Prepublished copy

Nature Environment & Pollution Technology

This is a peer-reviewed prepublished version of the paper

Review Paper

Evaluating the Benefits of Urban Greenery in Urban Heat Island Mitigation: Methods, Indicators and Gaps

Sweta Rupapara[1]†, Vishva Rathod1, Harsh Rupapara[2], Nandini Halder[3] and Deepak Kumar[3]

[1] School of Architecture and Design, New York Institute of Technology, New York-10023, USA

[2] Department of Civil Engineering, Babaria Institute of Technology, Vadodara-391240, Gujarat, India

[3] Department of Architecture and Planning, National Institute of Technology Patna-800005, Bihar, India

† Corresponding author: Sweta Rupapara; swetarupapara52@gmail.com

ORCID IDs of Authors: Sweta Rupapara: 0009-0003-2271-1284, Vishva Rathod: 0000-0002-0591-1693, Nandini Halder: 0009-0007-0667-5112, Deepak Kumar:0000-0001-5846-5255

Key Words	Urban greenery, Urban heat island, Thermal comfort, Green infrastructure, PRISMA, VOSviewer
DOI	https://doi.org/10.46488/NEPT.2025.v24i04.D1812 (DOI will be active only after the final publication of the paper)
Citation for the Paper	Rupapara, S., Rathod, V., Rupapara, H., Halder, N. and Kumar, D., 2025. Evaluating the benefits of urban greenery in Urban Heat Island mitigation: Methods, indicators and gaps. *Nature Environment and Pollution Technology*, 24(4), D1812. https://doi.org/10.46488/NEPT.2025.v24i04.D1812

ABSTRACT

Urban Heat Island (UHI) effects pose a significant environmental challenge in contemporary urban planning, driven by accelerating climate change, rapid urban development, and changes in land use patterns. This study explores the potential of urban greenery as a mitigation strategy for UHI by conducting a systematic and bibliometric review of 42 peer-reviewed studies, selected using the PRISMA 2020 protocol. A mixed methods approach was employed, integrating a systematic review with a critical content synthesis of selected studies using PRISMA 2020 and bibliometric mapping using VOSviewer (1.6.19). The results indicate that urban greenery, encompassing green roofs, vegetated facades, urban forests, and street trees, plays a critical role in mitigating surface and air temperatures by enhancing evapotranspiration, increasing surface reflectivity (albedo), providing shading, and improving urban ventilation dynamics. Widely used indicators in these studies include Land Surface Temperature, the Normalized Difference Vegetation Index, and canopy coverage. The bibliometric analysis reveals exponential growth in related publications between 2014 and 2024 is $R^2 = 0.8263$, along with emerging thematic clusters centered on thermal comfort modeling, nature-based solutions, and urban climate resilience. China, Australia, and the United States account for the majority of contributions, while tropical and lower-income regions remain underrepresented. The findings highlight critical thematic and geographic gaps, emphasizing the need for future research incorporating

empirical validation, field experimentation, and integrative modeling to advance equitable and context-sensitive UHI mitigation strategies.

INTRODUCTION

Urban areas are increasingly experiencing elevated air temperatures, significantly impacting public health and human thermal comfort (Algeciras et al., 2016; Pigliautile et al., 2020; W. Yang & Wong, 2013). In response, urban planners and designers face the dual challenge of maintaining the quality of life while accommodating expanding populations (D. He et al., 2022; Nikezić & Marković, 2015). Over recent decades, the translation of urban climate data into actionable design strategies has gained prominence (Su et al., 2024; Kumar et al., 2025), alongside a growing emphasis on developing mitigation strategies to address the complex impacts of climate change (Kyriakodis & Santamouris, 2018).

The integration of vegetation into urban design has emerged as a promising approach to mitigate the adverse effects of the UHI phenomenon while enhancing thermal comfort (Balany et al., 2020; de Quadros & Mizgier, 2023a; Rouse & Bunster-Ossa, 2013). Diverse forms of urban vegetation, such as green roofs, tree-lined streets, and park systems, contribute to urban cooling by moderating surface and air temperatures, enhancing thermal comfort, and supporting microclimatic regulation (H. Herath et al., 2018; Galagoda et al., 2018). UHIs, characterized by higher temperatures in urban areas compared to their rural surroundings, have become increasingly prevalent due to rapid urbanization and global climate change (Ulpiani, 2019; WONG et al., 2018; L. Zhang et al., 2020; Zou & Zhang, 2021).

Elevated urban temperatures pose significant threats to human health and comfort, necessitating the development of innovative, sustainable cooling solutions (Y. Zhang et al., 2021). Numerous studies have demonstrated that urban greenery—including parks, green roofs, and street trees—can effectively mitigate UHI impacts (Aboelata & Sodoudi, 2019; W. Zhou et al., 2019). Among these, green roofs have received particular attention for their thermal insulation properties, ability to reduce building energy consumption, and contribution to creating favorable microclimates for outdoor activities (Doucet, 2021; Park et al., 2021; Baniya et al., 2018; Lehmann, 2014; D. Li et al., 2014; Mutani & Todeschi, 2021).

Enhancing outdoor cooling through urban parks, recreational areas, and commercial spaces has been shown to improve thermal comfort for visitors while promoting the sustainable use of outdoor environments (Chàfer et al., 2020; Farnham et al., 2015). The UHI effect, largely driven by heat absorption and retention on surfaces such as asphalt and concrete (Shahidan et al., 2012; Rathod, 2025), is one of the primary challenges addressed by outdoor cooling initiatives. Evaluating the effectiveness of urban greenery is therefore critical for understanding its role in reducing UHI impacts, improving urban microclimates, and enhancing liveability (Fahmy et al., 2018; B. J. He, 2019).

Urban greenery offers evidence-based insights for sustainable urban planning, optimizing green infrastructure design, and informing policy decisions aimed at addressing climate change, public health, and environmental concerns (Gago et al., 2013; Santamouris et al., 2019; C. Wang et al., 2021). This study conducts a systematic and bibliometric review to assess the effectiveness of urban greenery in mitigating UHI impacts. The objectives are threefold:

(i) to evaluate the methodologies employed in existing research,

(ii) to identify the key indicators used to quantify cooling effects, and

(iii) to highlight research gaps and suggest future directions.

By synthesizing evidence across diverse geographic and climatic contexts, this study seeks to advance knowledge on urban greenery's role in fostering climate-resilient and thermally comfortable cities. This review is distinctive in its integration of systematic bibliometric mapping with an indicator-based content synthesis, allowing for both quantitative and qualitative assessments of UHI mitigation strategies. Additionally, a novel conceptual framework is developed, linking urban greenery types to specific cooling mechanisms and socio-ecological contexts.

2. MATERIALS AND METHODS

The present literature was thoroughly reviewed using established criteria and techniques. To do this, extensive databases were searched for relevant research articles. The SCOPUS database was used as the primary data source for the study as almost all the publications found in the Web of Science databases were also found in the Scopus database (Meho & Sugimoto, 2009). The selection of search strings was informed by preliminary scoping reviews and analysis of frequently occurring terms in prior studies on UHI mitigation. Keywords such as 'Urban Greenery', 'Green Roof', 'Street Trees', and 'Urban Heat Mitigation' were chosen to capture both the typologies of urban vegetation and their role in thermal regulation. Boolean operators (e.g., AND, OR) were strategically employed to maximize coverage while minimizing irrelevant results. This research examines studies conducted over the past ten years, specifically from 2014 to 2024, and retrieves data from all 785 documents in CSV format using keyword combinations searched in Scopus on March 23, 2024.

In the search, the following keywords and combinations were used:

Search String Set 1 – (“Urban Greenery” OR “Urban Green Infrastructure” OR “Green Space”) AND (“Urban Heat Island” OR “UHI” OR “Urban Climate Mitigation”);

Search String Set 2 – (“Urban Cooling” OR “Urban Heat Mitigation”) AND (“Green Roofs” OR “Street Trees” OR “Urban Parks” OR “Vegetation Cover”).

The next step is to generate search results using the afore mentioned keywords, and the process for selecting those results is described in greater detail in the following section. The literature review was conducted by systematically searching the Scopus database for relevant papers. A total of 785 articles were initially identified through the database search. To refine the dataset, an exclusion criterion was applied, which involved removing 430 articles that were either duplicates or published prior to 2014. This reduced the records to 355, which were then screened for relevance based on their titles and abstracts. During this stage, 230 records were excluded because their titles and abstracts did not align with the research focus. Subsequently, 125 full-text articles were assessed for eligibility. Of these, 83 were excluded due to reasons such as scope misalignment, lack of focus on the topic, or language barriers. Ultimately, 42 articles were deemed relevant and included in the review. These articles were categorized under themes such as urban greenery, UHI, and mitigation strategies. After a comprehensive evaluation of the research, the factors found are presented in a table for convenient access. A flow chart depicting the entire process is mentioned in the PRISMA created below showing the number of studies identified, screened, and included. Although moderate in size, this sample is consistent with similar systematic reviews in the urban climate and green infrastructure domains. It was deemed sufficient to capture a comprehensive range of methodologies, indicators, and research trends necessary for critical synthesis and gap identification. The search was restricted to peer-reviewed journal articles published between 2014 and 2024. Duplicates and irrelevant studies were excluded following title, abstract, and full-text screening. A total of 42 studies were ultimately included in the review. Following revisions, a validation checks confirmed that the selected articles comprehensively represent the current research landscape.

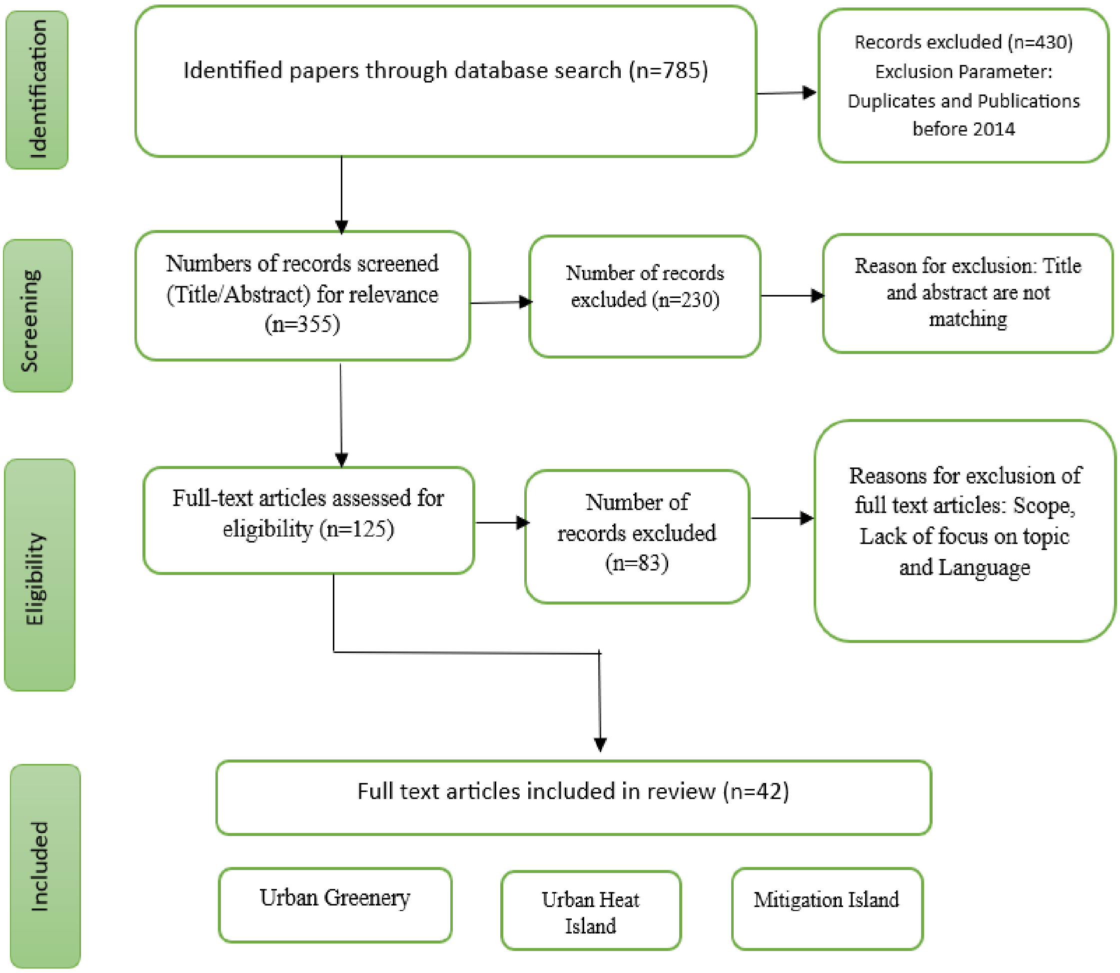

Figure 1. PRISMA framework of the study, Source: PRISMA 2020 (Page et al., 2021)

To make sure the papers included in systematic reviews are of high quality, Dyba and Dingsoyr (2008) developed a checklist of questions (Dybå & Dingsøyr, 2008). Three primary criteria serve as the foundation for these inquiries: relevance, rigor, and credibility. Depending on how well the nominated articles meet the three quality requirements, they are assigned a score of either 1 or 0. Content that receives a score of four or above is deemed to be of exceptional quality and is eligible for inclusion in the review.

The review also explores bibliometric analysis and that was conducted to provide a quantitative overview of the scholarly landscape related to urban greenery in UHI mitigation. This analysis encompassed three key aspects: keyword co-occurrence, country analysis, and publication trends over time. Keyword co-occurrence data, visualized using VOSviewer (1.6.19) (Arruda, 2022; van Eck, 2010), was derived from the metadata of the 42 documents that met the inclusion criteria following the PRISMA process. This analysis aimed to identify and map the prominent themes and their interrelationships within the research area. Furthermore, a country analysis was performed on these 42 documents to ascertain the geographical distribution of research contributions. Finally, the publication year data for the refined set of documents was analyzed to identify temporal trends. Notably, the analysis of publication per year revealed an exponential growth pattern, indicating an increasing scholarly interest and activity in UHI and urban greenery over the studied period.

3. RESULTS

3.1. Bibliometric Analysis

The bibliometric analysis conducted using VOSviewer software provides a quantitative visualization of research trends and intellectual structures within the domain of urban greenery and UHI mitigation. Based on the 42 refined studies identified through the PRISMA process, keyword co-occurrence mapping revealed several dominant thematic clusters. Country-level analysis revealed a pronounced geographic concentration in research output. Also, an analysis of publication trends by year illustrates a steep exponential growth in scholarly attention toward UHI mitigation via urban greenery.

3.1.1. Keyword Co-Occurrence Network and Thematic Clustering

The keyword co-occurrence network generated through VOSviewer (Figure 2) illustrates the intellectual landscape of research on urban greenery and UHI mitigation. Nodes represent keywords, while their size corresponds to frequency, and lines indicate co-occurrence relationships. The clustering algorithm identified five distinct thematic clusters, each represented by a unique color, signifying closely related research topics.

The keyword co-occurrence network reveals a strong research emphasis on biophysical strategies for UHI mitigation, with clusters centered around 'thermal comfort,' 'green infrastructure,' and 'urban cooling.' However, terms related to social dimensions, such as 'environmental justice,' 'vulnerability,' and 'public health,' are notably absent or underrepresented, suggesting a thematic imbalance. This indicates that current research predominantly addresses physical and technological aspects of UHI mitigation, with less attention to socioecological resilience and equity considerations. While the VOSviewer analysis identified clusters such as 'thermal comfort' and 'reforestation,' a deeper evaluation reveals a concentration of studies in high-income regions and a thematic bias toward physical cooling strategies, with comparatively less emphasis on social equity and long-term resilience frameworks. This highlights critical gaps in UHI mitigation research, notably the need for more integrative and interdisciplinary approaches.

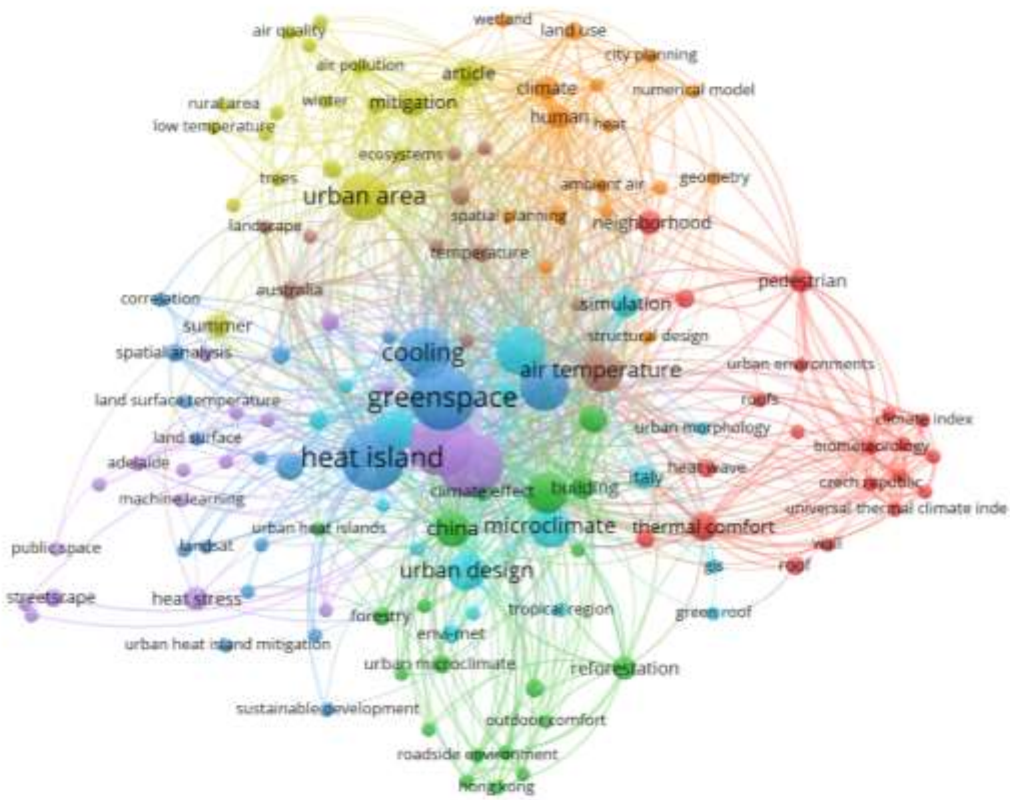

Figure 2. Keyword Co-occurrence Network in UHI-Green Infrastructure Research (2014–2024), Source: VOSviewer

Overall, the network reflects the maturity and multidimensionality of the field, while also revealing under-explored linkages that future research could target—especially involving social equity, long-term monitoring, and urban greenery typologies.

3.1.2. Country Network Analysis

The country network analysis (Figure 3) highlights the geographic distribution of research output among the 42 peer-reviewed articles refined through the PRISMA process. The country-level analysis shows that research on UHI mitigation is heavily concentrated in China, Australia, and the USA, which together account for a substantial proportion of the literature. This geographic clustering reflects strong research capacity and investment in urban climate resilience in high-income nations. However, it also highlights a significant imbalance, with limited contributions from tropical and low-income regions where UHI effects are often more severe and resilience resources more constrained. The underrepresentation of these vulnerable areas signals a critical gap in the global knowledge base and underscores the need for expanding empirical studies and context-specific mitigation strategies in diverse climatic and socio-economic settings.

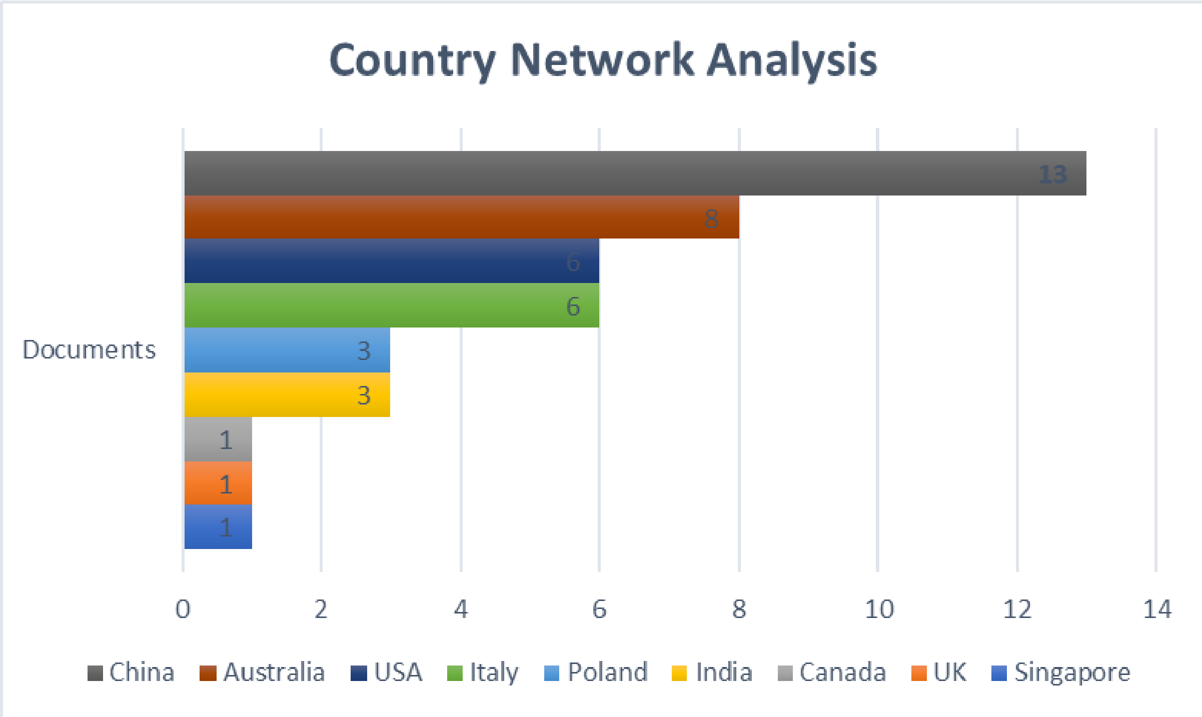

Figure 3. Country-wise Contribution to Urban Greenery and UHI Mitigation Research (2014–2024), Source: Author

The bibliometric analysis, while revealing dominant themes such as thermal comfort, green infrastructure, and urban cooling, also uncovers critical gaps in the current research landscape. The thematic focus remains heavily skewed toward biophysical and technical mitigation strategies, with limited integration of social equity, public health, and long-term resilience considerations. Furthermore, the concentration of research outputs in high-income countries, notably China, Australia, and the USA, highlights a geographic imbalance that risks overlooking context-specific challenges faced by rapidly urbanizing and climate-vulnerable regions in the Global South. These findings suggest that future UHI mitigation research must adopt a more interdisciplinary approach, integrating environmental, social, and policy dimensions, and prioritize empirical studies in underrepresented areas to ensure globally relevant and equitable solutions."

3.1.3. Publication Trend Analysis

An analysis of the temporal distribution of publications (Figure 4) reveals a clear and sustained upward trajectory in research activity surrounding urban greenery and UHI mitigation between 2014 and 2024. While early contributions remained modest, averaging 1 to 2 publications per year from 2014 to 2017, interest in the topic began to accelerate from 2018 onward, coinciding with rising global awareness of climate-related urban vulnerabilities and the mainstreaming of nature-based solutions (NBS) in policy frameworks. The exponential trendline ($R^2 = 0.8263$) fitted to the publication data underscores this momentum, reflecting a near doubling of output every few years.

By 2021, publication numbers had reached 6 per year, and the upward trend continued through 2024, peaking at 9 publications. The curve's shape suggests that the field is in a phase of rapid expansion, driven by interdisciplinary integration and increased urgency to adapt cities to extreme heat events. This exponential growth in scholarly output not only highlights the evolving maturity of the research domain but also signals a growing international commitment to evidence-based urban greening practices for climate resilience.

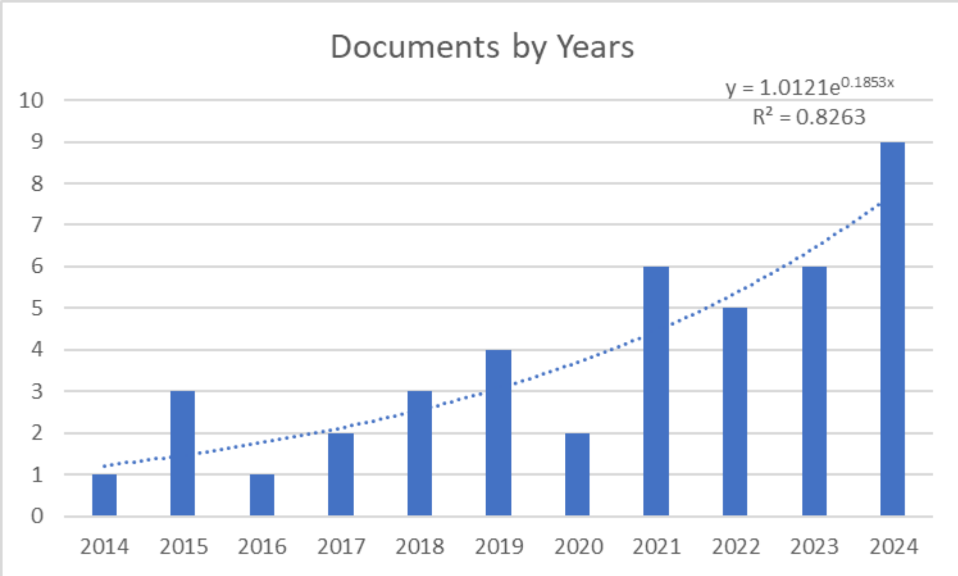

Figure 4. Annual Publication Trend on Urban Greenery and UHI Mitigation (2014–2024), Source: Author

3.2. Content Analysis

The content analysis of the 42 studies, meticulously selected through the PRISMA process, involved a systematic examination of their core components to extract meaningful insights. For each study, key information was recorded, including the source of publication, the explicitly stated objective, the research methodology employed, the factors or variables investigated, and the key findings reported. This detailed extraction process allowed for a structured comparison and synthesis of the existing literature, enabling the identification of common research themes, methodological approaches, and significant outcomes within the field of UHI and urban greenery. By systematically categorizing and analyzing these elements across the body of literature, this content analysis aimed to provide a comprehensive understanding of the current state of research and highlight potential areas for future investigation. The results from the data extraction process conducted is as follows –

Table 1. Summary of Content Analysis of the 42 Selected Studies.

Sl. No.	Source	Objective	Research Methodology	Factors	Key Finding
1.	(de Quadros & Mizgier, 2023b)	Role of UGI strategies on pedestrian the thermal comfort in different climatic contexts	Qualitative	Urban green coverage, climate, UHI, environmental benefits	UGI can improve pedestrian thermal comfort across climates; vegetation types and placement are key determinants.
2.	(Cui et al., 2021)	To assess urban gardening's role in mitigating UHI effect.	Quantitative	UHI, urban gardening, green spaces, spatial analysis, thermal comfort, flood risk, energy conservation	Urban gardens effectively reduce local temperatures, especially with dense vegetation and shade elements.

3.	(Song et al., 2023)	To develop refined greenery design strategies to mitigate UHIs.	Quantitative	UHIs, rapid urbanization, street canyons, greenery design, tree spacing, cooling effect, carbon sequestration, nature-based solutions, morphological characteristics, urban heat mitigation	Refined greenery design significantly enhances microclimate cooling when combined with strategic urban layout.
4.	(Akbari et al., 2016)	To analyze urban typologies' impact on mitigating UHI effect	Quantitative	Urban climate, Urban heat island, Urban heat island mitigation, cool materials, urban green	Urban typology strongly influences UHI mitigation potential; compact greening strategies can be highly effective.
5.	(Health Organization Regional Office for Europe, 2016)	To model UGI's impact on UHI reduction in European cities.	Qualitative	Urban green infrastructure, UHI, Microclimate regulation, Nature-based solutions	UGI implementation scenarios show measurable reductions in UHI, particularly in temperate European cities.
6.	(Uribe, 2022)	To analyze green infrastructure types and their effectiveness in mitigating UHIs	Quantitative	Green infrastructure, UHI, ecosystem services	Green infrastructure types vary in mitigation efficiency; tree canopies and green corridors show highest impacts.
7.	(Y. Wang et al., 2022)	To analyze urban green space efficiency in mitigating UHIs globally	Quantitative	UHIs (UHI), urban green space (UGS), cooling effect, climate zones, urban cooling islands	Green spaces contribute to measurable cooling globally; effectiveness depends on size and urban integration.
8.	(Wong et al., 2021)	To evaluate green infrastructure's potential to mitigate urban heat and thermal stress.	Qualitative	UHI, thermal stress, green infrastructure, parks, green roofs, green walls, evapotranspiration, urban cooling, heat mitigation strategies.	GI elements reduce both air temperature and perceived thermal stress, particularly in compact urban zones.
9.	(Abdi et al., 2020a)	To analyse the impact of small-scale tree planting patterns on outdoor cooling.	Quantitative	Outdoor Cooling, Thermal comfort, Tree planting, tree size, Tree species	Optimal small-scale planting patterns improve cooling through enhanced evapotranspiration and wind channeling.
10.	(Balany et al., 2020)	To review green infrastructure strategies and simulation tools for urban heat mitigation.	Qualitative	Green infrastructure; UHI, human thermal comfort	Simulation tools vary in their GI modeling accuracy; integrated approaches yield more robust planning insights.
11.	(Sharifi, 2015)	To analyse streetscape on outdoor cooling.	Quantitative	Vertical Structure, Outdoor Cooling, Urban Greenery	Streetscape vegetation significantly enhances outdoor cooling and thermal comfort in dense urban areas.

12.	(W. Zhou et al., 2019)	To evaluate urban cooling strategies in a megacity block using ENVI-met.	Quantitative	UHI, global warming, cooling strategies, pedestrian thermal environment, urban microclimate	Vegetation-based cooling is highly effective in dense urban blocks, with configuration and placement being key.
13.	(Aikoh, 2023)	To challenge conventional UHI views and propose urban heat mitigation strategies.	Qualitative	UHI, urban heat mitigation, urban thermal climate, heat mitigation strategies	Calls for a paradigm shift in UHI mitigation strategies to include social, ecological, and design perspectives.
14.	(M. Xu et al., 2019)	To analyse the effect of building configuration on pedestrian-level wind.	Quantitative	Building Orientation, Outdoor Cooling, proximity of buildings	Building orientation and configuration influence pedestrian wind flow, which impacts thermal stress.
15.	(Santamouris et al., 2019)	To explore UHI mitigation technologies across various climatic contexts.	Qualitative	UHI, climate change, mitigation technologies, urban greening, interactive water features, high-tech materials, human health, wellbeing, sustainable development	UHI mitigation strategies must be adapted to regional climates for maximum effectiveness.
16.	(Ulpiani, 2019)	To analyse the existing literature on outdoor cooling.	Qualitative	Outdoor Cooling, Water mist Spray, soil moisture	Outdoor cooling is a multidimensional challenge requiring integrative strategies involving GI and water features.
17.	(Zhao et al., 2019)	To analyse the influence of urban green spaces on precipitation	Quantitative	Precipitation, humidity, surface temperature	Urban greenery influences precipitation patterns, but effects vary seasonally and spatially.
18.	(R. Wang et al., 2019)	To analyze trends of surface UHI and vegetation.	Quantitative	Surface UHI, LST, EVI, vegetation, global cities, rural greening	Vegetation is inversely correlated with urban heat across time, emphasizing greening importance.
19.	(Chun & Guldmann, 2018)	To analyze seasonal effects of greening on UHIs.	Quantitative	UHI, seasonality, vegetation, land surface temperature, greening strategies, green roofs, urban canyons	Seasonal planting can enhance UHI mitigation, with variable effects across climate phases.
20.	(H. M. P. I. K. Herath, 2018)	To assess urban green infrastructure's impact on microclimatic conditions in tropical cities.	Quantitative	Urban green infrastructure, UHI, microclimatic conditions, thermal comfort, green roofing	Urban greenery positively affects microclimate in tropical cities, especially when vegetation is dense and layered.
21.	(Klemm et al., 2015)	To analyse the impact of urban greenery for cooling cities.	Qualitative	Shading, Outdoor Furniture, Tree Canopy, tree spacing, greenery pattern	Urban greenery significantly enhances cooling when integrated with spatial planning and sufficient canopy cover.

22.	(Dahanayake, 2018)	To compare thermal effects of green facade and green wall in buildings	Quantitative	Vertical greenery, green facade, green wall, energy savings, thermal analysis, tropical climate, building envelope, outdoor temperature, cooling effect, energy efficiency	Green walls and facades provide meaningful cooling and energy savings depending on structure orientation and greenery extent.
23.	(W. Yang et al., 2016)	To analyse greenery as a heat mitigation factor	Quantitative	Location, proximity to buildings, Vertical structure, albedo	Vegetation density is inversely associated with LST; urban greenery mitigates heat stress effectively in compact areas.
24.	(Xiao, 2018)	To analyze urban green spaces' cooling effects based on size, design, and features.	Quantitative	UHI, urban green spaces, cooling effects, canopy density, leaf area index (LAI), park shape, green space design, wind environment, urban warming mitigation	Design, size, and spatial layout of urban parks critically affect their thermal cooling performance.
25.	(Aflaki et al., 2017)	To analyze UHI mitigation strategies and urban greening impacts in East Asia	Quantitative	UHI, City green areas, High-density urban area, Heat mitigation strategies, Outdoor temperatur	UHI reduction is greatest where GI is integrated with planning policy, especially in compact East Asian cities.
26.	(Hiemstra et al., 2017)	To assess urban green infrastructure's role in mitigating the UHI effect	Qualitative	UHI, urban green infrastructure, urban trees, thermal comfort, heat stress, climate mitigation, urban population	Green infrastructure is climate-effective and adaptive but needs standardized evaluation for broader implementation.
27.	(Park et al., 2021)	To identify green space types that reduce air temperature effectively.	Quantitative	Small green spaces, UHI, air temperature, spatial characteristics, urban blocks, cooling effect	Certain green space types, especially those with contiguous tree coverage, are more efficient in reducing air temperature.
28.	(Soltani & Sharifi, 2017)	To investigate urban heat variations, impacts, and mitigation through urban greenery.	Quantitative	UHI effect, Mobile traverse method, Heat stress, Urban greenery	Urban heat mitigation is context-dependent and must consider built form, GI type, and air pollution interaction.
29.	(S. Sun et al., 2017)	To evaluate green space changes and urban temperature impacts in Beijing.	Quantitative	Urban greenery, green space dynamics, green expansion, green loss, ecosystem services, urban heat mitigation	Vegetation growth over time reduces LST significantly, especially with high NDVI levels in warmer months.
30.	(Huang et al., 2022)	To tabulate the factors of urban greenery which affect outdoor cooling and thermal comfort.	Qualitative	Outdoor Cooling, Thermal Comfort, Outdoor Cooling, Greenery, vegetation, shading, tree canopy cover	Tree species and layout design impact outdoor cooling; alignment with street orientation improves thermal comfort.

31.	(Y. Wang et al., 2016)	To evaluate mitigation measures addressing UHI summer effects.	Qualitative	UHI, energy use, air pollution, outdoor temperature, cool roofs, cool pavements, urban vegetation, summertime effects, citizen health, mitigation measures.	Combined mitigation strategies (green roofs, tree planting) are most effective in summer temperature reduction.
32.	(Huang, 2022)	To analyze UHI mitigation effects on air pollutants using WRF-Chem simulations.	Quantitative	UHI, Heat Wave, urban canopy model	Urban greenery can reduce pollutant concentration and surface temperature simultaneously when strategically deployed.
33.	(Tan et al., 2016)	To evaluate urban greenery strategies for mitigating UHI.	Quantitative	UHI, cooling effect, tree planting, wind-path design, air temperature reduction, urban greenery,	Urban greenery significantly enhances thermal comfort, particularly in shaded and vegetated areas.
34.	(Nasrollahi et al., 2020)	To review and analyze strategies to mitigate UHI effects.	Qualitative	UHI, high temperatures, urban discomfort, urbanization, climate decline, UHI mitigation	Multifactorial strategies involving greenery outperform isolated interventions in improving thermal comfort.
35.	(Knight et al., 2021)	To evaluate the integration of vegetation and vertical plant walls for UHI mitigation.	Qualitative	UHI, vegetative green space, vertical plant walls, mitigation strategy, urban microclimates	Vertical greenery and plant walls contribute significantly to UHI mitigation when integrated with building facades.
36.	(Christopher O'malley et al., 2015)	To assess and test resilience and effectiveness of UHI mitigation strategies."	Quantitative	UHIs (UHI), mitigation strategies, resilience, effectiveness	Case comparisons show that early implementation of greenery correlates with better long-term resilience outcomes.
37.	(Gonçalves et al., 2019)	To provide a comprehensive list of outdoor thermal comfort and outdoor cooling factors which are directly influenced by Urban greenery factors.	Qualitative	Outdoor Cooling, Thermal Comfort, Greenery	Thermal comfort is directly influenced by vegetation configuration; comprehensive design improves outdoor livability.
38.	(Feyisa et al., 2014)	To examine vegetation's cooling effect on urban temperatures.	Quantitative	Urban green infrastructure, urban warming, cooling effect, spatial design, air temperature, humidity	Urban parks serve as effective cool zones in high-density cities, particularly with dense canopy coverage.
39.	(Mutani & Todeschi, 2020)	To review UHI effects and mitigation strategies with greenroofs.	Qualitative	UHI, mitigation strategies, greenroofs, surface reflectivity, vegetation density, air conditioning	Green roofs are efficient at reducing rooftop heat and improving overall building energy performance.

40.	(Lehmann, 2014)	To explore green urbanism to mitigate UHI and promote sustainable cities.	Qualitative	Sustainable urban development, UHI effect, Green roofs, Green urbanism, Low carbon precinct	Green urbanism is a foundational principle for sustainable cities, with direct effects on temperature moderation.
41.	(Mutani, 2021)	To assess cooling impacts of green and cool roofs on UHI.	Quantitative	UHI, green roofs, cool roofs, albedo, temperature reduction	Green roofs combined with reflective materials are most effective in reducing heat load in urban environments.
42.	(Wolch et al., 2014)	To analyse the impact of urban green space, public health, and environmental justice.	Qualitative	Urban Greenery	Equitable access to greenery reduces heat exposure and improves health outcomes in vulnerable urban communities.

A few research have explored the function of urban greenery in moderating the UHI effect, using both quantitative and qualitative methodologies. UHIs are created in part by the lack of greenery, which significantly raises thermal stress for locals and increases illness and death. Therefore, mitigation techniques are required to minimize urban heat, especially considering global warming, urbanization, and the growing frequency and severity of heatwaves (Wong et al., 2021). Using satellite imaging, mobile air temperature profiling, and spatial metrics including green space area, canopy density, and the perimeter-to-area ratio, several research concentrated on recording land surface temperatures to quantify temperature decreases. These studies have been carried out in a variety of geographic settings, such as Seoul, South Korea; Suzhou and Beijing, China; and Adelaide, Australia (B. Zhang et al., 2019). As cities grow quickly, UHIs, or UHIs, have received a lot of attention lately and are quickly becoming a major global concern. Evaluating the cooling benefits of various foliage kinds, such as street trees, tiny green areas, and green roofs, has been a major focus of these studies. Through improved wind dynamics and increased evapotranspiration, the results consistently demonstrate that urban greenery has a large potential to reduce air and surface temperatures, particularly during the warmer months (Balany et al., 2020).

3.2.1. Key Indicators for Assessing the Cooling Effects of Urban Greenery

A comprehensive evaluation of the benefits of urban greenery in mitigating the UHI effect necessitates the use of appropriate indicators that can effectively quantify the cooling impacts. Researchers have employed a diverse set of indicators, derived from various methodologies, to assess the influence of vegetation on the urban thermal environment. These indicators provide insights into different aspects of UHI mitigation, including surface temperature reduction, ambient air cooling, and improvements in human thermal comfort.

Land Surface Temperature (LST) stands as a widely utilized indicator, primarily obtained from thermal remote sensing data. It measures the radiative temperature of the ground surface and serves as a direct proxy for the heat stored in urban materials. A reduction in LST in vegetated areas compared to non-vegetated areas is a clear indication of the cooling effect provided by urban greenery (Nath, 2025). The Normalized Difference Vegetation Index (NDVI) is another frequently employed indicator, derived from the red and near-infrared bands of satellite imagery. NDVI quantifies the amount and health of vegetation present in an area. Higher NDVI values typically correlate with denser and more vigorous vegetation, which is generally associated with greater cooling potential through evapotranspiration and shading (Bobo Merga et al., 2024).

Canopy Coverage is a crucial indicator for assessing the extent of tree cover in urban areas. Measured using remote sensing or field surveys, canopy coverage represents the proportion of the ground shaded by tree crowns. Higher canopy coverage is directly linked to increased shade, which plays a significant role in reducing surface and ambient air temperatures (Semenzato & Bortolini, 2023). Air Temperature (Ta), measured at a standard height above the ground, is a fundamental indicator of the cooling effect of urban greenery. Studies often compare air temperatures in green spaces with those in surrounding developed areas to quantify the magnitude of the cooling provided by vegetation (Kotharkar et al., 2023). To assess the impact on human well-being, researchers often use Thermal Comfort Indices such as the Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI) (Blazejczyk et al., 2012). These indices integrate various meteorological parameters to provide a comprehensive measure of how comfortable humans feel in a given thermal environment. Improvements in these indices in vegetated areas indicate enhanced outdoor comfort due to the presence of greenery.

Beyond these primary indicators, a range of other metrics are used to evaluate specific aspects of UHI and the role of urban greenery. These include Relative Humidity (RH), which can increase in vegetated areas due to evapotranspiration, potentially enhancing the cooling sensation 9; Mean Radiant Temperature (MRT), representing the average temperature of the surrounding surfaces affecting human thermal comfort; Wind Speed (WS), which can be influenced by vegetation and affect heat dissipation; Solar Irradiance, indicating the amount of solar radiation reaching the surface, which is reduced by shading from vegetation; and Sensible Heat Flux, representing the heat exchange between the surface and the air (Azmeer et al., 2024). Additionally, indicators like Cooling Effect Intensity (CEI) and Cooling Effect Distance (CED) are used to quantify the magnitude and spatial extent of the cooling provided by urban green spaces (Aram et al., 2019), while Park Cooling Intensity (PCI) and Park Cooling Area (PCA) are specific to the assessment of urban parks. The Cooling Index (CI) provides a standardized approach to assess vegetation's cooling performance. To quantify visible greenery and three-dimensional urban structure, indicators such as the Green View Index (GVI) (Li et al., 2020) and Building Volume Fraction (BVF) and Tree Volume Fraction (TVF) (Zhao et al., 2018) have been widely applied. As summarized by (Halder et al., 2025) the integration of these indices enables a comprehensive evaluation of urban greenery's impact on thermal comfort and microclimate regulation.

The diverse array of indicators used in the literature reflects the multifaceted nature of UHI and the various ways in which urban greenery can influence the urban thermal environment. Researchers often employ a combination of these indicators to provide a comprehensive assessment of the cooling effects from different perspectives, including surface temperature, ambient air temperature, and human thermal comfort. The selection of appropriate indicators should align with the specific objectives of the study and the scale of analysis to ensure a robust and meaningful evaluation of the benefits of urban greenery in mitigating the UHI effect.

3.2.2. Contributions of Different Types of Urban Greenery to UHI Mitigation

Greening cities as a means of mitigating urban heat is gaining attention due to the combined effects of global warming and the growth of UHIs. The included research offers insightful information about the traits, approaches, and constraints of assessing the contribution of urban greenery to the reduction of UHIs. To quantify the cooling effects of greenery, most of the research used quantitative approaches like spatial regression (Chun & Guldmann, 2018) and numerical simulation tools like ENVI-met (Balany et al., 2020). Many city people have experienced increased thermal stress because of the persistent impacts of UHIs, which have been made worse by global warming. This is especially true for individuals who are more susceptible during times of intense heat. Urban trees and green infrastructure in general are crucial for reducing urban heat and improving human comfort (Hiemstra et al., 2017). Geographical sites included mid-sized cities like Columbus, Ohio (Chun & Guldmann, 2018) and high-density cities like Hong Kong (Tan, 2016). Urban parks, woods, green roofs, walls, and street trees were among the frequently assessed kinds of greenery (Ma et al., 2023). Human thermal comfort, evapotranspiration rates, air temperature, land surface temperature, and shading impacts were among the indicators evaluated (Knight et al., 2021).

Evaluating the impact of urban greenery on the UHI effect requires the application of rigorous and appropriate methodologies. Researchers have employed a variety of techniques to quantify the cooling benefits of vegetation in urban settings, each with its own strengths and limitations. The primary methodologies used in this field include remote sensing techniques, field measurements, and numerical simulations (Weng, 2009; D. Zhou et al., 2016). The assessment techniques were divided into three categories: modeling-based, experimental, and observational. While experimental approaches examined site-specific treatments, such as wind-path and sky view factor-based designs (Tan, 2017), observational research used satellite data to analyze vegetation indicators like NDVI (Wong et al., 2011). To quantify the effect of vegetation on microclimates, modeling studies simulated several scenarios (Balany et al., 2020). Most of the included research on urban greenery and its function in reducing the impacts of UHIs employ both quantitative and qualitative methodologies. The negative consequences of climate change can be lessened by mitigating the effects of UHI. To estimate the cooling effects of urban greenery, quantitative research frequently uses satellite images, climate models, and temperature data (both surface and air temperatures) (Andersson-Sköld, 2018; Darkwah & Cobbinah, 2014). Large metropolitan centers like Beijing, New Delhi, and American cities are the subject of this research, which are carried out in a variety of geographical settings, including temperate and tropical regions like Europe, North America, and Southeast Asia. Parks, green rooftops, vertical gardens, green walls, and street trees are among the urban greenery types evaluated. By reducing UHI, they all provide shade, boost evapotranspiration, and change the local microclimate. UHI reduction has been successfully achieved using highly reflecting materials in place of traditional paved surfaces on highways and roofs, as well as the incorporation of vegetative green space into urban design (Almazán et al., 2012; Knez, 2018; Uggla, 2014). Although these techniques work well when used separately, new technology has made it possible for vegetation to make up for the shortcomings of previous roof-cooling techniques with greening roofs (Cimburova & Blumentrath, 2022; Hui & Jim, 2022; Y. Yang et al. 2020).

Table 2. Comparison of strengths and limitations of each methodology.

Methodology	Strengths	Limitations	Examples from Literature
Remote Sensing	Broad spatial coverage; temporal monitoring capability; derivation of key indicators (LST, NDVI); analysis of large urban areas; historical trend analysis.	Limited resolution for microclimate analysis; accuracy affected by atmospheric conditions; requires ground truthing; may not directly measure pedestrian-level air temperature.	Analysis of LST and NDVI to assess cooling effects of parks (Zheng et al., 2022); mapping vegetation change trends using EVI (G. Li et al., 2025); use of Landsat imagery to measure LST.(Marando et al., 2022)
Field Measurements	High accuracy for specific locations; detailed microclimate information; measurement of various meteorological parameters; essential for validation.	Limited spatial coverage; labor-intensive and costly for large areas; results may be localized and not representative; challenges in deploying and maintaining sensors.	On-site temperature measurements in parks (Aram et al., 2019); use of wireless sensors to collect temperature data (H. Xu et al., 2023); measurement of albedo and emissivity of urban surfaces.(Battista et al., 2020)
Numerical Simulations	Enables testing of different scenarios; prediction of cooling effects; analysis of complex interactions; optimization of urban design and greenery placement.	Accuracy dependent on input data and model calibration; can be computationally intensive; model simplifications may not fully capture real-world complexity.	Use of ENVI-met to simulate microclimate (Azmeer et al., 2024); application of InVEST model for urban cooling (Bosch et al., 2021); prediction of air temperature with i-Tree Cool Air.(Semenzato & Bortolini, 2023)

The effectiveness of urban greenery in mitigating UHI is assessed using a variety of techniques. The most efficient method of urban cooling is generally thought to be UHI, and urban trees and forests (Hwang, 2017). This is mostly due to shade and lowering ground surface temperatures; however, evapotranspiration is also sometimes used. Direct measurements of the cooling effects are frequently made using remote sensing technologies and ground-based sensors (Jang, 2024). To evaluate how green spaces affect temperature and forecast future events, studies also use modeling and simulation approaches like Urban Canopy Models (UCMs) and Geographic Information Systems (GIS) (Esfehankalateh et al., 2021). These studies usually evaluate temperature decrease, evapotranspiration rates, biodiversity, and energy savings as key markers. Many studies use both direct observations and satellite data to measure temperature decline, which is frequently the main emphasis (Kumar & Shukla, 2022).

While urban greenery provides significant benefits for UHI mitigation, several limitations must also be acknowledged. In arid and semi-arid regions, the high-water demand of green infrastructure can strain already limited water resources, potentially undermining sustainability goals (Norton et al., 2015). Furthermore, the maintenance and operational costs associated with urban green spaces can be substantial, posing challenges for long-term upkeep, particularly in cities with constrained municipal budgets (Meerow & Newell, 2017; Frantzeskaki, 2019). Another emerging concern is the phenomenon of 'green gentrification,' where the introduction of green amenities can lead to increased property values and the displacement of economically vulnerable populations (Anguelovski et al., 2019). These challenges highlight the need for careful planning, inclusive policy-making, and the integration of adaptive management strategies to ensure that urban greenery interventions are both environmentally sustainable and socially equitable (Elmqvist et al., 2017).

However, there are significant gaps in the literature even if these studies offer insightful information. Traditional parks, forests, wetlands, rivers, private gardens, street trees, allotments, playing fields, cemeteries, and more recent inventions like green roofs and sustainable drainage systems are examples of green infrastructure networks in urban settings (Barau, 2015; Detommaso et al., 2021). Smaller-scale or more localized greenery interventions, such community gardens or street trees, have received less attention in studies that have concentrated on large-scale green infrastructures (Abdi et al., 2020b; F. Sun et al., 2023). Furthermore, comparatively little study has been done in tropical, desert, or suburban settings where the impacts of greenery may differ. Instead, most studies have been carried out in densely populated, temperate metropolitan regions. In addition, secondary advantages like biodiversity, carbon sequestration, and the socioeconomic effects of greenery—such as improved public health and energy savings—are not given enough attention. Chun and Guldmann (2018) highlighted the opposing functions of greenery in summer and winter, demonstrating that few research addressed seasonal fluctuations in greenery's cooling benefits (Chun & Guldmann, 2018). Furthermore, research frequently concentrated on localized scales, restricting the findings' wider application, even if numerical techniques like ENVI-met were commonly employed (Balany et al., 2020). Furthermore, there aren't much thorough research in the literature on health-related indicators like the physiological and psychological effects of urban greenery, especially regarding lowering heat stress and improving mental health (Santamouris, 2015). The necessity for more uniform and comparable assessment frameworks across all locations and types of greenery is further highlighted by the lack of established measures for assessing urban greenery's efficacy in mitigating UHI (Santamouris, 2017).

4. DISCUSSION

4.1. Conceptual Framework for Urban Greenery and UHI Mitigation

Climate warming is projected to intensify the UHI effect (Tsoka, 2020). Despite the abundance of scientific information available, little is known about the overall and global impact of increasing urban green infrastructure (GI) on urban climate, environmental quality, and health, as well as lowering both surface and air temperatures, particularly during warmer months (Santamouris et al., 2018). In an examination of the cooling impacts of tree changes such as decreasing canopy density and increasing the number of trees in a particular canopy, it was shown that high-density trees can result in temperature decreases of up to 2.5 °C in a tropical environment (Y. Yang, 2021). These impacts have been evaluated using a variety of methodologies, including satellite images, mobile air temperature monitoring, and spatial metrics such as canopy density and green space area. The research covers a wide range of urban environments, from congested cities like Hong Kong to mid-sized cities like Columbus, Ohio, with consistent results of temperature decreases and microclimate benefits (Chun & Guldmann, 2018; Tong et al., 2017). Furthermore, various plant types—such as green roofs, vertical gardens, and street trees—have been shown to contribute differently to UHI mitigation depending on their location and layout.

Based on a synthesis of findings from the selected peer-reviewed studies, a conceptual framework has been developed to systematically illustrate the relationships between urban greenery types, cooling mechanisms, and contextual factors influencing UHI mitigation. This framework integrates diverse evidence from the literature, capturing how biophysical processes and socio-ecological, infrastructural, and policy dimensions interrelate to determine the effectiveness of urban greenery interventions. The framework is presented in Figure 5.

Figure 5. Conceptual framework illustrating the relationships between urban greenery types, their primary cooling mechanisms, influencing socio-ecological and infrastructural factors, policy supports, and UHI mitigation outcomes.

Conceptual framework developed to illustrate the pathways through which different types of urban greenery—such as street trees, parks, green roofs, and vertical greenery—contribute to UHI mitigation. Each greenery type operates through primary cooling mechanisms including shading, evapotranspiration, and albedo enhancement. These mechanisms are further influenced by socio-ecological factors like biodiversity, species selection, and maintenance practices; infrastructural characteristics such as urban form and surface materials; and policy and governance elements including greening incentives and urban zoning regulations. The interaction of these factors ultimately determines the effectiveness and equity of UHI mitigation outcomes, such as surface and air cooling and improvements in human thermal comfort. This integrative framework highlights the need for a holistic approach that combines ecological, infrastructural, and policy dimensions in designing resilient urban cooling strategies.

4.2. Urban Planning and its implications

The findings of these research offer significant information for urban planning and policy development. Urban planners are urged to take a more holistic approach to implementing green infrastructure, acknowledging the value of both large-scale solutions like urban parks and local interventions like street trees and community gardens (Cai, 2018). A green infrastructure approach to spatial planning has arisen, viewing land and water networks as vital societal infrastructure that must be conserved, built, planned, and maintained in the future, as well as completely incorporated into spatial planning processes (Mcpherson et al., 2005). Mitigation of UHI impacts can help reduce the negative consequences of climate change. Such techniques may be adjusted to meet local demands, increasing their effectiveness in minimizing UHI impacts (Z. Zhang et al., 2022). Policies should also stress the incorporation of vegetation into both new and retrofitting projects, therefore improving microclimates and urban liveability. To guarantee that these initiatives are sustainable and scalable, policies must incorporate provisions for long-term green space preservation and administration.

4.3. Limitations and gaps

While the evidence for urban greenery's cooling advantages is strong, the analysis highlights substantial gaps and limits. A major difficulty is a lack of methodological consistency between research, which makes comparisons and generalization difficult (J. Zhang et al., 2023). The cooling capacity varies significantly according to the scale of interest (city or building level), greenery extent (park design and size), plant selection, and plant location. Urban planners must thus optimize design to maximize mitigation advantages, such as interspersing parks across a city, assigning more trees than grass space, and employing different techniques in locations where the most cooling is necessary (Wong et al., 2021). Various study methods and indicators, such as temperature decrease, evapotranspiration rates, and shading effects, are applied without established procedures. Furthermore, most research concentrate on temperate urban locations, leaving tropical, desert, and suburban regions unexplored, despite their unique climatic and urban dynamics (Wong & Jusuf, 2013). Another drawback is that many studies focus on the short term, paying little attention to the long-term sustainability, maintenance, and larger ecological, economic, and social implications of urban greenery, such as biodiversity improvement, carbon sequestration, and public health benefits. Urban green infrastructure (UGI) is critical in balancing biodiversity protection and sustainable urban development via adaptive management techniques (Xi et al., 2023).

A critical evaluation of the 42 reviewed studies reveals several common methodological limitations. First, a large proportion of studies exhibit a strong reliance on remote sensing and satellite data, often without adequate ground-truth validation, potentially reducing the accuracy of temperature and vegetation assessments. Second, many studies are geographically concentrated in a limited number of high-income, temperate-climate countries, leaving tropical and low-income urban regions underexplored. Third, most analyses are cross-sectional, lacking longitudinal data that would allow for the assessment of long-term cooling effects and vegetation dynamics over time. Fourth, socio-economic and demographic factors, which are crucial for understanding the equity of UHI mitigation outcomes, are frequently omitted from models and analyses. Finally, few studies employed mixed-methods approaches that combine quantitative assessments with qualitative community insights, limiting the holistic understanding of how greenery interventions affect diverse populations. Addressing these methodological weaknesses is essential for advancing the field toward more robust, equitable, and generalizable findings.

4.3.1. Gaps in Socio-Ecological and Health Dimensions

The reviewed studies reveal a limited focus on socio-ecological aspects, such as the distributional equity of cooling benefits, community engagement in greening initiatives, and environmental justice implications. Few studies address how UHI mitigation efforts may differentially impact various socio-economic groups or neighborhoods. Additionally, the co-benefits of urban greenery for public health, including reductions in heat-related illnesses and improvements in mental well-being, remain underexplored in the current literature. Future research should integrate socio-ecological variables and health outcomes into the assessment of UHI mitigation strategies to ensure holistic and equitable urban adaptation planning.

4.3.2. Neglect of Seasonal Variability

Another limitation is the lack of attention to seasonal variability. Most studies assess UHI mitigation based on summer-time data, neglecting the performance of urban greenery across different seasons. Understanding how vegetation functions during varying climatic conditions is crucial for optimizing its design and maintenance schedules and ensuring year-round thermal comfort. Longitudinal and multi-season studies are needed to capture these dynamics more accurately.

4.3.3. Context-Specific Feasibility and Socioeconomic Constraints

While green roofs, urban trees, and parks are widely recommended for UHI mitigation, few studies critically assess their context-specific feasibility. High installation and maintenance costs, competition for land in densely built environments, water scarcity in arid regions, and lack of technical capacity can significantly constrain the implementation of these solutions, particularly in low-income and rapidly urbanizing areas. Future research must evaluate not only the technical effectiveness but also the economic and social feasibility of green interventions to ensure sustainable and equitable deployment across diverse urban contexts.

4.3.4. Assessment of Instrumentation and Data Collection

The reviewed studies predominantly rely on remote sensing datasets such as Landsat and MODIS for temperature and vegetation assessments. Field-based meteorological measurements (e.g., air temperature loggers, anemometers) are also employed, albeit less frequently. While remote sensing provides extensive spatial coverage, it is limited by temporal resolution and potential inaccuracies in surface temperature retrieval. Field-based measurements offer higher precision but are often restricted in spatial scale. Simulation tools like ENVI-met and SOLWEIG are commonly used to model microclimatic effects, but their reliability depends heavily on accurate calibration and input data. The limited integration of remote, field, and modeling approaches in many studies highlights a methodological gap that future research should address for more robust and comprehensive assessments.

4.4. Future Research Direction

Future research should fill the gaps indicated in present studies. This includes long-term evaluations of greenery's cooling benefits, investigations of its effects in various geographical and climatic situations, and analyses of seasonal fluctuations in efficacy. Creating standardized evaluation frameworks for analyzing greenery's involvement in UHI reduction is critical for producing comparable and practical results. Furthermore, future study should look at indirect advantages such as emotional well-being, health, and energy savings, which are frequently disregarded in existing studies. A comprehensive strategy that includes ecological, economic, and social elements will not only improve urban planning techniques but will also increase the ability of urban greenery to reduce UHI impacts and contribute to sustainable urban development. Future research should address the current thematic and geographic imbalances by integrating socioecological perspectives and expanding empirical studies to include underrepresented regions, particularly those most vulnerable to UHI effects.

While this review synthesizes key insights into the role of urban greenery in mitigating UHI effects, it is important to acknowledge that the findings are primarily derived from studies conducted in temperate and high-income urban contexts. The limited representation of tropical, arid, and low-income regions constrains the generalizability of the conclusions. Urban heat dynamics, vegetation performance, and socio-economic interactions may vary considerably across different climatic zones and socio-economic settings. Therefore, further empirical research is urgently needed in underrepresented regions to develop context-specific strategies that address the unique challenges and opportunities in diverse urban environments.

5. CONCLUSIONS

This review provides a comprehensive synthesis of current knowledge on the effectiveness of urban greenery in mitigating UHI effects. Drawing on 42 selected studies, the findings confirm that urban green infrastructure including street trees, green roofs, parks, and green walls plays a significant role in reducing both surface and ambient air temperatures. The mechanisms of mitigation, particularly evapotranspiration, shading, and albedo enhancement, consistently demonstrate measurable cooling benefits across various climatic and urban typologies. The study also revealed important methodological trends and disparities. Remote sensing tools, especially NDVI and LST derived from satellite imagery, remain central to quantitative assessments, while simulation models such as ENVI met enable scenario testing and design optimization. Field based measurements complement these approaches by offering localized validation.

While this study is based on a systematic review and bibliometric analysis of existing literature, it offers a critical synthesis of current research on UHI mitigation through urban greenery. By highlighting thematic gaps, such as the underrepresentation of socioecological resilience and geographic imbalances in research focus, this review provides a strategic framework for future investigations. Moving forward, there is a pressing need for empirical validation through field experiments, long-term monitoring studies, and integrative modeling approaches to enhance the understanding and effectiveness of urban greenery interventions. Future research should prioritize context-specific studies, particularly in tropical and low-income regions, to ensure the development of equitable and resilient UHI mitigation strategies. From a planning and policy perspective, the integration of green infrastructure into urban design must become both a mitigation and adaptation strategy. Policymakers should prioritize inclusive, context sensitive solutions that combine ecological performance with social equity. Ultimately, urban greenery stands out as a critical tool for building climate resilient, healthy, and sustainable cities in the face of accelerating urban heat challenges. This study synthesized current knowledge on the cooling benefits of urban greenery in mitigating UHI effects and identified significant research gaps. While urban greenery remains a vital strategy for UHI mitigation, future implementations must carefully balance its environmental benefits with considerations of water resource management, maintenance sustainability, and social equity to avoid unintended negative consequences. Further interdisciplinary research, including empirical validation and context-specific studies, is needed to enhance the resilience and equity of urban climate adaptation strategies.

Author Contributions: Conceptualization and methodology, S.R.; software, V.R.; validation, S.R., N.H.; formal analysis, V.R.; investigation, S.R.; resources, S.R., H.R.; formal analysis, data curation, V.R.; writing—original draft preparation, S.R.; writing—review and editing, V.R., H.R.; visualization, S.R.; supervision, D.K.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors would like to express their sincere gratitude to all the researchers whose work was reviewed and synthesized in this study. Their valuable contributions have shaped the knowledge base surrounding urban greenery and its role in mitigating UHI effects. We also acknowledge the use of VOSviewer software for the bibliometric analysis, which provided critical insights into thematic trends and research networks. Special thanks are extended to the institutions and libraries that provided access to academic databases, making the systematic literature review possible. Finally, the authors appreciate the support and feedback received from colleagues and academic peers throughout the development of this manuscript.

Conflicts of Interest: Authors declare no conflicts of interest.

REFERENCES

Abdi, B., Hami, A., & Zarehaghi, D. (2020a). Impact of small-scale tree planting patterns on outdoor cooling and thermal comfort. *Sustainable Cities and Society*. https://www.sciencedirect.com/science/article/pii/S221067072030072X

Abdi, B., Hami, A., & Zarehaghi, D. (2020b). Impact of small-scale tree planting patterns on outdoor cooling and thermal comfort. *Sustainable Cities and Society*, *56*. https://doi.org/10.1016/j.scs.2020.102085

Aboelata, A., & Sodoudi, S. (2019). Evaluating urban vegetation scenarios to mitigate urban heat island and reduce buildings' energy in dense built-up areas in Cairo. *Building and Environment*. https://www.sciencedirect.com/science/article/pii/S0360132319306171

Aflaki, A., Mirnezhad, M., Ghaffarianhoseini, A., & ... (2017). Urban heat island mitigation strategies: A state-of-the-art review on Kuala Lumpur, Singapore and Hong Kong. *Cities*. https://www.sciencedirect.com/science/article/pii/S0264275116305303

Aikoh, T. (2023). Comparing conventional manual measurement of the green view index with modern automatic methods using google street view and semantic segmentation. *Urban Forestry and Urban Greening*, *80*. https://doi.org/10.1016/j.ufug.2023.127845

Akbari, H., Cartalis, C., Kolokotsa, D., & ... (2016). Local climate change and urban heat island mitigation techniques–the state of the art. *Journal of Civil …*. https://doi.org/10.3846/13923730.2015.1111934

Algeciras, J. A. R., Coch, H., & ... (2016). Human thermal comfort conditions and urban planning in hot-humid climates—The case of Cuba. *International Journal of …*. https://doi.org/10.1007/s00484-015-1109-4

Almazán, J., Radovic, D., & Suzuki, T. (2012). Small urban greenery: Mapping and visual analysis in Kyojima-Sanchome. *Archnet-IJAR: International …*. https://mediatum.ub.tum.de/doc/1141900/document.pdf#page=60

Andersson-Sköld, Y. (2018). A framework for assessing urban greenery's effects and valuing its ecosystem services. *Journal of Environmental Management*, *205*, 274–285. https://doi.org/10.1016/j.jenvman.2017.09.071

Anguelovski, I., Connolly, J. J., Garcia-Lamarca, M., Cole, H., & Pearsall, H. (2019). New scholarly pathways on green gentrification: What does the urban 'green turn' mean and where is it going? Progress in Human Geography, 43(6), 1064–1086. https://doi.org/10.1177/0309132518803799

Aram, F., Higueras García, E., Solgi, E., & Mansournia, S. (2019). Urban green space cooling effect in cities. *Heliyon*, *5*(4), e01339. https://doi.org/10.1016/j.heliyon.2019.e01339

Arruda, H. (2022). VOSviewer and Bibliometrix. *Journal of the Medical Library Association : JMLA*, *110*(3), 392–395. https://doi.org/10.5195/jmla.2022.1434

Azmeer, A., Tahir, F., & Al-Ghamdi, S. G. (2024). Progress on green infrastructure for urban cooling: Evaluating techniques, design strategies, and benefits. *Urban Climate*, *56*. https://doi.org/10.1016/j.uclim.2024.102077

Balany, F., Ng, A. W. M., Muttil, N., Muthukumaran, S., & ... (2020). Green infrastructure as an urban heat island mitigation strategy—a review. *Water*. https://www.mdpi.com/2073-4441/12/12/3577

Baniya, B., Techato, K., Ghimire, S. K., & ... (2018). A review of green roofs to mitigate urban heat island and Kathmandu valley in Nepal. *Appl. Ecol. Environ …*. https://www.academia.edu/download/58166888/Review_-_Green_Roofs_to_Mitigate_UHI_-_Binod_Bania_et_al..pdf

Barau, A. S. (2015). Perceptions and contributions of households towards sustainable urban green infrastructure in Malaysia. *Habitat International*, *47*, 285–297. https://doi.org/10.1016/j.habitatint.2015.02.003

Battista, G., Evangelisti, L., Guattari, C., De Lieto Vollaro, E., De Lieto Vollaro, R., & Asdrubali, F. (2020). Urban Heat Island Mitigation Strategies: Experimental and Numerical Analysis of a University Campus in Rome (Italy). *Sustainability*, *12*(19), 7971. https://doi.org/10.3390/su12197971

Blazejczyk, K., Epstein, Y., Jendritzky, G., Staiger, H., & Tinz, B. (2012). Comparison of UTCI to selected thermal indices. *International Journal of Biometeorology*, *56*(3), 515–535. https://doi.org/10.1007/s00484-011-0453-2

Bobo Merga, B., Tabor, K. W., & Melka, G. A. (2024). Analysis of the cooling effects of urban green spaces in mitigating micro-climate change using geospatial techniques in Adama City, Ethiopia. *Sustainable Environment*, *10*(1). https://doi.org/10.1080/27658511.2024.2350806

Bosch, M., Locatelli, M., Hamel, P., Remme, R. P., Jaligot, R., Chenal, J., & Joost, S. (2021). Evaluating urban greening scenarios for urban heat mitigation: a spatially explicit approach. *Royal Society Open Science*, *8*(12). https://doi.org/10.1098/rsos.202174

Cai, B. (2018). Treepedia 2.0: Applying Deep Learning for Large-Scale Quantification of Urban Tree Cover. *Proceedings - 2018 IEEE International Congress on Big Data, BigData Congress 2018 - Part of the 2018 IEEE World Congress on Services*, 49–56. https://doi.org/10.1109/BigDataCongress.2018.00014

Chàfer, M., Pisello, A. L., Piselli, C., & Cabeza, L. F. (2020). Greenery system for cooling down outdoor spaces: Results of an experimental study. *Sustainability*. https://www.mdpi.com/2071-1050/12/15/5888

Christopher O'malley, M., Piroozfar, P., Farr, E. R. P., & Pomponi, M. F. (2015). *Urban Heat Island (UHI) Mitigating Strategies: A Case-based Comparative Analysis*.

Chun, B., & Guldmann, J. M. (2018). Impact of greening on the urban heat island: Seasonal variations and mitigation strategies. *Computers, Environment and Urban Systems*, *71*, 165–176. https://doi.org/10.1016/j.compenvurbsys.2018.05.006

Cimburova, Z., & Blumentrath, S. (2022). Viewshed-based modelling of visual exposure to urban greenery–An efficient GIS tool for practical planning applications. *Landscape and Urban Planning*. https://www.sciencedirect.com/science/article/pii/S0169204622000445

Cui, L., Rupprecht, C. D. D., & Shibata, S. (2021). Climate-responsive green-space design inspired by traditional gardens: Microclimate and human thermal comfort of Japanese gardens. *Sustainability*. https://www.mdpi.com/2071-1050/13/5/2736

Dahanayake, K. C. (2018). Comparing reduction of building cooling load through green roofs and green walls by EnergyPlus simulations. *Building Simulation*, *11*(3), 421–434. https://doi.org/10.1007/s12273-017-0415-7

Darkwah, R. M., & Cobbinah, P. (2014). Stewardship of urban greenery in an era of global urbanisation. *International Journal of …*. https://researchoutput.csu.edu.au/en/publications/stewardship-of-urban-greenery-in-an-era-of-global-urbanisation

de Quadros, B. M., & Mizgier, M. G. O. (2023a). Urban green infrastructures to improve pedestrian thermal comfort: A systematic review. *Urban Forestry &Urban Greening*. https://www.sciencedirect.com/science/article/pii/S1618866723002625

de Quadros, B. M., & Mizgier, M. G. O. (2023b). Urban green infrastructures to improve pedestrian thermal comfort: A systematic review. In *Urban Forestry and Urban Greening* (Vol. 88). Elsevier GmbH. https://doi.org/10.1016/j.ufug.2023.128091

Detommaso, M., Gagliano, A., Marletta, L., & Nocera, F. (2021). Sustainable urban greening and cooling strategies for thermal comfort at pedestrian level. *Sustainability (Switzerland)*, *13*(6). https://doi.org/10.3390/su13063138

Doucet, M. B. (2021). *… vertical greenery systems in urban residential areas to mitigate urban heat island, reduce energy loads, and improve thermal comfort conditions in a hot humid climate*. repositories.lib.utexas.edu. https://repositories.lib.utexas.edu/items/e597d756-5fdc-4288-a449-dff14e143e42

Dybå, T., & Dingsøyr, T. (2008). Empirical studies of agile software development: A systematic review. In *Information and Software Technology* (Vol. 50, Issues 9–10, pp. 833–859). https://doi.org/10.1016/j.infsof.2008.01.006

Elmqvist, T., Andersson, E., McPhearson, T., & Bai, X. (2017). Urbanization and the future of cities: Synergies and trade-offs between urban sustainability and ecosystem services. Current Opinion in Environmental Sustainability, 26–27, 1–6. https://doi.org/10.1016/j.cosust.2017.04.020

Esfehankalateh, A. T., Ngarambe, J., & Yun, G. Y. (2021). Influence of tree canopy coverage and leaf area density on urban heat island mitigation. *Sustainability*. https://www.mdpi.com/2071-1050/13/13/7496

Fahmy, M., Ibrahim, Y., Hanafi, E., & Barakat, M. (2018). Would LEED-UHI greenery and high albedo strategies mitigate climate change at neighborhood scale in Cairo, Egypt? *Building Simulation*, *11*(6), 1273–1288. https://doi.org/10.1007/s12273-018-0463-7

Farnham, C., Emura, K., & Mizuno, T. (2015). Evaluation of cooling effects: Outdoor water mist fan. *Building Research and Information*, *43*(3), 334–345. https://doi.org/10.1080/09613218.2015.1004844

Feyisa, G. L., Dons, K., & Meilby, H. (2014). Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. *Landscape and Urban Planning*, *123*, 87–95. https://doi.org/10.1016/j.landurbplan.2013.12.008

Frantzeskaki, N. (2019). Seven lessons for planning nature-based solutions in cities. Environmental Science & Policy, 93, 101–111. https://doi.org/10.1016/j.envsci.2018.12.033

Gago, E. J., Roldan, J., Pacheco-Torres, R., & Ordóñez, J. (2013). The city and urban heat islands: A review of strategies to mitigate adverse effects. In *Renewable and Sustainable Energy Reviews* (Vol. 25, pp. 749–758). https://doi.org/10.1016/j.rser.2013.05.057

Galagoda, R. U., Jayasinghe, G. Y., Halwatura, R. U., & ... (2018). The impact of urban green infrastructure as a sustainable approach towards tropical micro-climatic changes and human thermal comfort. *… & Urban Greening*. https://www.sciencedirect.com/science/article/pii/S1618866718301687

Gonçalves, A., Ribeiro, A. C., Maia, F., Nunes, L., & ... (2019). Influence of green spaces on outdoors thermal comfort—Structured experiment in a mediterranean climate. *Climate*. https://www.mdpi.com/2225-1154/7/2/20

Halder, N., Kumar, M., Deepak, A., Mandal, S. K., Azmeer, A., Mir, B. A., Nurdiawati, A., & Al-Ghamdi, S. G. (2025). The Role of Urban Greenery in Enhancing Thermal Comfort: Systematic Review Insights. *Sustainability*, *17*(6), 2545. https://doi.org/10.3390/su17062545

He, B. J. (2019). Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building. *Sustainable Cities and Society*. https://www.sciencedirect.com/science/article/pii/S2210670719309503

He, D., Miao, J., Lu, Y., Song, Y., Chen, L., & Liu, Y. (2022). Urban greenery mitigates the negative effect of urban density on older adults' life satisfaction: Evidence from Shanghai, China. *Cities*. https://www.sciencedirect.com/science/article/pii/S0264275122000464

Health Organization Regional Office for Europe, W. (2016). *Urban green spaces and health. A review of evidence*. http://www.euro.who.int/pubrequest

Herath, H., Halwatura, R. U., & Jayasinghe, G. Y. (2018). Evaluation of green infrastructure effects on tropical Sri Lankan urban context as an urban heat island adaptation strategy. *Urban Forestry &Urban …*. https://www.sciencedirect.com/science/article/pii/S1618866717301826

Herath, H. M. P. I. K. (2018). Evaluation of green infrastructure effects on tropical Sri Lankan urban context as an urban heat island adaptation strategy. *Urban Forestry and Urban Greening*, *29*, 212–222. https://doi.org/10.1016/j.ufug.2017.11.013

Hiemstra, J. A., Saaroni, H., & Amorim, J. H. (2017). *The Urban Heat Island: Thermal Comfort and the Role of Urban Greening* (pp. 7–19). https://doi.org/10.1007/978-3-319-50280-9_2

Huang, J. (2022). A street-scale simulation model for the cooling performance of urban greenery: Evidence from a high-density city. *Sustainable Cities and Society*, *82*. https://doi.org/10.1016/j.scs.2022.103908

Huang, J., Hao, T., Wang, Y., & Jones, P. (2022). A street-scale simulation model for the cooling performance of urban greenery: Evidence from a high-density city. *Sustainable Cities and Society*. https://www.sciencedirect.com/science/article/pii/S221067072200230X

Hui, L. C., & Jim, C. Y. (2022). Urban-greenery demands are affected by perceptions of ecosystem services and disservices, and socio-demographic and environmental-cultural factors. *Land Use Policy*. https://www.sciencedirect.com/science/article/pii/S0264837722002812

Hwang, Y. H. (2017). Preference for site conservation in relation to on-site biodiversity and perceived site attributes: An on-site survey of unmanaged urban greenery in a tropical city. *Urban Forestry and Urban Greening*, *28*, 12–20. https://doi.org/10.1016/j.ufug.2017.09.011

Jang, S. (2024). Street-level urban heat island mitigation: Assessing the cooling effect of green infrastructure using urban IoT sensor big data. *Sustainable Cities and Society*, *100*. https://doi.org/10.1016/j.scs.2023.105007

Klemm, W., Heusinkveld, B. G., Lenzholzer, S., & ... (2015). Street greenery and its physical and psychological impact on thermal comfort. *Landscape and Urban …*. https://www.sciencedirect.com/science/article/pii/S0169204615000407

Knez, I. (2018). Wellbeing in urban greenery: The role of naturalness and place identity. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.00491

Knight, T., Price, S., Bowler, D., Hookway, A., King, S., Konno, K., & Richter, R. L. (2021). How effective is 'greening' of urban areas in reducing human exposure to ground-level ozone concentrations, UV exposure and the 'urban heat island effect'? An updated systematic review. In *Environmental Evidence* (Vol. 10, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13750-021-00226-y

Kotharkar, R., Dongarsane, P., & Keskar, R. (2023). Determining influence of urban morphology on air temperature and heat index with hourly emphasis. *Building and Environment*, *233*, 110044. https://doi.org/10.1016/j.buildenv.2023.110044

Kumar, D., Maurya, K. K., Mandal, S. K., Mir, B. A., Nurdiawati, A., & Al-Ghamdi, S. G. (2025). Life Cycle Assessment in the Early Design Phase of Buildings: Strategies, Tools, and Future Directions. *Buildings*, *15*(10), 1612. https://doi.org/10.3390/buildings15101612

Kumar, D., & Shukla, B. (2022). Urban Green Spaces For Promoting Healthy Living And Wellbeing: Prospects For Housing. *ECS Transactions*, *107*(1), 18835–18857. https://doi.org/10.1149/10701.18835ecst

Kyriakodis, G. E., & Santamouris, M. (2018). Using reflective pavements to mitigate urban heat island in warm climates-Results from a large scale urban mitigation project. *Urban Climate*. https://www.sciencedirect.com/science/article/pii/S2212095517300081

Lehmann, S. (2014). Low carbon districts: Mitigating the urban heat island with green roof infrastructure. *City, Culture and Society*. https://www.sciencedirect.com/science/article/pii/S1877916614000046

Li, D., Bou-Zeid, E., & Oppenheimer, M. (2014). The effectiveness of cool and green roofs as urban heat island mitigation strategies. *Environmental Research Letters*, *9*(5). https://doi.org/10.1088/1748-9326/9/5/055002

Li, X., Zhang, C., Li, W., Kuzovkina, Y. A., & Weiner, D. (2020). Who lives in greener neighborhoods? The distributional pattern of urban green spaces in the city of Hartford, Connecticut, USA. Sustainability, 12(18), 7434. https://doi.org/10.3390/su12187434

Li, G., Cao, Y., Fang, C., Sun, S., Qi, W., Wang, Z., He, S., & Yang, Z. (2025). Global urban greening and its implication for urban heat mitigation. *Proceedings of the National Academy of Sciences*, *122*(4). https://doi.org/10.1073/pnas.2417179122

Ma, Z., Wang, J., Ye, S., Wang, R., Dong, F., & Feng, Y. (2023). Real-time indoor thermal comfort prediction in campus buildings driven by deep learning algorithms. *Journal of Building Engineering*, *78*. https://doi.org/10.1016/j.jobe.2023.107603

Marando, F., Heris, M. P., Zulian, G., Udías, A., Mentaschi, L., Chrysoulakis, N., Parastatidis, D., & Maes, J. (2022). Urban heat island mitigation by green infrastructure in European Functional Urban Areas. *Sustainable Cities and Society*, *77*, 103564. https://doi.org/10.1016/j.scs.2021.103564

Mcpherson, G., Simpson, J. R., Peper, P. J., Maco, S. E., & Xiao, Q. (2005). *Municipal Forest Benefits and Costs in Five US Cities*. https://academic.oup.com/jof/article/103/8/411/4598681

Meerow, S., & Newell, J. P. (2017). Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit. Landscape and Urban Planning, 159, 62–75. https://doi.org/10.1016/j.landurbplan.2016.10.005

Meho, L. I., & Sugimoto, C. R. (2009). Assessing the scholarly impact of information studies: A tale of two citation databases-Scopus and Web of Science. *Journal of the American Society for Information Science and Technology*, *60*(12), 2499–2508. https://doi.org/10.1002/asi.21165

Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *Journal of Environmental …*. https://www.sciencedirect.com/science/article/pii/S0301479717303201

Mutani, G. (2021). Roof-integrated green technologies, energy saving and outdoor thermal comfort: Insights from a case study in urban environment. *International Journal of Sustainable Development and Planning*, *16*(1), 13–23. https://doi.org/10.18280/ijsdp.160102

Mutani, G., & Todeschi, V. (2020). The effects of green roofs on outdoor thermal comfort, urban heat island mitigation and energy savings. *Atmosphere*. https://www.mdpi.com/2073-4433/11/2/123

Mutani, G., & Todeschi, V. (2021). Roof-integrated green technologies, energy saving and outdoor thermal comfort: Insights from a case study in urban environment. *Int. J. Sustain. Dev. Plan*. https://www.researchgate.net/profile/Valeria-Todeschi/publication/350417416_Roof-Integrated_Green_Technologies_Energy_Saving_and_Outdoor_Thermal_Comfort_Insights_from_a_Case_Study_in_Urban_Environment/links/6061c361458515e8347c3af9/Roof-Integrated-Green-Technologies-Energy-Saving-and-Outdoor-Thermal-Comfort-Insights-from-a-Case-Study-in-Urban-Environment.pdf

Nasrollahi, N., Ghosouri, A., Khodakarami, J., & Taleghani, M. (2020). Heat-mitigation strategies to improve pedestrian thermal comfort in urban environments: A review. *Sustainability*. https://www.mdpi.com/2071-1050/12/23/10000

Nath, R. (2025). *Modeling Urban Thermal Dynamics and Land Use Change in Guwahati: A Machine Learning-Based Analysis of Lst and Utfvi Trends (2000–2040)*. https://doi.org/10.2139/ssrn.5120897

Nikezić, A., & Marković, D. (2015). Place-based education in the architectural design studio: Agrarian landscape as a resource for sustainable urban lifestyle. *Sustainability (Switzerland)*, *7*(7), 9711–9733. https://doi.org/10.3390/su7079711

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134, 127–138. https://doi.org/10.1016/j.landurbplan.2014.10.018

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. In *The BMJ* (Vol. 372). BMJ Publishing Group. https://doi.org/10.1136/bmj.n71

Park, J., Kim, J. H., Sohn, W., & Lee, D. K. (2021). Urban cooling factors: Do small greenspaces outperform building shade in mitigating urban heat island intensity? *Urban Forestry &Urban Greening*. https://www.sciencedirect.com/science/article/pii/S1618866721002831

Pigliautile, I., Pisello, A. L., & Bou-Zeid, E. (2020). Humans in the city: Representing outdoor thermal comfort in urban canopy models. *Renewable and Sustainable Energy …*. https://www.sciencedirect.com/science/article/pii/S1364032120303944

Rathod, V. (2025). Assessing Impact of Urban Heat Islands and Mitigation Strategies Using GIS. *International Journal of Science and Research (IJSR)*, *14*(2), 1873–1877. https://doi.org/10.21275/SR25027113551

Rouse, D. C., & Bunster-Ossa, I. F. (2013). *Green Infrastructure: A Landscape Approach Green Infrastructure American Planning Association PAS Report Number 571*. www.planning.org

Santamouris, M. (2015). Regulating the damaged thermostat of the cities - Status, impacts and mitigation challenges. *Energy and Buildings*, *91*, 43–56. https://doi.org/10.1016/j.enbuild.2015.01.027

Santamouris, M. (2017). Passive and active cooling for the outdoor built environment – Analysis and assessment of the cooling potential of mitigation technologies using performance data from 220 large scale projects. *Solar Energy*, *154*, 14–33. https://doi.org/10.1016/j.solener.2016.12.006

Santamouris, M., Ban-Weiss, G., Osmond, P., & ... (2018). Progress in urban greenery mitigation science–assessment methodologies advanced technologies and impact on cities. *Journal of Civil …*. https://iris.unimore.it/handle/11380/1169196

Santamouris, M., Ding, L., & Osmond, P. (2019). Urban heat island mitigation. *Decarbonising the Built Environment …*. https://doi.org/10.1007/978-981-13-7940-6_18

Semenzato, P., & Bortolini, L. (2023). Urban Heat Island Mitigation and Urban Green Spaces: Testing a Model in the City of Padova (Italy). *Land*, *12*(2), 476. https://doi.org/10.3390/land12020476

Shahidan, M. F., Jones, P. J., Gwilliam, J., & Salleh, E. (2012). An evaluation of outdoor and building environment cooling achieved through combination modification of trees with ground materials. *Building and Environment*, *58*, 245–257. https://doi.org/10.1016/j.buildenv.2012.07.012

Sharifi, E. (2015). Correlation analysis of surface temperature of rooftops, streetscapes and urban heat island effect: Case study of central Sydney. *Journal of Urban and Environmental Engineering*, *9*(1), 3–11. https://doi.org/10.4090/juee.2015.v9n1.003011

Soltani, A., & Sharifi, E. (2017). Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide. *Frontiers of Architectural Research*. https://www.sciencedirect.com/science/article/pii/S2095263517300432

Song, J., Gasparrini, A., Fischer, T., Hu, K., & ... (2023). Effect Modifications of Overhead-View and Eye-Level Urban Greenery on Heat–Mortality Associations: Small-Area Analyses Using Case Time Series Design and …. *Environmental Health …*. https://doi.org/10.1289/EHP12589

Su, Y., Wu, Z., Gao, W., Wang, C., Zhao, Q., Wang, D., & Li, J. (2024). Summer outdoor thermal comfort evaluation of urban open spaces in arid-hot climates. *Energy and Buildings*. https://www.sciencedirect.com/science/article/pii/S0378778824007953

Sun, F., Zhang, J., Yang, R., Liu, S., Ma, J., Lin, X., Su, D., Liu, K., & ... (2023). Study on microclimate and thermal comfort in small urban green spaces in Tokyo, Japan—A case study of Chuo Ward. *Sustainability*. https://www.mdpi.com/2071-1050/15/24/16555

Sun, S., Xu, X., Lao, Z., Liu, W., Li, Z., García, E. H., He, L., & ... (2017). Evaluating the impact of urban green space and landscape design parameters on thermal comfort in hot summer by numerical simulation. *… and Environment*. https://www.sciencedirect.com/science/article/pii/S0360132317302962

Tan, Z. (2016). Urban tree design approaches for mitigating daytime urban heat island effects in a high-density urban environment. *Energy and Buildings*, *114*, 265–274. https://doi.org/10.1016/j.enbuild.2015.06.031

Tan, Z. (2017). Planning strategies for roadside tree planting and outdoor comfort enhancement in subtropical high-density urban areas. *Building and Environment*, *120*, 93–109. https://doi.org/10.1016/j.buildenv.2017.05.017

Tan, Z., Lau, K. K. L., & Ng, E. (2016). Urban tree design approaches for mitigating daytime urban heat island effects in a high-density urban environment. *Energy and Buildings*. https://www.sciencedirect.com/science/article/pii/S0378778815300566

Tong, S., Wong, N. H., Tan, C. L., Jusuf, S. K., Ignatius, M., & Tan, E. (2017). Impact of urban morphology on microclimate and thermal comfort in northern China. *Solar Energy*. https://www.sciencedirect.com/science/article/pii/S0038092X17305315

Tsoka, S. (2020). Urban warming and cities' microclimates: Investigation methods and mitigation strategies—A review. *Energies*, *13*(6). https://doi.org/10.3390/en13061414

Uggla, Y. (2014). Protecting urban greenery: the case of Stockholm's National City Park. *City &Community*. https://doi.org/10.1111/cico.12085

Ulpiani, G. (2019). Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts. In *Applied Energy* (Vol. 254). Elsevier Ltd. https://doi.org/10.1016/j.apenergy.2019.113647

Uribe, C. H. A. (2022). Potential of retrofitted urban green infrastructure to reduce runoff - A model implementation with site-specific constraints at neighborhood scale. *Urban Forestry and Urban Greening*, *69*. https://doi.org/10.1016/j.ufug.2022.127499

van Eck, N. J. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Wang, C., Wang, Z. H., Kaloush, K. E., & Shacat, J. (2021). Cool pavements for urban heat island mitigation: A synthetic review. In *Renewable and Sustainable Energy Reviews* (Vol. 146). Elsevier Ltd. https://doi.org/10.1016/j.rser.2021.111171

Wang, R., Helbich, M., Yao, Y., Zhang, J., Liu, P., Yuan, Y., & ... (2019). Urban greenery and mental wellbeing in adults: Cross-sectional mediation analyses on multiple pathways across different greenery measures. *Environmental …*. https://www.sciencedirect.com/science/article/pii/S0013935119303329

Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy and Buildings*, *114*, 2–19. https://doi.org/10.1016/j.enbuild.2015.06.046

Wang, Y., Lian, Z., & Chang, H. (2022). The correlation between the overall thermal comfort, the overall thermal sensation and the local thermal comfort in non-uniform environments with local cooling. *Indoor and Built Environment*, *31*(7), 1822–1833. https://doi.org/10.1177/1420326X221079819

Weng, Q. (2009). Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. *ISPRS Journal of Photogrammetry and Remote Sensing*, *64*(4), 335–344. https://doi.org/10.1016/j.isprsjprs.2009.03.007

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

WONG, L. P., Alias, H., Aghamohammadi, N., Aghazadeh, S., & Sulaiman, N. M. N. (2018). Physical, Psychological, and Social Health Impact of Temperature Rise Due to Urban Heat Island Phenomenon and Its Associated Factors. In *Biomedical and Environmental Sciences* (Vol. 31, Issue 7, pp. 545–550). Elsevier Ltd. https://doi.org/10.3967/bes2018.074

Wong, N. H., & Jusuf, S. K. (2013). Urban heat island and mitigation strategies at city and building level. *Adv Develop Cool Mater Built Environ*. https://books.google.com/books?hl=en&lr=&id=l6YTDgAAQBAJ&oi=fnd&pg=PA3&dq=%22urban+greenery%22%7C%22urban+heat+island%22+%22urban+greenery%22%7C%22mitigation+island%22&ots=mqE687ee4l&sig=S64xpJKKLdLzyOQx4Gtwl2ItrZ0

Wong, N. H., Tan, C. L., Kolokotsa, D. D., & Takebayashi, H. (2021). Greenery as a mitigation and adaptation strategy to urban heat. In *Nature Reviews Earth and Environment* (Vol. 2, Issue 3, pp. 166–181). Springer Nature. https://doi.org/10.1038/s43017-020-00129-5

Wong, N. H., Yong, A., Tan, K., Puay, ;, Tan, Y., Sia, A., & Wong, N. C. (2011). *Perception Studies of Vertical Greenery Systems in Singapore*. https://doi.org/10.1061/ASCEUP.1943-5444.0000034

Xi, C., Han, L., Wang, J., Feng, Z., Kumar, P., & ... (2023). How can greenery space mitigate urban heat island? An analysis of cooling effect, carbon sequestration, and nurturing cost at the street scale. *Journal of Cleaner …*. https://www.sciencedirect.com/science/article/pii/S0959652623023880

Xiao, H. (2018). Responses of urban land surface temperature on land cover: A comparative study of Vienna and Madrid. *Sustainability (Switzerland)*, *10*(2). https://doi.org/10.3390/su10020260

Xu, H., Sheng, K., & Gao, J. (2023). Mitigation of heat island effect by green stormwater infrastructure: a comparative study between two diverse green spaces in Nanjing. *Frontiers in Ecology and Evolution*, *11*. https://doi.org/10.3389/fevo.2023.1307756

Xu, M., Hong, B., Jiang, R., An, L., & Zhang, T. (2019). Outdoor thermal comfort of shaded spaces in an urban park in the cold region of China. *Building and Environment*. https://www.sciencedirect.com/science/article/pii/S0360132319302112

Yang, W., & Wong, N. H. (2013). Field study of human thermal perception in urban parks in Singapore. *International Journal of Sustainable Building Technology and Urban Development*, *4*(2), 125–133. https://doi.org/10.1080/2093761X.2013.768184

Yang, W., Wong, N. H., & Li, C.-Q. (2016). Effect of Street Design on Outdoor Thermal Comfort in an Urban Street in Singapore. *Journal of Urban Planning and Development*, *142*(1). https://doi.org/10.1061/(asce)up.1943-5444.0000285

Yang, Y. (2021). Urban greenery cushions the decrease in leisure-time physical activity during the COVID-19 pandemic: A natural experimental study. *Urban Forestry and Urban Greening*, *62*. https://doi.org/10.1016/j.ufug.2021.127136

Yang, Y., Lu, Y., Yang, L., Gou, Z., & Zhang, X. (2020). Urban greenery, active school transport, and body weight among Hong Kong children. *Travel Behaviour and Society*. https://www.sciencedirect.com/science/article/pii/S2214367X19303205

Zhang, B., Cadotte, M. W., Chen, S., Tan, X., You, C., Ren, T., Chen, M., Wang, S., Li, W., Chu, C., Jiang, L., Bai, Y., Huang, J., & Han, X. (2019). Plants alter their vertical root distribution rather than biomass allocation in response to changing precipitation. *Ecology*, *100*(11). https://doi.org/10.1002/ecy.2828

Zhang, J., Lu, J., Deng, W., Beccarelli, P., & Lun, I. Y. F. (2023). Thermal comfort investigation of rural houses in China: A review. In *Building and Environment* (Vol. 235). Elsevier Ltd. https://doi.org/10.1016/j.buildenv.2023.110208

Zhang, L., Wei, D., Hou, Y., Du, J., Liu, Z., Zhang, G., & Shi, L. (2020). Outdoor thermal comfort of urban park—a case study. *Sustainability*. https://www.mdpi.com/2071-1050/12/5/1961

Zhang, Y., Li, S., Fu, X., & Dong, R. (2021). Quantification of urban greenery using hemisphere-view panoramas with a green cover index. *Ecosystem Health and Sustainability*. https://doi.org/10.1080/20964129.2021.1929502

Zhang, Z., Paschalis, A., Mijic, A., Meili, N., Manoli, G., van Reeuwijk, M., & Fatichi, S. (2022). A mechanistic assessment of urban heat island intensities and drivers across climates. *Urban Climate*, *44*. https://doi.org/10.1016/j.uclim.2022.101215

Zhao, L., Hu, G., Zou, D., Wu, X., Ma, L., Sun, Z., Yuan, L., Zhou, H., & Liu, S. (2019). Permafrost Changes and Its Effects on Hydrological Processes on Qinghai-Tibet Plateau. *Bulletin of Chinese Academy of Sciences*, *34*(11), 1233–1246. https://doi.org/10.16418/j.issn.1000-3045.2019.11.006

Zheng, S., Liu, L., Dong, X., Hu, Y., & Niu, P. (2022). Dominance of Influencing Factors on Cooling Effect of Urban Parks in Different Climatic Regions. *International Journal of Environmental Research and Public Health*, *19*(23), 15496. https://doi.org/10.3390/ijerph192315496

Zhou, D., Zhang, L., Hao, L., Sun, G., Liu, Y., & Zhu, C. (2016). Spatiotemporal trends of urban heat island effect along the urban development intensity gradient in China. *Science of The Total Environment*, *544*, 617–626. https://doi.org/10.1016/j.scitotenv.2015.11.168

Zhao, C., Fu, G., Liu, X., & Fu, F. (2018). Urban building energy modeling for hot summer and cold winter zone in China. Building and Environment, 135, 98–113. https://doi.org/10.1016/j.buildenv.2018.02.042

Zhou, W., Cao, F., & Wang, G. (2019). Effects of spatial pattern of forest vegetation on urban cooling in a compact megacity. *Forests*, *10*(3). https://doi.org/10.3390/f10030282

Zou, M., & Zhang, H. (2021). Cooling strategies for thermal comfort in cities: a review of key methods in landscape design. *Environmental Science and Pollution Research*, *28*(44), 62640–62650. https://doi.org/10.1007/s11356-021-15172-y