

Global Knowledge Structure of Urban Green Space Research in Hot–Humid Regions (2000–2025): A Bibliometric Analysis

Bader A. Alhammad^{1*}, Ahmad K. Altwaijri², Abdulkarim K. Alhowaish³

¹ Department of Landscape Architecture, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia; balhammad@iau.edu.sa

² Department of Landscape Architecture, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia; akaltwaijri@iau.edu.sa

³ Department of Urban and Regional Planning, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia; abowaisb@iau.edu.sa

*Corresponding Author: balhammad@iau.edu.sa

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ABSTRACT

Urban green spaces (UGS) are widely discussed as contributing to livability and moderating heat stress, especially in hot–humid regions where microclimate challenges are more pronounced. However, research remains distributed across multiple themes without a unified synthesis of its intellectual development. This study uses bibliometric mapping to analyze UGS-related scholarship between 2000 and 2025, identifying dominant clusters, thematic linkages, and publication trends rather than evaluating on-ground performance. A total of 94 peer-reviewed publications indexed in Scopus and Web of Science were analyzed through co-occurrence networks, thematic clustering, and overlay visualization. The analysis indicates four major knowledge groupings: (1) green infrastructure and planning, (2) tropical and hot–humid climate contexts, (3) ecosystem-service-oriented literature, and (4) urban heat island and thermal comfort research. Temporal patterns further suggest a shift from early microclimate-focused studies toward more integrated discussions connecting ecosystem services, modelling, resilience, and planning. The study therefore maps how the field conceptually frames UGS, rather than proving their direct environmental or social outcomes, and may support future empirical work by highlighting where research is thematically expanding.

Keywords: Urban Green Space (UGS); Hot–Humid Regions; Bibliometric Analysis; Green Infrastructure; Thermal Comfort; Ecosystem Services; Urban Heat Island; VOSviewer

INTRODUCTION

The green spaces in cities (Urban green spaces or UGS) are significant in the preservation of the environment and human health across the globe. They provide numerous ecosystem services that are required in habitable cities, including air purification and climate regulation, noise reduction, and recreation [1]. UGS contribute to city sustainability by minimizing pollution, mitigating urban heat islands, and providing spaces for recreation and social interaction. Indeed, the models of sustainable cities emphasize the necessity of a compromise between the aspects of environmental security, economic development, and social justice, which is a green, profitable, and fair mix that can be provided by UGS [2]. Besides the ecological benefits, the availability of urban greenery is also linked to the enhancement of the community and personal health, yet the benefits are not fairly shared [3,4]. As an example, neighborhoods with lower income have lower quality parks, which is one of the reasons why the issue of

environmental health disparities is growing [3]. In the meantime, the large-scale greening can lead to so-called green gentrification, a trend that raises property prices and displaces poor people who live in disadvantaged neighborhoods, something that planners want to avoid by introducing the processes of just green enough [4]. These perspectives highlight that UGS function not only as environmental assets but also as social and political spaces central to urban quality of life.

The hot-humid cities can be described as the ones where certain environmental and social issues precondition the special topicality of UGS. These subtropical and tropical cities have a climatic temperature of hot and humid, seasonally heavy precipitation, and coastal flooding and storm risks. Vegetation shading and evapotranspiration provide rapid natural cooling, helping to lower temperatures in dense urban areas. But climate change is accelerating the extremes in heat and changing precipitation patterns, which are putting strain on urban ecosystems. A recent international study discovered that most urban tree and shrub species in cities are already developing below optimum temperature or precipitation ranges of pressure that will only intensify as climates warm up [5]. These conditions make it challenging to maintain healthy green cover in hot-humid cities, where biodiversity is high but sensitive to urbanization. In the social front, a large portion of this population increase and urban sprawl is taking place in the under-global south cities with hot-humid regions. This accelerated urbanization and lack of resources can lead to UGS deprivation and unequal availability of parks and trees, which can aggravate the outcomes of urban heat islands and environmental inequality. There is a need to incorporate climate resilience, including protection against heat waves and floods, and provide equitable access to green facilities, so the hot-humid urban scenario is especially urgent [6], [7]. One of the challenges that these cities experience is the capacity of urban systems and communities to sustain and recover after shocks caused by climatic conditions, referred to as socio-ecological resilience [6]. Well-planned UGS may be incorporated as natural infrastructure to convey storm water, cool air, and sustainable biodiversity to provide city resiliency to climatic extremes [7,8].

Despite the recognized importance of urban green space, a notable knowledge gap exists regarding the global knowledge structure of UGS research specifically in hot-humid regions. While numerous studies have examined UGS benefits and planning in general, there has been little comprehensive synthesis of research trends focused on tropical and humid subtropical city contexts. Current bibliometric reviews have started to inventory the vast terrain of urban green space research such as [9] have undertaken a 30-year comprehensive global survey and have found a spurt of UGS research since 2010 in line with the global sustainability efforts [10]. However, such reviews did not single out hot-humid regions, leaving questions about how research in these climate zones may differ in focus or growth. Regional studies are only starting to appear; for example, [11] highlight that urban ecology in tropical cities remains underrepresented in the literature and call for greater scholarly attention to these "windows into the ecosystems of our present and future." In fact, the relative dearth of studies in tropical urban centers has been observed to interfere with the formation of an all-encompassing structure of the urban sustainability in such settings [11]. This implies that there is a gap in the research: there is no bibliometric study so far that has explicitly focused on the development of UGS research in hot-humid areas as a specific branch of the world literature. Addressing this gap is important because cities in humid tropical climates often face unique green space challenges such as monsoonal flooding, year-round growing seasons, high biodiversity, and ecosystem service potential. that may shape research themes differently from cities in temperate or arid zones.

To address this gap, the present study systematically analyzes the global knowledge structure of urban green space research in hot-humid regions from 2000 to 2025. We undertake a bibliometric mapping of the literature to identify key themes, trends, and collaboration patterns in this domain. By doing so, we seek to understand how scholarly attention to UGS in hot-humid cities have evolved and what conceptual frameworks have been applied. The study is guided by several specific research questions: What are the main research themes and topics addressed in UGS studies focused on hot-humid region cities, and how have these themes evolved over the 2000–2025 period? How do these studies characterize the ecological, social, and governance dimensions of urban green spaces in hot-humid climates? What are the patterns of re-search output and collaboration in this field, such as leading countries, institutions, and authors, and do they indicate any geographic or knowledge imbalances? Where do gaps remain in the literature on UGS in hot-humid regions, and what opportunities exist for future research to support urban sustainability and resilience in these environments? By answering these questions, the study will fill a critical knowledge gap and provide a foundation for informed policy-making and planning in rapidly urbanizing hot-humid regions. These results will help determine whether the demands of the world UGS research agenda have already incorporated the requirements and specifics of urban hot-humid cities, or whether greater implementation of tropical out-looks is required to advance theory and practice in urban sustainability.

THEORETICAL AND CONCEPTUAL FRAMEWORK

This study draws on four interrelated theoretical foundations, urban sustainability, ecosystem services, socio-ecological resilience, and environmental justice, to interpret ecological, social, and governance dimensions of UGS in hot-humid regions. Together, these frameworks guide how we classify literature and understand knowledge clusters revealed by the bibliometric analysis.

Urban Sustainability Theory

Urban sustainability emphasizes balancing environmental integrity, social equity, and economic viability, as illustrated in Campbell's (1996) planner's triangle, where tensions among the three require negotiation [2]. Applied to UGS, sustainability thinking highlights that green spaces should deliver environmental benefits, such as cooler microclimates, cleaner air, ensure equitable access, and coexist with development goals. The theory cautions that these objectives rarely produce win-win scenarios; preserving land for parks may conflict with real estate development or raise housing prices. Consequently, governance becomes essential in navigating trade-offs and preventing environmental gains from undermining equity. This rationale underpins the inclusion of governance in our analytical structure, emphasizing how planning, policy tools, and stakeholder involvement shape sustainable UGS outcomes [2].

Ecosystem Services Framework

Ecosystem services explain the multifunctional benefits of UGS. Bolund and Hunhammar (1999) identified core services provided by urban green spaces, including air filtration, microclimate regulation, stormwater drainage, noise reduction, cultural value, and recreation [1]. Later classifications group these into provisioning, regulating, artistic, and supporting services. In hot-humid climates, regulating services such as cooling and stormwater management are especially crucial; vegetation can lower temperatures and mitigate the UHI effect, and permeable soils reduce runoff during intense rainfall [10]. This framework defines our ecological dimension, focusing on how studies measure temperature reduction, air quality improvement, biodiversity, and climate-related performance. It also highlights UGS multi-functionality, reflected in multi-criteria planning tools designed to optimize benefits such as heat mitigation, recreation, and runoff retention [12,13]. Thus, ecosystem services theory helps evaluate how ecological functions are prioritized in literature and how they align with the environmental needs of tropical cities.

Socio-Ecological Resilience

Resilience theory conceptualizes cities as adaptive human-nature systems capable of absorbing shocks and reorganizing in response to stress [8,14]. In urban contexts, resilience emphasizes flexibility, learning, and adaptive management rather than stability. UGS contribute by reducing vulnerability to climate extremes: wetlands absorb floods, tree canopies mitigate heat, and coastal mangrove systems enhance storm protection. Resilience research argues that social and ecological well-being are inseparable [8,15], a claim that is especially relevant for hot-humid cities facing rising heat and intensified rainfall. Meerow et al. (2016) define urban resilience as the capacity of urban socio-ecological networks to maintain, adapt, or transform toward desired functions [14]. Within our framework, resilience informs both ecological and governance dimensions, highlighting climate-risk reduction, adaptive planning, and long-term management of UGS.

Environmental Justice

Environmental justice addresses who benefits from urban green space and who bears environmental burdens. Jennings and Johnson Gaither (2015) emphasize disparities in access to parks, tree canopy, and climate resilience, noting that lower-income or minority neighborhoods often suffer from limited green space and higher exposure to heat and pollution [3]. Additionally, efforts to expand greening in underserved areas may unintentionally trigger green gentrification, where improvements attract higher-income residents and raise housing costs, as described by Wolch, Byrne, and Newell (2014) [4]. Their concept of "just green enough" encourages small-scale community-led greening to prevent displacement. This theory structures our social dimension, guiding assessment of themes such as greenspace equity, public health, inclusivity, and community participation. It helps identify how literature addresses differential access and whether UGS benefits are distributed fairly across demographic groups.

Analytical Dimensions (Ecological, Social, Governance)

Synthesizing these theories, we define three analytical dimensions: (1) Ecological Dimension, rooted in ecosystem services and resilience. Focuses on biophysical benefits: cooling, biodiversity, climate mitigation, stormwater control, and air quality. (2) Social Dimension, grounded in environmental justice and sustainability equity, examines well-being, health, recreation, inclusivity, cultural relevance, and equitable distribution [3,4]. (3) Governance Dimension, informed by sustainability trade-offs and resilience planning. Concerns institutions, planning tools, policy frameworks, financing, maintenance, and stakeholder engagement. These dimensions enable systematic coding of the literature and interpretation of bibliometric clusters. They also reflect integrated urban sustainability thinking, in which ecological performance, social equity, and governance mechanisms interact to shape UGS's potential. As Folke (2006) notes, cities are socio-ecological systems [15], and Campbell (1996) underscores the need to balance environmental, social, and economic goals [2]. This framework helps identify whether UGS research in hot-humid regions emphasize ecological services at the expense of social equity or governance, and where empirical or conceptual gaps persist.

METHODOLOGY

Bibliometric analysis is a quantitative assessment of scholarly literature and is the approach that is more and more frequently used in urban and environmental studies to trace the research paths, collaboration networks, and trends in the study topic [16]. Even though bibliometric methods have been discussed since the mid-20th century, their application today has become possible due to the availability of big bibliographic databases like Scopus and Web of Science. Within the framework of the literature of urban green space (UGS), bibliometric techniques have been adopted as crucial means to map the global research productivity, visualize co-author networks, and establish the changing themes in the three ecological, social, and governance dimensions [17]. In recent applications, gaps in social inclusion have been revealed, the development of the ecosystem services research agenda has been identified, and the addition of green infrastructure to urban sustainability agendas has been tracked [18]. Based on this, this research utilizes bibliometric analysis to investigate the knowledge systematization of UGS research in hot-humid areas systematically to reveal the patterns of publications, prevailing themes and research advancement perspectives. This study adopts the methodological framework outlined by Alhawaish (2025) [19], structured around three stages: scanning, curating, and analyzing. In the scanning phase, relevant studies, including journal articles, book chapters, and conference proceedings, were identified using carefully constructed search strings and keywords. The curating phase involved refining this dataset according to inclusion and exclusion criteria designed to ensure alignment with the study's objectives. Finally, in the analyzing phase, the shortlisted records were examined using a combination of bibliometric and thematic techniques. The analytical toolkit included bibliographic coupling, citation analysis, co-authorship analysis, and co-citation analysis, alongside the construction of Globally-level publication and collaboration maps to assess international networks and alliances in the global knowledge structure of urban green space research in hot-humid regions [20,21].

Scanning Phase

This paper uses a quantitative bibliometric research methodology with qualitative thematic interpretation as a supplementary measure in accordance with the principles of best practices [16]. A three-phase framework was embraced, which included scanning, curating, and analyzing. To begin with, there was a large-scale literature search of the key scientific databases, such as Scopus and Web of Science Core Collection, published in 2000-2025 [22]. These databases were selected due to their generalized disciplinary range of peer-reviewed urban and environmental messages. Guided by well-defined objectives, we constructed Boolean search queries combining terms for urban green space, include: ("urban green space" OR "urban greening" OR "urban parks" OR "green infrastructure" OR "urban vegetation" OR "urban forest") AND ("hot humid" OR "humid tropical" OR "tropical climate" OR "equatorial climate" OR "monsoon region" OR "wet tropical") Queries were applied to the title, abstract, and keyword fields. Consistent with standard practice, the search was limited to English-language journal articles and reviews [22]. This scanning phase generated an initial corpus of records, which were then exported for screening.

Data Screening

In the screening, which is in other words, the curating phase, we applied inclusion and exclusion criteria to refine the dataset. Articles that were duplicates, editorials, book chapters, or conference papers, or without abstracts, were also excluded. We also excluded studies that were obviously not related to urban green space or to hot-humid environments, such as temperate climate studies. Furthermore, following the initial search in Scopus and Web of Science using the predefined Boolean string, a total of 241 records were retrieved (Scopus: 95; Web of Science: 146). The screening process applied a set of inclusion and exclusion criteria to refine the dataset. These criteria included limiting results to peer-reviewed journal articles, reviews, and conference proceedings published in English between 2000 and 2025, and excluding records without abstracts, duplicates, or non-research content. A manual comparison of document titles revealed no overlapping entries between the two databases. After this filtering process, 94 unique, thematically relevant publications were retained for bibliometric analysis. This selection formed the final dataset for subsequent mapping of research trends, thematic structures, and collaboration networks in the field of urban green space in hot-humid regions. It is illustrated in a PRISMA flowchart as shown in Figure 1.

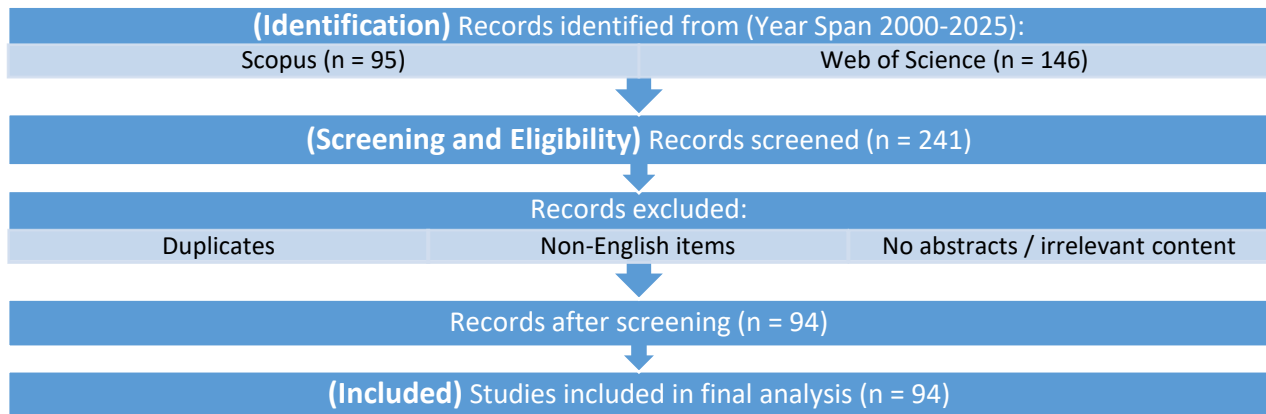


Figure 1: PRISMA flowchart for recording the relevant papers from the searches. Prepared by the author based on the PRISMA 2020 template

Analytical Tools

During the analysis stage, we used a collection of bibliometric and network analysis methods. The bibliometric package was used in VOS viewer for visualization [22]. This tool uses well-known science mapping tools, and all parameters are set with standard parameters, including a minimum co-occurrence threshold, in order to ensure reproducibility. In practice, Bibliometric computed descriptive statistics and performed key analyses, including multiple correspondence analysis for conceptual mapping. At the same time, VOS viewer generated network graphs of co-authorship, co-citation, and co-word co-occurrence. This combined toolkit enabled both performance analysis, such as publication and citation counts, and science mapping, such as collaboration networks, thematic clusters [23].

Bibliometric Indicators

The bibliometric analysis in this study applied a set of standard performance indicators to assess the structure and dynamics of research on urban green space (UGS) in hot-humid regions. The most important metrics were annual publication trends, prolific authors, most popular journals, and highly cited documents. The intellectual influence was measured by the number of citations, and the productivity of a scholar was estimated by the number of publications. Besides the performance of various authors, the research also looked at the institutional and national input on UGS research, identifying the countries and universities that are the most active in the research. The co-authorship patterns were analyzed to determine the level of collaboration and the geographic connection among hot-humid regions with the help of the network visualizations produced by VOS viewer. The analysis of keyword co-occurrence was done to indicate prevalent and repeated topics in research, which illuminated the topical foci in the ecological, social, and governance aspects of UGS. All these indicators provided a quantitative prism through which the research landscape was systematically described, as was advised in known bibliometric studies [16].

Anticipated Thematic Patterns

Prior to conducting the bibliometric analysis, this study identified several key research patterns from a preliminary review of the literature. To begin with, the discourse on urban green space (UGS) in hot-humid climates was supposed to be dominated by the ecological themes, urban heat mitigation, microclimate control, and biodiversity increase, because of the environmental pressures typical of hot-humid climates. Second, social dimensions, including environmental justice, public health equity, and community engagement, were predicted to be underrepresented, particularly in studies from developing tropical countries. Third, themes related to governance, including the integration of urban planning, policy frameworks, and coordination in institutions, were to be less prevalent, as they represent wider issues in cross-sectoral management of green infrastructure. These predictions helped guide the interpretation of the bibliometric findings and assess whether emerging trends aligned with or diverged from global research expectations.

RESULTS

The systematic first bibliographic search on the Scopus and Web of Science (WoS) databases produced 241 records in the 2000–2025 range, which were subsequently filtered and cleansed after a systematic screening, including the elimination of duplicates, the elimination of incomplete records, or editorials, resulting in 94 eligible documents.

This is indeed a sign of a strict inclusion of the study criteria, which includes all those publications that qualitatively (and quantitatively) discuss urban green space (UGS) in a larger environment of urban heat reduction, sustainability, and livability, particularly in hot-humid climatic environments.

The 94 validated records span 2000 to 2025, showing a progressive, sustained increase in scholarly production over time. Figure 2 demonstrates that the temporal dynamics of publications show relatively low productivity in the early 2000s, followed by a significant increase after 2015, when the Sustainable Development Goals (SDGs) were globally implemented and the idea of green infrastructure began to be discussed in the context of urban research.

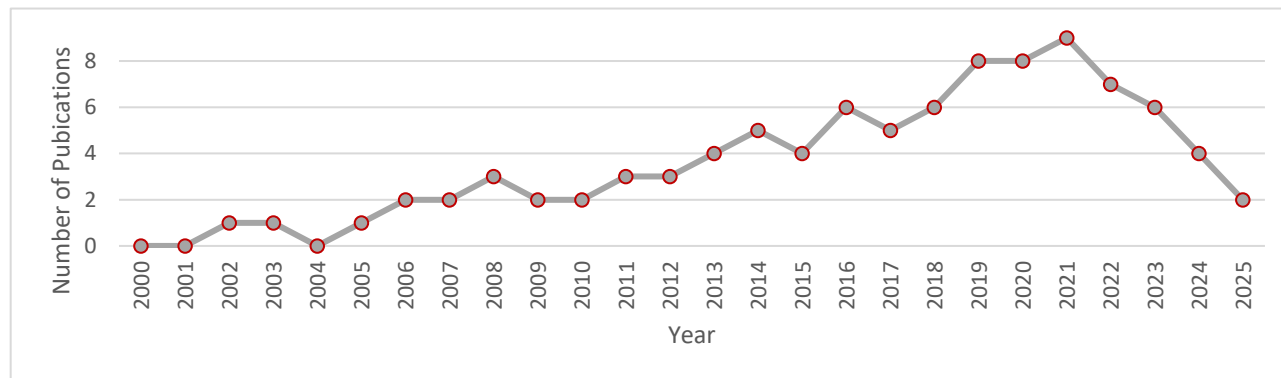


Figure 2: Publication Trends on Urban Green Space Research in Hot-Humid Regions (2000–2025)

Document-wise, the corpus consists primarily of articles (78), with conference papers (7), book chapters (5), and review articles (4) being the other types of documents, which demonstrate the interdisciplinary and changing scholarly tone of UGS issues. Regarding the pattern of authorship, Author-supplied keywords 812, Keywords Plus (from cited references) 829, Total contributing authors 355, Author appearances 358, Average authors per document 3.82, Average authors per document 3.9, Collaboration index 3.78, indicating that there is a high level of co-authorship and collaboration with outside institutions in the discipline, as shown in Table 1. The sources are distributed to show that the majority of the research has been published in the most popular international journals, such as Urban Forestry and Urban Greening, Sustainable Cities and Society, Journal of Cleaner Production, and Remote Sensing, which, combined, are the main platforms of research in the urban environment.

Table 1. Overview of Study.

Indicator	Value
Total records identified (before screening)	241
Records screened	241
Records after screening (included)	94
Document types (included set)	78 journal articles, 7 conference papers, 5 book chapters, 4 reviews
Timespan of publications	2000-2025
Author-supplied keywords	812
Keywords Plus (from cited references)	829
Total contributing authors	355
Author appearances	358
Average authors per document	3.82
Average co-authors per document	3.9
Collaboration index	3.78

The results indicate a clear increase in UGS-related publications after 2015, based on temporal growth trends observed in the dataset. The data highlights the interdisciplinary character and the ever-increasing cooperation among scholars and institutions. This discussion shows that UGS-related publications increasingly reference planning and sustainability contexts, as reflected in keyword frequency and publication themes rather than verified policy adoption.

Bibliometric Analysis

Citation Analysis

The most significant bibliometrics tools are those methods that can be used to quantify the impacts of science based on the number of citations a publication gets by another research. Citation analysis is one of them. This gives a good indication of its eminence and scholarly relevance [24,25]. It offers a complementary perspective that not only reveals the intellectual connections between publications but also the relative influence of journals and researchers within the field of urban green space studies in hot and humid environments, a central theme of contemporary research in the Arabian Gulf and Saudi Arabia [26].

Using an Excel-based platform for analyzing data, citation patterns were analyzed to identify the most prominent journals and researchers that constitute the knowledge base of Urban Green Spaces (UGS) research in the Arabian Gulf and surrounding regions. As demonstrated in Table 2, the International Journal of Applied Earth Observation and Geoinformatics took the first position in the number of times that it was cited in the sample, followed by Urban Forestry and Urban Greening and Sustainable Cities and Society. These findings point out that the most impactful journals often feature more advanced research on vegetation mapping, urban climate, and green space sustainability.

Table 2. Top 10 journals based on the number of citations.

Rank	Journal Title	Citations	Publisher
1	International Journal of Applied Earth Observation and Geoinformation	748	Elsevier
2	Urban Forestry and Urban Greening	324	Elsevier GmbH
3	Sustainable Cities and Society	245	Elsevier Ltd
4	PLOS ONE	104	Public Library of Science (PLOS)
5	Landscape and Urban Planning	100	Elsevier B.V.
6	International Journal of Biometeorology	73	Springer
7	Science of the Total Environment	62	Elsevier B.V.
8	Building Simulation	61	Tsinghua University Press
9	Journal of Environmental Management	60	Academic Press
10	Journal of Cleaner Production	57	Elsevier Ltd

Table 3 shows the most prolific researchers in the database, with Jayasooriya, V. M., Jim, C. Y., and Senthil, R. all having three publications. This is an indication of their leading positions in developing knowledge on the subject of green space management, ecosystem service evaluation, and climate performance simulation in cities. In contrast, several regional researchers, such as Elghezawy, D., and Ali, Z., have demonstrated an increasing presence thanks to their contributions to urban planning and local climate studies in the Middle East, indicating a growing regional research presence in this field.

Table 3. Top 10 authors based on the number of publications.

Author	Number of Publications
Jayasooriya, V. M. [27]	3
Jim, C. Y. [28]	3
Senthil, R. [29]	3
Pellegrino, P. R. M. [30]	3
Castañer, C. M. [31]	2
Eltarabily, S. [32]	2
Muthukumar, S. [33]	2

Li, X.-X. [34]	2
Elgheznawy, D. [35]	2
Ali, Z. [36]	2

On the whole, these reviews indicate that the research environment in UGS in hot and humid conditions is spread out between the high-impact international journals and the increasing regional research in the region. This is an indicator of both international scientific leadership and growing domestic concern over the problem of climate change, urban cooling, and neighborhood sustainability.

Keyword Co-Occurrence Analysis

The Co-Occurrence Analysis (CCA) of keywords is among the most significant bibliometric tools that disclose the thematic organization of the research areas. It quantifies the level of key words co-occurrence, and how these key words occur together in scientific publications [37]. Such an approach helps to determine common themes, the trends of research development, and points at the concept overlap between various knowledge areas [38].

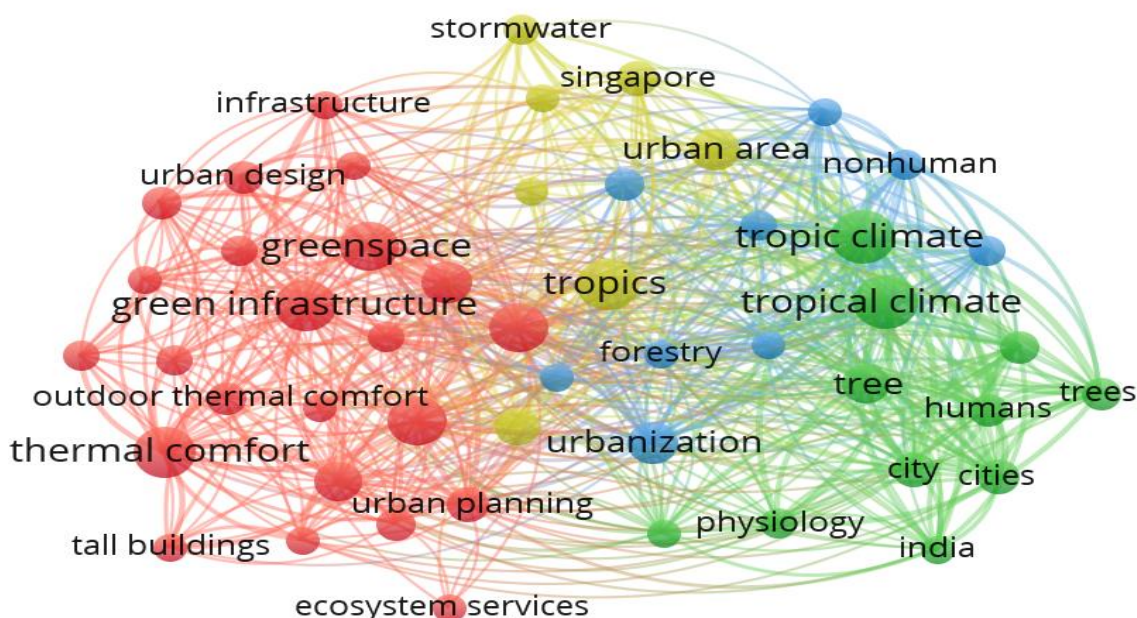


Figure 3. Keyword co-occurrence network visualization. This figure illustrates the thematic structure of research related to urban green spaces and hot-humid climate studies. Node size reflects the frequency of keyword occurrence, links represent conceptual associations between terms, and colors denote distinct thematic clusters within the literature.

The keyword co-occurrence network shown in Figure 3 illustrates four main thematic clusters derived from the dataset. These clusters are the prevailing research trends in the study of green space in urban areas and hot-humid climate. The analysis reveals that terms such as “Tropic Climate” (frequency = 17), “Tropics” (16), “Thermal Comfort” (16), “Green Infrastructure” (16), “Greenspace” (14), and “Climate Change” (14) dominate the field.

- Cluster 1 (red): Concentrates on green infrastructure, green space, and thermal comfort, which is the major topic of the urban microclimate enhancement.
- Cluster 2 (yellow): Focuses on tropical climate studies, and Singapore and stormwater management are the most important topics.
- Cluster 3 (green): Focuses on trees, ecosystem services, and ecological functions that focus on human well-being.
- Cluster 4 (blue): Focuses on the phenomenon of urban heat island and its relation to thermal comfort.

Overall, the clusters presented in the map show that it is the thematically varied, but interconnected field of research that connects the green infrastructure planning, tropical climate adaptation, ecological services, and urban heat mitigation to the common conceptual framework.

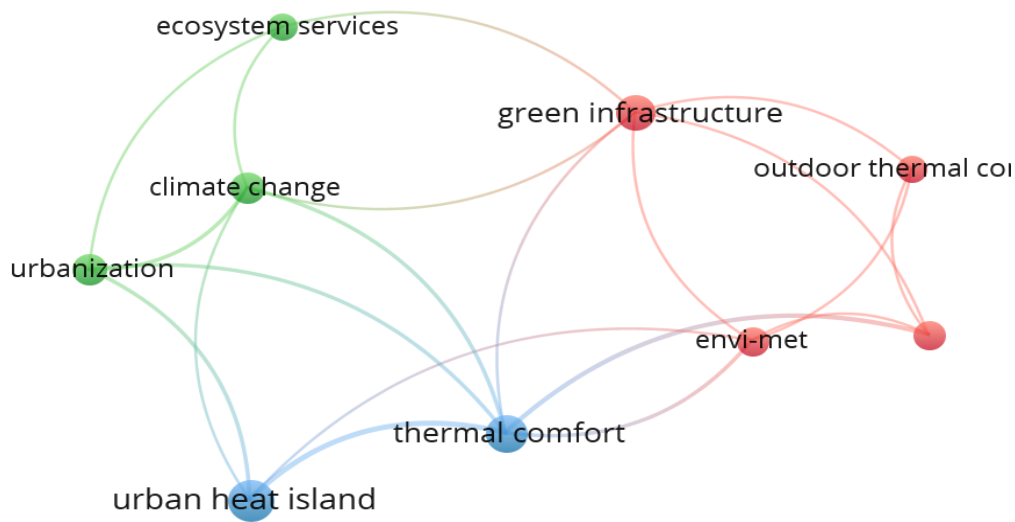


Figure 4. Author keyword co-occurrence network visualization. This figure shows the key thematic patterns according to author-assigned keywords. There is also a node size which displays the frequency of keywords, links which show co-occurrence associations, and color which depicts the main thematic clusters present in the literature.

The core thematic network in Figure 4 is the author keyword co-occurrence network that demonstrates the most common and important keywords used by authors in the dataset. A larger set of terms was found, but a much smaller set had strong co-occurrence to create meaningful clusters. Based on the visualization, three dominating thematic clusters that characterize the intellectual interest of research on urban green spaces in hot-humid environments are revealed. The analysis reveals that terms such as “Urban Heat Island” (frequency =12), “Thermal Comfort” (10), “Green Infra-structure” (9), “Climate Change” (7), “Urbanization” (7).

- Cluster 1 (red): Focuses on green infrastructure, outdoor thermal comfort, and ENVI-met, indicating work centered on modeling and evaluating microclimate improvements through green interventions.
- Cluster 2 (blue): Links thermal comfort with the urban heat island effect, reflecting studies addressing heat stress and urban climatic conditions.
- Cluster 3 (green): Includes ecosystem services, climate change, and urbanization, highlighting environmental and ecological perspectives related to UGS performance.

On the whole, the mapped clusters suggest that the research field is organized around three interrelated themes: green infrastructure design, urban climate modification, and ecosystem-based approaches to resilience in hot–humid regions.

Overall, the combined keyword co-occurrence analyses, based on both all extracted keywords and author, assigned keywords reveal a coherent thematic structure that defines research on urban green spaces in hot–humid environments. The larger network (All Keywords) presents four key themes regarding the green infrastructure planning, tropical climate contexts, ecological services, and urban heat mitigation, whereas the author keyword network combines these issues into three main clusters based on microclimate modeling, thermal comfort, and heat islands, and ecosystem-based adaptation. Together, these clusters demonstrate a research landscape that is interconnected yet thematically distinct, underscoring the central role of green infrastructure in improving thermal performance, supporting ecological functions, and enhancing climate resilience in rapidly urbanizing hot–humid regions.

Co-Citation and Intellectual Structure

Co-citation analysis is a fundamental bibliometric technique used to identify the intellectual structure of a research field by measuring how often two or more references are cited together in subsequent publications. When the names of certain studies, authors and journals are repeated in the same reference lists, then this tendency signifies strong conceptual links and overlapping theoretical grounds between them [39]. According to Small (1973), co-citation relationships demonstrate the research side of a discipline and how research ideas develop and cluster with time as they change [40].

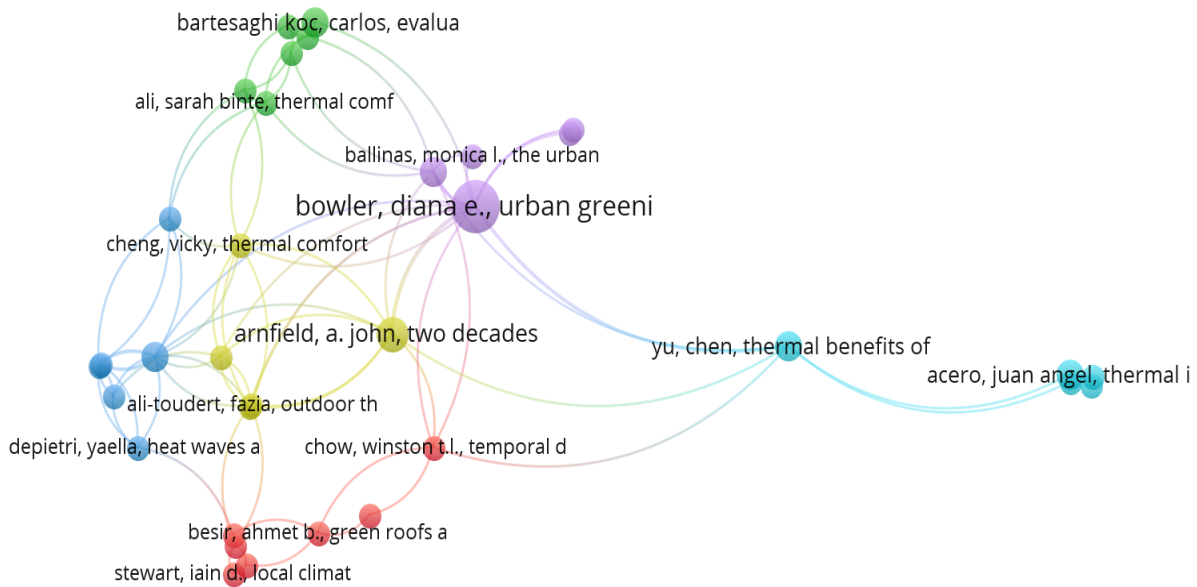


Figure 5. Co-citation network visualization. This figure illustrates the intellectual structure of the field based on co-cited references. Node size reflects the citation influence of each source, links represent the strength of co-citation relationships, and colors denote the major intellectual clusters that shape the foundational knowledge of literature.

Figure 5 displays the co-citation network to visualize the intellectual framework of research on the topic of urban green spaces and thermal comfort in hot-humid environments. Although a great number of references have been found throughout the dataset, a narrow group of highly co-cited works that represent a coherent component revealed a common underlying theoretical basis and influential work in the domain.

- Cluster 1 (green): Focuses on studies of ecosystem services and the role of vegetation in heat mitigation.
- Cluster 2 (purple): Represents foundational research on the cooling effects of urban green spaces, especially Bowler’s work.
- Cluster 3 (yellow): Contains theoretical contributions on urban climatology and microclimate processes, such as Arnfield’s studies.
- Cluster 4 (blue): Centres on outdoor thermal comfort and human thermal responses.
- Cluster 5 (cyan): Reflects simulation-based research using ENVI-met to evaluate the thermal benefits of vegetation.
- Cluster 6 (red): Includes studies on green roofs, local climate zones, and surface heat dynamics.

In general, the co-citation clusters on the map depict a highly organized intellectual base between urban climatology, microclimate modeling, thermal comfort evaluation, and ecosystem-service-based design strategies.

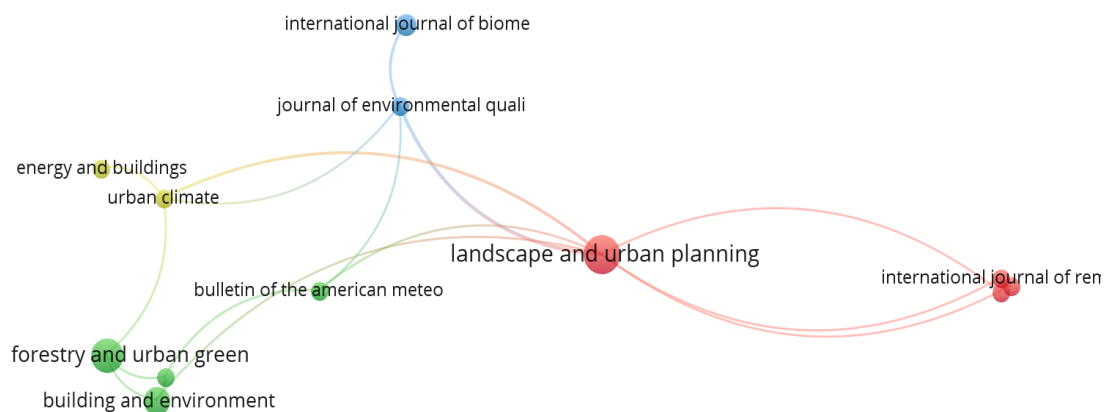


Figure 6. Cited-source network visualization. This figure presents the intellectual structure of the field based on the most frequently co-cited journals. Node size indicates the relative influence of each source, the connecting links represent the strength of co-citation relationships, and the color-coded clusters highlight the major groups of journals that collectively form the core knowledge base in research on urban green spaces and urban climate studies.

The co-citation network shown in Figure 6 illustrates the intellectual structure of the field based on the most frequently co-cited journals. Node size represents the in-fluence of each source, links indicate the strength of co-citation relationships, and colors distinguish the main intellectual clusters that underpin research on urban green spaces and urban climate studies.

- Cluster 1 (red): Focused on Landscape and Urban Planning and the Inter-national Journal of Renewable Energy, which represents those journals that add to background contributions in the fields of planning, design strategies, and environ-mental sustainability.
- Cluster 2 (green): Building and Environment, Forestry and Urban Green, and Energy and Buildings cluster, which captures applied environmental research aimed at building performance, the effect of vegetation, and heat mitigation.
- Cluster 3 (blue): This cluster contains sources like the International Journal of Biometeorology and the Journal of Environmental Quality, which are focused on journals covering the topic of biometeorology and environmental quality measurements.
- Cluster 4 (yellow): Includes journals like Urban Climate and Bulletin of the American Meteorological Society, which are based on the climate-science background of the field, in particular, the studies of urban atmosphere and microclimate processes.

The clusters broadly represent the essential intellectual underpinnings, in general, of the relationship between urban planning, climate science, environmental engineering, and urban green infrastructure.

Combining the two co-citation networks through the references to which the authors cited and sources cited, one can get a clear view of the intellectual underpinnings of the research on urban green spaces and urban climate in a hot-humid climate. The network mentioned above mentions the major theoretical input, the methodological progress, and the landmark studies on which modern-day research on the topic of thermal comfort, the modeling of microclimate, and the periphery of urban design re-lies. In the meantime, the cited-source network displays the central journals that, on a regular basis, support this scholarship to create discrete units of publications that re-late to urban planning, environmental engineering, biometeorology, and urban climate science. Collectively, this set of networks demonstrates a base of knowledge that is organized and networked, and how the base, influential research, and leading journals shape how this research field develops and evolves.

Country Publications, Affiliations, and Collaboration Map

This part will give an evaluation of the publications across countries to analyse the distribution of the research outputs, institutional involvement, and trends in global partnership in research regarding urban green spaces, thermal comfort, and hot-humid climatic conditions. The discussion demonstrates the geographical terrain of scientific works as well as cross-national networks that determine the formation of knowledge in this sphere. It is also required to map the country-level to understand which regions are doing well in the field of research on microclimate mitigation, green infrastructure, and climate-responsive urban planning, and how international collaboration can help to further research on heat-resilience [41,42]. Tables 4 and 5 show the Top 10 contributing countries in terms of published volume and citation impact, respectively, and provide information about the productivity as well as scholarly impact of the field.

Table 4. Top 10 countries based on the number of articles.

Country	Number of Articles
Singapore	13
Brazil	12
China	11
United States	11
Australia	9
India	8
Hong Kong	6
Sri lanka	6
Malaysia	6
United Kingdom	5

Table 5. Top 10 countries based on the number of citations.

Country	Total Citations
Japan	775
Singapore	492

China	372
Hong Kong	351
United States	284
India	201
Australia	165
United Kingdom	162
Brazil	107
Germany	73

The visualization of the country co-authorship network reflects the patterns of the global collaboration in the research of urban green spaces, thermal comfort, and the study of the hot-humid climate, as shown in Figure 7. The size of the node corresponds to the productivity of research in each country, and the relationships between the countries are the intensity of co-authorships. The color-coded clusters identify major regional collaboration groups contributing to the development of knowledge within the field. The visualization reveals three prominent clusters.

- Cluster 1 (Red): centered around China, Brazil, Sri Lanka, and Australia, indicating strong South–South and Asia–Pacific research partnerships, particularly in microclimate modeling and thermal comfort studies.
- Cluster 2 (Green): under the leadership of Malaysia, the United Kingdom, Tai-wan, and Thailand, a network on the ecosystem services, green infrastructure, and climate-adaptive urban design is established.
- Cluster 3 (Blue): consisting of Indonesia and Hong Kong, as evidence of new partnerships in reducing heat risk and urban atmospheric research.

Singapore and the United States are identified as hubs of bridging between clusters across regional networks and as points of cross-disciplinary research flows. On the whole, the map shows that the global research on the topic of UGS and urban development in hot and humid areas is diverse but interconnected, with Asian and tropical states taking the lead in the domain of scholarship development.

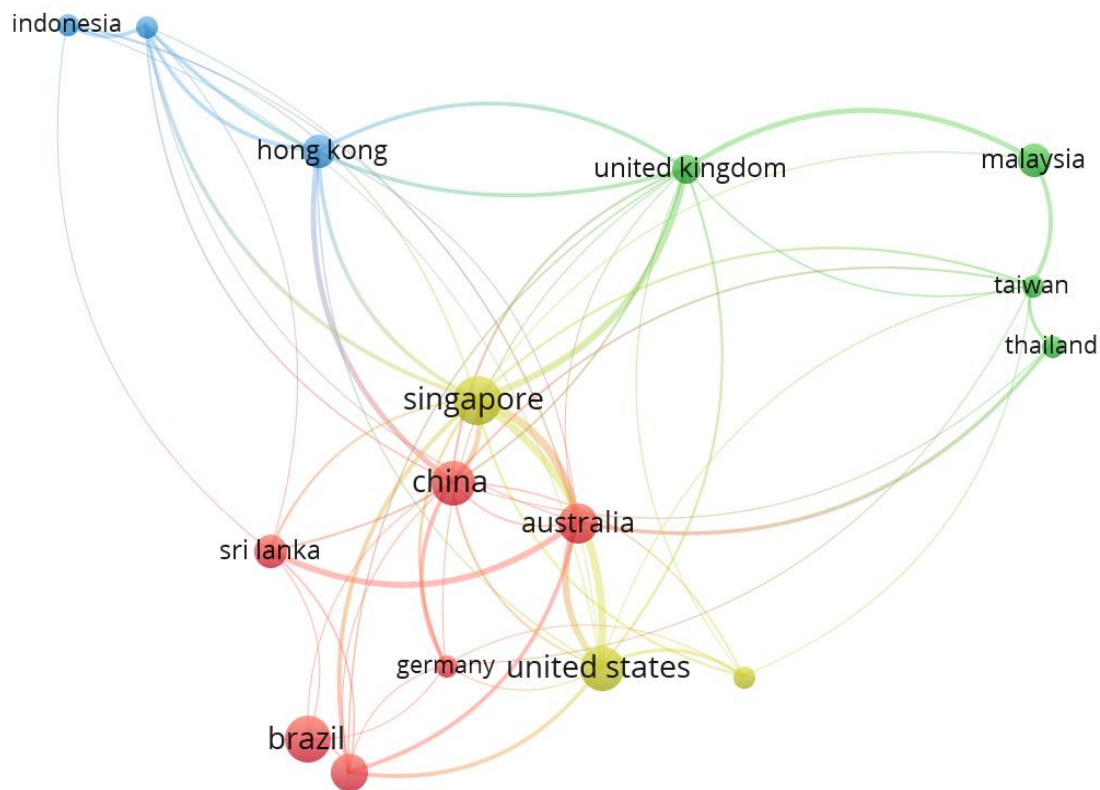


Figure 7. Country Co-authorship Network Analysis. This figure illustrates international collaboration patterns among countries contributing to research on urban green spaces and hot–humid climate studies. Node size reflects each country’s research output, links indicate the strength of co-authorship connections, and the color-coded clusters represent the major regional collaboration groups shaping knowledge production in the field.

The visualization of document citation overlay shows the distribution of publications that have had the most influence over time in the dataset, as shown in Figure 8. The size of a node depicts the citation impact of every

document, and using the color palette, which is dark blue (old documents) to bright yellow (new documents), one can see the mean year of publication. The map also indicates a few key foundational works, such as Tran (2006) and Chow (2016), which seem large and dark, signifying their substantial role in shaping the research whose scope covers the urban green spaces, thermal comfort, and the research of hot-humid climate. Newer publications (2022-2025) are displayed in lighter green and yellow tones, which means that the new research directions that focus on climate adaptation, microclimate modeling, and green infra-structure performance have emerged.

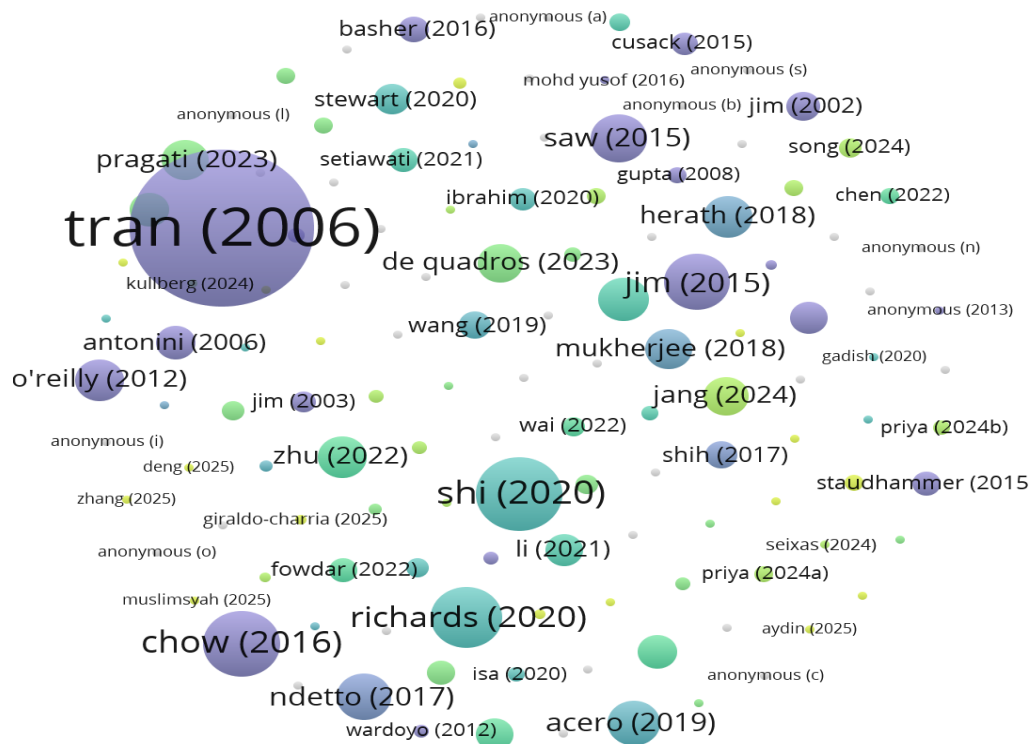


Figure 8. Document Citation Overlay Visualization. This figure visualizes the most influential documents in the dataset, where node size reflects citation impact and colors indicate publication year [43,44,45,46,47]. Larger, darker nodes represent older, highly cited foundational studies, while lighter yellow nodes highlight recent emerging research trends in urban climate and green infrastructure.

Thematic Evolution (2000–2025)

The emergence of the thematic evolution of literature on green spaces in urban areas (UGS) in hot-humid regions is evidenced by the apparent change in the first climate-related questions to those related to ecology and planning. In the early 2000s, descriptive research on urban climate processes, in particular, urban heat island (UHI) effect, urban microclimate regulation, and thermal contribution of vegetation dominated the research landscape [48,49]. The literature at this phase was mostly theoretical, with the aim of determining the fundamental physical knowledge of heat exchange, shading, and evapotranspiration in dense urban fabrics.

The period between 2010 and 2015 saw the field undergo a methodological shift, which was characterized by the use of simulation tools and systematic evidence re-views. One of the most powerful syntheses showing the temperature-reducing advantage of urban greening was Bowler et al. (2010), and the fast uptake of ENVI-met modeling was able to assess the vegetation structure, canyon geometry, and surface materials in a detailed way on a scenario-based analysis [50]. There is a thematic convergence to measure thermal comfort quantitatively and to correlate the results of microclimate with design practice during this period.

Between 2015 and 2020, the thematic framework was significantly expanded and incorporated the ideas of ecosystem services, urban resilience, and socio-ecological planning [41,51]. The idea of multifunctionality of UGS was getting actively studied, and such advantages as heat-risk reduction, health-enhancing, and stormwater regulation were brought out, and the geographical and climatic range was expanded to cities in the tropical and hot-humid areas.

These thematic shifts are clearly reflected in the VOSviewer keyword co-occurrence analysis, as visualized in Figures 3 and 4, which demonstrate how literature transitions from climate description toward resilience-oriented planning. The All-Keywords network reveals four major thematic clusters: (1) Green infrastructure and urban planning (red cluster) are the main concerns for improving microclimate and thermal comfort. (2) Tropical and hot-humid climate contexts (yellow cluster), with Singapore emerging as a key reference model. (3) Ecosystem services

and ecological performance (green cluster), linking vegetation structure to human well-being. (4) Urban heat island and climatic processes (blue cluster), indicating sustained attention to heat mitigation science. Similarly, the Author Keywords network condenses these themes into three principal clusters: (1) Modeling and evaluating microclimate performance through green infrastructure and ENVI-met. (2) Thermal comfort and UHI interactions. (3) Ecosystem-based approaches to climate adaptation. These clusters collectively illustrate how research priorities have evolved from climate description to climate-responsive design.

Thematic evolution in the latest stage (2020-2025) is characterized by high alignment with the global and regional climate agendas, especially Saudi Vision 2030 and SDGs 11, 13 and 15 that focus on livability, resilience and ecosystem restoration. The recent research employs the use of high-resolution modeling, multi-scenario modeling and interdisciplinary frameworks that integrate climate science, planning, public health and environmental engineering [52,53]. This period appears to reflect a more diversified research landscape, as inferred from cluster expansion in Figures 3–4 and temporal overlay distribution in Figure 9, rather than confirming complete maturity empirically.

On the whole, the thematic development of 2000-2025 supported by the framework identified in the clusters in the VOSviewer demonstrates the rise of a multi-dimensional research area that puts the green spaces in urban areas at the centre of resiliency, comfort, and ecological prosperity of hot-humid urban areas.

Overlay Analysis

The visualization created with VOSviewer (v1.6.20) represents the time-related development of the two research topics in urban green spaces (UGS) and hot-humid climate research between 2000 and 2025. The color gradient, from dark blue (old years of average publication) to bright yellow (newer years of average publication), gives a clear picture of how research priorities changed over the years within the field, as shown in Figure 9.

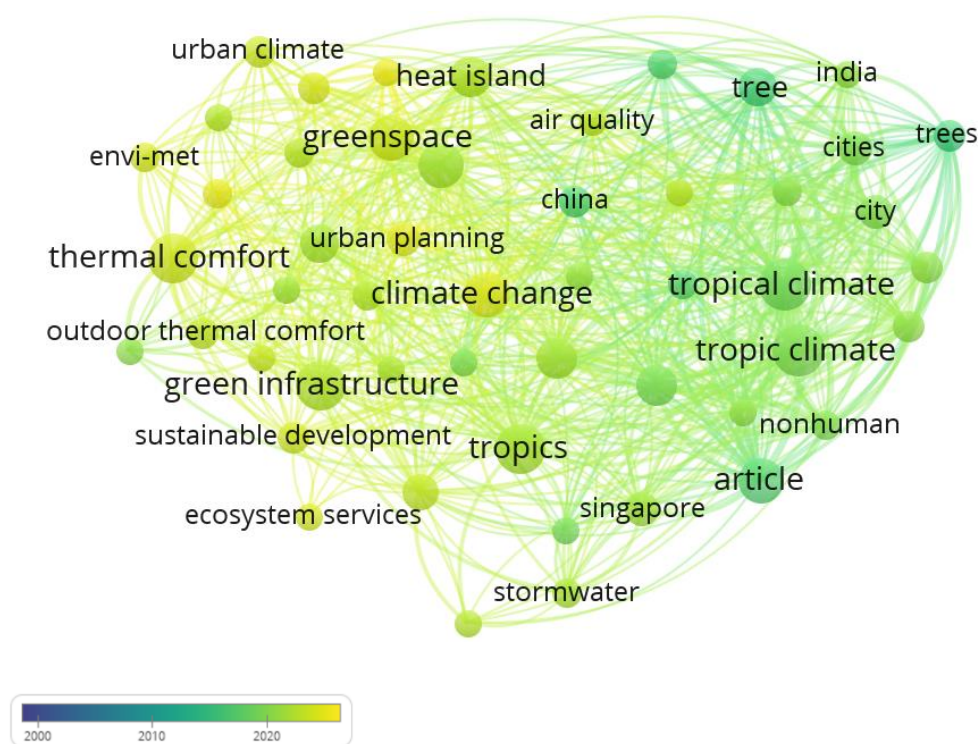


Figure 9. Keyword overlay visualization. Figure illustrates the time development of the research topics, where the color of the node represents the average publication date: blue topics are older, and the yellow topics are new, with the shift to the research topics of green infrastructure, climate change, and thermal comfort.

The older keywords, in blue and green outline, with the words tree, tropical climate, cities, city, air quality, and nonhuman at the beginning of the literature (2000-2010) show that the early literature was more concerned with the ecological background and the characterization of urban climate. These themes are indicative of the early attempts to come to terms with vegetation atmosphere interactions, climatic conditions of the region in question, and the environmental issues of the thick tropical cities.

In the medium period (2010-2018), the focus of research shifted to more practice-oriented and planning-oriented topics. The use of words in greenish colors, like green infrastructure, thermal comfort, ecosystem services, stormwater, and urban planning, suggests a change in methods that have been achieved through simulation tools,

such as ENVI-met, and increased interest in the measurement of cooling benefits and performance of UGS at the neighborhood scale. It is a period where the field shifted its focus from descriptive analysis of the environment to the development of evidence-based strategies of planning and design.

Publications of more recent date (2018-2025), with yellow nodes, point to the development of issues with sustainability at their core. Such keywords as climate change, heat island, sustainable development, greenspace, and urban climate depict the escalating overlap of UGS studies with the international climate-adaptation programs, with heat-reduction priorities. Their central position and vivid colors on the map prove their status as the prevailing themes in the latest wave of research on thermal resistance and habitability in urban areas of hot-humid climates.

Overall, the overlay analysis can be used to show that there have been three-step thematic development (1) ecological and climatic foundations (2000-2010), (2) applied microclimate and green infrastructure research (2010-2018), and (3) climate-oriented, resilience-centered approaches (2018-2025). This progression indicates the way in which UGS has developed to be a multidisciplinary project that brings together climate science, urban planning, and sustainability transitions.

DISCUSSION

According to the bibliometric findings of this paper, one can observe the intellectual development of the studies about the urban green space (UGS) in hot-humid lands. The 94 studies' data covering 2000-2025 give a vivid illustration of how the field has been evolving over time. The findings reveal a noticeable increase in UGS-related publications after 2015. This trend may be associated with the rise of sustainability discourse and climate adaptation priorities in academic work, although the biblio-metric data itself indicates correlation rather than proving direct causal influence [41,54]. The collaboration index is high, with an average of 3.9 authors per publication, showing that there is a growing interdisciplinary research network in the study, but there is less collaboration in the Gulf cities in comparison to the Southeast Asian settings.

The thematic progression of the dataset identified implies that at the beginning of the 2000s, with the definition of the urban heat island (UHI) effect and the mechanisms of microclimate as one of its aspects [48,55], more sophisticated methodological solutions between 2010 and 2015 are possible. This entails the mass implementation of the ENVI-met simulation models to establish the structure of vegetation, shading structures, and the geometry of canyons in urban settings. The cooling benefits of UGS were provided on the basis of quantitative evidence in such influential works as Bowler et al. (2010), which is critical towards the switch to scenario-based modeling and thermally responsive design strategies [56].

Bibliometric patterns suggest a noticeable increase in literature referencing eco-system services, resilience, public health, and socio-ecological planning between 2015–2025, although this reflects thematic presence rather than measured expansion in practical application. As shown in Figure 3, networks of co-occurring keywords revealed the analysis of the keywords and generated four central clusters, such as the green infrastructure and planning, tropical and hot-humid contexts, ecosystem services, and the urban heat island dynamics. As demonstrated in Figure 4, these thematic clusters illustrate how authors conceptually approach UGS as multi-dimensional urban systems, not only as cooling tools. This representation is literature-driven, and further empirical work is required to verify how these conceptual models perform in real climatic settings. Recent literature often associates or discusses UGS as potentially contributing to thermal moderation, well-being benefits, and stormwater management. However, such outcomes remain largely inferred rather than empirically validated, especially in hot–humid environments [53,57].

As indicated in Figure 9, The visualizations of overlays indicate that the keywords tree, tropical climate, and air quality were connected with more basic ecological and climatological studies, and the newer terms, thermal comfort, climate adaptation, and green infrastructure, were more related to a more developed stage of research. This shift appears to align conceptually with climate-related agendas such as SDG 11 and SDG 13, but the bibliometric evidence reflects alignment in research themes rather than proving implementation or policy outcome realization.

Though these are positive developments, the results demonstrate that there are a number of gaps, including the lack of consideration of social aspects and environmental justice. Limited literature investigated equity in green space access, community involvement, and the health outcomes of UGS, which has received a broad consensus as a critical topic in the worldwide planning field of study [3,58]. The area of governance is also underrepresented, particularly in connection to long-term models of maintenance, the financing modes, and even the partnerships between the public and the private environment that are of paramount importance to the continued existence of the UGS in adverse climatic conditions.

As shown in Figure 7, geographical concentration is evident, with Singapore and Hong Kong dominating publications while Gulf-region cities remain comparatively underrepresented, as the cities of Singapore and Hong Kong dominate the dataset. Conversely, hot, humid cities in Southwest Asia and the Gulf are still underrepresented. The imbalance restricts the literature from making context-specific planning recommendations. In addition to this,

another significant gap that exists is the absence of longitudinal empirical studies and research that can be used to determine the actual performance of UGS in extreme heat and humidity, because the majority of the current research is based on simulation as opposed to long-term field tests.

Such findings reveal the importance of a more holistic future research agenda that combines ecological, social, and governance-related characteristics, such as long-term field observations, and a more geographical coverage of the Gulf cities, which experience extreme thermal conditions. Based on these outcomes, the mapped patterns offer a platform for expanding bibliometric inquiry and exploring emerging collaboration pathways in the field. Additionally, observed cluster linkages imply potential interdisciplinary growth, although this reflects publication structure rather than proven developmental change. The priorities are to reinforce regional cooperation, employ more sophisticated modeling, and associate the simulation findings with the real planning policies. The incorporation of ecosystem services, equity, and governance perspectives will be necessary to create resilient and climate-adaptive urban environments in hot-humid regions.

LIMITATIONS AS CONSTRAINTS AND AS DIRECTIONS FOR FUTURE RESEARCH

Although this bibliometric study of research on the knowledge structure of urban green space in hot-humid regions has scientific advantages, it should be noted that several limitations exist. To start with, the sample relied solely on Scopus and Web of Science indexing, which may introduce database bias, as these platforms prioritize high-impact English-language journals. This means relevant research outside these repositories, particularly regional work or non-indexed planning output, may not be captured in the dataset. This resulted in the omission of Arabic-language sources and local planning studies that could contribute valuable regional insight. This linguistic filter creates a coverage bias and may underrepresent Gulf-based UGS knowledge and indigenous ecological practice.

The study also excluded government reports, municipal planning documents, and grey literature, despite their potential to contain valuable empirical evidence on UGS governance, climate-adaptation implementation, and on-ground performance in hot-humid cities. This omission particularly limits contextual understanding in regions where knowledge is produced institutionally rather than academically. This exclusion is a recognized constraint, particularly because planning knowledge in Gulf cities, tropical Asian regions, and parts of Africa is often produced in the form of municipal studies or national strategic reports rather than journal articles. As such, omitting these sources may limit the understanding of on-the-ground governance mechanisms and long-term maintenance strategies crucial to UGS performance.

An additional methodological constraint lies in keyword-based retrieval, which can produce false positives or overlook relevant publications if terminology varies across regions. This affects dataset completeness and precision. Besides source-based limitations, the bibliometric methodology comes with its own limitations. While bibliometric tools capture structural patterns such as keyword clustering and co-citation mapping, they cannot evaluate empirical validity, policy impact, or real-world implementation effectiveness. Accordingly, results represent knowledge circulation rather than performance evidence. What is more, the results are based on published academic data rather than on the real experience of planning and climate-adaptation measures implemented in real cities. Thus, the findings are expected as a structural mapping exercise, not a qualitative evaluation of the research area.

In view of these constraints, the research proposes several future research directions. It would be helpful to increase the contextual diversity of the knowledge base by including the Arabic-language publications, local planning documents, and regional studies. Empirical validation through field measurements, socio-spatial surveys, or mixed-methods strategies should also be included in future research to enrich the structural information produced by bibliometric mapping. These would help fill perceived gaps in the social and governance aspects and provide a broader picture of how UGS operate in hot-humid cities. All these improvements will contribute to more inclusive, climate-sensitive, and policy-relevant research agendas.

CONCLUSION AND RECOMMENDATIONS

The research questions this study seeks to answer are four in number:

1. What are the main research themes and topics in UGS studies focusing on hot-humid cities, and how have these themes evolved between 2000 and 2025?
2. How do these studies characterize the ecological, social, and governance dimensions of urban green spaces in hot-humid climates?
3. What are the patterns of research output and collaboration across countries, institutions, and authors, and do they reveal geographic or knowledge imbalances?
4. Where do gaps remain in the literature, and what opportunities exist for future research to support sustainability and resilience in hot-humid urban environments?

The bibliometric analysis of the 94 selected publications is an illustrative portrayal of the way knowledge in the field has progressed. The findings suggest that earlier re-research on the topic has been found on the concept of climatic and biophysical underpinnings: microclimate processes and urban heat island effect but has since progressed to broader conceptualizations of green infrastructure, ecosystem services, thermal comfort, and planning resilience. The keyword co-occurrence networks show that there is a presence of four overall clusters, such as green infrastructure and planning, hot-humid climatic contexts, ecosystem services, and UHI processes. These patterns reflect how literature conceptually frames UGS as multi-functional systems, but such roles remain theoretically described rather than empirically validated in practice.

The results also indicate that the ecological dimension appears well represented in literature, particularly through simulation-based studies using ENVI-met, although this reflects research volume rather than confirming full empirical maturity. Social-related themes, including equity, behavior, and participation, appear less emphasized in the reviewed literature, suggesting an area where further empirical investigation is needed. Governance-related research appears limited within the reviewed corpus, even though the literature discusses its importance for long-term UGS management in hot-humid cities.

Speaking of the results of the research and cooperation, the data shows that Asian cities are much ahead, and Singapore and Hong Kong are the top ones. Conversely, the Gulf cities are also grossly underrepresented, as the climatic conditions are quite harsh. The collaboration index reveals that the network is active and not evenly distributed over geographical areas, which presupposes inefficiencies in the generation of knowledge and regional participation.

Collaboration patterns indicate that Asian cities, particularly Singapore and Hong Kong, dominate research output, while Gulf-region cities remain underrepresented. Research collaboration should be strengthened between Gulf cities and other tropical regions with similar climatic conditions. The practical application of simulation tools needs to be broadened and closely connected to actual policy and planning procedures. Empirical tests of the performance of UGS would be required on a long-term basis to ascertain the actual performance of UGS in extreme conditions of heat and humidity. More social inquiry into behavioral trends, environmental justice, and benefits to people should also be included in future research. Additionally, innovative governance and financing frameworks are required to ensure the sustainability and maintenance of green infrastructure in hot-humid cities.

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REFERENCES

- Breuste, J.; Schnellinger, J.; Qureshi, S.; Faggi, A. Urban Ecosystem Services on the Local Level: Urban Green Spaces as Providers. *Ekologia* 2013, 32, doi:10.2478/eko-2013-0026.
- Campbell, S. Green Cities, Growing Cities, Just Cities?: Urban Planning and the Contradictions of Sustainable Development. In *Readings in Planning Theory*; Fainstein, S.S., DeFilippis, J., Eds.; John Wiley & Sons, Ltd: Chichester, UK, 2015; pp. 214–240 ISBN 978-1-119-08467-9.
- Jennings, V.; Gaither, C. Approaching Environmental Health Disparities and Green Spaces: An Eco-system Services Perspective. *Int. J. Environ. Res. Public Health* 2015, 12, 1952–1968, doi:10.3390/ijerph120201952.
- Wolch, J.R.; Byrne, J.; Newell, J.P. Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'Just Green Enough.' *Landsc. Urban Plan.* 2014, 125, 234–244, doi:10.1016/j.landurbplan.2014.01.017.
- Zhao, X.; Li, F.; Yan, Y.; Zhang, Q. Biodiversity in Urban Green Space: A Bibliometric Review on the Current Research Field and Its Prospects. *Int. J. Environ. Res. Public Health* 2022, 19, 12544, doi:10.3390/ijerph191912544.
- Adger, W.; Arnell, N.W.; Tompkins, E.L. Successful Adaptation to Climate Change across Scales. *Glob. Environ. Change* 2005, 15, 77–86, doi:10.1016/j.gloenvcha.2004.12.005.
- Meerow, S.; Newell, J.P.; Stults, M. Defining Urban Resilience: A Review. *Landsc. Urban Plan.* 2016, 147, 38–49, doi:10.1016/j.landurbplan.2015.11.011.
- Folke, C. Resilience: The Emergence of a Perspective for Social–Ecological Systems Analyses. *Glob. Environ. Change* 2006, 16, 253–267, doi:10.1016/j.gloenvcha.2006.04.002.

- Farkas, J.Z.; Hoyk, E.; De Morais, M.B.; Csomós, G. A Systematic Review of Urban Green Space Re-search over the Last 30 Years: A Bibliometric Analysis. *Heliyon* 2023, 9, e13406, doi:10.1016/j.heliyon.2023.e13406.
- Muhoza, J.P.; Zhou, W. Urban Green Spaces in Africa: A Bibliometric Analysis. *Environments* 2024, 11, 68, doi:10.3390/environments11040068.
- Bonebrake, T.C.; Tsang, T.P.N.; Yu, N.; Wang, Y.; Ledger, M.J.; Tilley, H.B.; Yau, E.Y.H.; Andersson, A.A.; Boyle, M.J.W.; Lee, K.W.K.; et al. Tropical Cities as Windows into the Ecosystems of Our Present and Future. *Biotropica* 2025, 57, e13369, doi:10.1111/btp.13369.
- Kremer, P.; Haase, A.; Haase, D. The Future of Urban Sustainability: Smart, Efficient, Green or Just? Introduction to the Special Issue. *Sustain. Cities Soc.* 2019, 51, 101761, doi:10.1016/j.scs.2019.101761.
- Menconi, M.; Abbate, R.; Simone, L.; Grohmann, D. Urban Green System Planning Insights for a Spa-tialized Balance between PM10 Dust Retention Capacity of Trees and Urban Vehicular PM10 Emissions. *Sustainability* 2023, 15, 5888, doi:10.3390/su15075888.
- Meerow, S.; Newell, J.P. Urban Resilience for Whom, What, When, Where, and Why? *Urban Geogr.* 2019, 40, 309–329, doi:10.1080/02723638.2016.1206395.
- Shumi, G.; Schultner, J.; Fischer, J.; Abson, D.J.; Senbeta, F.; Riechers, M.; Wahler, H. Resilience Principles and a Leverage Points Perspective for Sustainable Woody Vegetation Management in a So-cial-Ecological System of Southwestern Ethiopia - Ecology & Society Available online: <https://ecologyandsociety.org/vol28/iss2/art34/> (accessed on 29 October 2025).
- Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to Conduct a Bibliometric Analysis: An Overview and Guidelines. *J. Bus. Res.* 2021, 133, 285–296, doi:10.1016/j.jbusres.2021.04.070.
- Alhawaish, Abdulkarim.K. The Blue Economy in the Arabian Gulf: Trends, Gaps, and Pathways for Sustainable Coastal Development. *Sustainability* 2025, 17, 8809, doi:10.3390/su17198809.
- Zhang, S.; Li, X.; Chen, Z.; Ouyang, Y. A Bibliometric Analysis of the Study of Urban Green Spaces and Health Behaviors. *Front. Public Health* 2022, 10, 1005647, doi:10.3389/fpubh.2022.1005647.
- Alhawaish, Abdulkarim.K. The Blue Economy in the Arabian Gulf: Trends, Gaps, and Pathways for Sustainable Coastal Development. *Sustainability* 2025, 17, 8809, doi:10.3390/su17198809.
- Khanra, S.; Dhir, A.; Mäntymäki, M. Big Data Analytics and Enterprises: A Bibliometric Synthesis of the Literature. *Enterp. Inf. Syst.* 2020, 14, 737–768, doi:10.1080/17517575.2020.1734241.
- Secinaro, S.; Calandra, D.; Petricean, D.; Chmet, F. Social Finance and Banking Research as a Driver for Sustainable Development: A Bibliometric Analysis. *Sustainability* 2020, 13, 330, doi:10.3390/su13010330.
- Passas, I. Bibliometric Analysis: The Main Steps. *Encyclopedia* 2024, 4, 1014–1025, doi:10.3390/encyclopedia4020065.
- Zupic, I.; Čater, T. Bibliometric Methods in Management and Organization. *Organ. Res. Methods* 2015, 18, 429–472, doi:10.1177/1094428114562629.
- Aria, M.; Cuccurullo, C. Bibliometrix : An R-Tool for Comprehensive Science Mapping Analysis. *J. In-formetr.* 2017, 11, 959–975, doi:10.1016/j.joi.2017.08.007.
- Small, H. Co-citation in the Scientific Literature: A New Measure of the Relationship between Two Documents. *J. Am. Soc. Inf. Sci.* 1973, 24, 265–269, doi:10.1002/asi.4630240406.
- Hirsch, J.E. An Index to Quantify an Individual's Scientific Research Output. *Proc. Natl. Acad. Sci.* 2005, 102, 16569–16572, doi:10.1073/pnas.0507655102.
- Van Eck, N.J.; Waltman, L. Software Survey: VOSviewer, a Computer Program for Bibliometric Map-ping. *Scientometrics* 2010, 84, 523–538, doi:10.1007/s11192-009-0146-3.
- Jayasooriya, V.M.; Liyanage, C.T.; Muthukumar, S.; Nilusha, R.T. Impact of Green Wall Orientation on Building Energy Performance in a Tropical Climate: An Experimental Assessment. *PLOS Sustain. Transform.* 2025, 4, e0000156, doi:10.1371/journal.pstr.0000156.
- Jim, C.Y. Assessing Climate-Adaptation Effect of Extensive Tropical Green Roofs in Cities. *Landsc. Urban Plan.* 2015, 138, 54–70, doi:10.1016/j.landurbplan.2015.02.014.
- Priya, U.K.; Senthil, R. Enhancing Sustainable Thermal Comfort of Tropical Urban Buildings with In-door Plants. *Buildings* 2024, 14, 2353, doi:10.3390/buildings14082353.
- Pereira, M.C.S.; Martins, J.R.S.; Gonzaga, S.C.M.; Pellegrino, P.R.M. Bioretention System: Concep-tion, Implementation, and Instrumentation of Three Different Models in São Paulo, Brazil. In *Sustainable and Digital Building*; Gaspar, F., Mateus, A., Eds.; Springer International Publishing: Cham, 2023; pp. 195–205 ISBN 978-3-031-25794-0.
- Castañer, C.M.; Mesquita Pellegrino, P.R. Sustainable Urban Drainage Designing Approach for São Paulo and Humid Sub-Tropical Climates. In *Green Technologies and Infrastructure to Enhance Urban Ecosystem Services*; Vasenev, V., Dovletyarova, E., Cheng, Z., Valentini, R., Calfapietra, C., Eds.; Springer Geography; Springer International Publishing: Cham, 2020; pp. 151–162 ISBN 978-3-030-16090-6.

- Eltarabily, S.; Gamal, A.; Abo Eleinen, O.; Elgheznawy, D. Numerical Analysis of Outdoor Thermal Comfort of Block-Scale Vertical Greening Systems in a Hot Humid Climate. *Archit. Sci. Rev.* 2025, 1–28, doi:10.1080/00038628.2025.2493814.
- Muthukumar, S.; Jayasooriya, V.M.; Liyanage, C.T.; Nilusha, R.T. Impact of Green Wall Orientation on Building Energy Performance in a Tropical Climate: An Experimental Assessment. *PLOS Sustain. Transform.* 2025, 4, e0000156, doi:10.1371/journal.pstr.0000156.
- Li, X.-X.; Liu, X. Effect of Tree Evapotranspiration and Hydrological Processes on Urban Microclimate in a Tropical City: A WRF/SLUCM Study. *Urban Clim.* 2021, 40, 101009, doi:10.1016/j.uclim.2021.101009.
- Gamal, A.; Abo Eleinen, O.; Elgheznawy, D.; Eltarabily, S. Numerical Analysis of Outdoor Thermal Comfort of Block-Scale Vertical Greening Systems in a Hot Humid Climate. *Archit. Sci. Rev.* 2025, 1–28, doi:10.1080/00038628.2025.2493814.
- Zeeshan, M.; Ali, Z.; Ranjha, Q.A. Green Infrastructure with Actual Canopy Parameterization: A Simulation Study for Heat Stress Mitigation in a Hot-Humid Urban Environment. *Arboric. Urban For.* 2023, 49, 247–267, doi:10.48044/jauf.2023.016.
- Callon, M.; Courtial, J.-P.; Turner, W.A.; Bauin, S. From Translations to Problematic Networks: An Introduction to Co-Word Analysis. *Soc. Sci. Inf.* 1983, 22, 191–235, doi:10.1177/053901883022002003.
- Cobo, M.J.; López-Herrera, A.G.; Herrera-Viedma, E.; Herrera, F. Science Mapping Software Tools: Review, Analysis, and Cooperative Study among Tools. *J. Am. Soc. Inf. Sci. Technol.* 2011, 62, 1382–1402, doi:10.1002/asi.21525.
- Mongeon, P.; Paul-Hus, A. The Journal Coverage of Web of Science and Scopus: A Comparative Analysis. *Scientometrics* 2016, 106, 213–228, doi:10.1007/s11192-015-1765-5.
- Small, H. Co-citation in the Scientific Literature: A New Measure of the Relationship between Two Documents. *J. Am. Soc. Inf. Sci.* 1973, 24, 265–269, doi:10.1002/asi.4630240406.
- Haase, D.; Larondelle, N.; Andersson, E.; Artmann, M.; Borgström, S.; Breuste, J.; Gomez-Baggethun, E.; Gren, Å.; Hamstead, Z.; Hansen, R.; et al. A Quantitative Review of Urban Ecosystem Service Assessments: Concepts, Models, and Implementation. *AMBIO* 2014, 43, 413–433, doi:10.1007/s13280-014-0504-0.
- Van Eck, N.J.; Waltman, L. Visualizing Bibliometric Networks. In *Measuring Scholarly Impact*; Ding, Y., Rousseau, R., Wolfram, D., Eds.; Springer International Publishing: Cham, 2014; pp. 285–320 ISBN 978-3-319-10376-1.
- Tran, H.; Uchihama, D.; Ochi, S.; Yasuoka, Y. Assessment with Satellite Data of the Urban Heat Island Effects in Asian Mega Cities. *Int. J. Appl. Earth Obs. Geoinformation* 2006, 8, 34–48, doi:10.1016/j.jag.2005.05.003.
- Chow, W.T.L.; Akbar, S.N.; Assyakirin, B.A.; Heng, S.L.; Roth, M. Assessment of Measured and Perceived Microclimates within a Tropical Urban Forest. *Urban For. Urban Green.* 2016, 16, 62–75, doi:10.1016/j.ufug.2016.01.010.
- Shi, D.; Song, J.; Huang, J.; Zhuang, C.; Guo, R.; Gao, Y. Synergistic Cooling Effects (SCEs) of Urban Green-Blue Spaces on Local Thermal Environment: A Case Study in Chongqing, China. *Sustain. Cities Soc.* 2020, 55, 102065, doi:10.1016/j.scs.2020.102065.
- Jim, C.Y. Assessing Climate-Adaptation Effect of Extensive Tropical Green Roofs in Cities. *Landsc. Urban Plan.* 2015, 138, 54–70, doi:10.1016/j.landurbplan.2015.02.014.
- Richards, D.; Fung, T.; Belcher, R.; Edwards, P. Differential Air Temperature Cooling Performance of Urban Vegetation Types in the Tropics. *Urban For. Urban Green.* 2020, 50, 126651, doi:10.1016/j.ufug.2020.126651.
- Oke, T.R. *Boundary Layer Climates*; 2nd ed.; Routledge, 1987; ISBN 978-1-134-95134-5.
- Arnfield, A.J. Two Decades of Urban Climate Research: A Review of Turbulence, Exchanges of Energy and Water, and the Urban Heat Island. *Int. J. Climatol.* 2003, 23, 1–26, doi:10.1002/joc.859.
- Ali-Toudert, F.; Mayer, H. Effects of Asymmetry, Galleries, Overhanging Façades and Vegetation on Thermal Comfort in Urban Street Canyons. *Sol. Energy* 2007, 81, 742–754, doi:10.1016/j.solener.2006.10.007.
- Bowler, D.E.; Buyung-Ali, L.; Knight, T.M.; Pullin, A.S. Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence. *Landsc. Urban Plan.* 2010, 97, 147–155, doi:10.1016/j.landurbplan.2010.05.006.
- Bolund, P.; Hunhammar, S. Ecosystem Services in Urban Areas. *Ecol. Econ.* 1999, 29, 293–301, doi:10.1016/S0921-8009(99)00013-0.
- Emmanuel, R.; Krüger, E. Urban Heat Island and Its Impact on Climate Change Resilience in a Shrinking City: The Case of Glasgow, UK. *Build. Environ.* 2012, 53, 137–149, doi:10.1016/j.buildenv.2012.01.020.
- Carter, J.G.; Cavan, G.; Connelly, A.; Guy, S.; Handley, J.; Kazmierczak, A. Climate Change and the City: Building Capacity for Urban Adaptation. *Prog. Plan.* 2015, 95, 1–66, doi:10.1016/j.progress.2013.08.001.
- Bolund, P.; Hunhammar, S. Ecosystem Services in Urban Areas. *Ecol. Econ.* 1999, 29, 293–301, doi:10.1016/S0921-8009(99)00013-0.

- Arnfield, A.J. Two Decades of Urban Climate Research: A Review of Turbulence, Exchanges of Energy and Water, and the Urban Heat Island. *Int. J. Climatol.* 2003, 23, 1–26, doi:10.1002/joc.859.
- Bowler, D.E.; Buyung-Ali, L.; Knight, T.M.; Pullin, A.S. Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence. *Landsc. Urban Plan.* 2010, 97, 147–155, doi:10.1016/j.landurbplan.2010.05.006.
- Emmanuel, R.; Krüger, E. Urban Heat Island and Its Impact on Climate Change Resilience in a Shrinking City: The Case of Glasgow, UK. *Build. Environ.* 2012, 53, 137–149, doi:10.1016/j.buildenv.2012.01.020.
- Wolch, J.R.; Byrne, J.; Newell, J.P. Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'Just Green Enough.' *Landsc. Urban Plan.* 2014, 125, 234–244, doi:10.1016/j.landurbplan.2014.01.017.