Impact of Green Spaces on Urban Temperature

Author:Ar. Noorulsaba Akil Shaikh
Town and Country Planning dept.
COEP Tech, University
Pune, India
sabashaikh22422@gmail.com

Under the Guidance of: Jaspresst Kaur Chabda
Adjunct Faculty-Planning
COEP Tech, University
Pune, India

Abstract—

Urbanization has led to the proliferation of impervious surfaces, intensifying the Urban Heat Island (UHI) effect and exacerbating thermal discomfort in cities. The impact of green spaces on urban temperature is a critical area of study in the context of urban heat island (UHI) mitigation and climate-resilient city planning. This research explores the multifaceted role of the presence of green spaces and the absence of green spaces on urban temperature. Green spaces influence urban temperatures through evapotranspiration, shading, and albedo effects, reducing localized heat and improving thermal comfort. The study highlights how vegetation mitigates the UHI effect by lowering surface and air temperatures. It also examines spatial distribution, geometry, and vegetation types, emphasizing the need for strategic planning to maximize their cooling benefits. While green spaces provide substantial environmental and social benefits, challenges such as water management, land availability, and maintenance are addressed. The findings underscore the importance of integrating green infrastructure into urban design as a sustainable solution to mitigate urban heat and enhance urban livability.

Keywords—Urban Heat Island (UHI); Green spaces; Urban temperature; Vegetation cover; Thermal comfort; Urban planning.

I. INTRODUCTION (*Heading 1*)

As urban development continues to surge, cities are transforming into dense networks of concrete, asphalt, and steel. While this growth brings economic and social benefits, it also poses significant environmental challenges. One of the most pressing concerns is the Urban Heat Island (UHI) effect, where metropolitan areas experience considerably higher temperatures than surrounding rural landscapes. This phenomenon not only contributes to increased energy consumption and worsened air quality, but it also elevates risks to public health—especially during heatwaves.

These local heating issues are part of a much broader climate reality. Between 2014 and 2023, Earth recorded its ten warmest years since reliable data collection began. What was once considered record-breaking—like the heat levels of 2005—is now overshadowed, with that year ranking only twelfth in recent comparisons. Even more telling is that global temperatures have stayed above the long-term average for 47 consecutive years. This ongoing trend highlights the urgent need to rethink how we design and shape our urban environments.

Amid these challenges, green spaces—such as public parks, urban forests, green roofs, and community gardens—have emerged as vital components in creating climate-resilient cities. These spaces provide a natural and effective buffer against rising urban temperatures. They offer more than just visual relief; they actively cool the surrounding air, improve air quality, and enhance livability. This paper explores how green spaces function as natural climate moderators, examines their distribution and design, and discusses the importance of integrating them into future city planning.

II. COOLING EFFECT OF GREEN SPACES

A. Size and Shape:

Larger water bodies tend to deliver more substantial cooling benefits, owing to their higher thermal capacity, which allows them to absorb and store heat effectively. Additionally, compact geometries are more efficient in preserving localized cooling, whereas elongated or irregularly shaped water features often distribute the cooling influence across broader areas, potentially diminishing its intensity in any single location.

B. Proximity and Orientation:

Positioning blue spaces upwind of urban areas can help direct cooler air toward the city, thereby enhancing its overall thermal regulation and contributing to urban climate mitigation.

C. Aspect Ratio:

Elongated and narrower water bodies have been observed to extend their cooling influence up to 100–200 meters beyond their immediate edges, while broader water bodies tend to concentrate their cooling effects within a more confined area.

D. Shape and Orientation

When aligned with the direction of prevailing winds, water bodies can amplify their cooling impact by carrying cooler air deeper into the urban landscape.

III. GAPS IN CURRENT STUDIES

After A comprehensive review of over 100 studies was conducted to examine prevailing patterns and research gaps in the study of urban green space morphology *(Zou & Wang, Progress and Gaps in Research on Urban Green Space Morphology: A Review*)[3]

Geographic Focus: The analysis revealed a strong geographic bias, with approximately 70% of the studies concentrated in temperate climate zones, while tropical and arid regions accounted for just 10% of the research.

Scale of Study: A significant portion—over 60%—of the reviewed literature focused on large urban parks. In contrast, small-scale or fragmented green spaces were notably underrepresented, comprising only about 5% of the studies.

Temporal Scope: Most studies (around 85%) investigated short-term impacts of green space morphology, with relatively few adopting a longitudinal perspective extending beyond a decade.

Lack of Standardization: The review also highlighted inconsistencies in how green space morphology is defined and measured, indicating a lack of standardized frameworks. This variability poses challenges for comparative analysis and synthesis across different studies and contexts.

IV. Research Methodology

Literature Review: The literature review serves two main purposes: to gather existing knowledge and to identify theories, models, or frameworks that will guide the research. It also ensures the study is grounded in previous academic work.

Identifying Theories and Model: Based on insights from the literature review, relevant theories or models are selected. These help in shaping the research design and give structure to the study. Theories can provide analytical frameworks, while models may help visualize or simulate the processes being studied.

Delineation of the Study Area: After the objectives are finalized, the specific **geographic area** of the study is identified. This is crucial, especially for studies that involve mapping or spatial analysis. The area must be clearly defined to collect accurate and relevant data.

Data Collection: In this phase, data is gathered to support the analysis. This study primarily relies on **secondary data**, which includes:

1. **Ward maps** and **Existing Land Use (ELU)** data from the local municipal body (e.g., PCMC)
2. **Temporal imagery from Google Earth**, which helps track changes over time
3. **Landsat 8 satellite images**, used for analyzing environmental or land use pattern

Data Analysis: Once data is collected, it is processed and analyzed using specialized tools:

- **AutoCAD** – Used for drafting, marking boundaries, or visualizing spatial elements
- **ArcGIS** – A powerful tool for mapping, spatial analysis, and integrating various datasets

These tools help in identifying trends, patterns, and changes within the study area. The analysis often includes layering data, comparing changes over time, and interpreting results in relation to the research objectives.

V. Land Surface Temperature Calculation

Step 1: Download Satellite image - Landsat 8

Step 2: Calculation of Top of atmospheric spectral radiance (TOA)

Step 3: Conversion of TOA to Brightness temperature (BT)

Step 4: Calculation of Normalised Difference Vegetation Index (NDVI)

Step 5: Calculation of Proportion of Vegetation (Pv)

Step 6: Calculate Emissivity (E)

Step 7: Calculation of Land Surface Temperature (LST)

VI. Land Surface Temperature Calculation

Chennai

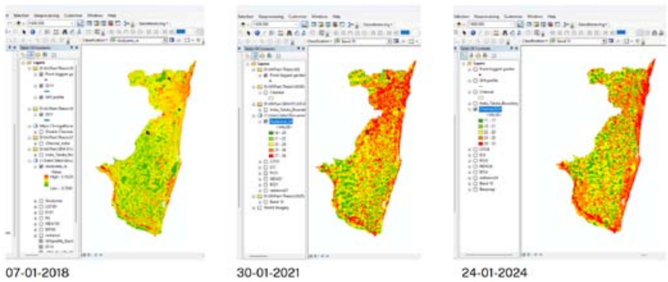

Fig. 1. *figure respresenting Chennai Land Surface Temperature throughout 2018-2024*

VII. Urban Heat Island and Stack Profile

Site: Miyawaki Forest, Krishna Nagar, West Tambaram, Chennai.

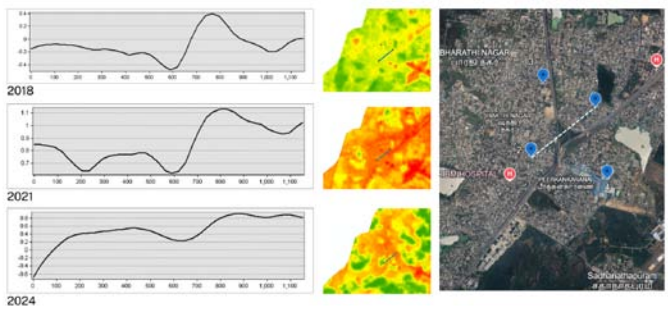

Fig. 2. *figure respresenting Urban Heat Islandand Stack Profile of site from 2018-2024 on first axis*

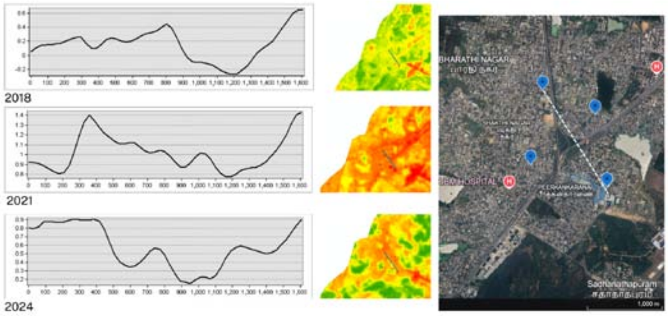

Fig. 3. *figure respresenting Urban Heat Islandand Stack Profile of site from 2018-2024 on second axis*

VIII. Conclusion

Between 2018 and 2021, there was a noticeable increase in temperature, which can be directly linked to rapid urbanization during this period. The highest average temperature was recorded in 2021, marking a peak in the warming trend. However, from 2021 to 2024, a gradual decline in temperature was observed. This reduction can be attributed to increased efforts in green space development and plantation drives undertaken in the region. As a result, the temperature graphs for 2024 appear smoother and show a less steep gradient, indicating a more stable and cooler environment due to the positive impact of newly introduced vegetation.

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