

Advancing Resilience in the Nexus of Urban Heat Islands, Global Warming, and Human Health

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The synergy between accelerated global urbanization and anthropogenic climate change has transformed the Urban Heat Island (UHI) [1] effect from a localized meteorological phenomenon into one of the most pressing environmental crises of the 21st century [2]. As natural landscapes are replaced by impervious, heat-absorbing materials, urban thermal dynamics are fundamentally altered, leading to a cascade of negative impacts, including compromised public health [3], destabilized energy infrastructures [4], and degraded ecosystem services [5]. This Special Issue, “Urban Heat Islands, Global Warming and Effects,” brings together a comprehensive body of research that utilizes high-resolution monitoring, advanced machine learning, and biometeorological assessments to provide a scientific foundation for sustainable and resilient urban planning.

1. Quantifying the Drivers of Urban Warming

A critical theme in this collection is the quantification of the drivers of temperature increase. Longitudinal research in Japan utilizing centennial observation data demonstrates that recent record-breaking summer heat is a complex result of three distinct factors: nationwide non-urban climate change, local urban warming, and year-specific climate anomalies. Fujibe (2025) found that each of these components contributed approximately 1 °C to the observed temperature increase, highlighting that while urban warming has slowed in some Japanese metropolises since the 2000s, the background of global climate change continues to raise the baseline temperature [6].

The role of socio-economic development is further explored in studies of Xinjiang, China, where Chen et al. (2024) identified Gross Domestic Product (GDP) and population density as the most significant drivers of Surface UHI (SUHI) intensity. In these arid regions, the annual average SUHI intensity was found to be significantly stronger at nighttime (1.90 °C) than during the day (0.84 °C) [7]. This suggests that urban materials, such as asphalt and concrete, absorb solar radiation during the day and release it gradually throughout the night, preventing vital nocturnal cooling.

Delving into the fundamental physical aspects of urban energy balances, a study conducted in the arid environment of Phoenix, Arizona, by Brazel et al. (2026) examined differences in shortwave radiation between urban and rural settings. Their analysis revealed that urban sites consistently received lower global radiation than their rural counterparts, with the most pronounced difference, exceeding 5%, occurring in winter. This disparity was linked to higher concentrations of particulate matter (PM10) in the urban atmosphere throughout the year, which attenuate total incoming shortwave radiation. These results highlight how urban modifications to the atmosphere, particularly through aerosol pollution, can alter the very energy available to drive the UHI effect [8].



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2. Human Biometeorology and Public Health Risks

The human cost of urban overheating is analyzed through diverse biometeorological lenses. Owczarek and Krzyżewska (2025) utilized the Universal Thermal Climate Index (UTCI) and heart rate (HR) monitoring to evaluate physiological strain during heatwaves across eleven Polish cities from 2020 to 2024. The findings reveal that summer heat events push human physiological responses to critical thresholds, with mean daily heart rates exceeding the warning value of 90 beats per minute and peak UTCI values indicating “strong and very strong heat stress” [9].

In the tropical context of Rio de Janeiro, Moreira et al. (2024) documented that the first quarter of 2024 saw unprecedented heat index values exceeding 60 °C at coastal stations like Guaratiba [10]. These extremes underscore the urgent necessity for Heat Warning Systems (HWSs) that incorporate microclimatic factors to protect both local populations and tourists. This risk extends to cultural dimensions; in Catalonia, Saladié et al. (2025) observed that high temperatures and humidity levels during traditional Human Tower (castells) exhibitions frequently reached the “extreme caution” threshold (32.1–40 °C), threatening the safety of participants and the preservation of communal rituals [11].

3. Nature-Based Mitigation and Inherent Trade-Offs

Mitigating urban heat requires an integrated approach to blue and green infrastructure. The cooling efficacy of urban water bodies, as exemplified by Dianchi Lake, is highly dependent on seasonality and surrounding land cover. Wang et al. (2025) indicated that the cooling extent is greater during the wet season (600 m) than during the dry season (400 m), and that impervious surfaces are the most sensitive to the thermal regulation provided by such large water bodies [12].

However, the role of vegetation is more nuanced. While green spaces provide transpirational cooling, they also present an ecological trade-off. In Hangzhou, Dong et al. (2025) noticed that while species like *Cinnamomum camphora* provide strong cooling, they also emit high levels of biogenic volatile organic compounds (BVOCs), which can react with other pollutants to form ground-level ozone (O₃) and PM_{2.5}. Identifying “high cooling–low emission” zones (covering 17.5% of the study area) is, therefore, essential for optimizing green space layouts to balance thermal comfort with air quality [13].

4. Advanced Modeling for Street-Scale Resilience

The future of urban heat management lies in high-precision modeling and machine learning. In Thimphu Thromde, Bhutan, Pasang et al. (2025) applied Artificial Neural Networks (ANN) and the CA-Markov model to predict that built-up areas will expand to 72.82% by 2031. This expansion is projected to lead to a corresponding growth in UHI and extreme UHI zones, which will account for approximately 14.26% and 6.08% of the total area, respectively, necessitating pre-emptive spatial management [14].

Furthermore, Gkirmipas et al. (2025) successfully employed Random Forest regression in Thessaloniki, Greece, to downscale mesoscale meteorological models to the street scale. By integrating micro-environmental features such as the Sky View Factor (SVF), building height, and proximity to walls, the model achieved high accuracy in predicting street-level temperature variations during intense heatwaves [15]. Moreover, the findings indicate that using the difference between observed and modeled temperatures as a target variable is the most reliable method for capturing the micro-climatic effects of dense urban geometries.

5. Conclusions

The research presented in this Special Issue confirms that the UHI effect is not a static meteorological anomaly, but a dynamic, multi-dimensional crisis influenced by global

climate trends, urban morphology, and socio-economic activity. From the arid cities of Xinjiang to the coastal squares of Catalonia, the data consistently point toward a future of intensified thermal stress. Only by integrating advanced simulation models with a refined understanding of biometeorology can urban planners design the resilient urban landscapes required to safeguard public health and cultural heritage in a warming world.

Modern cities can be viewed as thermal reservoirs: much like a giant stone left in a fireplace, they absorb the day's energy voraciously and continue to glow with invisible heat long after the sun has set, offering the life within them no sanctuary from the rising warmth.

Conflicts of Interest: The authors declare no conflict of interest.

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