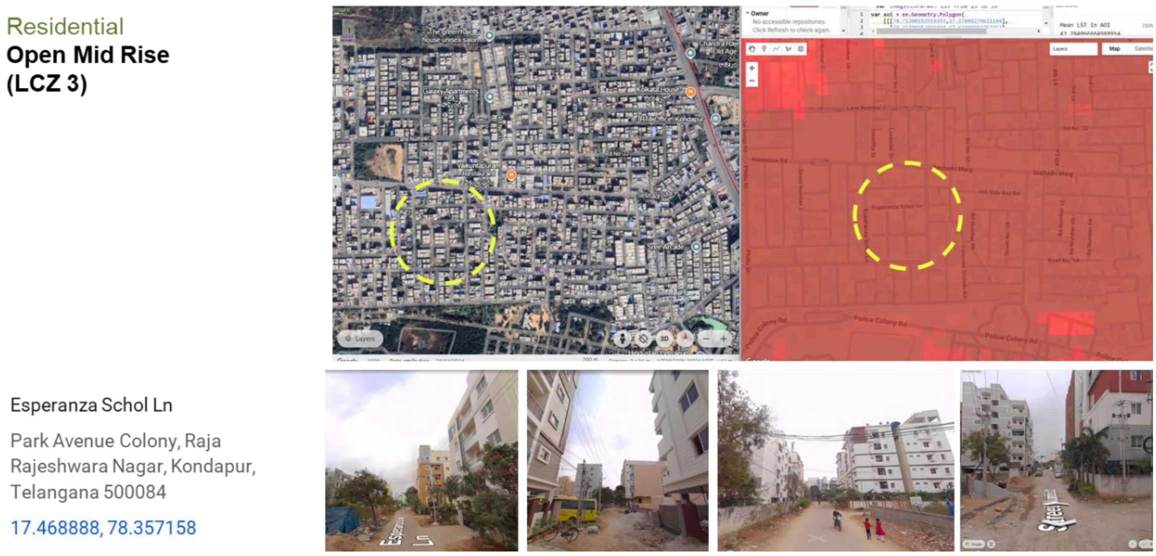


Figure 7.10 showing Esperanza Schol Ln

7.2.9 Rd Number 37

Similar to Esperanza Schol Ln, Rd Number 37 is an open mid-rise residential area, corresponding to LCZ 5 (Open Mid-rise).

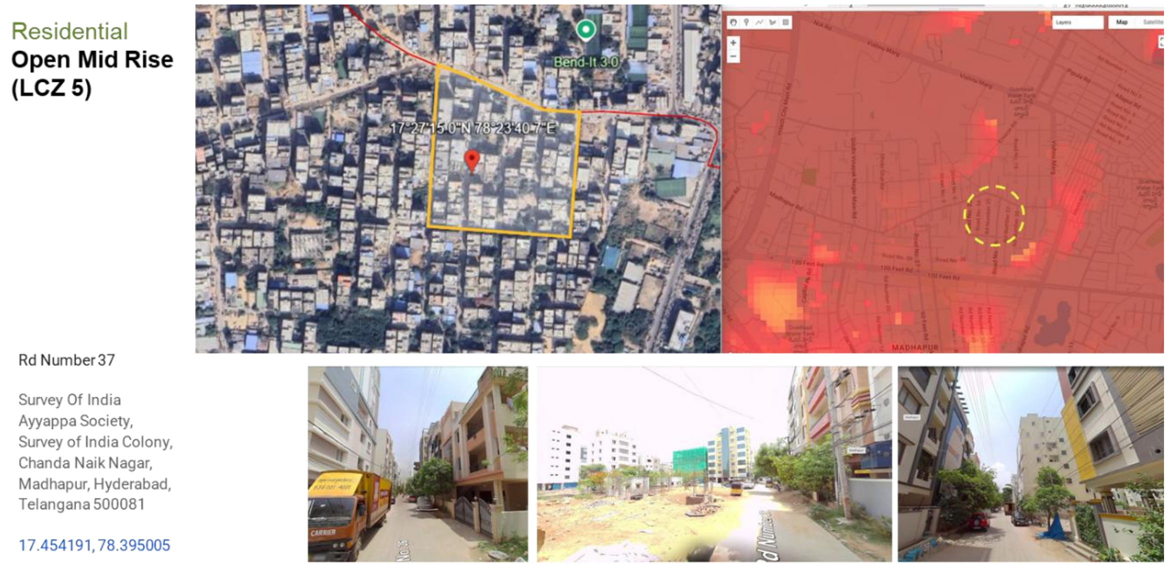


Figure 7.11 showing Rd Number 37 site

7.2.10 Parvathi Nagar

This residential area, characterized by compact low-rise buildings, aligns with LCZ 3 (Compact Low-rise).

Figure 7.12 showing Parvathi Nagar site

7.2.11 Gayathri Nagar

Featuring compact mid-rise buildings and residential land use, Gayathri Nagar can be classified as LCZ 2 (Compact Mid-rise).

Figure 7.13 showing Gayathri Nagar site

7.2.12 Shree Haripriya Provision

This site is a residential area with mid-rise and less low-rise buildings, corresponding to a mix of LCZ 2 (Compact Mid-rise) and LCZ 5 (Open Mid-rise).

Figure 7.14 showing Shree Haripriya Provision site

7.2.13 SBI Officers Colony

With mid-rise buildings and residential land use, this site aligns with LCZ 2 (Compact Mid-rise) or LCZ 5 (Open Mid-rise).

Figure 7.15 showing SBI Officers Colony

7.2.14 Siddiq Nagar 1260, Madhapur

Characterized by compact mid-rise buildings with a few low-rise structures and residential land use, 1260 Madhapur is classified as LCZ 2 (Compact Mid-rise).

Figure 7.16 showing Siddiq Nagar site

7.2.15 310

This site, featuring open mid-rise buildings and residential land use, corresponds to LCZ 5 (Open Mid-rise).

Figure 7.17 showing 310 site

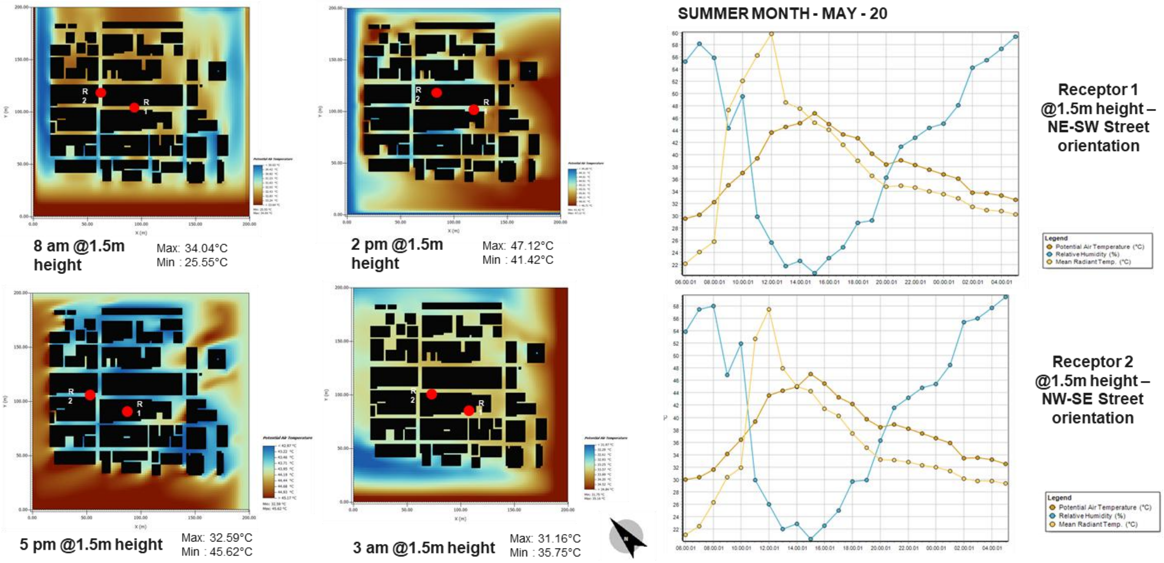
Chapter 8: Micro Climate Analysis

This chapter presents a detailed microclimate analysis conducted for identified UHI hotspots within the GHMC area. Utilizing weather data obtained from the Begumpet Airport station, simulations were performed using the ENVI-met software. These simulations covered a 24-hour duration over a one-week period, allowing for a comprehensive assessment of the microclimatic conditions within each hotspot. The results of these simulations will provide valuable insights into the local temperature variations, humidity levels, and wind patterns, which are crucial for evaluating the effectiveness of potential UHI mitigation strategies.

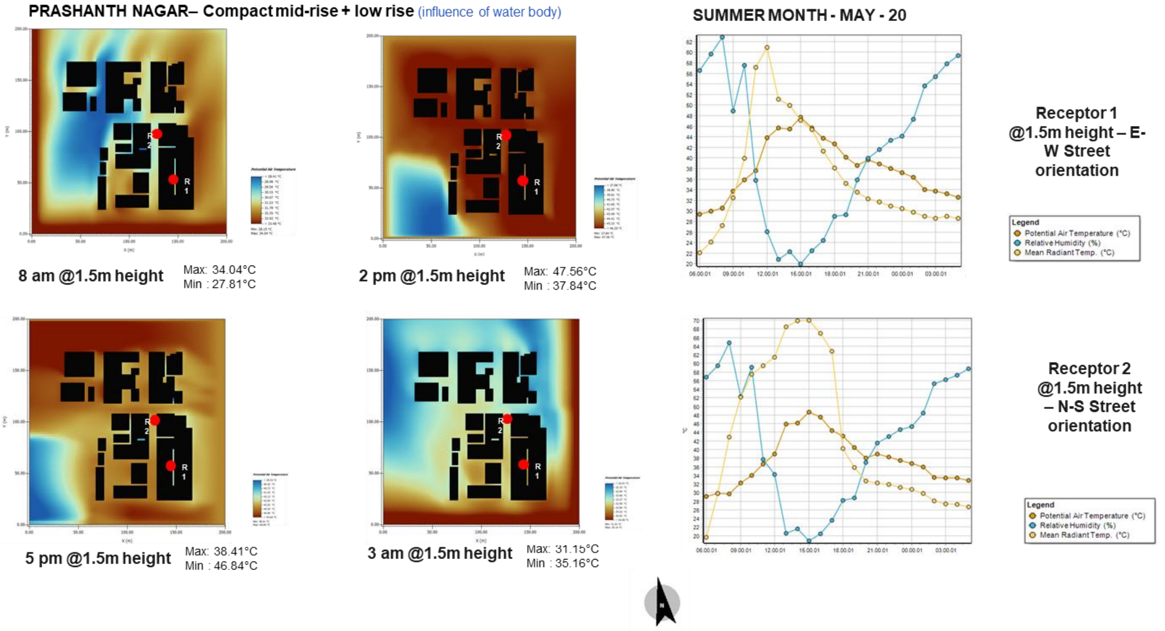
Following the ENVI-met simulations for the four selected UHI hotspots—Siddiq Nagar in HITEC City, Seshadri Marg (Open Mid-Rise, Commercial), HUDA Techno Enclave 1 (Open High-Rise + Low-Rise, Residential + Commercial), and 310, Rd No 7 (Open Mid-Rise, Residential)

8.1 <u>Siddiq Nagar</u>

The below are the results from the ENVI-Met simulations for the Siddiq Nagar site. These results need to be further processed.

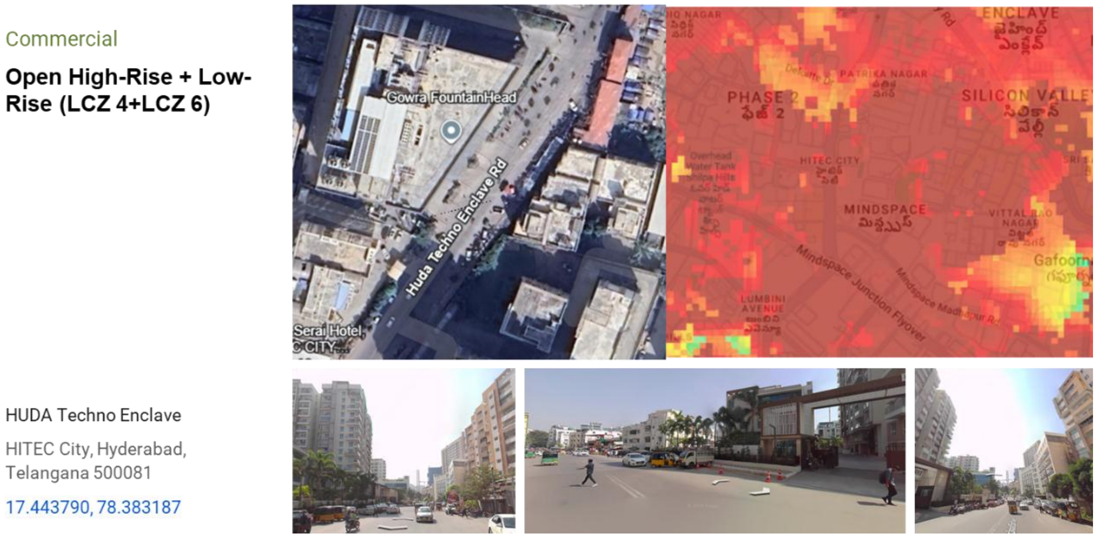


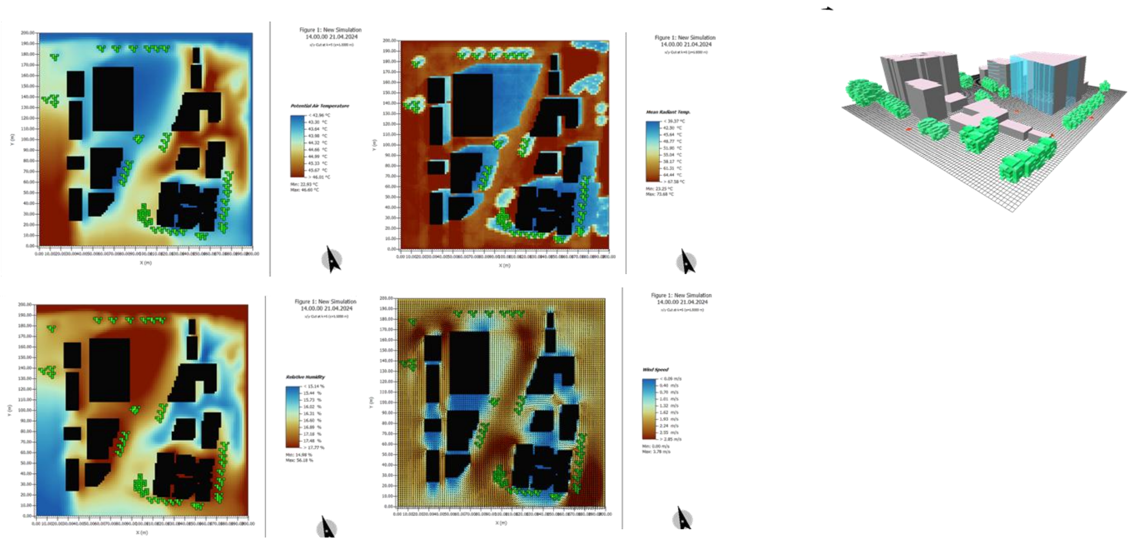
PRASHANTH NAGAR– Compact mid-rise + low rise (influence of water body)



8.2 <u>HUDA Techno Enclave</u>

The below are the results from the ENVI-Met simulations for the HUDA Techno Enclave site. These results need to be further processed.





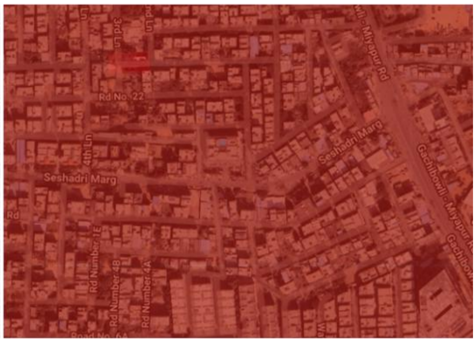
8.3 <u>Seshadri Marg</u>

The below are the results from the ENVI-Met simulations for the Seshadri Marg site. These results need to be further processed

Residential + Commercial

Open Mid-Rise (LCZ 5)

For comparison purposes with nearby Green patch

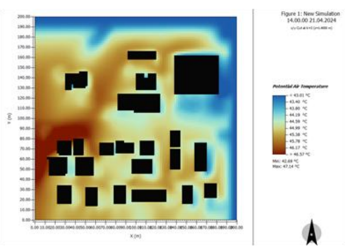


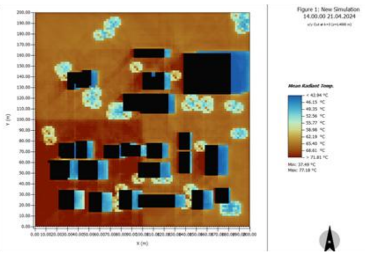
Seshadri Marg

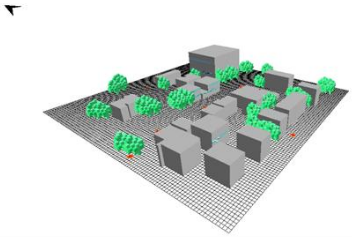
Raghavendra Colony, Kondapur, Telangana 500084

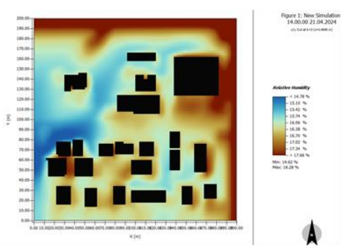
17.469647, 78.361930

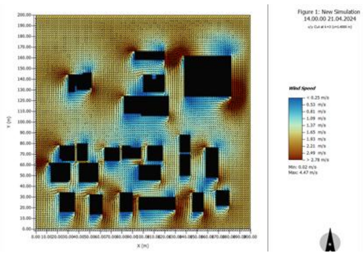
Seshadri Marg **LCZ 5**











Chapter 9: Way Forward

Moving forward, the following months will be dedicated to data collection and in-depth analysis to refine UHI mitigation strategies. Field visits are planned to the Telangana State Development Planning Society (TSDPS) to acquire comprehensive weather data for the GHMC Area, ensuring accurate inputs for microclimate simulations. Consultations with stakeholders from GHMC and HMDA will be scheduled to gather insights on current urban planning practices and potential implementation challenges.

Upon receiving the necessary data from TGDPS, detailed microclimate analyses will be conducted for all sites using ENVI-met. These simulations will inform the development and evaluation of tailored mitigation strategies, such as increasing green cover, implementing cool roof technologies, and optimizing building designs. The final phase will involve simulating the impact of these mitigation measures on each site to quantify their effectiveness in reducing the UHI effect. This comprehensive approach will enable the development of practical and impactful recommendations for mitigating UHI in the GHMC area.

Annexures

योजना तथा वास्तुकला विद्यालय, विजयवाड़ा
School of Planning and Architecture, Vijayawada
An Institute of National Importance, Ministry of Education Gov. of India

To,

Sri Shaik Meera
Chief Executive Officer, Telangana Development Planning Society,
Planning Department, Govt. of Telangana
Email: ceo-tgdps-plg@telangana.gov.in; tdgps-plg@telangana.gov.in

Sub: Seek appointment to discuss a project under "AMRUT Funded Centre for Urban Planning Capacity Building (A-CUPCB-SPAV)" funded by the Ministry of Housing and Urban Affairs, Govt. of India.

Respected Sir,

We take this opportunity to introduce the AMRUT Funded Centre for Urban Planning Capacity Building (A- CUPCB-SPAV), wherein the AMRUT Division of the Ministry of Housing and Urban Affairs (MoHUA, Government of India) has recognized SPA Vijayawada as one of the few centres in the country, that shall undertake cutting edge research, projects, and training in the field of urban planning and climate-sensitive development.

This Centre is testimony to SPAV's capability, resources, and potential to lead the path of research and advocacy in the domain of urban planning in India, as well as its profound expertise in various planning and architecture domains. Over the years, the institution has undertaken key Consultancy and Research projects, including GIS-based Master Plan Preparation under the AMRUT scheme, Zonal Master Plans, Revision of Planning Acts, etc. Additionally, the institution has earned recognition at national and international platforms for research outputs focusing on crucial areas like Climate Resilient Urban Planning, Urban Heat Islands, and many more.

"Canopy Layer UHI Mitigation Strategies for Hotspots of Hyderabad through Local Climate Zones (LCZs)" is an 8-month target urban research (TUR) Project that aims to formulate implementable UHI mitigation strategies at the urban block/neighbourhood level. **Regarding the same, our team would like to seek an appointment for our team to physically meet and discuss with your concerned personnel at any time during the third or fourth week of February 2025, at your convenience.**

A Summary of the project is annexed for your reference.

Sincerely,

Dr. Faiz Ahmed Chundeli
Principal Investigator
(M): +91-9445545513
(E-mail): faizahmed@spav.ac.in

Website: https://acupcb.spav.ac.in/

AMRUT Centre of Urban Planning for Capacity Building
A-CUPCB-SPAV

Atal Mission for Rejuvenation and Urban Transformation

27-02-2025

To

Chief Executive Officer,

Telangana Development Planning Society,

Govt. of Telangana, Khairatabad,

Hyderabad-500 004

Subject: Requesting Weather Data for a project under "AMRUT Funded Centre for Urban Planning Capacity Building (A-CUPCB-SPAV)" funded by the Ministry of Housing and Urban Affairs, Govt. of India.

Dear Sir/Madam,

We take this opportunity to introduce the AMRUT Funded Centre for Urban Planning Capacity Building (A- CUPCB-SPAV), wherein the AMRUT Division of the Ministry of Housing and Urban Affairs (MoHUA, Government of India) has recognized SPA Vijayawada as one of the few centres in the country, that shall undertake cutting edge research, projects, and training in the field of urban planning and climate-sensitive development.

One such project is "**Canopy Layer UHI Mitigation Strategies for Hotspots of Hyderabad through Local Climate Zones (LCZs)",** an 8-month target urban research (TUR) Project that aims to formulate implementable UHI mitigation strategies at the urban block/neighbourhood level, taking **Madhapur as a Study Area**.

In this regard, we are looking for **HOURLY/Hourly Weather Data** such as

1. Temperature Minimum & Maximum
2. Humidity Minimum & Maximum
3. Wind Speed
4. Wind Direction
5. Cloud Cover
6. Solar Radiation

Survey No.4, 4, ITI Road, Krishna Nagar, Vijayawada, Andhra Pradesh 520008

अमृत Atal Mission for Rejuvenation and Urban Transformation

AMRUT Centre of Urban Planning for Capacity Building
A-CUPCB-SPAV

We are specifically looking for weather data for the following AWS Station IDs, for **Whole of 2024 (Jan – Dec) and Whole of 2014 (Jane – Dec).**

Sl.No.	AWS IDs	Location
1	10014	Madhapur
2	10006	Jubileehills
3	30105	Kakatiya Hills: Madhapur
4	30052	Pillidarga Ward Office: Borabanda
5	30116	Venkatgiri Water Tank: Vengalrao Nagar
6	30061	Ward Office, Allapur Vivekananda Nagar
7	30051	Dr.MCRHRD IT Campus
8	30055	Community Hall, CBCID Colony: KPHB
9	30107	Urban Health Centre: Hafeezpet
10	11927	University of Hyderabad
11	30111	Khajaguda Sports Complex Gachibowli
12	10529	Manikonda
13	30115	Goutham Nagar Function Hall: Filmnagar
14	30026	Mothinagar Ward Office: Moosapet
15	10778	Shankarpalle
16	11563	Venkiryal
17	10522	ESS D.P.Pally
18	11513	Rajendranagar (ARS)
19	30103	Patigadda
20	11206	Sardarmahal (zonal commissioner office)

Kindly let us also know the required charges for the above dataset and the mode of payment.

Kind Regards

Dr. Faiz Ahmed Chundeli
Principal Investigator (PI)
School of Planning and Architecture, Vijayawada
+91 9445545513
Email: faizahmed@spav.ac.in
faizahmed.arch@gmail.com

Survey No.4, 4, ITI Road, Krishna Nagar, Vijayawada, Andhra Pradesh 520008

Chapter 10: Bibliography

Dimitrov, S., Popov, A., & Iliev, M. (2021). An application of the LCZ approach in surface urban heat island mapping in Sofia, Bulgaria. *Atmosphere*, *12*(11). https://doi.org/10.3390/atmos12111370

Eldesoky, A. H. M., Gil, J., & Pont, M. B. (2021a). The suitability of the urban local climate zone classification scheme for surface temperature studies in distinct macroclimate regions. *Urban Climate*, *37*(March), 100823. https://doi.org/10.1016/j.uclim.2021.100823

Eldesoky, A. H. M., Gil, J., & Pont, M. B. (2021b). The suitability of the urban local climate zone classification scheme for surface temperature studies in distinct macroclimate regions. *Urban Climate*, *37*. https://doi.org/10.1016/j.uclim.2021.100823

Hidalgo García, D., & Arco Díaz, J. (2021). Modeling of the Urban Heat Island on local climatic zones of a city using Sentinel 3 images: Urban determining factors. *Urban Climate*, *37*. https://doi.org/10.1016/j.uclim.2021.100840

Kotharkar, R., Bagade, A., & Singh, P. R. (2020a). A systematic approach for urban heat island mitigation strategies in critical local climate zones of an Indian city. *Urban Climate*, *34*(August), 100701. https://doi.org/10.1016/j.uclim.2020.100701

Kotharkar, R., Bagade, A., & Singh, P. R. (2020b). A systematic approach for urban heat island mitigation strategies in critical local climate zones of an Indian city. *Urban Climate*, *34*. https://doi.org/10.1016/j.uclim.2020.100701

Madhavan, G. R., & Kannamma, D. (2024a). Multi-objective method of selecting performance-based local climatic zones using binomial logistic regression in warm and humid climate. *Frontiers of Architectural Research*, *13*(1), 184–200. https://doi.org/10.1016/j.foar.2023.10.004

Madhavan, G. R., & Kannamma, D. (2024b). Multi-objective method of selecting performance-based local climatic zones using binomial logistic regression in warm and humid climate. *Frontiers of Architectural Research*, *13*(1), 184–200. https://doi.org/10.1016/j.foar.2023.10.004

Matzarakis, A., Martinelli, L., & Ketterer, C. (2016). Relevance of thermal indices for the assessment of the urban heat Island. In *Counteracting Urban Heat Island Effects in a Global Climate Change Scenario*. https://doi.org/10.1007/978-3-319-10425-6_4

NDMA. (2019). *National guidelines for preparation of action plan -prevention and management of heat waves* (p. 40).

NOAA. (2025). https://www.noaa.gov/

Oh, M., Jang, K. M., & Kim, Y. (2021). Empirical analysis of building energy consumption and urban form in a large city: A case of Seoul, South Korea. *Energy and Buildings*, *245*, 111046. https://doi.org/10.1016/j.enbuild.2021.111046

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). *Urban Climates by T.R. Oke, G. Mills, A. Christen, J.A. Voogt (z-lib.org).pdf*.

Rahmani, N., & Sharifi, A. (2025). Urban heat dynamics in Local Climate Zones (LCZs): A systematic review. In *Building and Environment* (Vol. 267). Elsevier Ltd. https://doi.org/10.1016/j.buildenv.2024.112225

Raymond, C., Matthews, T., & Horton, R. M. (2020). The emergence of heat and humidity too severe for human tolerance. *Science Advances*, *6*(19). https://doi.org/10.1126/sciadv.aaw1838

Sharmin, T., & Chappell, A. (2025a). Detecting the changing impact of urbanisation on urban heat islands in a tropical megacity using local climate zones. *Energy and Built Environment*, *August 2024*. https://doi.org/10.1016/j.enbenv.2025.02.002

Sharmin, T., & Chappell, A. (2025b). Detecting the changing impact of urbanisation on urban heat islands in a tropical megacity using local climate zones. *Energy and Built Environment*. https://doi.org/10.1016/j.enbenv.2025.02.002

Shi, Z., Fonseca, J. A., & Schlueter, A. (2017). A review of simulation-based urban form generation and optimization for energy-driven urban design. *Building and Environment*, *121*, 119–129. https://doi.org/10.1016/j.buildenv.2017.05.006

Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, *93*(12), 1879–1900. https://doi.org/10.1175/BAMS-D-11-00019.1

Urban Climates. (n.d.).

Wang, M., Yu, H., Yang, Y., Jing, R., Tang, Y., & Li, C. (2022). Assessing the impacts of urban morphology factors on the energy performance for building stocks based on a novel automatic generation framework. *Sustainable Cities and Society*, *87*(October), 104267. https://doi.org/10.1016/j.scs.2022.104267

Yunita, R., Wibowo, A., Supriatna, & Rais, A. F. (2022a). Urban Heat Island Mitigation Strategy based on Local Climate Zone Classification using Landsat 8 satellite imagery. *IOP Conference Series: Earth and Environmental Science*, *1039*(1). https://doi.org/10.1088/1755-1315/1039/1/012013

Yunita, R., Wibowo, A., Supriatna, & Rais, A. F. (2022b). Urban Heat Island Mitigation Strategy based on Local Climate Zone Classification using Landsat 8 satellite imagery. *IOP Conference Series: Earth and Environmental Science*, *1039*(1). https://doi.org/10.1088/1755-1315/1039/1/012013

Zhou, Y., Zhuang, Z., Yang, F., Yu, Y., & Xie, X. (2017). Urban morphology on heat island and building energy consumption. *Procedia Engineering*, *205*, 2401–2406. https://doi.org/10.1016/j.proeng.2017.09.862