

Mapping Thermal Transformation in India's Coastal Megacities: A Spatiotemporal Analysis of Land Surface Temperature and Urban Heat Island Expansion

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Abstract

Accelerated land transformation may exacerbate urban heat, however coastal municipalities can benefit from sea-breeze cooling, elevated humidity, and pronounced diurnal temperature variations. This research integrates documented remote-sensing metrics for Mumbai, Kolkata, and Chennai from 2001/2003 to 2023 to assess urban land-cover changes, daily cooling patterns, core-periphery temperature variations, and humid heat. The Centre for Science and Environment's 2024 evaluation obtained source metrics from MODIS land-surface temperature and Landsat land-use/vegetation datasets; this study independently recalculated alterations, rates, and precise small-sample statistics. The accumulated proportion rose throughout all urban areas, from an average of 46.37% in three cities to 68.57%, but the average green share declined from 28.33% to 21.67%. Chennai had the most rapid transformation, with the built-up area increasing by 42.8 percentage points and the green area decreasing by 13.7 points. In 2023, Kolkata retained its status as the most developed city with an 80.1% built-up area. Urban centers at night were warmer than their outskirts in Mumbai (+0.4°C), Kolkata (+1.2°C), and Chennai (+0.9°C), despite Mumbai's core being 3.5°C colder during the day. Documented daily cooling decreased by 24% in Mumbai and 5% in Chennai; the associated reconstructed cooling values from previous periods were 10.26°C and 10.21°C, respectively. Increased humidity contributed an estimated 5.0–6.6°C to perceived heat stress. The limited number of three cities rendered paired and exact permutation tests ineffective; the robust descriptive correlation between the ultimate built-up share and nighttime core heat ($r = 0.988$) lacked conventional significance. The results indicate that coastal urban heat is a multifaceted, temporally variable occurrence. Planning must emphasise nighttime thermal retention, uninterrupted blue-green infrastructures, cool materials, ventilation pathways, and humidity-sensitive heat management technologies.

Keywords: Land Surface Temperature, Surface Urban Heat Island, Coastal Megacity, Built-Up Expansion, Green Cover, Humidity

1. INTRODUCTION

Urbanisation alters surface energy transfer by substituting verdant and wet terrains with impermeable structures such as roofs and roadways. These surfaces accumulate solar energy, diminish evapotranspiration, and emit heat post-sunset, resulting in a surface urban heat island (SUHI) and, under favorable climatic circumstances, a canopy-layer heat island. The difference is significant: satellite-derived land surface temperature (LST) quantifies the radiometric temperature of the surface at the time of sensor passage, whereas near-surface air temperature and human thermal stress are influenced by factors such as wind, humidity, radiation, and physiological responses. Recent evaluations therefore advise viewing LST as a geographical marker of thermal land alteration instead of a direct gauge of the temperature felt by inhabitants (IPCC, 2022; Islam et al., 2024).

India's coastal metropolises are significant examples as fast development intersects with maritime climate. Marine winds may lower temperatures in the city center during the day, waterways and marshlands can provide localised cool zones, and moist air can hinder nighttime cooling while increasing the heat index. The same metropolis may thus exhibit a diurnal urban cool island and a nocturnal heat island. Mumbai, Kolkata, and Chennai exhibit variations in urban structure, coastal alignment, wetland ecosystems, monsoonal patterns, and historical development. Their juxtaposition helps elucidate why the proportion of built-up area alone is inadequate for characterising heat danger.

The existing Indian research shows significant correlations between land surface temperature, urbanisation metrics, vegetation depletion, and urban growth. Research in Kolkata indicates ongoing temperature increases and a growing thermal footprint (Halder et al., 2021; Mandal et al., 2022; Chatterjee & Majumdar, 2022). Investigations in Mumbai reveal significant alterations in green spaces and an urban climate that is tempered, albeit not eradicated, by coastal dynamics (Rahaman et al., 2021). Research in Chennai underscores fast land transformation and the significance of land-use zoning in urban development (Rajagopal et al., 2025). National and multi-city research indicates that urbanization exacerbates city warming beyond the effects of regional climate change, with nighttime heat being especially significant (Jain, 2023; Sethi & Vinoj, 2024).

The majority of research focuses on a single city, a solitary sensor, or a certain season, complicating intercity comparisons. This study employs a shared secondary source to align similar metrics for three coastal megacities, subsequently recalibrating land-cover alterations, annualised rates, and precise small-sample correlations. The aims are to measure changes in urban development and vegetation; analyse present-day temperature variations between urban centers and their outskirts; evaluate the correlations between land cover and nighttime heat; and convert findings into planning strategies. The examination distinctly categorises published metrics, derived metrics, and unreported data.

2. REVIEW OF LITERATURE AND IDENTIFICATION OF RESEARCH DEFICIENCIES

Remote sensing offers uniformly distributed heat data that is challenging to get from limited weather stations. Landsat delivers intricate thermal mapping at the neighborhood level, whilst MODIS supplies regular data appropriate for long-term and daily climatological studies. Open-source implementations of LST retrieval have improved repeatability, and USGS Collection 2 Level-2 goods now include atmospherically adjusted surface temperature together with documented scale factors and quality masks (Ermida et al., 2020; U.S. Geological Survey, 2024). Nonetheless, variations in flyover duration, cloud obstruction, emissivity, seasonal factors, and geographic resolution might generate misleading patterns when goods are amalgamated without standardization.

Flora and water affect land surface temperature via shade, evapotranspiration, and thermal capacity.

Cross-city data indicates that the extent of cooling provided by green spaces is influenced by patch size, layout, prevailing climate, and the time of day (Li et al., 2022). Compact urban structures often retain warmth throughout the night due to the gradual release of accumulated heat, although increased daytime albedo or coastal breezes may disrupt daily temperature trends. The configuration of urban areas, the alignment of streets, and the density of buildings also affect ventilation. In tropical coastal towns, relative humidity is crucial since it may exacerbate a little rise in air temperature by hindering evaporative cooling. The health literature associates elevated nighttime temperatures with heightened death rates due to diminished recuperation from daytime heat (He et al., 2022).

The body of Indian evidence is growing but remains disjointed. Veena et al. (2020) examined the methodological variations in Indian UHI research. Saha et al. (2021) illustrated the correlations between land cover and land surface temperature in eastern urban conglomerates, whereas Puppala and Singh (2021) recorded the thermal effects of urban expansion in Visakhapatnam. A nationwide assessment determined that Indian research used varied definitions of "urban," reference areas, and heat-island intensity, which limits comparability (Islam et al., 2024). The research gap addressed in this study is not only an additional independent categorisation, but rather a clear synthesis of a coordinated three-city dataset that provides day-night and humidity metrics with land-cover alterations.

3. RESEARCH FRAMEWORK AND DATA STANDARDISATION

The research encompasses Mumbai, Kolkata, and Chennai. Mumbai is a peninsula in the Arabian Sea characterised by significant marine impact and extensive urban growth. Kolkata is situated inland from the Bay of Bengal in the lower Ganges delta and is connected to the Hooghly River and East Kolkata Wetlands. Chennai is a swiftly growing city on the Bay of Bengal characterised by a highly fragmented blue-green infrastructure. The analysis begins in 2003 for Mumbai and Chennai, while it starts in 2001 for Kolkata, concluding in 2023. These initial years align with the analogous baseline years indicated in the source evaluation instead of enforcing an inaccurate uniform year.

The fundamental comparison measurements were documented from "Decoding the Urban Heat Stress among Indian Cities," released by the Centre for Science and Environment in May 2024 (Somvanshi & Kaur, 2024). The study of long-term surface temperature used MODIS monthly land data from NASA, while land use, land cover, and vegetation assessments were conducted using Landsat 7/8 products from the U.S. Geological Survey. Summer intervals were analysed to mitigate seasonal variability. The source indicated accumulated and verdant shares, present daily cooling, % reduction in cooling, thermal disparities between urban center and periphery, alterations in relative humidity, and the humidity's role in heat stress.

All data points were inputted into a municipal-level panel and verified separately for internal calculations. Alterations in built-up areas and vegetation cover were articulated in percentage points and relative percentages. The annualized alteration is calculated by dividing the percentage-point disparity by the number of years that have passed. The report indicated that the present diurnal cooling had diminished by a specified percentage compared to the previous period, and the prior cooling intensity was recalibrated as the current cooling divided by one minus the drop rate. This recalibrated figure does not represent a precisely measured yearly baseline. Kolkata was designated a zero reported decrease since the source indicated that cooling had not diminished; its individual ambient warming rate was noted as not recorded instead of being translated from qualitative terminology. The alteration in Chennai's heat-index percentage was not specified, since the report just said it above 5%.

Table 1. Source products and harmonization rules

Component	Source / resolution	Period	Use in this study
Long-term surface temperature	MODIS monthly land products; approximately 1 km for common LST products	City-specific summer comparisons to 2023	Diurnal cooling and core–periphery thermal interpretation
Land use / land cover and vegetation	Landsat 7/8, USGS; 30 m multispectral basis	2001/2003 and 2023 endpoints	Built-up and green-cover shares
Humidity and apparent heat	CSE synthesis of meteorological records	Long-period city comparison	Relative-humidity change and added heat-stress signal
Derived calculations	Arithmetic from reported values	Endpoint and earlier comparison period	Percentage-point change, annualized rate, reconstructed earlier cooling, exact tests

Note. The exact MODIS product identifiers and all preprocessing parameters were not reproduced in the comparative report; this paper therefore does not claim independent pixel-level replication.

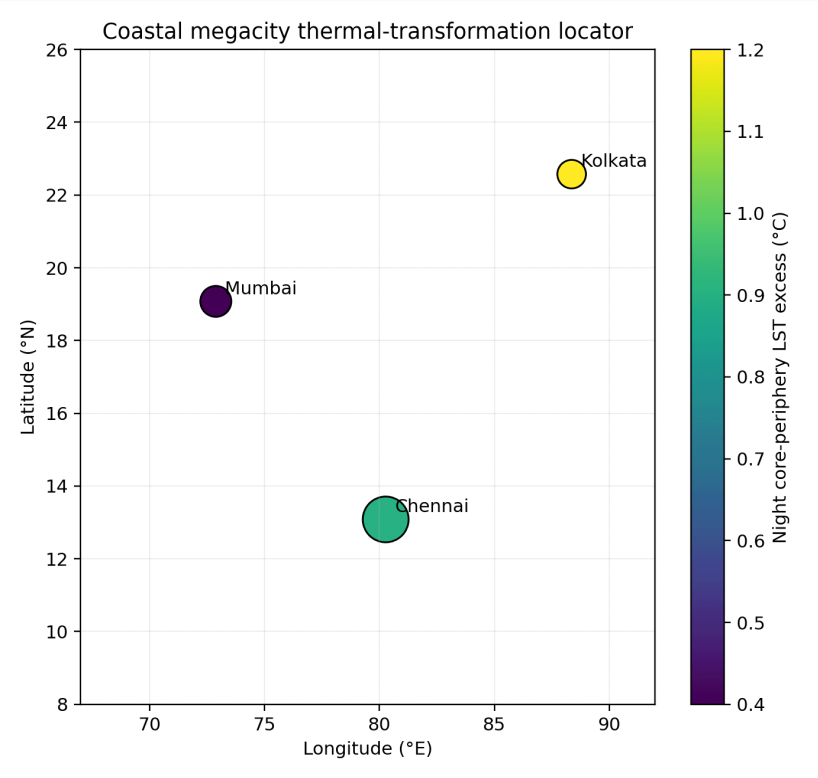


Figure 1. Locations of the three coastal megacities and their 2023 built-up shares.

Source: Author’s locator using city coordinates and land-cover values reported by Somvanshi and Kaur (2024); symbols are schematic.

4. ANALYTICAL FRAMEWORK

The examination employs both descriptive and precise inferential techniques suitable for three urban areas. For every city, the alteration in built-up and green proportions was determined by subtracting the baseline share from the 2023 endpoint. Relative variation divided that disparity by the baseline, and yearly change divided by the time elapsed. The daytime and nocturnal core–periphery metrics were regarded as signed thermal differentials: positive values indicate that the urban center exhibited higher temperatures than the

peripheral reference, whereas negative values denote a daytime urban cool-island phenomenon.

The intensity of the surface urban heat island is often described as the average urban land surface temperature subtracted from the average reference land surface temperature. The fundamental disparities between core and periphery in the source report are theoretically similar, although contingent upon its functional urban and peripheral areas. They ought not to be seen as synonymous with a static rural-ring SUHII in the absence of the original masks. Diurnal cooling refers to the decrease in temperature from day to night. A reduction in this decrease suggests less nocturnal respite, even if diurnal temperatures do not escalate correspondingly.

Paired t-tests evaluated baseline and endpoint shares, although their p-values are shown only as descriptive statistics due to $n = 3$. A bilateral sign test assessed whether all municipalities exhibited uniform directional changes. Pearson and Spearman correlations were combined with precise permutation p-values derived from all six potential configurations of the city result values. With just three observations, even a correlation approaching one cannot provide a standard two-sided $p < .05$. The examination therefore prioritises the magnitude of effects, consistency, evidential processes, and triangulation with peer-reviewed urban research above mere binary significance.

$$SUHII = \text{Mean } LST_{\text{urban}} - \text{Mean } LST_{\text{reference}}$$

(1)

$$\text{Annualized land-cover change} = (\text{Share}_{2023} - \text{Share}_{\text{baseline}}) / \text{elapsed years}$$

(2)

$$\text{Earlier diurnal cooling} = \text{Current cooling} / (1 - \text{reported decline fraction})$$

(3)

Interpretive boundary. LST, near-surface air temperature and heat index are different quantities. This paper uses the reported surface and humidity indicators to describe thermal transformation; it does not convert them into personal exposure or mortality estimates.

5. RESULTS

Built-up land increased and green cover decreased in every city. Across the three cases, mean built-up share rose from 46.37% to 68.57%, a gain of 22.20 percentage points, while mean green share fell from 28.33% to 21.67%, a loss of 6.67 points. The paired tests were not statistically significant because only three cases were available (built-up $t = 2.144$, $p = .165$; green $t = -1.759$, $p = .221$). The two-sided sign-test probability for three changes in the same direction was .25. These p-values do not negate the observed transformation; they show that a three-city sample cannot support population-level inference by itself.

Chennai experienced the fastest transformation. Built-up share increased from 30.7% in 2003 to 73.5% in 2023, a gain of 42.8 percentage points or 139.4% relative to the baseline. The annualized increase was 2.14 percentage points per year. Green share fell from 34.0% to 20.3%, a 13.7-point decline. Kolkata began from a much more urbanized baseline: built-up share increased from 70.0% in 2001 to 80.1% in 2023, while green share slipped from 15.2% to 14.5%. Mumbai showed an intermediate pathway, with built-up share rising from 38.4% to 52.1% and green share declining from 35.8% to 30.2%.

Table 2. Land-cover transformation in the three coastal megacities

City	Period	Built baseline (%)	Built 2023 (%)	Built change (pp)	Green baseline (%)	Green 2023 (%)	Green change (pp)
Mumbai	2003–2023	38.4	52.1	13.7	35.8	30.2	-5.6
Kolkata	2001–2023	70.0	80.1	10.1	15.2	14.5	-0.7
Chennai	2003–2023	30.7	73.5	42.8	34.0	20.3	-13.7

Note. Shares and baseline years are those reported by Somvanshi and Kaur (2024). pp = percentage points.

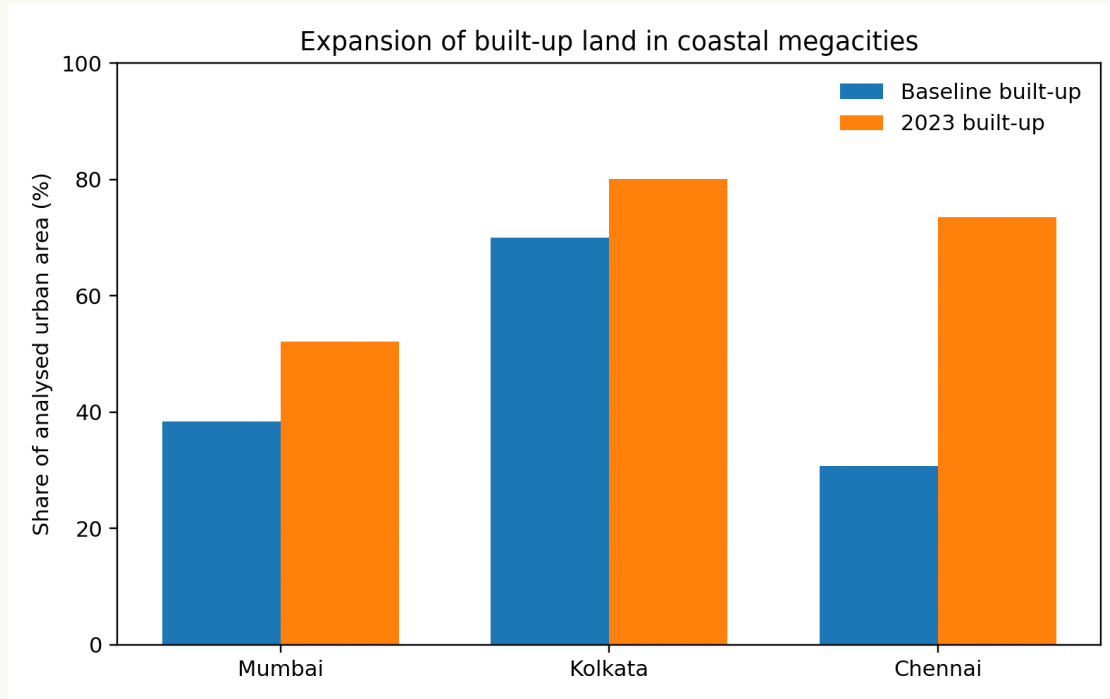


Figure 2. Built-up share at baseline and in 2023.

Source: Author's calculations from Somvanshi and Kaur (2024).

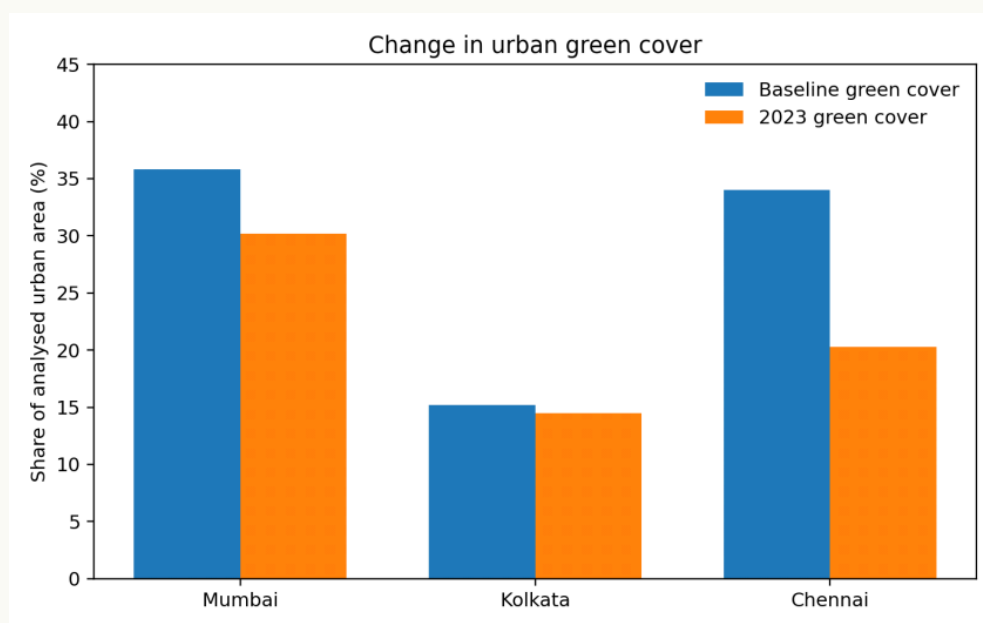


Figure 3. Green-cover share at baseline and in 2023.

Source: Author's calculations from Somvanshi and Kaur (2024).

The analysis of day and night demonstrated a shared nighttime heat island, however distinct daytime patterns. The metropolitan center of Mumbai was

3.5°C colder than its outskirts during the day, aligning with significant coastal moderating or variations in the chosen reference area. During the night, the indicator inverted, and the center temperature increased by 0.4°C. The central area of Kolkata had higher temperatures during the day (+1.8°C) and at night (+1.2°C), showcasing the most significant nighttime disparity among the three cities. Chennai had a higher core temperature throughout both intervals (+0.8°C during the day and +0.9°C at night). Consequently, all three cities preserved more warmth in the urban center post-sunset, despite daytime land surface temperature indicating a cooling trend. The latest documented diurnal cooling was 7.8°C in Mumbai, 6.2°C in Kolkata, and 9.7°C in Chennai. Mumbai's cooling has decreased by 24% compared to the previous assessment period, suggesting a revised earlier temperature of 10.26°C and a decrease of 2.46°C. The 5% decrease in Chennai indicates a prior temperature of 10.21°C and a drop of 0.51°C. The report from Kolkata showed no decrease, so its comparative value remained at 6.2°C. The reconstruction need to be seen as an algebraic reverse computation from approximated percentages, rather than a substitute for the initial time series. The intercity descriptive framework associated high-density urbanisation with nighttime warmth. The ultimate constructed share and the nocturnal core-periphery disparity exhibited a Pearson r of 0.988; the green share and nighttime heat demonstrated a r of roughly -1.000 . The precise two-sided permutation p -values were .167 due to the existence of just six permutations for $n = 3$. The relationship between built-up change and green-cover change was significantly negative ($r = -0.961$). These factors aid in pattern identification but are incapable of differentiating constructed density from topography, water, coastline, prevailing wind, or reference-zone delineation.

Table 3. Reported and derived thermal indicators

City	Current diurnal cooling (°C)	Reported cooling decline (%)	Reconstructed earlier cooling (°C)	Day core – periphery (°C)	Night core – periphery (°C)
Mumbai	7.8	24.0	10.26	-3.5	+0.4
Kolkata	6.2	0.0	6.20	+1.8	+1.2
Chennai	9.7	5.0	10.21	+0.8	+0.9

Note. Positive core-periphery differences denote a warmer urban core. Earlier cooling is reconstructed from the reported percentage decline and may differ slightly from unrounded source values.

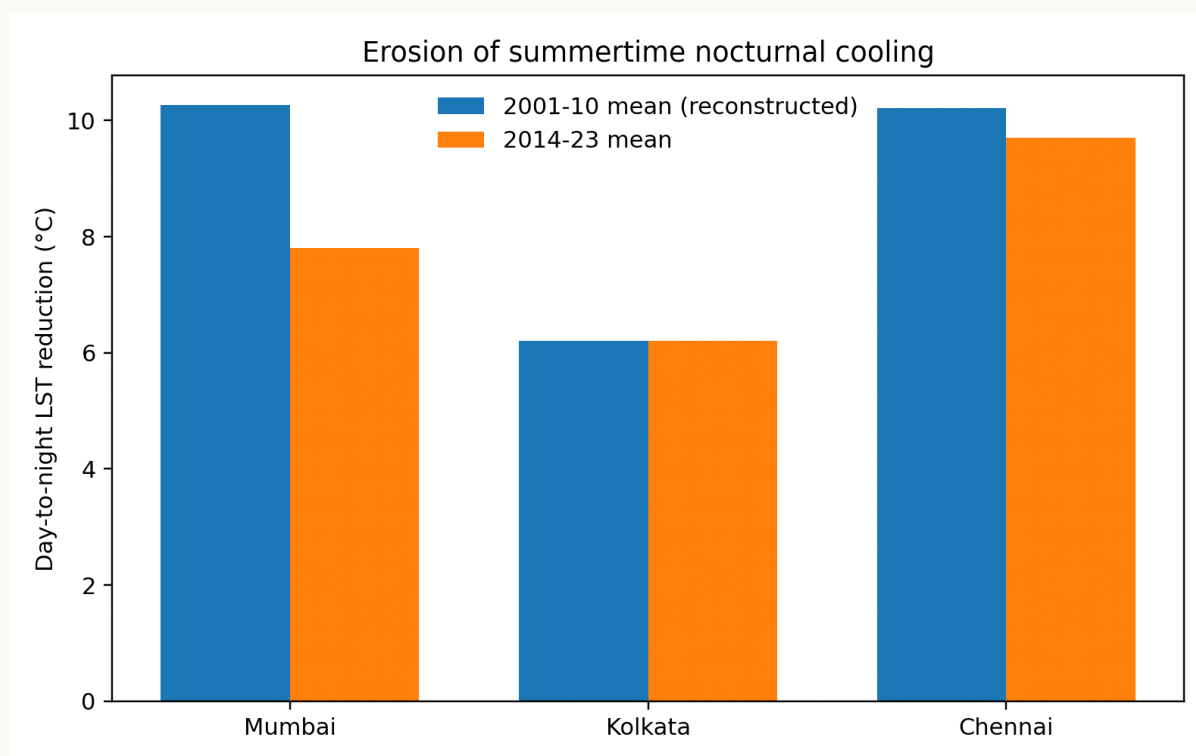


Figure 4. Current and reconstructed earlier-period diurnal cooling.

Source: Author's calculations from rounded values reported by Somvanshi and Kaur (2024).

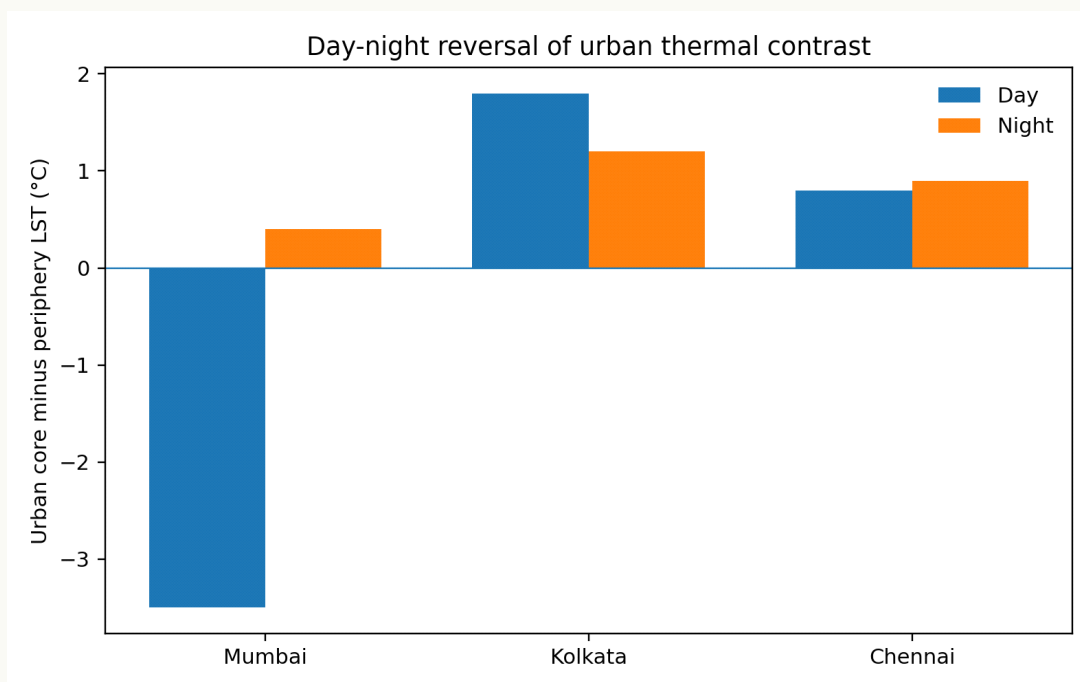


Figure 5. Daytime and night-time urban core–periphery thermal differences.

Source: Somvanshi and Kaur (2024), reorganized by the author.

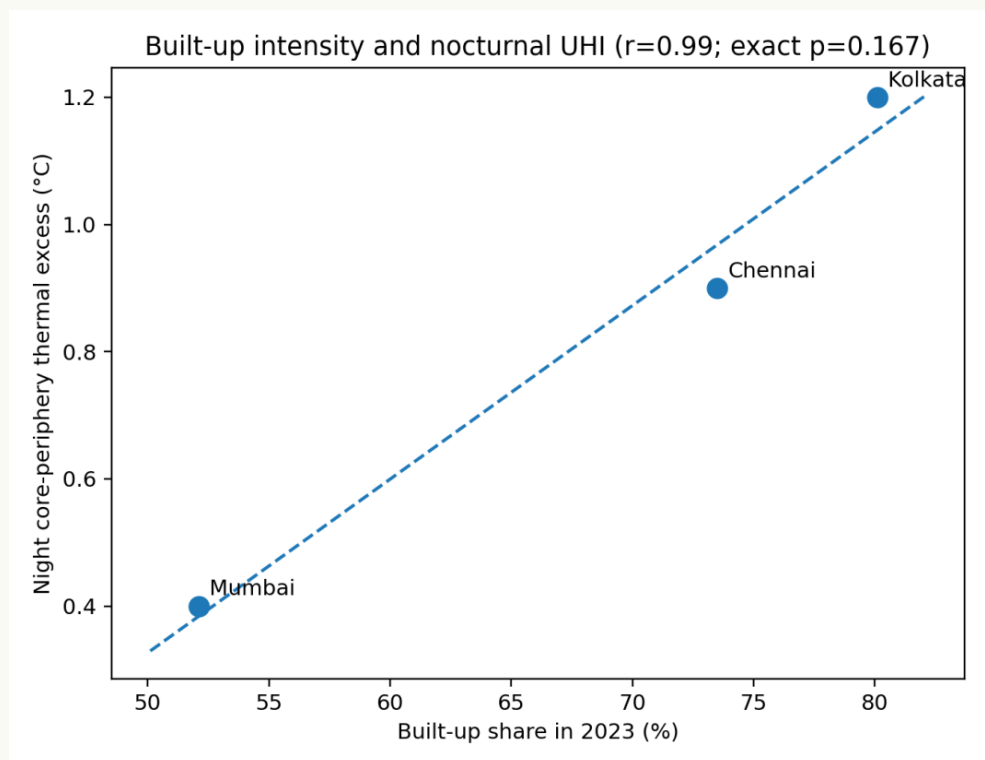


Figure 6. Final built-up share and nocturnal core–periphery temperature contrast.

Source: Author's exact three-city descriptive analysis.

Humidity amplified the thermal burden. Reported relative humidity increased by 7 percentage points in Mumbai and 5 points in Kolkata and Chennai. The estimated humidity contribution to heat stress was about 5.0°C in Mumbai, 6.6°C in Kolkata and 6.3°C in Chennai. Mumbai's heat index increased by about 7%, Kolkata's by 3.5%, and Chennai's increase was reported as greater than 5% without a precise value. Kolkata and Chennai also experienced a tripling of days with heat index above 41°C in the source assessment. These indicators demonstrate why coastal heat cannot be evaluated from dry-bulb temperature or LST alone.

The city profiles imply different forms of vulnerability. Kolkata combines very high built-up share, low green share and the largest nocturnal core heat contrast. Chennai combines the fastest land-cover transformation with substantial humid heat. Mumbai retains more green share and shows daytime coastal cooling, but its 24% decline in diurnal cooling indicates weakening night-time recovery. The common factor is not identical daytime LST; it is the persistence of heat after sunset within increasingly impervious urban fabric.

Table 4. Ambient warming and humidity-related heat indicators

City	Reported ambient warming (°C/decade)	Relative-humidity change (pp)	Humidity-added heat stress (°C)	Heat-index change (%)
Mumbai	0.6	7.0	5.0	7.0
Kolkata	NR	5.0	6.6	3.5
Chennai	0.4	5.0	6.3	>5.0

Note. NR = not separately reported. Chennai's heat-index change was stated as greater than 5%, so no exact value was imputed.

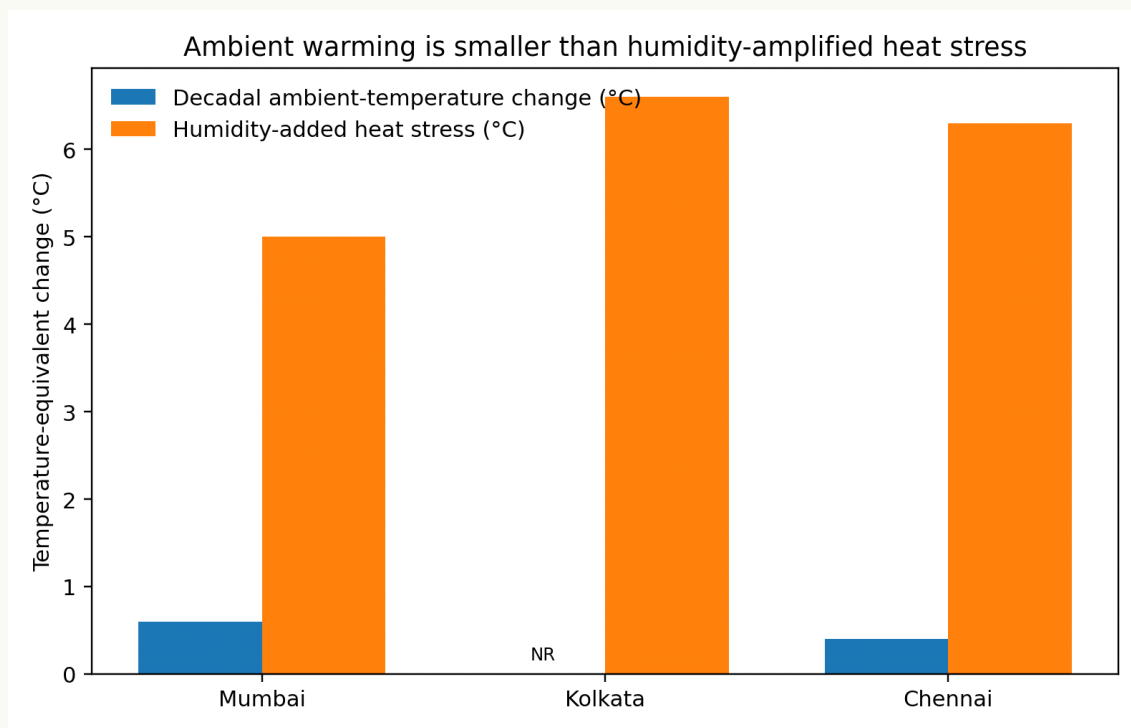


Figure 7. Reported long-term ambient and humidity-related heat signals.

Source: Somvanshi and Kaur (2024), with unreported values shown as NR.

Table 5. Small-sample statistical diagnostics

Test / relationship	Statistic	p	Interpretation
Paired built-up share	$t = 2.144$	.165	All three increased; $n = 3$
Paired green share	$t = -1.759$	.221	All three decreased; $n = 3$
Two-sided sign test	3/3 same direction	.250	Applies separately to built and green changes
Built share 2023 vs night core heat	Pearson $r = .988$	.167 exact	Strong descriptive association; six permutations
Green share 2023 vs night core heat	Pearson $r \approx -1.000$	.167 exact	Strong descriptive inverse association
Built change vs green change	Pearson $r = -.961$	.167 exact	Land conversion pattern; not causal

Note. Inferential power is extremely limited. Exact permutation probabilities are discrete and cannot be below .05 with $n = 3$ under the stated two-sided procedure.

6. DISCUSSION

The synthesis of the three cities indicates that a coastal position alters, however does not inhibit, the proliferation of urban heat islands. The swift augmentation of constructed areas and the decline of vegetation in Chennai exemplify a typical land-conversion trajectory: non-porous surfaces proliferate more rapidly than the cooling environment. Recent studies in Chennai indicate that designated land-use classifications exhibit unique thermal characteristics and that developmental pathways need heat-sensitive zoning (Rajagopal et al., 2025). The extent of the land-cover transformation renders Chennai a focal point for safeguarding remaining wetlands, river corridors, tanks, and peri-urban flora before they become disconnected remnants.

Kolkata exemplifies a highly developed high-density heat island. The constructed share was 70% at the

outset and increased to 80.1% by 2023, resulting in little green coverage. The city's favourable daytime and nighttime core disparities align with remote-sensing research that records a growing thermal footprint across the Kolkata Metropolitan Area (Halder et al., 2021; Mandal et al., 2022). The East Kolkata Wetlands and the Hooghly corridor may provide localised cooling, although their impact is inconsistent over a densely populated metropolitan environment. The result reveals a comparatively limited diurnal temperature variation and the most significant nighttime core surplus among the three cities analysed.

Mumbai illustrates the potential pitfalls of doing an only daytime SUHI study. A midday core exhibiting lower temperatures than the surrounding area may indicate the influence of sea-breeze incursion, coastal cloud formation, or a warmer inland benchmark. However, the same core temperature increases post-sunset when concrete, asphalt, and substantial structures emit retained heat as air circulation diminishes. The documented 24% reduction in diurnal cooling serves as a more relevant alert for policy than the daytime indicator by itself. Sethi and Vinoj (2024) differentiate warmth caused by urbanisation from overarching regional climate change, emphasizing the need to monitor both urban structure and the broader climatic signal.

The almost flawless correlation between developed land and nighttime core temperature is physically reasonable but statistically tenuous. With only three cities, it may be generated by a singular arrangement and fails to account for green configuration, water proximity, building elevation, anthropogenic heat, or border selection. Empirical research that have undergone peer review provide essential triangulation: studies conducted across many cities and localities often reveal elevated land surface temperatures (LST) associated with more constructed or impermeable surfaces, whereas cooler LST correlates with higher vegetation or water presence (Saha et al., 2021; Rao et al., 2023; Islam et al., 2024). The current association ought to be seen as a concise overview of these instances, rather than a presumed general impact.

The second significant discovery is humid heat. Elevations in relative humidity by five to seven percentage points contributed around 5.0–6.6°C to perceived heat stress in the source evaluation. Elevated humidity diminishes the efficacy of perspiration, but warm evenings hinder physiological recuperation. Research on nocturnal temperature elevation indicates that health consequences may escalate despite more public focus on daylight metrics (He et al., 2022). Coastal heat-action plans have to include humidity-sensitive indices, minimum temperatures, nocturnal interior environments, and energy dependability, instead of relying just on maximum air temperature thresholds.

Blue and green infrastructure have to be assessed as integrated systems instead of standalone parks. Cooling is influenced by patch dimensions, canopy coverage, water accessibility, and air circulation, with advantages potentially differing according to the prevailing environment (Li et al., 2022). Coastal wetlands, mangroves, riverbanks, and urban lakes contribute to flood management and biodiversity, yielding significant co-benefits. Nonetheless, aquatic environments with contaminated or stagnant edges do not inherently provide uniform cooling, and vegetation initiatives may fail when irrigation needs are unfeasible. Thermal design must thus include ecological considerations, drainage systems, maintenance protocols, and social accessibility.

A further consequence pertains to the selection of thermal indicators. Average daily land surface temperature is effective for identifying uncovered roofs and pavements; nevertheless, it may underestimate danger in shady, heavily populated areas where inside heat builds up. The highest LST may exaggerate minor barren areas, whereas citywide averages may diminish local extremes. A comprehensive monitoring system must thus include data on the distribution of land surface temperature, the extent and duration of elevated temperature categories, minimum air temperature, humidity-adjusted apparent temperature, and

the population residing in frequently affected hotspots. The metrics must be delineated distinctly for the pre-monsoon, monsoon, and post-monsoon phases due to variations in cloud cover, soil moisture, and sea-breeze intensity affecting temperature patterns. Regular local flyover timing is crucial for trend analysis. Nocturnal thermal imaging has a lower resolution compared to Landsat nevertheless is crucial for detecting postponed heat emission.

The juxtaposition of cities also prompts an inquiry into environmental justice that cannot be resolved only by land-cover statistics. Cooling resources are often allocated unevenly, resulting in low-income families having less tree shade, smaller living spaces, metal or asbestos-cement roofing, restricted water access, and reduced financial ability to afford air conditioning. Simultaneously, elevated commercial zones may exhibit significant surface temperatures while safeguarding inside residents via mechanical cooling that expels heat outside and escalates power consumption. Exposure evaluation must therefore integrate thermal maps with home classification, occupation, age, health condition, electrical dependability, and availability of public cooling facilities. Community-oriented temperature monitoring and inside sensors may uncover circumstances overlooked by satellites. Heat interventions must refrain from "green upgrading" that increases rents or displaces the inhabitants whose susceptibility warranted the expenditure.

A uniform study approach will significantly enhance the comparability across coastal cities in India. Researchers have to use the same urban border criteria, choose cloud-free images from a limited seasonal timeframe, implement uniform Collection 2 quality filters, and record all emissivity and resampling choices. Urban and reference areas must be established prior to analysing temperature results, thereafter evaluated using different buffers. Land-cover categorisation must include water, wetlands, thick vegetation, sparse vegetation, barren land, and a minimum of two built-density classifications, accompanied by independent validation and confidence intervals for class areas. Thermal models must include proximity to the coastline, water percentage, altitude, albedo, plant cover, urbanisation ratio, and synoptic meteorological conditions. Disseminating analysis-ready grids and code would enable the replication of findings instead of deducing them from map hues or approximated chart figures.

Ultimately, local urban development influences regional climatic changes. A city may experience warming due to an increase in the surrounding environment, changes in its surface and shape, or a combination of these factors amplifying each other. Sethi and Vinoj (2024) demonstrate that urbanisation has a significant role in the recent temperature increases seen in Indian cities, while IPCC evaluations forecast a rise in the frequency and severity of heat extremes in South Asia. The planning approach must therefore integrate the alleviation of the local heat island effect with adaptation to an inevitable regional trend. Arboreal vegetation, aquatic ecosystems, and reflecting surfaces may mitigate local exposure, although they cannot replace low-carbon energy, robust electrical infrastructures, and emission abatement. Infrastructure authorised today for longevity must be evaluated for resilience against elevated future temperatures, including extreme heat, humidity, floods, and power disruptions.

Coastal processes need to be assessed directly. Proximity to the seashore just serves as an indicator of marine impact; the moderating effects of a sea breeze is contingent upon wind direction, velocity, coastal configuration, atmospheric stability, and the porosity of the urban canopy. Narrow building hallways may facilitate movement in one direction while obstructing it in the other direction. Fluvial winds, moisture loss from wetlands, and heat transfer from warmer inland areas further complicate the gradient. Subsequent initiatives need to include stationary meteorological stations, Doppler or ultrasonic wind measurements, mobile surveys, and detailed urban topography. These observations would aid in differentiating genuine coastal cooling from artifacts produced by a warmer surrounding reference area or varying land-cover types.

Governance dictates whether technical evidence alters exposure. Thermal maps need to be included into comprehensive plans, construction approvals, revitalization projects, and local government finances, with explicit accountability for execution and upkeep. Public dashboards are capable of disseminating ward-specific data on canopy coverage, cool-roof implementation, surface temperature trends, and nocturnal heat warnings; nonetheless, it is essential that indicators undergo auditing to avert biased reporting. Procurement guidelines may delineate solar reflectance and thermal emittance for public roofing and pavements, while maintenance agreements might safeguard tree vitality and aquatic ecosystem functionality. Inter-agency collaboration is crucial since heat, drainage, housing, energy, health, and transport are administered independently, despite citizens seeing them as a singular, compounded danger. This institutional framework is as crucial as the precision of sensors, since a technically accurate hotspot map holds less significance if no organization is responsible for taking timely action.

7. CONSEQUENCES OF URBAN PLANNING ON PUBLIC HEALTH

Initially, municipalities need to delineate distinct thermal zones for daylight and nighttime at a ward or 100–250 m grid size. Areas with consistent nighttime heat accumulation have to be prioritized for the installation of cool roofs, reflecting or permeable pavements, continuity of tree canopies, and building renovations that minimize inside heat retention. Informal settlements need particular attention, since flimsy roofing, inadequate ventilation, overcrowding, and inconsistent power may transform an external heat anomaly into significant inside exposure. Assessment of the intervention must quantify both interior and outdoor air temperatures together with land surface temperature (LST).

Secondly, land-use policies must safeguard cooling corridors prior to their obstruction by redevelopment. Chennai necessitates protective measures for its tanks, marshes, and river-associated open areas; Kolkata demands enhanced safeguarding and hydrological rehabilitation of its wetlands and canals; Mumbai ought to maintain ventilation corridors from the coastline and refrain from erecting high-rise structures that obstruct sea-breeze access without providing adequate public open spaces. Development permits may need a thermal-impact assessment predicated on surface energy metrics, canopy conditions, and ventilation parameters before and after the project.

Thirdly, heat-action strategies must include considerations for humid heat and nocturnal responses. Triggers may integrate air temperature, relative humidity, minimum temperature, and anticipated duration. Night shelters, prolonged cooling-center operations, access to potable water, health monitoring, and uninterrupted power are particularly crucial during periods of warm, humid nights. Remote-sensing maps ought to facilitate targeting; nonetheless, public health choices need validation via stationary, mobile, and interior measures.

8. CONSTRAINTS

This research has five constraints. Initially, it constitutes a synthesis of secondary data and is incapable of replicating pixel-level preprocessing, cloud masking, emissivity adjustments, or urban-reference polygons that were inadequately described in the comparison analysis. Secondly, the reference years vary, and the municipal limits may not accurately reflect uniform functional urban definitions. Third, endpoint land-cover proportions conceal intra-period nonlinearity and seasonal fluctuations. Fourth, the prior diurnal-cooling metrics for Mumbai and Chennai are derived using approximated decrement percentages. Fifth, a sample size of $n = 3$ renders traditional inference inadequate and inhibits multivariable regression or population-exposure assessment. The outcomes need to inform hypotheses and strategic goals, rather than function as a causal hierarchy of urban performance.

9. SUMMARY

By 2023, Mumbai, Kolkata, and Chennai saw significant thermal land alterations. The constructed share increased while the green share decreased in all three cities, with Chennai exhibiting the swiftest transformation and Kolkata possessing the greatest ultimate urbanised share. All three metropolitan centers had higher temperatures than their outskirts throughout the night, notwithstanding Mumbai's daytime cool-island phenomenon. Diurnal cooling decreased most significantly in Mumbai, but humidity substantially heightened the perceived heat across the sample. Exact tests are unable to determine general statistical significance with just three examples; nonetheless, the findings' direction and physical coherence correspond with previous studies in Indian remote sensing. The first lesson in planning is temporal: daytime land surface temperature alone is inadequate. Coastal megacities need nocturnal thermal mapping, humidity-responsive alert systems, safeguarded blue-green infrastructures, ventilation-adaptive urban designs, and construction strategies that minimize heat retention. Subsequent investigations need to reanalyse prevalent MODIS and Landsat datasets using standardised urban perimeters, reference areas, quality filters, and exposure matrices to facilitate the examination of comparative SUHI trends over a more extensive coastal-city cohort.

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