Nimesha, J.S., Kulatunga, U. and Subhasingha, H.D., 2026. Microclimate-aware urban planning in tropical climates: A review. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Chandanie, H. and Tennakoon, G.A. (eds). *Proceedings of the 14th World Construction Symposium*, 10-11 July 2026, Sri Lanka. pp. 1180-1194. DOI: https://doi.org/10.31705/WCS.2026.86. Available from: https://ciobwcs.com/papers/

MICROCLIMATE-AWARE URBAN PLANNING IN TROPICAL CLIMATES: A LITERATURE REVIEW

J.S. Nimesha[1], U. Kulatunga[2] and H.D. Subhasingha[3]

ABSTRACT

Rapid urbanization has adversely affected urban microclimates, especially in tropical regions, where high temperatures, humidity, and seasonal monsoon patterns exacerbate environmental degradation. In tropical urban environments, replacing natural landscapes with man-made structures during urbanisation alters microclimatic parameters such as air temperature, relative humidity, and wind speed. These microclimatic changes cause negative impacts on urban areas, such as leading to thermal discomfort and increased energy demand. Despite these risks, economic interests often take precedence because in tropical climates, urban planning lacks the necessary regulatory frameworks and microclimatic awareness to prioritize sustainability by addressing the localised characteristics. Therefore, the present research aims to develop a comprehensive framework that promotes microclimate-aware urban planning in tropical climates. Initially, a background study was conducted to establish a clear research problem, aim, and objectives. This was followed by a comprehensive literature review to identify key relationships between microclimate, urban planning, and urban design strategies. To further refine these concepts, a bibliometric analysis was executed using VOSviewer software. Through the comprehensive literature review, this study identifies the linkage between urban design strategies, their key mitigation mechanisms, the negative impacts of urbanisation, and broader negative consequences for the overall tropical urban environment. By linking urban design strategies such as nature-based solutions, sustainable materials, and building morphology to specific environmental outcomes, the developed framework provides a clear pathway for utilising passive and bioclimatic urban design strategies to improve the quality of life in tropical cities. The developed framework serves as a foundational tool for initiating these essential planning interventions.

Keywords: *Microclimate; Tropical Climate; Urban Design Strategies; Urbanization.*

1. INTRODUCTION

In recent decades, urbanization has experienced significant growth, and as a result, rapid industrialization has taken place (Roy et al., 2025). According to the United Nations Department of Economic and Social Affairs, 2018, by 2050, it is anticipated that two-thirds of the world's population will live in urban regions (Czachura et al., 2022). This significant growth in urbanization has led to a variety of environmental problems (Roy et

[1] Undergraduate, Department of Building Economics, University of Moratuwa, Sri Lanka, snimesha501@gmail.com

[2] Professor, Department of Building Economics, University of Moratuwa, Sri Lanka, ukulatunga@uom.lk

[3] Temporary Instructor, Department of Building Economics, University of Moratuwa, Sri Lanka, subhasinghahd.20@uom.lk

al., 2025). Furthermore, the researcher states that, according to NASA/GISS, in 2023, the Earth's temperature increased by approximately 2.45°F compared to the 19th century. These climatic changes globally affect people's health and livelihoods, as well as ecosystem health and biodiversity (Zhu et al., 2023). With rapid urbanization, natural surroundings are replaced by man-made structures. Under a changing climate, the physical properties of these man-made structures directly affect the living environment of the urban microclimate (Yang et al., 2023).

According to Roy et al. (2025) microclimates are the localized climates within small areas that focus on atmospheric conditions near a specific point on Earth's surface, often related to living organisms such as insects or crops. These climates are influenced by factors such as building size and shape, surface albedo, vegetation, and water bodies (Ghiasi et al., 2024). Jia et al. (2024) and Gupta and Haque (2025) stated that an urban local microclimate is reflected by parameters such as local air temperature, relative humidity, wind speed, and direction, which directly affect the health, comfort, and energy consumption of city residents. Due to changes associated with urbanization, such as land use and energy consumption, urban areas can retain and generate more heat than rural regions, leading to higher ground surface and air temperatures near the ground, ultimately resulting in the urban heat island effect, urban pollution island, and urban moisture island (Jia et al., 2024; Yang et al., 2023). In addressing the impact of urbanization on the microclimate, different design strategies can be considered since the amount of energy needed to cool buildings can be reduced as these elements can improve natural cooling and effectively reduce heat loss and heating needs (Roy et al., 2025).

Due to consistent high temperatures with a two-season cycle of wet and dry periods, buildings in tropical regions consume disproportionately more energy to achieve indoor thermal comfort than those in temperate zones (Lee et al., 2021; Pragati et al., 2023). During urban planning, failing to account for these specific characteristics leads to significant microclimatic environmental failure. For instance, while dense urban clusters in four-season temperate climates are designed to trap heat and block cold winter winds as seen in frameworks by Taleghani et al. (2015) for the Netherlands or Jia et al. (2024) for continental zones, this same strategy in a tropical setting blocks the prevailing breezes essential for physiological cooling. Without strategic wind corridors, humidity becomes oppressive, and air pollutants settle at the street level, creating a detrimental stagnant heat effect (Giridharan & Emmanuel, 2018).

Despite these risks, a critical geographical bias exists in urban microclimate literature. While many studies focus on microclimates where seasonal variation dominates, there is a profound lack of evidence-based research specifically for the humid tropics (Roth, 2007). This lack of data has created a situation where current urban design guidelines are often based on temperate-climate evidence and forced to rely on general planning guidelines that are fundamentally incompatible with the high-humidity, high-solar-intensity nature of tropical climates, ultimately leading to unsustainable and thermally uncomfortable urban growth (Emmanuel, 2021; Wong et al., 2021).

Therefore, addressing how to mitigate the negative impacts of urbanisation in tropical climates through integrated urban design strategies is essential for managing microclimatic conditions within a tropical climate. To resolve this geographical mismatch, this study addresses a fundamental question: How can integrated urban design strategies mitigate the negative impacts of urbanization on microclimates within tropical regions? To address this gap, the present research aims to develop a comprehensive framework that promotes microclimate-aware urban planning in tropical climates. Four key objectives are developed to achieve the aim: to comprehensively review the key concepts related to urban planning and microclimate, to identify the impact of microclimate on the urban environment, to comprehensively review the influence of urban design strategies on microclimatic conditions in tropical climates, and to develop a comprehensive framework that promotes microclimate-aware urban planning in tropical climates. Hereinafter, the paper comprises a methodology, findings, conclusions, and recommendations.

2. RESEARCH METHODOLOGY

Research methodology is the science of studying how research is conducted systematically, and here the procedural steps that have been taken to study the research problem are explained (Mishra & Alok, 2017). To address the critical geographical bias in urban microclimate literature, specifically the lack of evidence-based guidelines for humid tropical climates, this study adopted a comprehensive literature review. This methodology establishes a transparent, rigorous process to answer the core research question: How can integrated urban design strategies mitigate the negative impacts of urbanization on microclimates within tropical regions? The overview of the most important findings in the field in which the study will be conducted is described in the first background study. To precisely define the research problem, aim, and objectives of the study, a background study was conducted. Afterwards, a comprehensive literature review was conducted, and the collected literature was analysed to address the identified literature gap. A literature review is a systematic method for collecting and synthesizing previously conducted research (Snyder, 2019). The review progressed through a four-stage process, as illustrated in Figure 1.

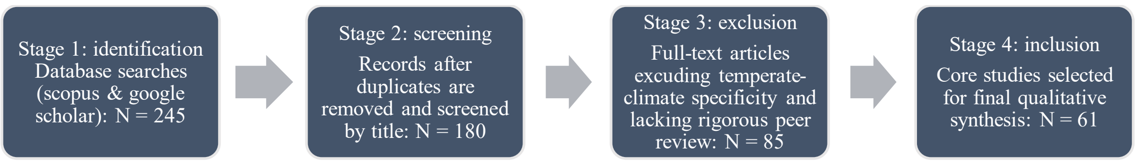


Figure 1: Review process

To ensure a comprehensive and reliable academic foundation, literature was systematically gathered from primary electronic databases, including Google Scholar and Scopus. To maintain high methodological rigour, clear boundaries were applied during the screening process. While these procedural frameworks originate from non-tropical academic contexts such as Snyder (2019) in Sweden and Donthu et al. (2021) in the US/India, they provide universal, climate-independent methodological guidelines for structuring rigorous systematic reviews. Furthermore, this review included peer-reviewed journal articles, foundational books, and major conference papers that focus on microclimates and urban design. It excluded grey literature lacking peer review as well as journal articles that were strictly specific and unique to temperate climates. To extract the meaning of microclimate to accomplish objectives 1 and 2, a bibliometric analysis was conducted. Bibliometric analysis is used by researchers for numerous purposes, including investigating the intellectual structure of a specific area within the existing literature and identifying emerging trends in article and journal performance, collaboration patterns, and research elements (Donthu et al., 2021). In this research, the bibliometric analysis was done using VOSviewer and data sourced from PubMed data source. While Google Scholar and Scopus were utilized to search for and read the core papers used in the literature tables, PubMed was used exclusively for the visual keyword map due to the technical requirements of the mapping software, VOSviewer. VOSviewer is built to natively support files from only a few specific databases, and Google Scholar was excluded because it does not allow users to bulk-download the structured data files required to create the map. Furthermore, while Scopus is a great search tool, it enforces strict download limits per file. PubMed was chosen for this specific task because it integrates perfectly with VOSviewer, is completely free, and easily allows the download of up to 10,000 records at once without breaking the files or losing critical information. When referring to journal articles, books, and conference papers that are related to research and theory, the impact of urbanization on microclimate and the impact of microclimate on various aspects of the urban environment were identified. Furthermore, the literature review discovered methods to reduce the negative impact of microclimatic conditions on various aspects of the urban environment through urban variables. At last, a framework has been developed by analysing gathered data from the literature review.

3. RESULTS AND FINDINGS

3.1 MICROCLIMATE AND MICROCLIMATIC PARAMETERS

Microclimate is defined as the climatic conditions at a microscale on the Earth's underlying surface, differentiating it from macroscales and mesoscales (Yang et al., 2023). The microscale spans under 1 km horizontally, up to about 2 km at most (Zhu et al., 2023). In meteorology, a microclimate arises within this range, driven mainly by features close to the ground (Fujiwara et al., 2024). Urban local microclimate refers to the local climatic conditions within a micro-scale area (Jia et al., 2024). More broadly, the urban microclimate encompasses the immediate surrounding environment around building clusters inside the urban boundary layer, including any climatic phenomena of urban physics, with a height of two to five times the average building height (Yang et al., 2024). According to Li et al. (2022), the microclimate in small-scale spaces can be significantly influenced by urban planners through various artificial means during city design and construction, helping the city better adapt to larger macro-climatic conditions.

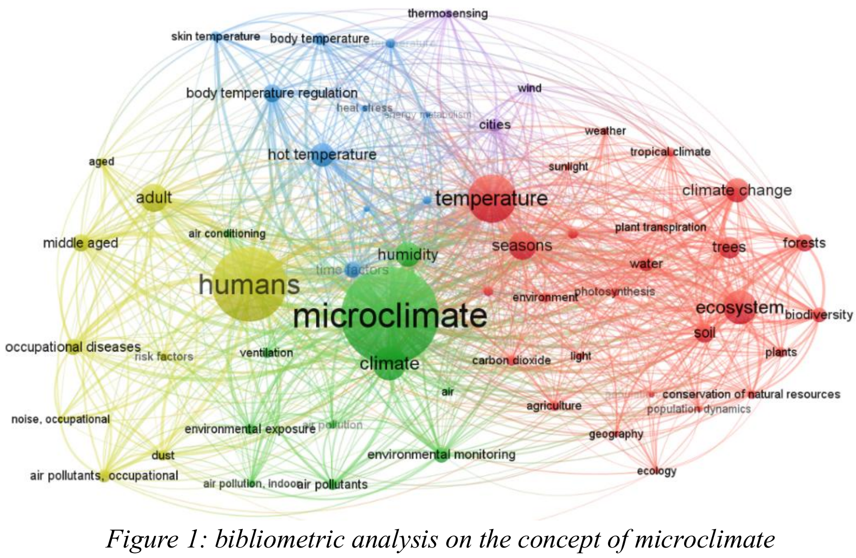


Figure 1: bibliometric analysis on the concept of microclimate

The above Figure 2 illustrates a bibliometric network regarding the concept of microclimate. The specific analysis presented here was conducted using data sourced from PubMed. According to the above Figure 2, the green cluster serves as the bridge between the physical environment and the other thematic areas. The red cluster focuses on the broader environmental scale linking climate change, ecosystems, and forests, and the yellow & blue clusters connect the environmental data to the biological reality of urban dwellers. This map serves as a powerful evidence-based justification for the research, showing that urban planning in the tropics is not just about buildings, but about managing a complex relationship between nature and human biology.

Microclimate encompasses factors such as wind aerodynamics, thermal comfort, energy demand, and pollutant dispersion (Yang et al., 2023). The following Table 1 shows the microclimatic parameters that have been identified by researchers.

Table 1: Microclimatic parameters

Item No	Microclimatic Parameter	Source
1	Wind Speed	[2], [3], [4], [5], [6], [7], [11], [14], [18], [20], [21]
2	Wind Direction	[7], [11], [18], [20]
3	Wind Aerodynamics.	[1]
4	Pollution Dispersion	[1], [3], [15], [17]
5	Wind-Driven Rain	[1]
6	Air Temperature	[2], [3], [4], [5], [6], [8], [9], [10], [11], [14], [16], [18], [19], [21]
7	Relative Humidity	[2], [3], [5], [6], [8], [11], [14], [16], [18], [19], [21]
8	Solar Radiation	[2], [3], [5], [6], [8], [14], [18], [20]
9	Air Pressure	[3], [10]
10	Shadow Effect	[11], [12], [13], [14]

[1] (Yang et al., 2023) [2] (Zhu et al., 2023) [3] (Roy et al., 2025) [4] (Toparlar et al. 2017) [5] (Jia et al., 2024) [6] (Fujiwara et al., 2024) [7] (Yang et al., 2024) [8] (De Groeve et al., 2024) [9] (Antoniou et al., 2024) [10] (Fu et al., 2025) [11] (Ghiasi et al., 2024) [12] (Song et al., 2025) [13] (Liu et al., 2024) [14] (Ni et al., 2025) [15] (Li et al. 2022)[16] (Salmanian & Ujang, 2022) [17] (Leng et al., 2022) [18] (Shafaghat et al., 2016) [19] (Lai et al., 2019) [20] (Toparlar et al., 2017) [21] (Peng et al., 2018)

3.2 IMPACTS OF URBANIZATION ON MICROCLIMATE

Rapid urbanization is a key characteristic of modern economic and social development, particularly in highly populated cities (Roy et al., 2025). The researcher further stated that this growth significantly impacts the urban microclimate, leading to a variety of environmental problems. Urban areas, dominated by rigid structures, differ greatly from rural or vegetated settings because land cover and morphology change the surface atmosphere heat exchange (Jia et al., 2024). A primary consequence of this transition is the UHI effect, where urban air temperatures remain consistently higher than those in surrounding rural areas (Salmanian & Ujang, 2022; Toparlar et al., 2017; Yang et al., 2023). This phenomenon is most pronounced in regions with rapid population surges and urban growth (Meng et al., 2024). UHI occurs because urban surfaces, such as asphalt, brick, and concrete, possess different thermal and radiative properties compared to natural landscapes (Lee et al., 2021). These materials have high heat capacities and low albedo, meaning they absorb more solar radiation during the day and release it as waste heat at night (De Groeve et al., 2024; Lee et al., 2021). The negative implications of UHI are extensive, including increased monthly rainfall, prolonged growing seasons, and the deterioration of air and water quality, all of which compromise human health and ecosystem stability (Lee et al., 2021). To counter these effects, researchers have proposed the Urban Cooling Island (UCI) effect utilising blue and green infrastructure as a natural air conditioning method (Meng et al., 2024).

Beyond materials, the physical arrangement of a city, its morphology, plays a critical role in microclimatic variation (Meng et al., 2024). While dense, high-rise developments provide shading that can improve outdoor comfort by reducing direct sunlight, they simultaneously lower the Sky View Factor (SVF) (Czachura et al., 2022; Yi et al., 2023). A reduced SVF restricts the ability of the ground to cool itself through long-wave radiation to the sky (Giyasova, 2021; Yi et al., 2023). Furthermore, the close proximity of buildings increases solar and infrared inter-reflections between adjacent surfaces, trapping heat within the urban canyon (Lauzet et al., 2019). The loss of vegetation exacerbates these issues. The replacement of green spaces with paved surfaces eliminates evapotranspiration, a vital natural cooling process (Lee et al., 2021). Consequently, the sensible heat flux increases while the latent heat flux decreases, further intensifying localised warming.

Urbanisation also fundamentally reshapes the urban wind environment (Leng et al., 2022). High-rise structures can channel high-altitude, high-speed winds down to the surface, creating hazardous conditions for pedestrians (Tse et al., 2017). Conversely, densely packed building clusters can block natural ventilation, preventing the dissipation of heat and pollutants (Leng et al., 2022; Yim et al., 2009).

3.3 IMPACT OF MICROCLIMATE ON VARIOUS ASPECTS OF THE URBAN ENVIRONMENT

The urban microclimate, including phenomena such as urban heat island, influences many aspects of cities, from health to building energy use (Roy et al., 2025). Table 2 presents such impacts according to the conducted studies.

Table 2: Impact of microclimate on the environment

Item No	Impact of microclimate on the environment	Source
1	Thermal discomfort	[1], [4], [5], [6], [7], [11], [12], [14], [16]
2	Building energy consumption	[1], [3], [4], [5], [6], [8], [12], [13], [17]
3	Health and wellbeing of residents	[1], [2], [4], [5], [7], [10], [11], [15], [16]

Item No	Impact of microclimate on the environment	Source
4	Air quality	[3], [4], [5], [9]
5	Urban wind environment	[3]
6	Urban pollution island	[3], [10]
7	Health of the ecosystem and biodiversity	[2]

[1] (Czachura et al., 2022) [2] (Zhu et al., 2023) [3] (Yang et al., 2023) [4] (Toparlar et al., 2017) [5] (Roy et al., 2025) [6] (Jia et al., 2024) [7] (Fujiwara et al., 2024) [8] (Yang et al., 2024) [9] (Meng et al., 2024) [10] (De Groeve et al., 2024) [11] (Antoniou et al., 2024) [12] (Fu et al., 2025) [13] (Ghiasi et al., 2024) [14] (Song et al., 2025) [15] (El-Bahrawy, 2024) [16] (Wang et al., 2023) [17] (Pragati et al., 2023)

3.4 Strategies to Reduce the Negative Impact of Microclimatic Conditions on Various Aspects of the Urban Environment During Urban Planning

The urban design strategies play a significant role in reducing the negative impacts of microclimatic changes caused by urbanization (Semeraro et al., 2024). With the help of the strategic combination of various factors, urban planners and designers can improve thermal comfort, reduce energy usage, and develop more sustainable and liveable cities (Salvati & Kolokotroni, 2023). Urban strategies are particularly relevant, given that the urban microclimate directly impacts the quality of life of the people living in it (Li et al., 2022).

- Trees / Vegetation

Urban vegetation is a primary strategy for mitigating negative microclimate impacts and improving pedestrian thermal comfort (Adıgüzel, 2023; Dissanayake et al., 2023; Liu et al., 2024). Trees provide significant cooling by shading surfaces and regulating radiation, with the effect magnitude determined by species, leaf density, and canopy arrangement (Adıgüzel, 2023; Fu et al., 2025; Fujiwara et al., 2024; Guerri et al., 2023). Complementary infrastructure, such as green walls and roofs, supports Sustainable Development Goal 11 by lowering ambient temperatures through transpiration and shadowing (Adıgüzel, 2023; Pragati et al., 2023; Roy et al., 2025). The performance of these systems depends on plant species, orientation, and local environmental conditions (De Groeve et al., 2024; Pragati et al., 2023).

- Water Bodies

Water bodies significantly mitigate urban overheating by reducing ambient temperatures by 1-2°C (Roy et al., 2025; Shafaghat et al., 2016). This cooling and humidifying effect is most notable within a 9-18 meter radius, enhancing overall human comfort (Lai et al., 2022). Despite these benefits, water bodies can negatively impact nighttime temperatures due to thermal storage (Ampatzidis & Kershaw, 2020). Their cooling potential is particularly vital for tropical cities, though high evaporation rates can limit their effectiveness in coastal areas (Yang et al., 2023).

- Courtyards

Courtyards are also identified as a sustainable approach that enhances thermal comfort and reduces energy use (Taleghani et al., 2015). The geometry of a courtyard, its orientation, openings, wall materials, and landscaping define the microclimate of a courtyard (Zhu et al., 2023). Wei et al. (2016) observed that the geometry of a courtyard and especially its shape may have an impact on solar radiation and airflow, which are essential parameters of the microclimate.

- Building Morphology (Building Height, Density, Orientation)

Urban morphology, including building height, density, and orientation, critically influences microclimates by regulating sun exposure and shadowing (Liu et al., 2024; Meng et al., 2024; Song et al., 2025). While increased density and lower building heights generally elevate temperatures, building density has a negligible impact on nighttime heat (Lin et al., 2017; Meng et al., 2024). Urban canyons further modify environments by retaining heat and reducing natural ventilation (Salvati & Kolokotroni, 2023). Although dense structures offer beneficial street-level shade, they also act as wind shields. However, high-rise buildings can counteract this by amplifying street-level winds via downwash flow (Fujiwara et al., 2024; Lin et al., 2023; Middel et al., 2014; Ng et al., 2011).

- Material permeability and surface roughness

Reflective surfaces and "cool" materials effectively mitigate the urban heat island effect, though they can occasionally decrease pedestrian comfort due to glare (Elnabawi & Jamei, 2024; Yang et al., 2023). Thermal efficiency is further improved by using lightweight concrete and phase-change materials, which reduce cooling loads, while high-heat materials like stone and petroleum-based flooring should be limited (Adıgüzel, 2023; Lee et al., 2021). Urban surface roughness significantly impacts ventilation, reducing wind speeds by up to 30% generally and 60% in dense areas (Salvati & Kolokotroni, 2023). The researcher further states that these changes increase turbulence and limit the natural cooling potential of free-stream air above buildings.

- Shadow Areas

Building layouts can be strategically designed to create beneficial shadows, improving local thermal conditions and mitigating urban heat island effects (Han et al., 2023; Liu et al., 2023). Artificial structures, such as man-made urban trees, serve as efficient shading tools that can even surpass vegetative cooling in high-rise residential areas (Sun et al., 2024). The extent of daytime shading significantly impacts thermal comfort and is negatively correlated with the sky view factor, a key shading indicator (Ni et al., 2025). Consequently, sky view factor should be integrated into thermal comfort studies alongside vegetation coverage and pavement material types (Liu et al. 2024). These architectural and environmental interventions, summarized in Table 3, represent essential strategies for stabilizing urban ambient conditions.

Table 3: Urban design strategies

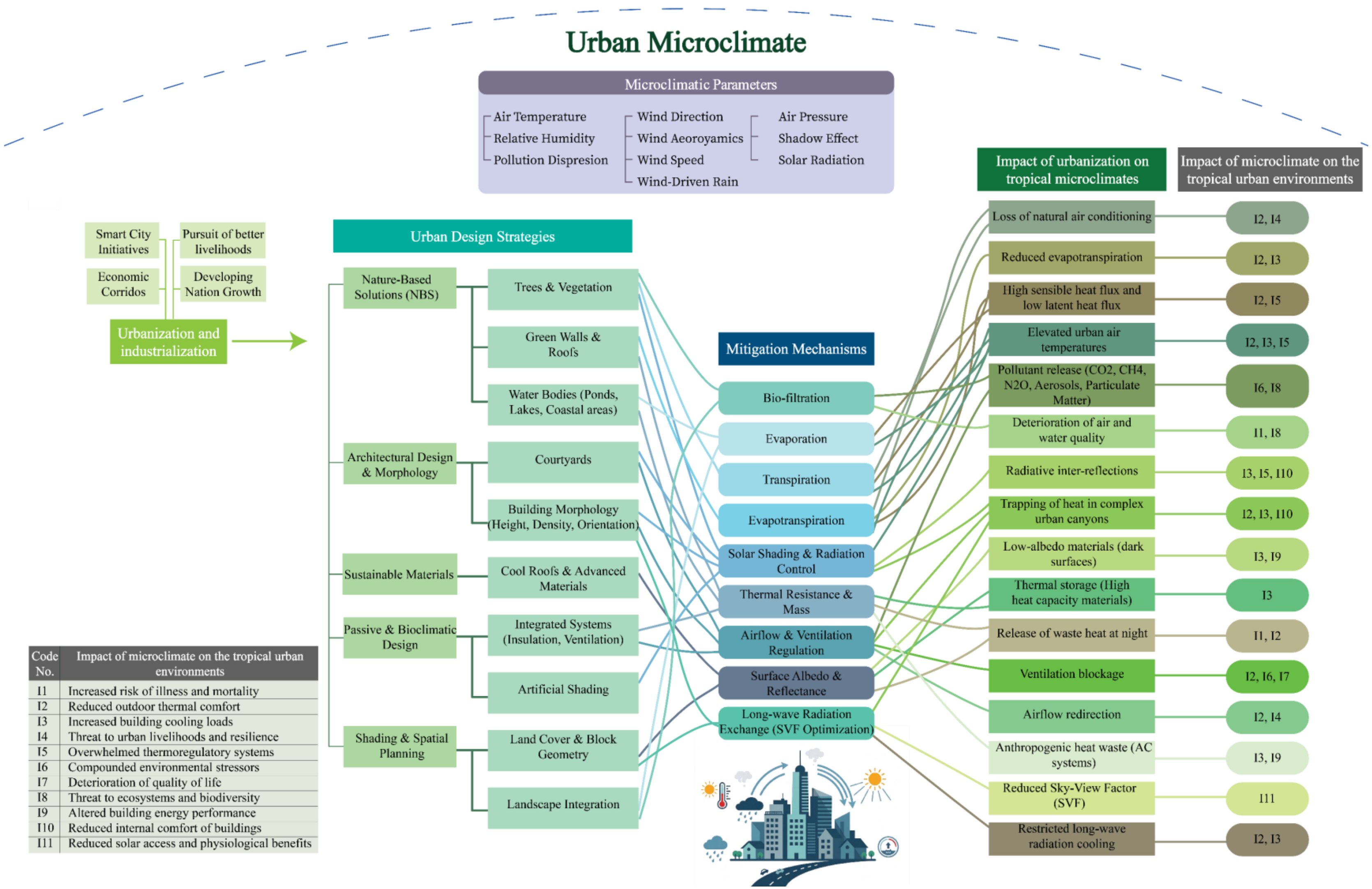
Item No	Urban design strategies	Source
1	Trees/vegetation	[1], [3], [4], [5], [6], [7], [8], [9], [11], [15], [16], [17], [18], [19]
2	Water bodies	[1], [3], [6], [13], [17]
3	Green walls and roofs.	[1], [3], [7], [19]
4	Street canyons.	[1], [6], [14]

Item No	Urban design strategies	Source
5	Courtyards	[2], [11]
6	Topography	[3]
7	Block geometry	[4], [11]
8	Land cover	[4], [11]
9	Building morphology (building height, density, orientation).	[2], [4], [5], [6], [10], [11], [14]
10	Landscape	[6], [17]
11	Nature of building materials	[1], [5], [8], [14], [15], [20]
12	Canopy covers	[8], [12], [18]
13	Shadow effect from neighbouring objects	[9], [10], [11], [12]
14	Passive design strategies such as combined night Ventilation, shading in the building envelope, light-colored coatings, and thermal insulation	[19]

[1] (Yang et al., 2023) [2] (Zhu et al., 2023) [3] (Roy et al., 2025) [4] (Jia et al., 2024) [5] (Fujiwara et al., 2024) [6] (Meng et al., 2024) [7] (De Groeve et al., 2024) [8] (Fu et al., 2025) [9] (Ghiasi et al., 2024) [10] (Song et al., 2025) [11] (Liu et al., 2024) [12] (Ni et al., 2025) [13] (Shafaghat et al., 2016) [14] (Salvati & Kolokotroni, 2023) [15] (Adıgüzel, 2023) [16] (Dissanayake et al., 2023) [17] (Lai et al., 2022) [18] (Wang et al., 2023) [19] (Pragati et al., 2023) [20] (Lee et al., 2021)

3.5 FRAMEWORK

The conceptual framework was logically derived by systematically mapping the findings from the literature synthesis into a causal, step-by-step structural pathway. The process begins with urbanisation and industrialisation, driven by factors such as smart city initiatives, economic corridors, and the pursuit of better livelihoods in developing nations. These urban shifts directly alter the core microclimatic parameters established in Table 1, including air temperature, humidity, wind dynamics, and solar radiation, leading to significant environmental impacts. To address these changes, the framework proposes urban design strategies extracted from Table 3, such as nature-based solutions, architectural morphology, and sustainable materials. Rather than presenting these strategies as isolated concepts, the framework explicitly maps them to the specific functional mechanisms they trigger, such as transpiration (Adıgüzel, 2023; Pragati et al., 2023), evaporation (Roy et al., 2025), biofiltration (Abdo & Huynh, 2021), evapotranspiration (Lee et al., 2021), and solar shading (Adıgüzel, 2023; Han et al., 2023; Wei et al., 2016), which serve as the direct link for counteracting the negative impacts of urbanisation. For instance, the loss of natural air conditioning caused by urbanisation is conceptually mapped to, and neutralized by, the transpiration and evaporation mechanisms provided by integrated greenery. Finally, the framework achieves logical completeness by linking these microclimatic shifts directly back to the broader urban ecosystem consequences categorized in Table 2. For example, the loss of natural air conditioning is mapped directly to its corresponding alphanumeric indicators, showing how it triggers reduced outdoor thermal comfort (I2) and significant threats to urban livelihoods and resilience (I4). By explicitly mapping strategies to active physical mechanisms and mechanisms to final environmental outcomes, this framework provides a clear and logically derived pathway for utilising passive and bioclimatic urban design strategies to improve the quality of life in tropical cities. The following Figure 3 illustrates the conceptual framework derived from this systematic mapping of the literature review.



Code No.	Impact of microclimate on the tropical urban environments
I1	Increased risk of illness and mortality
I2	Reduced outdoor thermal comfort
I3	Increased building cooling loads
I4	Threat to urban livelihoods and resilience
I5	Overwhelmed thermoregulatory systems
I6	Compounded environmental stressors
I7	Deterioration of quality of life
I8	Threat to ecosystems and biodiversity
I9	Altered building energy performance
I10	Reduced internal comfort of buildings
I11	Reduced solar access and physiological benefits

Figure 3: Framework for microclimate-aware urban planning in tropical climates

4. CONCLUSIONS AND RECOMMENDATIONS

Through a rigorous combination of a comprehensive literature review and bibliometric mapping, this research establishes that managing a tropical microclimate requires moving beyond standard physical development to orchestrate a complex relationship between the physical environment and human biology. Ultimately, integrating passive and bioclimatic design variables into urban frameworks is not just a structural choice, but an essential public health and environmental intervention necessary to foster long-term urban liveability.

To achieve the overarching aim of this study, four integrated research objectives were pursued. First, the key concepts of urban planning and microclimate were comprehensively reviewed, establishing that localized parameters such as temperature, wind, and radiation within a 1km microscale can be deliberately modified through urban design. Second, the study identified the direct impacts of altered microclimates on the urban environment, showing how localized warming accelerates building energy consumption, degrades air quality, and causes severe outdoor thermal discomfort. Third, a comprehensive review of urban design strategies in tropical climates revealed that while vegetation, water bodies, and building morphology can mitigate heat, their placement must be carefully balanced to prevent wind obstruction or nighttime heat retention. Finally, these findings were synthesized to develop a comprehensive, microclimate-aware framework for tropical cities, providing a structured pathway that links passive bioclimatic strategies to functional mitigation mechanisms like evapotranspiration and solar shading to enhance urban resilience.

The conceptual framework developed in this study serves as a foundational blueprint to operationalize microclimate-aware urban planning in tropical regions. It explicitly illustrates the structured pathway, and the framework bridges the gap between spatial interventions, including nature-based solutions, altered building morphology, and sustainable materials, and their environmental outcomes. These interventions activate critical mitigation mechanisms, such as evapotranspiration, solar shading, and airflow regulation, which directly counteract the localized heat accumulation, wind blockage, and pollutant stagnation caused by dense man-made structures. Furthermore, the framework maps exactly how these microclimatic shifts translate to broader negative consequences for the overall tropical urban ecosystem. By clearly linking specific design strategies to the mitigation of distinct environmental failures (such as the restricted long-wave radiation cooling caused by low sky-view factors), the framework equips urban planners and policymakers with a clear, predictive tool. This allows decision-makers to shift away from generalized planning methods and prioritize targeted bioclimatic interventions, offering an evidence-based pathway to improve the thermal safety, energy efficiency, and overall quality of life in tropical cities.

5. REFERENCES

Abdo, P., & Huynh, B. P. (2021). An experimental investigation of green wall bio-filter towards air temperature and humidity variation. *Journal of Building Engineering*, *39*, 102244. https://doi.org/10.1016/j.jobe.2021.102244

Adıgüzel, F. (2023). Effects of green spaces on microclimate in sustainable urban planning. *International Journal of Environment and Geoinformatics*, *10*(3), 124–131. https://doi.org/10.30897/ijegeo.1342287

Ampatzidis, P., & Kershaw, T. (2020). A review of the impact of blue space on the urban microclimate. *Science of The Total Environment*, *730*, 139068. https://doi.org/10.1016/j.scitotenv.2020.139068

Antoniou, N., Montazeri, H., Blocken, B., & Neophytou, M. (2024). On the impact of climate change on urban microclimate, thermal comfort, and human health: Multiscale numerical simulations. *Building and Environment*, *260*, 111690. https://doi.org/10.1016/j.buildenv.2024.111690

Czachura, A., Gentile, N., Kanters, J., & Wall, M. (2022). Identifying potential indicators of neighbourhood solar access in urban planning. *Buildings*, *12*(10), 1575. https://doi.org/10.3390/buildings12101575

De Groeve, M., Kale, E., Godts, S., Orr, S. A., & De Kock, T. (2024). Impact of vertical greening on urban microclimate and historic building materials: A meta-analysis. *Building and Environment*, *253,* 111365. https://doi.org/10.1016/j.buildenv.2024.111365

Dissanayake, C., Kawshalya, L. W. G., & Weerasinghe, U. G. D. (2023). The influence of planting arrangement on outdoor thermal comfort. *International Review for Spatial Planning and Sustainable Development*, *11*(3), 78–101. https://doi.org/10.14246/irspsd.11.3_78

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

El-Bahrawy, A. M. F. (2024). Investigating ladybug as a tool for measuring outdoor thermal comfort in urban neighborhoods. *Journal of Engineering Sciences*, *52*(1), 33–57. https://pdfs.semanticscholar.org/dc15/2d53c73520133c2ec320bc0d74e226312505.pdf

Elnabawi, M. H., & Jamei, E. (2024). The thermal perception of outdoor urban spaces in a hot arid climate: A structural equation modelling (SEM) approach. *Urban Climate*, *55*, 101969. https://doi.org/10.1016/j.uclim.2024.101969

Emmanuel, R. (2021). Urban microclimate in temperate climates: a summary for practitioners. *Buildings and Cities*, *2*(1), 402–410. https://doi.org/10.5334/bc.109

Fu, H., Jiao, Y., Deng, L., & Wang, W. (2025). Dynamic impacts of vegetation growth and urban development on microclimate and building energy consumption. *Sustainable Cities and Society*, *126*, 106382. https://doi.org/10.1016/j.scs.2025.106382

Fujiwara, K., Khomiakov, M., Yap, W., Ignatius, M., & Biljecki, F. (2024). Microclimate vision: Multimodal prediction of climatic parameters using street-level and satellite imagery. *Sustainable Cities and Society*, *114,* 105733. https://doi.org/10.1016/j.scs.2024.105733

Ghiasi, S., Passe, U., & Thompson, J. R. (2024). Addressing the need for microclimate considerations in doe reference building prototypes for urban energy simulation with a focus on the urban shadow effects. *Proceedings of SimBuild conference 2024* (pp. 511 – 517). International Building Performance Simulation Association. https://publications.ibpsa.org/conference/paper/?id=simbuild2024_2177

Giridharan, R., & Emmanuel, R. (2018). The impact of urban compactness, comfort strategies and energy consumption on tropical urban heat island intensity: A review. *Sustainable Cities and Society*, *40*, 677–687. https://doi.org/10.1016/j.scs.2018.01.024

Giyasova, I. (2021). Factors affecting microclimatic conditions in urban environment. *E3S Web of Conferences*, *244,* 06010. https://doi.org/10.1051/e3sconf/202124406010

Guerri, G., Crisci, A., & Morabito, M. (2023). Urban microclimate simulations based on GIS data to mitigate thermal hot-spots: Tree design scenarios in an industrial area of Florence. *Building and Environment*, *245*, 110854. https://doi.org/10.1016/j.buildenv.2023.110854

Gupta, K., & Haque, M. (2025). Optimizing microclimatic design in urban environments: Study of methods and strategies for residential clusters. *Civil Engineering and Architecture*, *13*(3), 1858–1874. https://doi.org/10.13189/cea.2025.130330

Han, Y., Jo, Y., & Kim, E. J. (2023). Influence of landscape interventions on thermal comfort under time-varying building shadow; new Gwanghwamun square case, Seoul, South Korea. *Heliyon*, *9*(9), e19436. https://doi.org/10.1016/j.heliyon.2023.e19436

Jia, Q., Zhu, Y., Zhang, T., Li, S., Han, D., Feng, Q., Tan, Y., & Li, B. (2024). Urban microclimate differences in continental zone of China. *Renewable and Sustainable Energy Reviews*, *197*, 114392. https://doi.org/10.1016/j.rser.2024.114392

Lai, D., Liu, W., Gan, T., Liu, K., & Chen, Q. (2019). A review of mitigating strategies to improve the thermal environment and thermal comfort in urban outdoor spaces. *Science of The Total Environment*, *661*, 337–353. https://doi.org/10.1016/j.scitotenv.2019.01.062

Lai, Y., Ning, Q., Ge, X., & Fan, S. (2022). Thermal regulation of coastal urban forest based on ENVI-Met model: A case study in Qinhuangdao, China. *Sustainability*, *14*(12), 7337. https://doi.org/10.3390/su14127337

Lauzet, N., Rodler, A., Musy, M., Azam, M.-H., Guernouti, S., Mauree, D., & Colinart, T. (2019). How building energy models take the local climate into account in an urban context - A review. *Renewable and Sustainable Energy Reviews*, *116*, 109390. https://doi.org/10.1016/j.rser.2019.109390

Lee, Y. H., Amran, M., Lee, Y. Y., Kueh, A. B. H., Kiew, S. F., Fediuk, R., Vatin, N., & Vasilev, Y. (2021). Thermal behavior and energy efficiency of modified concretes in the tropical climate: A systemic review. *Sustainability, 13*(21), 11957. https://doi.org/10.3390/su132111957

Leng, S., Li, S. W., Hu, Z. Z., Wu, H. Y., & Li, B. Bin. (2022). Development of a micro-in-meso-scale framework for simulating pollutant dispersion and wind environment in building groups. *Journal of Cleaner Production*, *364*, 132661. https://doi.org/10.1016/j.jclepro.2022.132661

Li, J., Mao, Y., Ouyang, J., & Zheng, S. (2022). A Review of urban microclimate research based on CiteSpace and VOSviewer Analysis. *International Journal of Environmental Research and Public Health*, *19*(8), 4741. https://doi.org/10.3390/ijerph19084741

Lin, P., Lau, S. S. Y., Qin, H., & Gou, Z. (2017). Effects of urban planning indicators on urban heat island: a case study of pocket parks in high-rise high-density environment. *Landscape and Urban Planning*, *168*, 48–60. https://doi.org/10.1016/j.landurbplan.2017.09.024

Lin, Q., Ishida, Y., Tanaka, H., Mochida, A., Yang, Q., & Tamura, Y. (2023). Large eddy simulations of strong wind mechanisms at pedestrian level around square-section buildings with same aspect ratios and different sizes. *Building and Environment*, *243*, 110680. https://doi.org/10.1016/j.buildenv.2023.110680

Liu, J., Tang, H., & Zheng, B. (2023). Simulation study of summer microclimate in street space of historic conservation areas in China: A case study in Changsha. *Frontiers in Environmental Science*, *11,* 1146801. https://doi.org/10.3389/fenvs.2023.1146801

Liu, J., Tang, H., & Zheng, B. (2024). Thermal environments of residential areas: Sunlight and building shadow in a Chinese city with hot and humid summers. *Buildings*, *14*(9), 2730. https://doi.org/10.3390/buildings14092730

Meng, Q., Gao, J., Zhang, L., Hu, X., Qian, J., & Jancsó, T. (2024). Coupled cooling effects between urban parks and surrounding building morphologies based on the microclimate evaluation framework integrating remote sensing data. *Sustainable Cities and Society*, *102*, 105235. https://doi.org/10.1016/j.scs.2024.105235

Middel, A., Häb, K., Brazel, A. J., Martin, C. A., & Guhathakurta, S. (2014). Impact of urban form and design on mid-afternoon microclimate in phoenix local climate zones. *Landscape and Urban Planning*, *122*, 16–28. https://doi.org/10.1016/j.landurbplan.2013.11.004

Mishra, S. B., & Alok, S. (2017). *Handbook of research methodology* (1st ed.). Educreation. https://www.researchgate.net/publication/319207471

Ng, E., Yuan, C., Chen, L., Ren, C., & Fung, J. C. H. (2011). Improving the wind environment in high-density cities by understanding urban morphology and surface roughness: A study in Hong Kong. *Landscape and Urban Planning*, *101*(1), 59–74. https://doi.org/10.1016/j.landurbplan.2011.01.004

Ni, Y., Lin, L., Xia, H., & Wang, X. (2025). Urban street greening and resident comfort: An integrated approach based on high-precision shadow distribution and facade visual assessment. *Sustainability*, *17*(3), 1026. https://doi.org/10.3390/su17031026

Peng, L., Liu, J.-P., Wang, Y., Chan, P., Lee, T., Peng, F., Wong, M., & Li, Y. (2018). Wind weakening in a dense high-rise city due to over nearly five decades of urbanization. *Building and Environment*, *138*, 207–220. https://doi.org/10.1016/j.buildenv.2018.04.037

Pragati, S., Shanthi Priya, R., Pradeepa, C., & Senthil, R. (2023). Simulation of the energy performance of a building with green roofs and green walls in a tropical climate. *Sustainability*, *15*(3), 2006. https://doi.org/10.3390/su15032006

Roth, M. (2007). Review of urban climate research in (sub)tropical regions. *International Journal of Climatology*, *27*(14), 1859–1873. https://doi.org/10.1002/joc.1591

Roy, T. B., Middey, A., & Krupadam, R. J. (2025). Unveiling the microclimate: A comprehensive review of tools, techniques, and future directions for sustainable cities. *Building and Environment*, *274*, 112726. https://doi.org/10.1016/j.buildenv.2025.112726

Salmanian, M., & Ujang, N. (2022). Emerging need for micro-climatic considerations in urban design process: A review. *Jurnal Teknologi*, *84*(1), 129–148. https://doi.org/10.11113/jurnalteknologi.v84.15111

Salvati, A., & Kolokotroni, M. (2023). Urban microclimate and climate change impact on the thermal performance and ventilation of multi-family residential buildings. *Energy and Buildings*, *294,* 113224. https://doi.org/10.1016/j.enbuild.2023.113224

Semeraro, T., Calisi, A., Hang, J., Emmanuel, R., & Buccolieri, R. (2024). Nature-based solutions planning for urban microclimate improvement and health: An integrated ecological and economic approach. *Land*, *13*(12), 2143. https://doi.org/10.3390/land13122143

Shafaghat, A., Manteghi, G., Keyvanfar, A., Bin Lamit, H., Saito, K., & Ossen, D. R. (2016). Street geometry factors influence urban microclimate in tropical coastal cities: A review. *Environmental and Climate Technologies*, *17*(1), 61–75. https://doi.org/10.1515/rtuect-2016-0006

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Song, J., Liu, Y., Chow, D. H. C., Liu, B., & Cho, S. (2025). Correlation between the insolation shadow ratio and thermal comfort of urban outdoor spaces in residential areas in Xi'an. *Buildings*, *15*(12), 1995. https://doi.org/10.3390/buildings15121995

Sun, T., Chen, L., & Sun, R. (2024). Cooling effects in urban communities: Parsing green spaces and building shadows. *Urban Forestry & Urban Greening*, *94*, 128264. https://doi.org/10.1016/j.ufug.2024.128264

Taleghani, M., Kleerekoper, L., Tenpierik, M., & van den Dobbelsteen, A. (2015). Outdoor thermal comfort within five different urban forms in the Netherlands. *Building and Environment*, *83*, 65–78. https://doi.org/10.1016/j.buildenv.2014.03.014

Toparlar, Y., Blocken, B., Maiheu, B., & van Heijst, G. J. F. (2017). A review on the CFD analysis of urban microclimate. *Renewable and Sustainable Energy Reviews*, *80,* 1613–1640. https://doi.org/10.1016/j.rser.2017.05.248

Tse, K. T., Weerasuriya, A. U., Zhang, X., Li, S., & Kwok, K. C. S. (2017). Pedestrian-level wind environment around isolated buildings under the influence of twisted wind flows. *Journal of Wind Engineering and Industrial Aerodynamics*, *162*, 12–23. https://doi.org/10.1016/j.jweia.2017.01.002

Wang, H., Cai, Y., Deng, W., Li, C., Dong, Y., Zhou, L., Sun, J., Li, C., Song, B., Zhang, F., & Zhou, G. (2023). The effects of tree canopy structure and tree coverage ratios on urban air temperature based on ENVI-Met. *Forests*, *14*(1), 80. https://doi.org/10.3390/f14010080

Wei, R., Song, D., Wong, N. H., & Martin, M. (2016). Impact of urban morphology parameters on microclimate. *Procedia Engineering*, *169*, 142–149. https://doi.org/10.1016/j.proeng.2016.10.017

Wong, N. H., He, Y., Nguyen, N. S., Raghavan, S. V., Martin, M., Hii, D. J. C., Yu, Z., & Deng, J. (2021). An integrated multiscale urban microclimate model for the urban thermal environment. *Urban Climate*, *35*, 100730. https://doi.org/10.1016/j.uclim.2020.100730

Yang, S., Wang, L., Stathopoulos, T., & Marey, A. M. (2023). Urban microclimate and its impact on built environment: A review. *Building and Environment*, *238*, 110334. https://doi.org/10.1016/j.buildenv.2023.110334

Yang, S., Zhan, D., Stathopoulos, T., Zou, J., Shu, C., & Wang, L. L. (2024). Urban microclimate prediction based on weather station data and artificial neural network. *Energy and Buildings*, *314,* 114283. https://doi.org/10.1016/j.enbuild.2024.114283

Yi, P., Liu, L., Huang, Y., Zhang, M., Liu, H., & Bedra, K. B. (2023). Study on the coupling relationship between thermal comfort and urban center spatial morphology in summer. *Sustainability*, *15*(6), 5084. https://doi.org/10.3390/su15065084

Yim, S. H. L., Fung, J. C. H., Lau, A. K. H., & Kot, S. C. (2009). Air ventilation impacts of the "wall effect" resulting from the alignment of high-rise buildings. *Atmospheric Environment*, *43*(32), 4982–4994. https://doi.org/10.1016/j.atmosenv.2009.07.002

Zhu, J., Feng, J., Lu, J., Chen, Y., Li, W., Lian, P., & Zhao, X. (2023). A review of the influence of courtyard geometry and orientation on microclimate. *Building and Environment*, *236*, 110269. https://doi.org/10.1016/j.buildenv.2023.110269