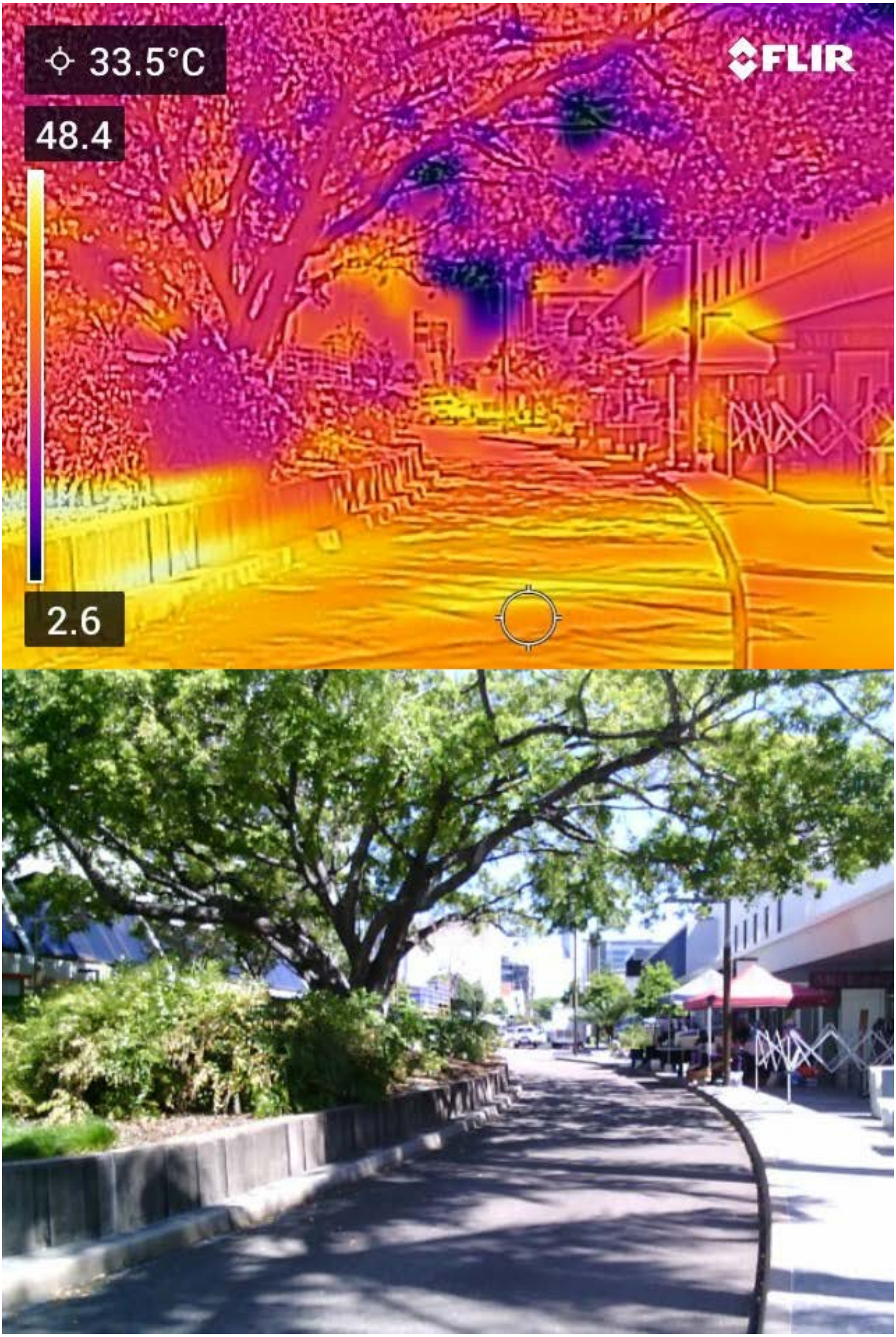

Urban form, materials, vegetation and the resulting urban microclimates (image by Jiawei Fu, 2022).

LANDSCAPE REVIEW

Landscape and urban design for improved urban microclimate

Silvia Tavares and Jiawei Fu

Context

Global mean temperatures are forecast to rise by as much as 5.5 degrees Celsius by the end of the twenty-first century due to climate change (IPCC, 2018). While climate change is more frequently associated with flooding, storms and sea-level rise, it will also increase the frequency and intensity of heatwaves, making already hot urban environments even hotter. In this context and considering the rapid rate of urbanisation, continuous temperature increases place urban populations at great risk (Aleksandrowicz et al, 2017), as elevated urban temperatures notably raise energy demand for cooling, heat-related fatalities and illnesses, air pollution levels, and both indoor and outdoor thermal discomfort (H Fu et al, 2025; Wang, Berardi and Akbari, 2016).

Urban heat islands (UHIs) are generated as cities experience warmer temperatures than surrounding rural areas. In urban areas, the modified landscapes that result from built infrastructure absorb and retain more heat than the natural environments and, when combined with anthropogenic activity such as transportation and industrial activity, contribute to the formation of UHIs (Paolini and Santamouris, 2023). These UHIs intensify the severity of heatwaves for the populations living within them (Rizvi, Alam and Iqbal, 2019). The human consequences of extreme heat events can be severe. The deadly heatwaves in Chicago in 1995 and Paris in 2003, for example, together led to more than 5,300 fatalities (Dousset et al, 2011; Whitman et al, 1997). Given these challenges, implementing effective and sustainable strategies to mitigate urban heat and reduce heat stress is essential.

In this paper, we discuss the important role of landscape architecture and urban design in implementing urban heat mitigation strategies. We discuss how these professions relate to and are considered in studies focused on urban climate and outdoor thermal comfort. Strategies available through landscape architecture and urban design are closely associated with an improved urban thermal environment (Chu et al, 2024). Street orientation, building height and density, green cover ratio, building materials, and the shape and size of water bodies can mitigate urban heat by adjusting urban microclimate and reducing energy use (Abd Elraouf et al, 2022; Liu et al, 2022; Xu et al, 2019). In the context of climate change, it is therefore essential to properly design and plan the built environment for mitigating urban heat, and it is increasingly important to ensure effective communication between the science community and built environment professionals.

Silvia Tavares is Senior Lecturer in Urban Design and Town Planning and Leader of the Bioclimatic and Sociotechnical Cities Lab (BASC Lab), University of the Sunshine Coast, 90 Sippy Downs Drive, QLD 4556, Australia.
Telephone: +61-7-5446-5884
Email: stavares@usc.edu.au

Jiawei Fu is Research Fellow, BASC Lab, University of the Sunshine Coast.
Email: jfu@usc.edu.au

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Built environment and heat mitigation: opportunities and challenges

Landscape architecture and urban design strategies play a vital role in shaping social, economic and environmental sustainability through design choices. For instance, thoughtfully designed microclimates can promote outdoor activities, encouraging physical exercise and in turn enhancing public health. These microclimates also help mitigate exposure to excessive ultraviolet radiation, lowering the risk of skin cancer (Carvolth and Tavares, 2025; McWilliam et al, 2020), while contributing to energy efficiency in buildings (H Fu et al, 2025). Furthermore, microclimates can create unique weather effects, such as icing and fog, adding visual appeal to landscape projects and serving as a tourist attraction. They play a crucial role in preserving natural habitats, protecting and improving biodiversity, for example by supporting plant health and the photosynthesis process

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(Nassar et al, 2018) and protecting animal habitat (Ghosh, Arvind and Dobbie, 2019; Lin and Brown, 2021; Nassar et al, 2018).

Given the substantial influence of microclimates on human health and overall wellbeing, it is essential to refine relevant policies to recognise the significance of microclimate design. However, microclimate is often treated as a general rule of thumb, such that policies overlook the intricate interplay between weather, climate and the built environment, and fail to account for the nuanced effects these interactions produce. For example, the relationship between building height and street width generates different thermal environments depending on street orientations (Abd Elraouf et al, 2022; Ahmadi Venhari, Tenpierik and Taleghani, 2019). In addition, the effect of various built elements on urban heat changes across different seasons and times of the day. For instance, the way that building height affects air temperature differs between day and night (Chen et al, 2023); and tall buildings can improve human thermal comfort during summer, but compromise it in winter (Mittermüller et al, 2021). These are nuanced variations that need to be known and acted on, but in general few existing policies are capable of implementing strategies that harness the benefits of microclimate effects (Brandsma et al, 2024).

Despite the importance of making design and planning decisions that take account of urban microclimates, their implementation is frequently compromised by the complex processes involved in delivering successful outcomes (Lin and Brown, 2021). The recent call from the Intergovernmental Panel for Climate Change (IPCC) to apply climate science to cities (IPCC, 2025) has highlighted that landscape architecture and urban design have an important role in the process of defining urban microclimates and improving urban resilience. Urban climate science is a well-developed field of research, and disciplines such as urban climatology provide a wealth of information on the factors affecting urban environments. Yet built environment professions frequently disregard this large body of knowledge as it falls within the domain of other – seen as quite disconnected – professions such as meteorology and atmospheric sciences. As a result, the scientific knowledge is usually not available for built environment professionals to comprehend, see connections with what they do and implement design that results in optimal microclimates. In addition, urban design and planning processes, as well as related policies, need to be improved so that they better support the understanding and application of urban climate science. Moreover, there has been little incentive to study and quantify climate processes at the urban scale, and many policies aimed at mitigating and adapting to climate change fail to consider the distinct climatic effects that city users experience. This, in turn, restricts the development of effective adaptation and mitigation strategies, increasing the risks to society's long-term resilience (Nazarian et al, 2024).

There is a need for ways to incorporate urban climate knowledge into built environment professions, but the complexity of the methods and tools most commonly used to assess urban climate can hold back professionals from using them. Numerical simulation is the method most frequently employed to assess urban microclimate due to recent computational progress (Aflaki et al, 2017). It is used both to analyse existing urban environments, including microclimates on a wide range of scales, from regional to local, and to test proposed design solutions. However, to achieve reliable results, studies commonly apply it alongside other methods and tools, such as field measurement, Geographic Information System (GIS) and questionnaires, making the process complex and lengthy. As a tool for studying urban climate, GIS is used for mapping and analysing the thermal performance of urban environments at larger scales, covering all cities and regions (Agathangelidis et al, 2025; Lin and Brown, 2021).

While academic research is fundamental to inform professional practice, most commonly used methods of investigating urban climate are largely unavailable to professionals or incompatible with day-to-day office life. Certainly throughout the design process, landscape architects and urban designers often use 3D modelling to visualise their design decisions. However, unlike other aspects of the design such as built form and materials, most microclimate elements are invisible and intangible (Lin and Brown, 2021), making it difficult for traditional 3D software to visualise these elements and, consequently, for designers and stakeholders to understand, quantify and respond to environmental conditions. Khan (2024), for instance, highlights that while some 3D analysis of urban climate has been integrated, most of the available resources for developing climatic modelling were designed for study and complex analysis, and have not been optimised for professional practice. The integration of visual tools Grasshopper and Dynamo with Rhino and Revit respectively, for example, facilitates microclimatic architectural design, but that design is limited by its reliance on precise input data and key assumptions as some of the complex calculations are simplified for efficiency.

More promisingly, integrating microclimate parameters into visualisation techniques is beneficial (de Munnik and Lenzholzer, 2020). The use of virtual reality technology might also help to fill this gap as it enables non-experts to understand the implications of design and planning choices that affect thermal comfort (Latifi, Burry and Prohasky, 2000) because, by wearing specially made temperature-sensitive clothing, users can experience real-time thermal sensation (Günther et al, 2020).

For professionals to take action, they must first recognise that designing for improved microclimates is an available option. Research undertaken in Australia indicates that within built environment professions, architects and architectural designers are aware of how the built environment influences the resulting microclimate, but professionals focused on public spaces (landscape architects and planners) are less aware and therefore miss opportunities (McNeilly Smith, Tavares and Stevens, 2023). While architects are exposed to building sciences throughout their undergraduate degrees and can often extrapolate that knowledge to urban environments, landscape architects and planners have a significant training gap to address (Lin and Brown, 2021).

Urban design and planning are fundamental in driving urban adaptation to the pressures of climate change. As we better understand that human activities are driving climate change on a large scale, landscape and urban design and planning are becoming increasingly important in climate discussions. Addressing climate change requires both atmospheric and climate science research and thoughtful design of urban areas that reduce reliance on mechanical systems for cooling, fossil fuel consumption and carbon emissions. Recognising the scale at which to identify and address this issue is crucial. While strategic planning and action are fundamental to the success of efforts to mitigate climate change, landscape architecture and urban design play a fundamental role in bridging the gap, determining where processes impact public space users and identifying actionable changes.

Science, design and practice: bridging the gap

A main current concern for the scientific community – and particularly in light of the recently established group to deliver a special report on climate change and cities (IPCC, 2025) – is to address the gap between science and practice. But while urban climate research has been poorly represented in the IPCC (Nazarian et al, 2024), research and practice focused on microclimate design have even less space in the dialogue, despite being a fundamental part of implementing climate-responsive strategies (Brown et al, 2015; Lenzholzer and Brown, 2016; Requena-Ruiz et al, 2022).

Landscape architecture and urban design have an important role in filling this gap so that urban climate knowledge is translated into practice and implemented in a consistent way in built environment professions. Green infrastructure offers significant potential for mitigating urban heat (J Fu et al, 2022) and is usually seen as a beneficial strategy to apply (Wesener et al, 2017). In contrast, other similarly efficient strategies are at times seen as conflicting with the preferred aesthetics, and policy instruments aimed at strategically implementing climate-responsive design are most frequently guidelines rather than binding documents (Brandsma et al, 2024). Fortunately, awareness of the need to implement climate-responsive strategies is growing, as is the sense of urgency to do so (Lenzholzer et al, 2020a, 2020b), because IPCC outcomes are unattainable without bridging landscape and urban design as well as urban planning and governance. With this awareness of the gap between science and practice, professional associations and government must develop relevant guidelines for professionals to put climatic knowledge into practice.

Also required is an integration of multidisciplinary techniques for analysing the combined effects of different built environmental elements on the urban thermal environment (de Munnik and Lenzholzer, 2020). In addition, particular gaps need to be addressed. Notably, case study analysis and place-specific solutions are less frequent in the urban regions of the southern hemisphere. Attention should also be given to cities undergoing rapid urban expansion and significant population surges and experiencing intense effects of extreme weather events (Huang et al, 2019).

A further gap to address when undertaking site analysis is the need to take account of place history and culture and how local thermal perceptions and thresholds may be specific to their location (Tavares and Swaffield, 2017; Tavares, Swaffield and Stewart, 2019; Tavares et al, 2024). Site analysis should consider how local cultures and identities can affect the way people perceive and adapt to urban microclimates, and how a site's microclimate can have a strong relationship with culture and history, affecting urban comfort (ibid). In view of the current lack of observational research on identity and cultural meanings of climate and weather in urban spaces (Kwong et al, 2021), it is important to consider this background and use it to inform design processes.

Finally, there is a need to incorporate urban microclimate design in the curriculum of landscape architecture, urban design and planning schools. Although discussion of this proposal has occurred for decades, it has not yet led to implementation (Bai et al, 2018; de Schiller and Evans, 1996; Eliasson, 2000; Lenzholzer and Brown, 2013; Lin, Li and Brown, 2022), despite evidence of the need for further training (Lin and Brown, 2021; McNeilly Smith et al, 2023). Alongside this, professional bodies have an important role to play in providing guiding documents for professional practice, and making climate-responsive design and planning knowledge into a professional requirement. This will help to prepare the future generation of designers and planners to address the challenges imposed by a changing climate, with an understanding and appreciation of the role of microclimate design in urban health, wellbeing and resilience.

About the authors

Dr Silvia Tavares is an urban designer with a background in architecture, urbanism, and building and city science. She is the founder and leader of the Bioclimatic and Sociotechnical Cities Lab (BASC Lab) at the University of the Sunshine Coast (UniSC). As chief investigator, she has undertaken several projects focused on improving urban climate through design and planning. These projects aim to inform strategies related to human thermal comfort, green infrastructure, public health and climate change impacts in urban areas. Before UniSC, she worked at James Cook University in Australia, Lincoln University in Aotearoa New Zealand, the Research Institute for Regional and Urban Development in Germany and the Universidade Federal do Tocantins in Brazil.

Dr Jiawei Fu is currently a visiting scholar at UniSC. Her research focuses on the impact of vegetation on microclimate and human thermal comfort in urban streets. As a landscape architect and lecturer, she has extensive professional and teaching experience in urban planning and landscape design, including developing urban green strategies in Macau and mentoring students to win landscape design awards. Dedicated to designing with nature for optimal outcomes, her research interest lies in urban green infrastructure for sustainable city development.

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