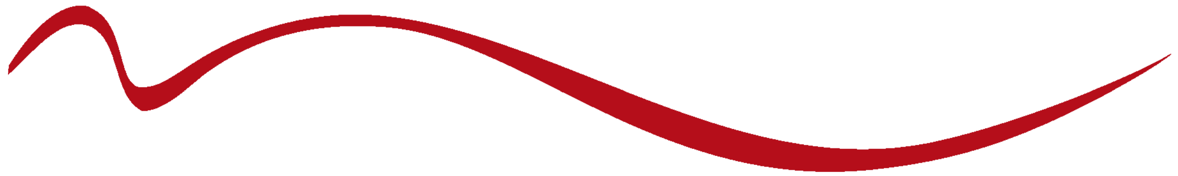
LANDSCAPE REVIEW



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LANDSCAPE REVIEW
An Oceania Journal of Landscape Architecture

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The aim of *Landscape Review* is to showcase the relationship between research and professional practice in the field of landscape architecture. It offers a forum for scholarly writing and critique on a wide range of topics that particularly impact Oceania and, more broadly, the rest of the world.

We encourage articles that further develop research ideas and findings from previously published peer-reviewed sources, critiques or reflections, to analyse and synthesise them for impact within professional practice and/or academic research.

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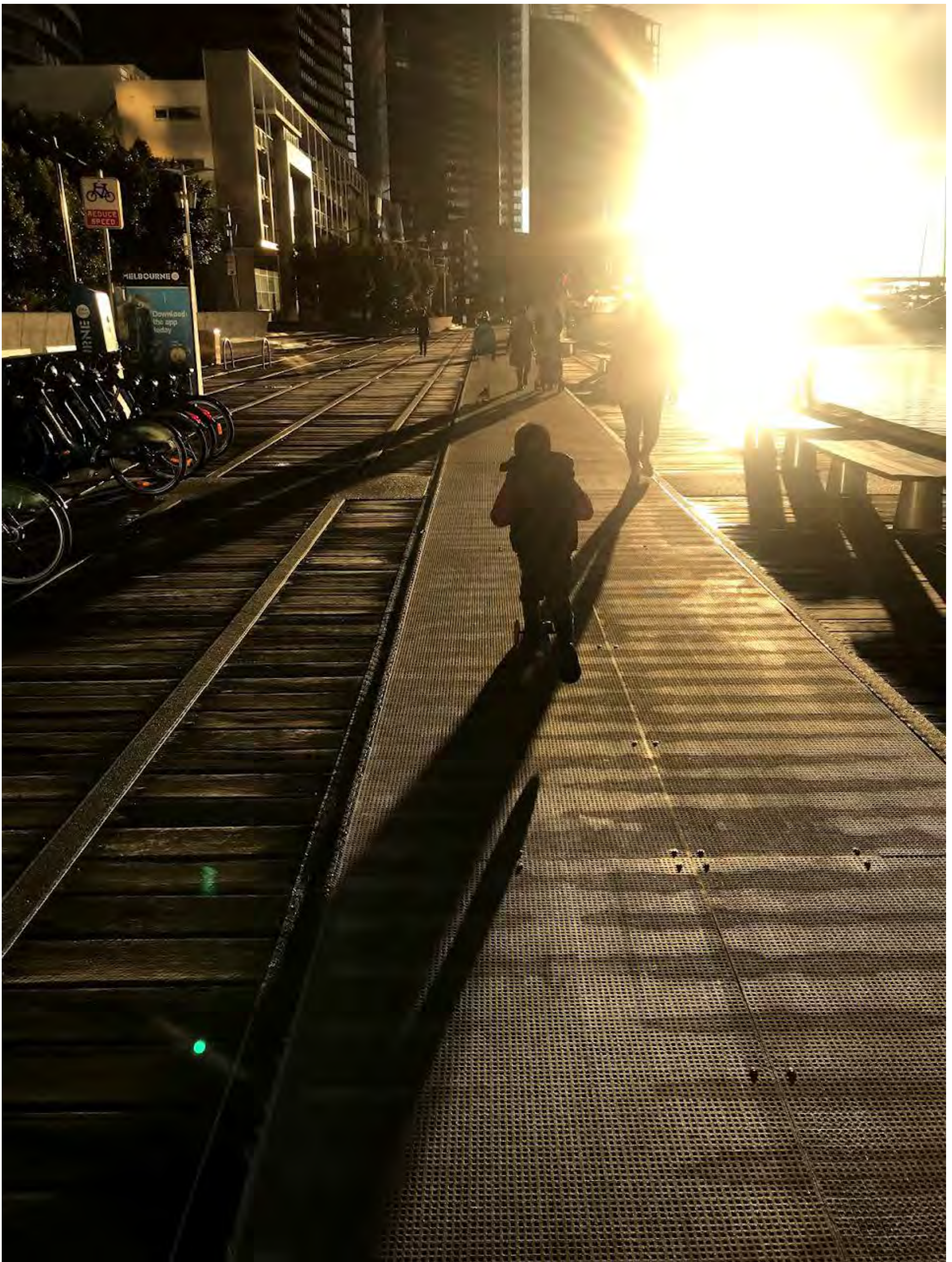

Sun setting between buildings in Melbourne’s Docklands precinct (image by Wendy Walls, 2019).

Foreword

WENDY WALLS

It's getting hot in here.

The world is estimated to heat 2.7 degrees Celsius above the pre-industrial average by 2100. The impact of just a few degrees will be vast. Expect hotter cities and changing weather, higher energy consumption, human health effects and even more fundamental questions about how we spend time outdoors (Climate Action Tracker 2025; Climate Council, 2025; CSIRO, 2025; IPCC, 2018). When such problems are perceived as isolated, heat mitigation strategies are often single-factor responses, separated from concurrent social, cultural or political concerns and measured accordingly. However, heat is an interconnected force with a wide-ranging influence.

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This special issue of *Landscape Review* looks to heat as a question for design at the intersections of environment and culture, physical space and lived experience. The collection of papers offers a range of perspectives on landscape architecture design and the complications of collaborating in this heating world – from responding to the material impacts of heat on plant communities, to how we work with fluctuating thermal conditions. This diversity of topics is all the more important as we approach the global warming threshold of 1.5 degrees Celsius set by the Paris Agreement and yet governments continue to debate policy and emissions targets (UNFCCC, 2025; United Nations, 2025). Whether we mitigate or adapt, working with the diverse effects of heat will be core to the future of landscape architecture. The papers in this special issue offer valuable ideas and methods in support of navigating this uncertain future.

Penny Allan, Martin Bryant, Peter Ridgeway and Andrew Toland from the University of Technology Sydney examine the link between groundwater and cool environments. Using map-based research, their investigation looks at Chain of Ponds networks in the Cumberland Plain in Western Sydney – one of the hottest urban environments in Australia (and sometimes the world). They present critical disciplinary mapping practices that navigate landscape histories and unfold deep stories of place. More so, they offer insight into practices of care linked to recognising and regenerating Chain of Ponds landscapes as part of healthy and resilient cities.

Paul Quinlan, landscape architect, opens a provocative discussion on the future of weeds in Aotearoa New Zealand. His paper reflects on the impact of climate change and the ecological forecast for native forests and ecosystems. As weeds continue to flourish, despite strategies involving their removal, herbicides and regeneration of native plants, he asks how we might reconcile our approaches with this evolving environmental state. Quinlan calls for a new mindset, posing the need for a major reconceptualisation of nature and its practical management where 'working *with* rather than warring *against* these weeds is undoubtedly the only pragmatic option'.

KEY WORDS
heat; design;
landscape architecture

Silvia Tavares and Jiawei Fu, based at the University of the Sunshine Coast, discuss the role of landscape architecture and urban design in implementing heat mitigation strategies in complex urban environments. While this work often demands multidisciplinary knowledge, the authors highlight the many barriers to practice arising from funding models, policy boundaries and training gaps. They argue for designers and planners positioning the challenge of heat with local culture, identities and thermal perception, as well as for more effective communication between the science community and built environment professionals.

Jillian Walliss and I reflect on a decade of teaching design studio on heat at the University of Melbourne. Despite the growth and accessibility of data and digital tools over this period, students' attitudes towards learning about complex conditions of climate and

atmosphere are often reductive rather than expansive. Whereas technology should be enabling creative rigour in design responses, too often students rely on quantification with little interest in exploring possibilities. These tensions about holistic competencies are growing as artificial intelligence continues to influence higher education, highlighting how critical thinking needs to remain central to teaching design.

Yanhan Li, Liang Li, Wenqing Wang and Lanxi Yang from Beijing Forestry University, along with Gillian Lawson from Lincoln University, introduce the concept of *thermal alliesthesia* as an important complement to physical design responses to urban heat. Illustrating this work through the design of an urban greenway in Beijing, the paper offers lessons to designers and planners on how to enhance the thermal comfort of walking through cities. This approach not only addresses heat as a physical effect but also expands to account for experience and subjective perception. Bringing these different perspectives together promotes greater socio-physical activities like walking and other forms of exercise, further building the resilience of urban communities.

Finally, I examine the design potential of heat in the unique cultural landscape of the Melbourne General Cemetery. This paper suggests that the design theory of microclimatic materiality can offer a useful perspective for engaging with small-scale fluctuations in temperature over time and can inform design for both environmental and social diversity.

I warmly (pun intended) thank the authors for sharing ideas, the reviewers for their generous feedback, and the *Landscape Review*'s editorial and production team for their expertise and care in bringing this work together.

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Sawyer's Meadow near Camden on the Cumberland Plain, Western Sydney, Australia. The meadow is in a Chain of Ponds system, in which water slowly migrates downstream through a soil bed of semi-porous alluvium and surfaces ephemerally in leaky ponds. The surrounding meadows are seasonally to persistently wet, with a structurally diverse micro-topography that has fostered complex biodiversity (image by Penny Allan, August 2025).

Fields of potential: recovering hidden Chains of Ponds in a rapidly urbanising landscape

PENNY ALLAN, MARTIN BRYANT, PETER RIDGEWAY AND ANDREW TOLAND

A Chain of Ponds is an ancient, mostly underground and almost forgotten riparian system that once sustained abundant, biodiverse life in many of the warm and dry regions of Australia. Unlike incised water courses, it forms swampy meadows that detain water and encourage infiltration, which cleans water and mitigates flooding and erosion. It also cools the atmosphere. This critical landscape system was once an extensive and prolific network of slow water movement in the Cumberland Plain in Western Sydney, Australia. It has now, unfortunately, been heavily degraded by colonising agricultural practices and Sydney's inexorable urban sprawl. Drawing on the link between groundwater and a cool environment, this paper looks into the potential for regenerating Chains of Ponds where, due to urbanisation, hard, water-excluding surfaces and the heat island effect are proliferating. The research reassembled a Chain of Ponds history of the Plain from nineteenth-century parish maps and mid-twentieth-century aerial photos, supported by ground truthing and heat analysis. The findings form the basis of a discussion on the potential of this endemic landscape system, with its intrinsic adaptability, to address the vulnerabilities that urbanisation creates for both fragile landscape systems and the increasing population of residents and workers.

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KEY WORDS
Chain of Ponds, heat island; Cumberland Plain; critical mapping; regional landscapes; blue-green infrastructure; water-sensitive urban design

Introduction

On 29 December 2019, during the Australian summer, the city of Penrith in Sydney's far west was named the hottest place on Earth that day, at 48.9 degrees Celsius (McPhee, 2020). The region's geomorphology contributed to this condition: the shallow undulations of the Cumberland Plain, sitting below the surrounding escarpment of the Blue Mountains to the west and the sandstone ridges to the east, create a depression that traps hot air in a rain shadow (Rachwani, 2021). Today's urban surfaces exacerbate the heat and its effects, and will continue to do so. In the coming years, predictions indicate that Western Sydney will experience more extreme heat (Whetton et al, 2012), and that heat will be a major concern to the rapidly increasing number of people who live there and will live there (Resilient Sydney, 2025).

As urban settlement intensifies, one critical and potentially invaluable ecosystem within the Cumberland Plain that may have significant implications for long-term urban and landscape resilience in the region is its Chain of Ponds network. Chains of Ponds, which once occurred extensively across the Plain, are small, ephemeral bodies of water – 'windows in the floodplain water table' (Hawkesbury-Nepean Catchment Management Trust, 1998). Evidence from elsewhere in Australia suggests they can hold and release water according to the fluxes of flood and drought, with the potential to moderate air temperatures and attenuate water flows (Callan, 2018; Mactaggart, Bauer and Goldney, 2007).

Although many in the Cumberland Plain were drained for agricultural purposes and substantially modified due to urbanisation, remnants still exist either as extant Chains of Ponds or as modified farm dams. Many were surveyed and recorded on nineteenth-century parish maps (figure 1), described in historical and botanical records, and designated as a geomorphological River Style (NSW Department of Climate Change, Energy, the Environment and Water, 2023). While Chains of Ponds on the Cumberland Plain in particular have never been formally identified or legally protected as an ecosystem, their specific combination of soil, topography and geomorphology characteristics means such systems are still readily identifiable in the region. On this basis,

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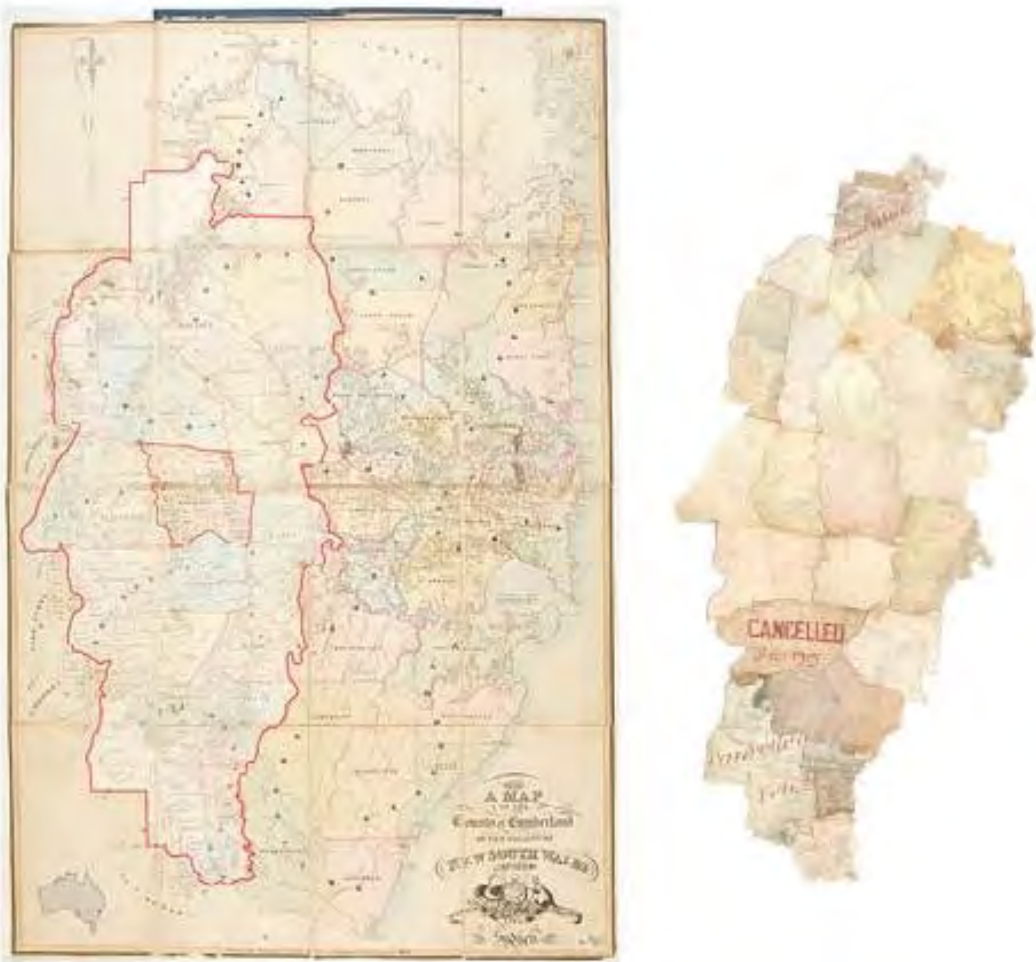
we hypothesise, Chains of Ponds exist here as a ‘field of potential’. If society can gain knowledge about them and value them, it may catalyse future development to make adjustments, consider alternatives, or remove or modify certain limiting conditions to encourage Chains of Ponds to recover, re-emerge and regenerate.



(a) **(b)**

Figure 1. (a) An 1840 map of the County of Cumberland and its parishes. Outlined in red are the Cumberland Plain study area and, within that, the Parish of Melville (referred to in detail in figure 6). Sydney’s coastline and harbours are to the east, and the Blue Mountains to the west. **(b)** This composite of early nineteenth-century parish map surveys reveals the earliest documented locations of Chains of Ponds on the Cumberland Plain. (Images by Nathan Galluzzo, May 2025, based on County of Cumberland map 1840, and survey drawings from the New South Wales (NSW) State Archives.)

Approach

The broad aim of our research is to understand how modern cities can evolve in place. It builds on research that suggests a correlation between settlement and its adaptive relationship to the local landscape. The focus of this paper is our research on the Cumberland Plain, the site of Sydney’s growing third city and a region that, for geomorphological and anthropogenic reasons, is already dangerously vulnerable to extreme heat. We set out to learn about the Plain’s hyper-specific and fragile Chain of Ponds ecosystems: how extensive they were, what constrains them now and how they work. Because they evolved to adapt to the fluxes of heat and drought, we investigated how their regeneration might offer possibilities for resilient life on the Plain, offset the dramatic loss of biodiversity over the last 200 years and mitigate the heat, floods and drought generated by a combination of climate change and rapidly sprawling urban areas.

Our approach entailed three fields of study. First, we analysed the landscape systems of the Cumberland Plain: its geomorphology, climate, soils and biodiversity; the colonisation of the landscape systems; and the effects of urbanisation. Second, we framed these findings with a review of literature on urban heat. This covered the research already done in Western Sydney, as well as global work on the connection between urban heat and groundwater, blue-green infrastructure and nature-based solutions; and the interplay between cities, landscape and community. Third, we searched for any correlation between the presence of Chains of Ponds and heat levels by mapping the extent of Chains of Ponds and analysing data on their potential to cool the landscape. The concluding discussion draws on these studies to suggest disciplinary mapping practices that can enhance knowledge of local landscape riparian systems and help address urbanisation-related issues such as extreme heat.

The Cumberland Plain

The geomorphology of the Cumberland Plain's Chains of Ponds

The Cumberland Plain, a small depression in the much larger Sydney Basin, was once part of the delta of a river five times the size of the Amazon. It was thick with swamp forest that flourished and died when the river dropped masses of sediment, which was compressed by advancing and retreating sea, creating layers of mudstone, shale and sandstone that were up to 6 kilometres thick. Then, 200 million years ago, the Pacific and Australian continental plates collided, causing an orographic uplift on the western circumference that defines the Basin, and reversing the tilt of the Plain westwards. In the valley formed by the arc of subduction, the Dyarrubin/Hawkesbury-Nepean River now flows, rising in the high plateau of the Blue Mountains, collecting water for some 350 kilometres as it circumnavigates the rim of the Plain to empty into the drowned valley estuary of Broken Bay.

Despite this geological drama, the landscape of the Plain is strangely subtle. Because it is expansive and relatively flat, it is difficult to 'read'. The vegetation, although diverse, is not spectacular; the terrain is not particularly dramatic; and it is not easy to capture in a photograph. But the layering of sediments and gentle folding of the land, the subsequent differential weathering of rock to create a variety of soils, and the extensive estuarine environments have combined to create a remarkable array of habitat for terrestrial and aquatic life (Karskens, 2020). In the past, these conditions made it one of the most biodiverse regions in the country. Now, however, many of its plant and animal communities are classified as 'threatened' under state and federal legislation (NSW Department of Climate Change, Energy, the Environment and Water, 2009).

While we can imagine what Chains of Ponds looked like, much of what we know of their structure and function comes from:

- a few research papers describing Chains of Ponds in areas beyond the Cumberland Plain (Mactaggart et al, 2007, 2008)
- a document that speaks generally to the geomorphology of the Hawkesbury-Nepean River system (Hawkesbury-Nepean Catchment Management Trust, 1998)
- geomorphological evidence from archaeological excavation (White and McDonald, 2010)
- excerpts from two unpublished BSc Honours theses by geographers from the University of Sydney in the 1980s, which specifically focused on the Cumberland Plain.

Most sources in NSW focus on the Southern Highlands and Tablelands. One of these (Cripps Creek) is in the southern extremity of the Hawkesbury-Nepean catchment, though not on the Cumberland Plain.

Both in the Cumberland Plain (White and McDonald, 2010) and at Cripps Creek (Mould and Fryirs, 2017), the evolution of Chain of Ponds geomorphology began around 22,000 years ago. That was in the late Pleistocene during the last glacial maximum, when dry, cold conditions caused the erosion of gravel and sand, which settled in shallow

riparian positions above impermeable clay or sandstone beds. As the climate warmed during the early Holocene, finer clay-loaded silts were deposited among these gravels and sands. These semi-permeable alluvia formed swampy meadows, along with Chains of Ponds – the 'fields of potential'. Chains of Ponds are typically set into broad, low-gradient valleys, which are characterised by irregularly spaced ponds separated by multiple preferential flow paths that do not carry water under low-flow (baseline) conditions (Eyles, 1977; Williams, Fryirs and Hose, 2020). The dense hydrophobic clay substrates act as an 'aquitard' so that water is perched above it in the alluvial deposits that support the lateral flow of subterranean groundwater.

Elliptical ponds may have been formed through surface scouring, although the processes of their formation remain poorly understood. What is better known is how the system degrades: under persistent high-flow conditions, flow paths erode channels, which become deeply incised, creating a feedback loop where groundwater is rapidly released, leading to further erosion (figure 2). But this sequence is known to be reversible in its early stages: if flows are slowed, silt and sediments settle, and the structural diversity of the Chain of Ponds can potentially recover, as can biodiversity (Mould and Fryirs, 2017).

Figure 2. Eroded Blaxlands Creek, formerly a Chain of Ponds, Orchard Hills. The increased flow of upstream runoff, resulting from soil compaction and urban surfaces, has eroded the alluvium layer and left an incised creek bed, which cuts into the underlying clay and will continue to do so. The remnant alluvium of the Chain of Ponds is still present in the flat surrounds, but in this circumstance, it ceases to function as a medium for slowing water flow or encouraging infiltration (image by Martin Bryant, May 2025).

The disturbance of the Cumberland Plain's Chains of Ponds

The meadows and their ponds are likely to have provided a near-permanent water source for First Nations peoples in their campgrounds. This has been evidenced through archaeological excavations at Second Ponds Creek, where considerable stone tool deposits suggest people inhabited reaches of Cumberland Plain's Chains of Ponds (White and McDonald, 2010).

Disturbance of Chain of Ponds landscape systems in the Cumberland Plain began from the earliest days of British colonisation, in 1792, after Governor Philip had granted the first parcels of land to settler convicts on the banks of Dyarrubin (the Hawkesbury River). Hard-hoofed European livestock compacted the delicate upper-soil horizons and scoured the meadow vegetation, both of which were fundamental to hydrological structure and function. The result was less infiltration, more erosion and the incision of free-draining channelised waterways. Some farmers accelerated this degradation by deliberately cutting drains to transform Chains of Ponds into free-flowing channels (figure 3), a practice that continued in some local creeks until at least the late 1940s (Brian Bradley, pers comm, 2012).

(a)

(b)

Figure 3. Agricultural farming practices, Menangle, have (**a**) scoured this Chain of Ponds meadow and (**b**) converted leaky Chains of Ponds to water-fast dams. In so doing, the practices have degraded the structure and function of the Chains of Ponds (images by Nathan Galluzzo, 2024).

The alteration of this natural system, as part of the larger transformation of the Cumberland Plain, was core to the intent of European colonisation to establish a viable agricultural and grazing economy west of the first European settlement in Port Jackson, and thereby to make it possible to consolidate the precarious Sydney colony (Karskens, 2009; Perry, 1963). On the Cumberland Plain, surveying land, subdividing land grants, 'enclosing' private property and modifying the Chain of Ponds systems entailed both procedural and legal abstractions, and a material transformation. The enterprise ultimately identified, possessed and controlled resources, such as soils, vegetation and water systems, giving a measure of its relative success.

Fundamental to this enterprise was how the region's land could, in the language of the eighteenth century, be 'improved'. 'Improvement' was the fulcrum around which the abstraction of 'land' into 'property' turned, naturalising possession and occupation by

Europeans (Bhandar, 2018, p 3), and the dispossession of the Dharawal and Dharug. A perceived absence of 'improvement' founded the claim of *terra nullius*, and the right of the colonial state to appropriate this 'no one's land' (Gascoigne, 2002). Research suggests that, in traditional ecologically based civilisations, how human settlement operated is correlated with local landscape systems (Isendahl et al, 2025). The same correlation does not apply where human settlement involves the establishment of colonial property systems.

It is unsurprising, therefore, that the 'improvements' made by the European colonisers demonstrated their lack of knowledge of the land and its ecosystems, including knowledge of how to care for them. The clearing of trees and forests eroded valuable topsoil. The change to endemic grassland ecosystems disrupted foodwebs, microclimates and soil drainage. The alteration of riparian conditions changed flow rates and the environmental health of the water courses. The proximity of the Plain to the Dyarrubin/Hawkesbury-Nepean and Tucoerah/Georges rivers, as well as the ephemeral Wianamatta/South Creek system, had given settlers access to favourable soils and water, but the soils, while initially productive, lost fertility after only one or two seasons of cultivation, and the water resources proved fickle, subject to unpredictable drought and sudden floods (Perry, 1963).

The disappearance of the Chains of Ponds from the land, and from the maps, provides a very specific example of the processes by which colonisation disempowered a functioning ecosystem. In a landscape already prone to unpredictable seasons of wet and dry, the introduction of cultivation and grazing, and the subdivision of natural systems into land grants disregarded hydrological function in these ecosystems. Yet, while the vegetation has been removed and water redirected, the topography and the alluvial soils are, by and large, still there. However, by now they have also been affected by urbanisation.

Today: rapid urbanisation and its effects on Chains of Ponds

The recent rapid growth of Sydney into the Cumberland Plain further fragmented the landscape systems. In 1946, in anticipation of a post-war population boom, Australia's Department of Post-War Reconstruction commissioned 150 square miles (388 square kilometres) of detailed aerial photographs of the Cumberland Plain, which made it 'the most exhaustive survey … for the purposes of town planning ever carried out [in Australia]' (Cumberland County Council, 1948).

Two years later, the County of Cumberland Plan, hailed as the first holistic planning solution to Sydney's urban challenges, was released. The Plan's aerial photos show a flat agricultural landscape largely devoid of trees. Its authors describe the state of the Cumberland Plain landscape in some detail, imagining how its 'even profile and gentle slopes' indicate that it was 'readily lending itself to exploitation'. Moreover, they note how the land presented no obstacles to the location or construction of major roads and railways, and how it could be developed cheaply for housing. Because the lowland rivers and creeks were 'unhealthy and liable to flooding, featureless and monotonous', floodplains were excellent sites for industry or housing, interspersed with treatment to 'make a very desirable open space pattern even though the watercourse itself may eventually become no more than a stormwater channel'. However, the authors did warn that there was 'always the danger of over-exploitation' and that planning required 'sound judgement and careful analysis of natural resources' (Cumberland County Council, 1948, pp 21–23).

The Plan was never implemented, and the newly formed Cumberland County Council was disbanded due to lengthy delays, land ownership battles, political infighting, lack of funds and a cumbersome planning system (Winston, 1957). Nevertheless, Sydney spilled westward into what must have seemed like an endless expanse of available land. In a more recent development, vast tracts of land have been cleared for the construction of Sydney's 'third city' and 20 million cubic metres of earth excavated, with inordinate change to the hydrology, for Sydney's new 'aerotropolis' (Dowling, 2021). Nonetheless, the aerotropolis has been promoted by the NSW government as a high skill jobs hub across aerospace and defence, manufacturing, healthcare, freight and logistics, agribusiness, education and research industries (NSW Department of Planning, Housing and Infrastructure, 2024). Proponents

claim its development will involve a 'landscape-led' approach that will create a cooler, greener city for the 300,000 people who are projected to live in the proximity of the airport.

Elsewhere on the Cumberland Plain, the ongoing residential growth and intensity of development, together with a rapidly changing climate, have generated unprecedented problems. These include the poor provision of ecologically functioning open/green space, flood and bushfire risks, urban heat island effects and more biodiversity loss. The ensuing complexities, risks and uncertainties affect the liveability, health and safety of the city (Holemans, 2017).

One factor contributing to this complexity is the trend towards building bigger houses that support fewer people on smaller lots that have minimal setbacks and no room for significant vegetation (figure 4). Because of the proliferation of hard surfaces, and because the interface between riparian corridors and people is poorly managed, the extensive removal of alluvium and the massive increase in stormwater runoff further degrades remnant Chains of Ponds. While green space and trees are desperately needed in Western Sydney (Brunner and Cozens, 2013), most urgently for urban cooling, councils appear to actively discourage them in new housing developments (Allan and Plant, 2022). In the human-centric world of planning for open space, trees are classified as expenses rather than (natural) assets and, in some contexts, councils are forced to cut down trees because they cannot afford to maintain them (ibid). This problematic state of acquisition and investment points to an underlying issue: existing waterways, ecologies and green space are rarely valued, except selectively as an 'ecological service' or 'ecosystem service', and therefore can be easily abandoned if end users of such services lose interest or are unwilling to pay for them (ibid).

Figure 4. Aerial photo of new housing in Marsden Park, which typifies the current approach to housing and water management in urbanised parts of Western Sydney (imagery ©2025 Airbus, Maxar Technologies, Vexcel Imaging US, Inc, map data ©2025 Google, accessed June 2025).

The landscape of urban heat

Heat on the Cumberland Plain

All of the human activity described above has led to extreme heat events on the Cumberland Plain. This represents a serious threat into the future. Heatwaves have killed more Australians since 1890 than bushfires, cyclones, earthquakes, floods and severe storms combined. Moreover, in its most recent assessment, the Intergovernmental Panel on Climate Change predicts 'species extinction, more widespread disease, unliveable heat, ecosystem collapse, cities menaced by rising seas' (Jackson, 2021). Yet, until recently, the problem of extreme heat has not attracted much attention. Perhaps the reason is that, as Tom Vanderbilt suggests in reflecting on Chicago's 1985 heatwave, it doesn't *look* like a disaster: it offers no dramatic aerial views such as bushfires bearing down on houses, flood-submerged suburbs or earthquake-flattened cities (Vanderbilt, 2002). Or perhaps it is because of the perception that extreme heat happens 'somewhere else', like New Delhi

in 2022, when the temperature reached 49 degrees Celsius and satellite imagery from NASA's Ecosystem Spaceborne Thermal Radiometer (Ecostress) revealed 'fiery red pockets dispersed evenly over the city' for days (Thomas, 2022).

The concept of Penrith as the hottest place on Earth on that December day in 2019 is shocking, but not unexpected. Heat scientist Dr Sebastian Pfautsch of Western Sydney University says that black suburban roofs and synthetic playground surfaces in Western Sydney can reach up to 80–100 degrees Celsius in summer. Pfautsch, whose media profile on this issue has reached more than one billion readers with 350 headlines in five languages and 21 countries, has publicly expressed his grief that even the simplest strategy, such as changing the colour of roofs, had been ignored (The Project, 2022).

Pfautsch and colleagues released the report *Benchmarking Summer Heat across Penrith NSW* (Pfautsch, Wujeska-Klause and Rouillard, 2020) in the year after the hottest day, documenting the near-surface air temperatures at various locations across Penrith (figure 5). The report highlights the risks of building a city on a plain already geographically compromised, with no sea breezes, low rainfall, very little surface water and fragmented vegetation. It blames the recent rapidly rising temperatures on 'human activity' or, in other words, continuing to build in a way that exacerbates heat. It concludes with 10 key recommendations, including to implement specific policy and monitoring initiatives, reduce hard surfaces, increase canopy cover and introduce nature-based cooling initiatives in those suburbs that regularly record the hottest temperatures. The report further notes that while blue-green infrastructure is an important cooling strategy, large water bodies actually contribute to the urban heat island effect by holding heat and then re-radiating it overnight into the atmosphere.

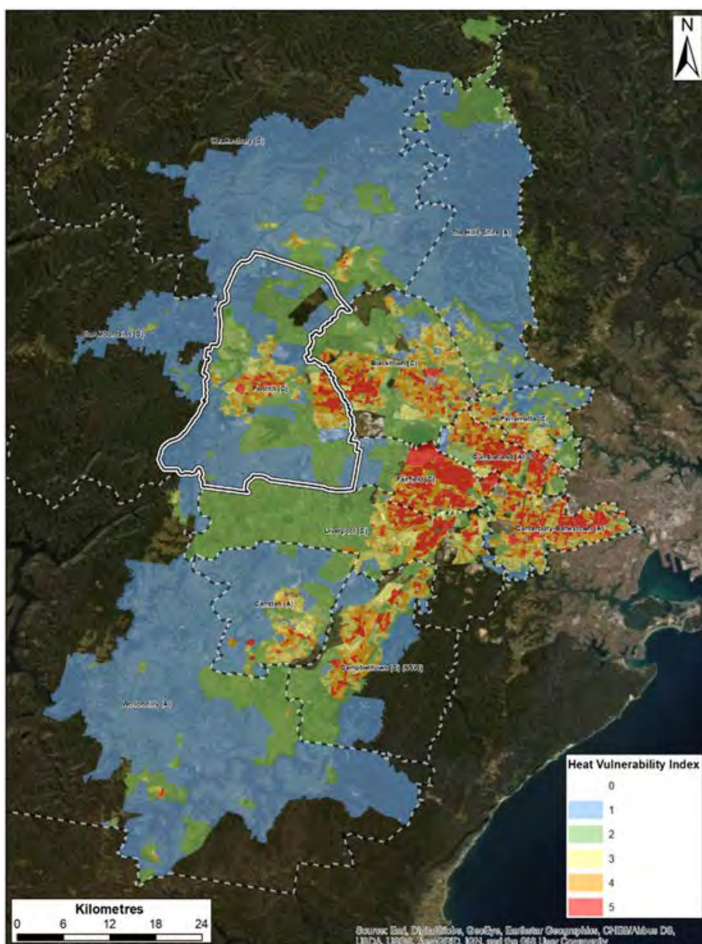


Figure 5. The map shows heat vulnerability in the summer of 2015/16 in Western Sydney, with Penrith outlined top left. The unfragmented red areas trace the intense areas of extant urbanisation. As urban areas expand in the future, so too will heat vulnerability (image by Pfautsch et al, 2020; published with permission).

Urban heat solutions: blue-green infrastructure and water-sensitive urban design

Blue-green infrastructure, a design strategy using trees to shade hard surfaces and environmental water to cool ambient temperatures, can have a cumulative mitigating effect on conditions of extreme heat. Networks of blue-green infrastructure act like a refrigerator coil, spreading the benefits of cooling across a city as they encourage cooling air flow to permeate across the hot surfaces of a city. Integrating green spaces and water to form a network in urban areas can provide significant environmental, economic and social benefits (Drosou et al, 2019).

Groundwater, including the groundwater associated with Chains of Ponds, makes an important contribution to this network effect in many ways. Approximately 34 per cent of land areas in Australia has the potential to have groundwater-dependent ecosystems (Mengyuan et al, 2022). Although studies on the relationship between groundwater and heatwaves are rare, emerging evidence suggests the role of groundwater can be beneficial. One study showed that shallow groundwater moistens the soil and supporting vegetation, which in turn cools and moistens 'the lower atmosphere via evaporation, slowing the accumulation of heat … and potentially suppressing heatwave intensity' (ibid). Another suggests that groundwater associated with wetlands and marshes in temperate climates has a more pronounced impact on heat at higher temperatures, making a significant contribution to regional cooling (Gohr et al, 2021). In addition, recent studies in China indicate that a *network* of wetland fragments (much like a Chain of Ponds) can greatly enhance hydrological connectivity and, therefore, the spatial extent of heat mitigation because their surface water and groundwater rely on heat exchange and local circulation to cool the atmosphere (Xue et al, 2019; Zhang, Shen and Lin, 2021).

Water-sensitive urban design is a type of blue-green infrastructure where nature-based principles are abstracted and applied in urban areas, typically when ecosystems have been damaged or completely destroyed. Emerging in the late 1980s as a land development approach (Coutts et al, 2013; Zhang et al, 2021), it employs the hydrologic processes of retention, infiltration, storage and evaporation to replicate a site's pre-development hydrology (Ahiablame and Shakya, 2016; Davis et al, 2009; Dietz, 2007). Its biotic components help promote natural filtration, improve water quality, enhance biodiversity and reduce the volume and velocity of stormwater runoff (Sayers et al, 2015).

The best examples of projects using water-sensitive urban design have been highly influential in urban planning. One is China's Sponge City programme for wetlands and wet gardens to capture, store and retain rainstorm water in urban areas to prevent flooding (Li, Li and Wu, 2016; Sallustio et al, 2019). Australia's Water Sensitive Cities strategy, designed to enhance adaptability and resilience to broad-scale climate changes, is another leading example (Wong and Brown, 2009; Wong et al, 2013). But the effectiveness of the design can be limited by the tendency, especially in urban environments, to repeat the engineering pattern and blue-green infrastructure componentry without much reference to local conditions.

Another way of thinking about blue-green infrastructure is as an already existing hyper-specific, living, life-support system that is characteristic of a bioregion and fundamental to its resilience. Close attention to these systems can provide clues on how to live with natural landscape systems rather than in spite of them. The focus here is on an adaptive balance among environment, city and community, with the needs of the environment guiding the way. It is a subtle reversal of the ecosystems service-to-humans approach, where characteristics are extracted and deployed elsewhere without understanding how integral those characteristics are to the ecosystems of a place. Conversely, in the hyper-specific approach, humans care for the environment because they understand its critical role in the long-term survival of themselves and the planet.

Traditional ecologically based knowledge-holders already understand this reciprocal relationship. Indigenous Peoples worldwide are stewards of more than 80 per cent of the world's biodiversity, with knowledge systems that span millennia (Garnett et al, 2018; Reihana et al, 2021). In Aotearoa New Zealand, for example, kaitiakitanga, the guardianship of natural landscapes, is grounded in the interrelationship of humans and nature. Attuned

to the rhythms and pulses of the environment, humans enact kaitiakitanga through practices of responsibility and reciprocity (Marras Tate and Rapatahana, 2023). Potawatomi botanist and author Robin Wall Kimmerer foregrounds this reciprocity in her latest book, *The Serviceberry* (Kimmerer, 2024). She begins with the words 'all flourishing is mutual', and defines the production of a bountiful harvest of berries not as a natural resource or ecosystem service, but as a 'gift'.

The notion of mutual flourishing might be a good place to start when considering how best to live in many places that are becoming hostile environments. However, this is not yet part of urban planning scholarship and practice. A recent survey of literature on urban blue-green infrastructure between 2001 and 2024 found an overwhelming emphasis on its ecological, technical and economic dimensions, and much less on its sociological aspects. The focus is beginning to change, driven 'by the challenges of urbanization, industrialization, pollution, and growing awareness of how environmental issues, such as climate change, affect social well-being' (Suárez, García and Leiras, 2025). Some approaches that might precipitate the shift include: undertaking interdisciplinary research and practice to better understand how urban blue-green infrastructure influences community dynamics, social cohesion and wellbeing (ibid); identifying multiple, locally derived values and incorporating them into green infrastructure planning (Kati and Jari, 2016; Orantes, Kim and Kim, 2017); and developing educational materials to foster broader social and environmental awareness and advocacy (Suárez et al, 2025).

Remapping the Cumberland Plain's Chains of Ponds

Archival maps; historical aerial photos

Despite the scarcity of information on Chains of Ponds on the Cumberland Plain, we have developed a chronicle of their pervasiveness by reassembling and matching historical maps with aerial photographs and Geographic Information System (GIS) analysis. While research into First Nations histories will take more time and will be a focus for the future, in this research archival maps revealed the whereabouts, the extent and the configuration of some of the ancient hydrological pattern and hinted at the contextual correlations between water and landscape, topography, vegetation, property lines, road alignments and built form. These findings lead to a position on the value of regenerating Chains of Ponds in the rapidly urbanising context of Western Sydney.

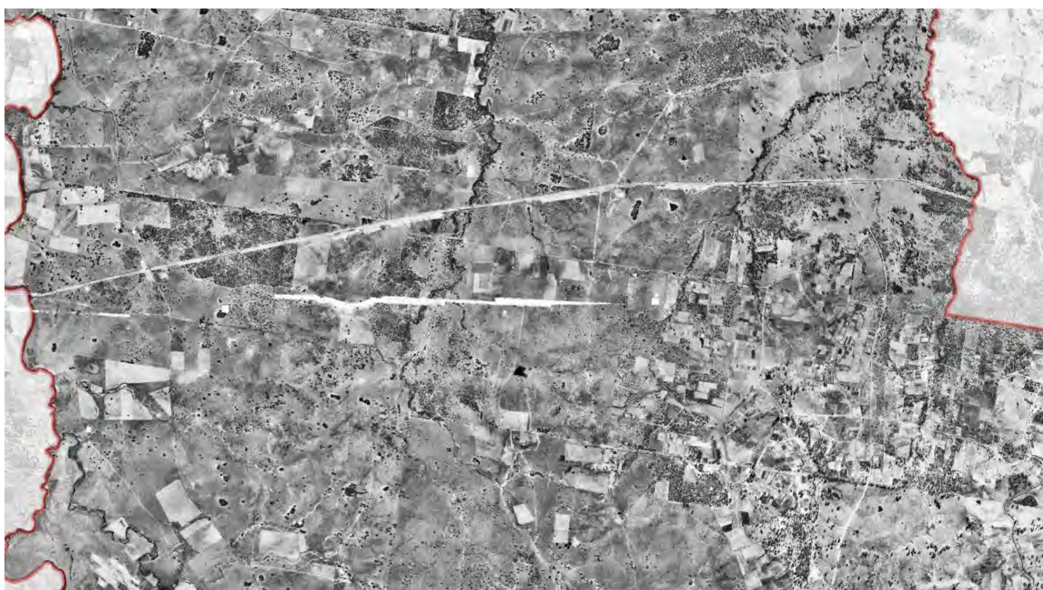
The earliest recorded data are the parish maps, which follow the British land management system of counties and parishes. The County of Cumberland was the first county established following British colonisation in 1788. The first map of the county, published in 1840, contains two primary catchments divided by a north–south ridge. The hand-drawn parish maps, dating from the 1830s to early 1900s, clearly depicted water lines, roads and property boundaries and, sometimes, gave scant indications of topography via relief mapping, though contours were never used. Undoubtedly, there would have been multiple surveyors doing this work across the Cumberland Plain, and their primary goal would have been to 'render … property and topography commensurable' (Pottage, 1994, p 362). On the maps, property boundaries of land holdings and road alignments are clear. The gently undulating topography would have been hard to measure and depict, as well as being information that was probably less important for the farming community audience. But geolocating water courses would have been essential in this dry region intent on agriculture, and simply done by identifying grass meadows with Chains of Ponds surrounded by woodland.

We found 24 parishes in the study area, sourced hundreds of maps from the NSW Land Registry Services and downloaded their corresponding digital records in an Excel file to account for each map we surveyed. To catalogue Chain of Ponds features within each parish, we prepared an index of indicators, such as place names, geology, terrain and water bodies. We documented the range of terms for water courses that our sources used: what we, in this research, collectively call Chains of Ponds were labelled variously in the parish maps as 'Chains of Ponds', 'swampy meadows', 'swamps', 'dells', 'mires' and 'marsh'. It is difficult to

know whether the differences arose because these terms had nuanced interpretations, or whether the nomenclature was a result of the wet or dry season in which the nineteenth-century fieldwork took place, or whether surveyors used different terms based on their own personal and professional background. The graphic used for the Chain of Ponds also varies from map to map: solid lines, dashed lines (perhaps ephemeral?), or solid lines with a sequence of pond outlines. But certain consistencies in the recurrence of Chains of Ponds across the Plain confirm that the maps provide the foundational material for the research.

We combined data from two or three maps for each parish, selecting those that contained the most comprehensive Chain of Ponds data, and then stitched them together. Using Photoshop, we realigned and rescaled each parish map to modern geospatial coordinates (GA94), by overlaying them with GIS layers that included key landscape markers such as roads, rivers and contours. The composite collage was then imported into computer-aided design (CAD) software (Rhino), where digital layers were extracted to isolate historical hydrological features, including major rivers and their tributaries. The digitised layers were overlaid with the earliest available (1947) aerial imagery. Each hydrological line was examined in high resolution to identify Chain of Ponds characteristics in as much detail as possible. Many permanent dams appeared on the 1947 imagery, but, more significantly, there were strong clues that the presence of Chains of Ponds was more extensive than the parish maps had suggested (figure 6).

(a)



(b)

(c)

Figure 6. Mapping historical Chains of Ponds using the Parish of Melville as an example (see figure 1). The composite **(a)** is a combination of parish maps. The 1947 aerial **(b)** is similarly a composite of combined aerial photos. The two data sources were combined. The combined product **(c)** showed that many smaller Chains of Ponds (still present in 1947) were overlooked in the original parish maps. (Images by Nathan Galluzzo, 2025.)

We estimate that at the time the aerial photographs were taken, each parish contained up to 30 times more Chain of Ponds systems than indicated in the early hand-drawn maps. We attribute this discrepancy to the scope and context of the surveying. Perhaps only some hydrological systems were apparent at the time of survey, perhaps only major lines were surveyed, and so the extensive networks of smaller Chains of Ponds ephemerally present throughout the landscape were omitted.

What is distinctive about them, as evident from the mapping, is that Chains of Ponds operated upstream from the main waterways, such as Wianamatta/South Creek, the Nepean River and their lagoons. The Chains of Ponds are thus first- and second-order Strahler water courses, dendritically arranged, and invariably long and meandering, which reflects the nature of the vast Plain with its low-lying undulating terrain. These characteristics contrast with the nature of the first- and second-order creeks in the sandstone geology to the east and west, where the first- and second-order creeks are short, direct and incised into the valleys.

Heat mapping correlations

We concurrently investigated heat to find correlations with water in the landscape. We undertook a limited investigation to measure temperatures around water corridors in Western Sydney. Drawing from LandSAT land surface temperature (LST) data collected during the 2022/23 summer, we were able to correlate the surface temperatures adjoining different river styles during a heatwave season. The 10-metre grid resolution was coarse, but sufficient to provide an indication of the contribution of different river styles, including Chains of Ponds, to adjoining LSTs.

The data in table 1 show the average LSTs beside each major geomorphic creek type in the Cumberland Plain, based on the Interim Biogeographic Regionalisation for Australia subregion ('Western Sydney'). Large bodies of water are the best ways of cooling, but what is not evident in this table is that they would inculcate problems in maintaining storage and they may emit heat at night. Of all the other ephemeral types of water bodies, the intact Chain of Ponds significantly reduces heat relative to degraded (incised/channelised) streams or urban streams. Note also that the data belie the benefits that a Chain of Ponds brings in terms of biodiversity and water quality, compared with other types of water bodies.

Table 1. Average land surface temperatures (LST) in degrees Celsius

Geomorphic creek type/river style	LST (degrees Celsius)
Water storage (dam or weir)	30.3
Chain of Ponds	31.1
Channelised stream in a degraded Chain of Ponds	31.9
Planform controlled, low sinuosity, natural surface	32.2
Urban stream – highly modified, concrete	35.9

Source: LandSAT 2022–2023

Ground truthing

Current cartographic and aerial photographic data offered clues on the most appropriate locations for intensive case studies of relatively intact systems that might provide, at a later date, a more detailed inventory of exemplar sites across the Plain. But the Cumberland Plain is notoriously gridlocked by private landholdings, the legacy of some of the first land grants by Governor Philip in the late 18th century (Rogers et al, 2025). So when, as a preliminary exercise, we ground-truthed three local systems, we chose locations not only because they were meadow-like, but also because they were readily accessible. These three examples served as the starting point for examining the condition more broadly.

Within the Defence Establishment Orchard Hills, an ephemeral 'gilgai meadow' was evident as a 1-hectare meadow of grass species ringed by Cumberland Plain Woodland of *Eucalyptus tereticornis* and *Eucalyptus amplifolia*. While not a Chain of Ponds, the meadow has vertosolic soils that perform a similar function by absorbing and holding water during wet seasons, a process that naturally prevents the establishment of trees and shrubs. This environment also shares many of the wetland flora native to Cumberland Chain of Ponds meadows, including *Eleocharis cylindrostachys*, *Craspedia variabilis*, *Isotoma fluviatilis* and *Lachnagrostis aemula*.

Nearby was a section of Blaxlands Creek that was formerly a Chain of Ponds meadow but is now incised (figure 2). Erosion has exposed the soil profile, which reveals the semi-porous alluvium material above the dense clays derived from Wianamatta shale, suggesting that this place once supported a Chain of Ponds meadow.

The interrogation turned to a functional Chain of Ponds, which had recovered after urbanisation. An excellent example is at Harrington Grove (figure 7), a new suburb developed in 2015, where residential houses have been built in a configuration that retains a 150-metre-wide buffer of regrowth woodland and forest along Cobbitty Creek. Residential runoff is fed into a 1.5-megalitre bioretention basin, which releases filtered water slowly into the creek. As a result, the historically incised Cobbitty Creek has begun a process of natural recovery toward a Chain of Ponds function, structure and character. Notably, silts are gradually re-sedimenting, ponds are re-forming, *Eleocharis cylindrostachys* and other Chain of Ponds meadow flora are colonising the creek, and natural dieback of regrowth sapling trees is occurring on grounds that have rehydrated.

Protected by bioretention basins from any urbanised concentrations of water flow, and with minimal human-led deterministic design, Cobbitty Creek is therefore a passively recovering Chain of Ponds system. This is a harbinger of what may be possible, indicating how ancient in-place systems have a tendency to adapt and why the regeneration of Chains of Ponds might be possible in urbanised areas and specifically in the Cumberland Plain. But it is only one small example. For such recovery to be effective in addressing the much more widespread issue of urban heat, further work is needed to investigate how this might recur across a network, and how the cooling effects can influence nearby urbanised precincts.

Figure 7. The recovering Chain of Ponds meadow at Harrington Grove is identifiable by its clean, shallow water, diversity of ground-cover plants, and the dieback of trees caused by the elevation of the water table. The tracings of mist in the background indicate the relationship between groundwater and a cool atmosphere (image by Penny Allan, 2025).

Discussion

Two main discussion points from this work may be salient to regenerating Chains of Ponds as part of Western Sydney's urban expansion.

Critical mapping

While we recognise that mapping is an instrument of those charged with acting in geospatial terms, critical mapping is a way of reading a landscape and its systems. By piecing the parish maps together (something that the nineteenth-century surveyors did not or could not do) and then re-interpreting them with later geospatial information, we could gain a new understanding of the whole landscape. Just as the nineteenth-century maps appear to be, our reassembled and collated remapping is objective. However, it is also inherently critical of the piecemeal mapping of parishes, which served to atomise the landscape through land division. With LandSAT data and GIS, we are using new tools to map old systems. The approach belies the idea that new technologies catalyse new solutions. To the contrary, what this work shows is the potential for new tools to re-read landscapes as their own broad network.

The mapping shows the value of having a deep understanding of the story of a landscape system that is inherently fragile and unfortunately smothered by the processes of colonisation and urbanisation, which is so commonly evident in the Antipodes. Re-making the composite parish maps and then ground-truthing reveal both the detailed and the broad-scaled landscape systems that operated and might continue to operate here. This mapping process is a powerful tool to reimagine this landscape's role in urbanisation. It enables a rekindling of landscape systems, not for some nostalgic revival, but to respect their intrinsic resilience and adaptability, and what that might offer to future urbanisation and the liveability of Western Sydney.

Making space to cool down

Our literature review revealed that connected networks of blue-green infrastructure are an effective way to mitigate heat. Our mapping shows that networks of Chains of Ponds are dispersed throughout the Cumberland Plain, and our ground truthing at Harrington Grove shows their regeneration is possible. These pieces of evidence can be connected in a

place where urbanisation is inevitable, and that experiences some of the worst heat effects in Australia, to show that the role of Chains of Ponds as a heat-mitigating performative entity is compelling. But to focus only on regenerating Chains of Ponds may be overlooking other hurdles that must be addressed if this is to be a sustained solution to urban heat.

One of the significant hurdles that faces any regeneration of Chains of Ponds is that most of them exist on privately owned land, and different authorities manage or own different parts of the system, creating an uncoordinated approach to managing any regeneration. Another issue is that local development codes and town planning instruments prescribe floor to space ratios (FSR), which usually limit built area in relation to site area, and deep soil percentages where soil profiles connect with the ground plane on a lot-by-lot basis. Herein is little nuance about the land's potential to integrate water systems that could feed Chain of Ponds systems. FSRs leave the management to individuals, who may not act on landscape in community-minded or ecosystems-centric ways. Moreover, economies of scale in building encourage a business-as-usual approach to housing and factory, which invariably results in large-format buildings with some left-over deep-soil landscape. This suggests that an effective approach to regenerating Chains of Ponds must involve all the actors and institutions in Western Sydney.

In the subtleties of the fragile Cumberland Plain, a landscape-led approach is unlikely to be productive if landscape systems are not fully understood for their regenerative potential. What may be apparent is that the optimum approach to landscape and urbanisation needs to involve the whole catchment. Because Chains of Ponds were once a widespread network across the Plain, and because they sit in a delicate balance that may not necessarily accommodate generic solutions, they present a case for acting differently. Perhaps there is a need for different development policies to support the regeneration of Chains of Ponds, or different building designs that involve less slab on ground, and more water-sensitive built-form articulation. And perhaps there is a need for a recognised planning instrument that gives space to a Chain of Ponds. Making space allows a Chain of Ponds to exist in its own right.

Conclusions

Peter Andrews, in his seminal book *Back from the Brink* (2006), describes Chains of Ponds as fundamental to the resilience of the Australian rural landscape. Charles Massy (2017) explains that, because the country is often prone to drought and flood, and the soils have compacted over time, Chains of Ponds in water corridors have co-evolved in a natural sequence with the flora and fauna to keep the land moist and habitable. Both these authors write with knowledge of Australia's inland climate, soils and hydrology in order to reconfigure Australian farming practice. In doing so, they share knowledge that Chain of Ponds systems are inherently adaptive and, if healthy, can generate resilience for the landscape.

This paper suggests that this knowledge may also be inherently applicable to the landscapes of cities. The hypothesis that we put forward is that, rather than inventing new engineered systems of water management, and rather than trying universal technologies to deal with heat and water, there is potential in endemic geomorphic water systems in places like the Cumberland Plain that can not only contribute to urbanisation, but also care for the landscape systems themselves. Through this adaptive coupling, a healthy landscape and a healthy city can each make the other more resilient.

In this research, we have described how European land-use practices have degraded Chains of Ponds. We have seen through the mapping of the Cumberland Plain that its historical Chain of Ponds system was both extensive and prolific, and that by remapping we can look at this landscape as a regional working system, rather than one threatened by its geomorphic basin and anthropogenic acts. Further, through some grounded evidence we have shown that it has potential to be re-established as a working system, as long as it has the space needed for ecological function. This suggests that rather than interpreting the regeneration as a discrete component of land development on a distinct

parcel of land, what is needed is a whole-of-place concept. If Western Sydney's future urbanisation is to be landscape-led, it is necessary to ensure that landscape is not just a spatial concept, and not just a structural device, but also one that encourages a landscape ecosystem to function effectively.

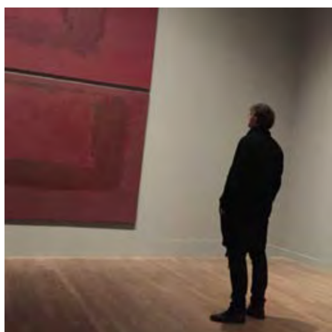
But there is more to do. We know the research reported here is at the tip of what needs to be explored. We know that a remit to expedite development means that time is running out to address the social-equity demands for housing and the industry demands for the new aerotropolis. Addressing these demands presents a need to learn more about this landscape from the stories and archaeology of the campgrounds of First Nations peoples in the Cumberland Plain. There is a need to interrogate further the evidence of surveyors who developed the parish maps and, concurrently, the flaws in the persistent colonial knowledge constructs of these systems. There is a need for further on-ground studies and piloting to determine how Chains of Ponds adapt to the diverse soil conditions and microclimates across the Plain, and how they might regenerate and redevelop biodiversity. Further, we need to model how Chain of Ponds systems can generate cooling effects that operate across the region.

This list of urgent needs may be long, but perhaps even more pressing is the need to recognise and protect Chains of Ponds in the Cumberland Plain. As yet, there is no official policy to protect them. A key barrier to protection is the current lack of any official classification of this ecosystem. No government programme has mapped Cumberland Plain Chain of Ponds meadows or officially categorised this ecosystem, and they are not included in the official NSW plant community types database (NSW Department of Planning and Environment, 2023), which is used to assess land clearing proposals and biodiversity offsets. Similarly, while Cumberland Plain Chain of Ponds meadows clearly meet the International Union for Conservation of Nature criteria for a listing as a Critically Endangered ecological community (Bland et al, 2017) and associated NSW and Commonwealth Biodiversity Conservation Act listings, no application for a protection listing has been made under any biodiversity protection schemes.

Official classification and a Critically Endangered listing would significantly assist efforts to conserve and restore this ecosystem. Such recognition would lead to work that is fundamental to urban resilience. Seeing Chain of Ponds networks as integral components of urban development might enable their wet meadows to mitigate urban heat. Moreover, the beauty of these landscapes might encourage urban communities to connect with and care for them.

About the authors and collaborator

Penny Allan is Professor of Landscape Architecture at the University of Technology Sydney (UTS). She has spent the last eight years teaching and researching on landscapes and resilience on the Cumberland Plain, with NSW coastal water bodies and their local communities, and on a catchment-wide collaborative governance approach to river health with the Living Lab Northern Rivers. Together with Martin Bryant, she made two short films about adaptation strategies for coastal communities affected by fire and flood, which were exhibited at the Venice Architecture Biennale in 2021.



Martin Bryant is Professor of Landscape Architecture at UTS and an architect, urban designer and landscape architect who has expertise in connecting building, urban and landscape design with ecological principles and the characteristics of resilience. His knowledge draws on four decades of experience in award-winning research and professional projects, as both an academic and a practitioner. He is currently Director of the UTS Green Infrastructure Lab and is working with the Living Lab Northern Rivers on numerous projects in the flood-affected region.

Peter Ridgeway is a conservation ecologist specialising in conservation and restoration of the Cumberland Plain. He has led over 200 on-ground restoration projects in Western Sydney and dozens of government–industry partnerships, as well as providing professional advisory services to local, state and federal agencies. Since 2020 Peter has been leading partnerships to further the understanding and recognition of Cumberland's unique Chain of Ponds meadow ecosystems. He is a research fellow at UTS, is a partner in a University of New South Wales School of Ecosystem Science grant investigating the paleoecology of Cumberland Chains of Ponds and, with the Soil Science team in the Department of Climate Change, Energy, the Environment and Water, is investigating soil properties of Cumberland Chains of Ponds.

Andrew Toland is a senior lecturer in landscape architecture at UTS. As a transdisciplinary scholar of the natural and built environment, he focuses his research on the capacity of architecture to change how we view and understand our environmental realities. Andrew's work explores the cultural dimension of technological practices, large-scale landscape modification and infrastructure, and their normalisation in our everyday urban and natural surroundings. Collaborator Nathan Galluzzo is a research assistant and PhD student at UTS School of Architecture.

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Environmental weeds beyond control within a drinking-water catchment (image by author, 2025).

Weeds, war and reconceptualising nature in Aotearoa New Zealand: a provocation to theorists from a practitioner at the coalface

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Warning: This essay contains disturbing ecological forecasts and challenges to mainstream cultural attitudes towards weeds, our idea of nature, and the future management of native forests in Aotearoa New Zealand. It argues for dismantling popular but inadequate environmental dogmas, which will be galling to many. However – *spoiler alert* – it concludes, optimistically, that environmental weeds will ultimately force us to create more robust conceptions of nature, and pragmatic management approaches. In short, it will be good for us, even if we hate this prospect at present. And no, the word *hate* is not too strong. (I predict the strongest reactions will come from those who love native forests the most. And I sympathise completely.) Let's cut straight to the nub. An insurmountable environmental weed problem is coming to rural Aotearoa New Zealand. It won't be beaten by chemical or biological warfare, updating noxious pest-plant lists, mobilising the unemployed, volunteers and high-tech drones, or planting native trees. This apprehension is based on observations and decades of professional experience and has led to my premise that it's a battle that can be won only with a change of mindset. Environmental weeds will eventually force us to reconceptualise 'nature' in Aotearoa New Zealand.

Introduction

KEY WORDS
weeds; native; exotic; invasion; war; novel ecosystems

It is well substantiated that some weeds can threaten the native ecosystems providing important biodiversity that ultimately underpins life on Earth as we know it (and that we want to continue). In dry, sciency terms, displacement of indigenous flora and fauna by exotic species can have significant adverse effects on local ecologies – possibly triggering a cascade to collapse. Weeds and pests can also have significant economic impacts and affect cultural landscape values, including perceptions of natural character. Colloquially though, the weed threats to native forests are described calamitously, and responses adopt the language of war. And it's these popular attitudes that are my target. For as much as it terrifies me, I consider the war on weeds is unwinnable and, therefore, the war-like attitude is simply inadequate. It's a shonky dogma that needs reforming.

Another forewarning: Part of the rationale used in this essay unconventionally links prevailing contemporary conservation attitudes towards weeds with negative impacts on our mental health and ability to enjoy our landscape.

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Figure 1. Weed upon weed (image by author, 2025).

The present situation

Some facts

- Aotearoa New Zealand now has more exotic plant species naturalised (that is, reproducing in the wild) than indigenous plant species – 2,390 exotic versus 2,158 native, as at 2008 (Howell, 2008).
- In 2008, the Department of Conservation published a consolidated list of 328 exotic vascular plant species considered to be environmental weeds (Howell, 2008). Given the rate of new naturalisations and latent offenders, the list was expected to grow annually.
- Up until 2021, just 11 exotic plant species introduced since the start of European settlement are believed to have been eradicated from the whole of Aotearoa New Zealand (Parliamentary Commissioner for the Environment, 2021, p 115).
- Old man's beard (*Clematis vitalba*) can produce over 35,000 seeds per square metre (ibid, p 50).
- Each fluffy tuft of pampas (*Cortaderia jubata*) averages one million seeds in its first year (New Zealand Plant Conservation Network, nd). Some seeds travel up to 50 kilometres on the wind.

Some experiences

Pampas grass is a cutty-grass sometimes erroneously mistaken for toetoe. It trucked its way into our neighbourhood within the roading metal. Twenty years later, it now forms impenetrable verges, swishing literally billions of seeds to the breeze. It has invaded every fringe of bush, as well as every roadside cutting, slip, firebreak and pine cutover, in the area. I pull young sprouts out on my tracks and note where to come back with a knapsack sprayer.

Two years ago, I discovered the first sneaking pup of the dreaded weed, Kahili ginger (*Hedychium garderianum*), within my beloved forest. It was an emotional body blow. I felt sick with shock and heavily defeated. Yet, hadn't I always known this day would come? Birds were always going to trickle the seed in from the unconquerable local infestations beyond my boundaries. Last week I found four more ginger pups. It is simply a numbers game and a function of time. Words like 'innocuous' slip sideways into 'insidious', 'incremental' bends into 'exponential', 'shade-tolerance' adjusts its grip to become 'smothering', and 'manageable' gradually morphs into 'the impossible'.

We are surrounded by thousands of hectares of steep, scrub-covered farms, lifestyle blocks and reverting bush. None of our neighbours has the time and resources, nor the physical ability to be crawling through their thick gorse and pampas infested patches, searching for the first incursions of new local weeds like ginger, moth plant, brush wattle, privet and Taiwanese cherry. And even if they did, what about all the other existing weeds? Waves will follow waves – 'and still they come'.

A musically talented ecologist might rap out the contemporary hit list in song:

> Bind weed, devil weed, tobacco weed, giant reeds, bat-wing, banana passionfruit, bamboo and tree privet too. Chinese privet, African club moss, jasmine, Japanese honey suckle, English ivy and morning glory ...

Or maybe the botanicals like *Selaginella* sound more sinister, and *Azolla* for a more monstrous fear*?* '*Aristea, Cotoneaster, Elaeagnus*, *Agapanthus* and ...' The hits go on.

The flurry of new dwellings on our road has unleashed more invaders. When first visiting one of our new neighbours, I pointed out a furtively fruiting moth plant vine (*Araujia hortorum*) amongst the gorse on the side of a neighbour's driveway. Presumably it hitched in with the earthwork machines. This is a devastating weed around anyone's neck of the woods – and it is terrifying to find it around mine. Moth plant, or kapok vine, is tolerant of sun, shade, dry, wet, wind and salt, and is resistant to grazing. It rampantly clambers over the canopy producing numerous choko-like pods, each releasing 250 to 1,000 wind-dispersed seeds (Weedbusters, nd). Its sap is poisonous and it's very hard to kill. Roots break off when pulled. Fortunately, our new neighbours are very nice people and were genuinely concerned to learn of it. However, they have an aversion to the use of herbicides, and with a building project demanding most of their focus and energy I worry that this one will get away from them.

Drive around the old settlements of Hokianga with an ecologist's eye and you will see the result of past ignorance of the propensity for exotic species to naturalise and become pest weed infestations. These days, enthusiasm rather than ignorance is probably more common. People tend to overestimate their ability to keep control of their garden menageries and underestimate the likelihood that their changing and unpredictable health, finances or life circumstances will curtail their capacity to successfully do so. Such optimism is a remarkable and loveable human trait, but nevertheless delusional, and in the context of the unfolding weeds crisis, it should be called out as such. However, not everyone shares my values, preferences and fears for native forest – even those living out in the bush.

'Food-forest' has become a term that strikes panic in me. This year was the first time I noticed loquats invading my forest. Kererū keep planting them beneath the pūriri trees. I've pulled out hundreds of them, but I can't get around all the trees of my forest. This will become yet another unsustainable effort. When I told the food-forester who I suspect to be the source of this new weed invasion, he said, 'It's good. It's food.' His response was similar when I found a banana passionfruit vine. I worry now about his guavas too. Pandora's box is busted wide open. Clearly, there are many more fugitives to come.

*

Of course, I'm seeing this all too dark. Just like the needless self-doubts the early climate-change scientists had. Whistleblower, crackpot, down a rabbit hole, or just stuck down paranoia street?

Some people point to successful pest-plant control efforts. But generally killing off one weed species just provides opportunity for another or restarts the process. Where natives do displace the weeds, the question remains: how will they fare in the face of incessant future invasions – how sustainable or enduring was the control effort? Funding must be ongoing to keep our feet on the throats of these dogs when they're down. One battle won't win the war.

For many of our messed-over, modified landscapes, weed species dominate, co-dominate, or are at least an inextricable fibre of the vegetation matrix. The popular

dichotomy of native forest as something pure and distinct from a mix of native and exotic vegetation doesn't really exist any more in many landscapes, and it certainly won't in the future. Eventually, not even the giant Puketī, the largest block of pure bush in Northland, will be immune. Ginger, *Tradescantia*, *Aristea* and other shade-tolerant weeds are all around the edges and already infiltrating its veins. Given the leverage of numbers, time and scale, overlain on steep terrain with few roads or tracks, and hopelessly thin budgets, the weeds will wriggle in. Just like ginger is already doing around the forests of Warawara and Waipoua. Don't worry; be happy.

Under the long white cloud – the temperate blanket and vapours of Aotearoa – Northland provides a particularly fecund climate and incubatory cover for these ecological counter-cultures. In many places, the scale of the existing weed problem is already unmanageable and any expectation to achieve landscape-scale eradication is delusional. However, it is the inevitable and exponential future trajectory that is my key point. In this respect, I believe Northland is the canary in the coalmine, and the losing battlefield that foreshadows the future for the whole country. Someone please tell the generals and work out what this means.

Figure 2. Tree privet, Taiwanese cherry and wild ginger already infest local pine forests at an unmanageable scale. Drones won't help with this (image by author, 2025).

The language of war

I'm not the first to notice the hallmarks of hate speech when New Zealanders get going on weeds, pests and predators. Nor am I the first to sense that this fervour has some connection to contemporary social ideas about the value of indigeneity and a cultural sense of belonging (Steer, 2015). To this end, planting native trees and fighting exotic weeds has become an ideological cause. A post-colonial guilt salve perhaps? And, in this cultural construction, there are clear goodies and baddies. Natives good, exotics bad. We all want a simple world. Gimme a target!

In 2015, Maggie Barry, the then Minister of Conservation, announced a 'war on weeds' and encouraged New Zealanders to roll up their sleeves and join in (Department of Conservation, 2015). In 2016, she identified the 'Dirty Dozen' – weed species to receive targeted extra funding. The campaigns against weeds were complemented by government policies for a predator-free Aotearoa New Zealand and to plant a billion trees – two-thirds of them native. Indeed, the initiatives are intertwined. Under the heading 'A billion trees

and a trillion weeds', Farah Hancock of *Newsroom* pointed out, 'Planting trees is only part of the battle to scale up native tree regeneration efforts. In order for the trees to thrive, a war must be waged on weeds and wildings' (Hancock, 2018).

Killing for conservation has been described as a 'national pastime' in Aotearoa New Zealand (Linklater, 2017). Running over possums is practically part of our national identity (White, 2016). War-talk rolls easily off New Zealanders' tongues, and we are encouraged to be weekend warriors. Despite the atrocious connotations, the language of war seems to be totally acceptable for use in these environmental circles and for these environmental purposes. But what are the ramifications of living in such a war-torn country?

Oversimplifications, half-truths, omissions and demonisation are common features of war propaganda. Should we be concerned when these same strategies are used in our environmental campaigns? In 2017, Dr Wayne Linklater, Associate Professor of Ecology at Victoria University, wrote about his discomfort with a Brownie's guidebook recommending his eight-year-old daughter make a poster to advocate the killing of exotic species (Linklater, 2017). This highlights how prejudiced language and attitudes against weeds and pests can creep in to our thinking and pervade it more widely. I have often heard incredulous reactions to others' complaints about cutting down trees: 'Why [are they complaining]? It wasn't a native', as if exotic species somehow cannot also be magnificent living beings. Who refuses to marvel at the buttressed roots of a 147-year-old Moreton Bay fig in Kororareka, Russell? Do we really want the redwoods in Rotorua to be killed by zealous Brownies?

Dr Linklater wrote, 'I don't like them [children] being taught to demonise an entire species of animal, … I'd like my daughter to have empathy much more than I want her to have a reason and willingness to kill.' I can relate to this too. Once, as I was about to put down a wild tomcat in a cage trap, my own five-year-old daughter came lashing out at me in distress and desperation. 'It's not his fault! He can't help being born a cat. He wants to live too! How would you like being shot?' Of course, I countered with a cold ecological rationale. Yet all her points were valid and true, and I told her so. Then, not wanting my hard-nosed dogma to crush something so young, so beautiful and so precious, I let the cat go. The inability to reconcile our popular environmentalist attitudes with some other important value-sets still troubles me.

A paper titled 'Native vs exotic: cultural discourses about flora, fauna and belonging in Australia' (Trigger and Mulcock, 2005) sets out:

> Isis Brook, an environmental philosopher, cautions that 'debate around invasive species needs careful handling for both ecological and social reasons'. Like other writers, she notes that 'the rhetoric of invasion and degradation [can] apply both ecologically and culturally', and that 'nativism in ecology' can be uncomfortably linked to racism.

What exactly are we teaching our Brownies and budding Girl Guides in Aotearoa New Zealand?

*

In social spheres, we've been progressively trying to expunge language, labels and attitudes that foster and support such things as wars, slavery, cruelty, cultural imperialism, racism and sexism. Yet in our environmental war campaigns we still use language and attitudes that, if applied to social or cultural matters, would be criticised, and condemned as being discriminatory, divisive, dangerous, toxic and totally unacceptable. Surely some sort of a double-think is occurring here. On one hand, in the wake of the abhorrent Christchurch mass-murder, slogans reassured us that 'we are not like that', but, on the other hand, when it comes to some things, like certain plants and certain animals – oh, in fact, we are.

Aren't we humans amazing harbours of brilliance and blindness? At one level, our top scientists try to reconcile the least accessible and most intricate discrepancies of the universe. Yet, nearer the surface and much closer to shore, the discord between our

environmental and social attitudes goes unchallenged. Who is calling for this conversation apart from a few concerned ecologists such as Dr Linklater? I guess it requires an avant-garde in the first instance or, in the absence of that, this role often falls by default to artists and outsiders. In respect to our societal attitudes towards exotic plants and our war on weeds, famous artist and Austrian-born New Zealander Friedensreich Hundertwasser definitely had something challenging to say.

Hundertwasser

Friedrich Stowasser, the name he was born to, experienced the true horrors of war and discrimination as an adolescent half-Jew in Austria under Nazi rule. He joined the Hitler-youth as a cover, while his Jewish mother, auntie and grandmother hid in the basement. At not quite 10 years old, it fell on him to deflect the SS-youth commanders at the house door (Harry, 2005). Unfortunately, not always successfully. His auntie and grandmother were taken and never seen again. He and his mother survived, but in constant fear of denouncement. Later, as an artist, he changed his name to Friedensreich Hundertwasser and eventually the internationally renowned architect-artist very proudly became a citizen of Aotearoa New Zealand. He gifted a koru-inspired flag design to the nation, proposing it as a second flag – not a replacement (Hundertwasser, 1983). An accompanying design manifesto explained, amongst other things, that the flag represents peace with nature. Yet, when I had the privilege of visiting Hundertwasser's property, Kaurinui, near Opua, I found his frame on 'nature' confronting.

What I saw was a hodgepodge pizza of unrelated plants, including many weeds, all incoherently poked around the bush and let free. I couldn't enjoy it. And I've worried about that response ever since. What threatened me most was his obvious indiscriminate appreciation of plants irrespective of their whakapapa, weeds and all. He didn't divide nature by human classifications or prejudices. This comes out in his writings on ecology: 'It is your duty to use all means to help spontaneous vegetation be instated in its rights' (Hundertwasser, nd).

The third tenet of his 1983 Peace Treaty with Nature is 'Tolerance of spontaneous vegetation'. He refined this theme over the decades. 'There are no evils in nature …' and 'When man thinks he has to correct nature, it is an irreparable mistake every time. A community should not consider it an honour how much spontaneous vegetation it destroys …' (Hundertwasser, 1990).

It seems, from people who knew him well (Noma Shepard, pers comm, nd), that he took great delight in weeds as 'spontaneous vegetation' and a pure expression of nature.

Unfortunately, there is plenty of history to support Hundertwasser's conviction that our meddling with nature usually is an ignorant mistake. For example, I recall a story in the *New Zealand Herald* (2023), titled '"Drastic" rat tactic to fight messy birds in wetland', about Rotopiko, a small lake in Waikato, with a predator-proof fence. Rats had been eradicated within the area and, consequently, local bird populations greatly enjoyed roosting in the safe zone created. As a result, the estimated population of starlings grew to over 500,000 and their defecation began eutrophying the lake, ruining the freshwater habitat. The managers reintroduced 30 rats to deter the birds! Reality close to satire. Reintroducing browsers in *some* places to help control weeds is no longer inconceivable to me.

Hundertwasser's hands-off approach is presumably based on the belief that nature will find a dynamic equilibrium. Other artists and authors (for example, Thomas, 2014) also argue that, in time, we will reach that elusive state where we can all comfortably call ourselves 'native' in a newly balanced ecosystem that includes us all – Māori, subsequent settlers and immigrants, and all the plants and animals we have on board. However, I understand most ecologists have abandoned outdated notions of equilibrium and now talk more about non-equilibrium, unpredictable fluxes, and open-ended systems. Hundertwasser was an artist first and foremost, as well as a thinker and an activist, but not a trained ecologist. Nevertheless, I am deeply envious of how he could see sublime beauty where I winced my eyes at an incoherent environmental mess.

The ideological congruency of his ecological activism with immigrant-friendly and anti-discrimination social policies still somehow feels important. Given Hundertwasser's traumatic formative years, this not only makes sense, but makes it much harder to dismiss. Dare we suggest he lacked prejudices against exotic weeds only because he wasn't a *true* New Zealander? His Peace Treaty with Nature has no prejudices, no hate and no futile war. It is a gospel offering alleviation to depressed environmentalists and perhaps a salving absolution for the descendants of immigrant settlers too. Of course, I had to try it out.

The small town of Kawakawa was already adorned with a public loo designed by the famous artist and, years after his death, a community trust had an expansion project under way – Te Hononga, Kawakawa Hundertwasser Memorial Park. Inevitably, this became a multifunctional thing; a Hundertwasser tribute with a community cultural service centre, plus visitor facilities, all conflated to 'embody the joining of cultures'. I was invited to offer my services for its landscape design. Spontaneous vegetation, here I come!

The landscape concept I presented to the trustees was radical but, I believe, robustly based on Hundertwasser's writings. I related what I understood from his various manifestos, his delight in weeds as an expression of nature 'uncorrected by man', and his lack of species-based discrimination. Alarm rose noticeably amongst the sideways glances of the trustees. Ploughing on, I described a wild, unkempt aesthetic and the handing over of total freedom to nature. The feature piece should be a raised area of fresh, raw earth, laid open and bare. It would be receptive to the vagaries of contemporary nature, chance and time, creating a living sculpture, a real-time real-life nature show, from the earliest germinations through to scrummaging battles between weeds, trees and vines. It would be the celebration of spontaneous vegetation that he wrote so fervently about.

One panel member, who had known the artist well, seemed to nod in support, but the others appeared to be embarrassed by this preposterousness. Later, I heard it had polarised the panel and they chose a safer option. I wasn't disappointed or surprised. Maybe I was even relieved. It probably saved me from infamy and hatred. While intrigued by this ideology, I was never a true convert. There are issues with the doctrine. It is hard to reconcile it with any responsibility to protect indigenous biodiversity. Furthermore, in Aotearoa New Zealand, Hundertwasser's Peace Treaty with Nature must be subjugate to a much better-known treaty.

Te Tiriti o Waitangi

It has often struck me as odd that many Māori, even those with hard anti-colonialism sentiments, frequently still have exotic garden plants around their houses and farms. But then when I think about it, Māori were always keen adopters of introduced things, from pigs and potatoes to the latest technologies and media. On Matariki weekend in 2024, Kai Tahu artists used computer-controlled drones for a lightshow spectacle in Logan Park, Dunedin. Māori tend to accommodate things and make them their own.

The same inclination is echoed at a landscape scale. For example, when the government proposed removing exotic forest species, such as pines, from the 'permanent forest' category of the Emissions Trading Scheme, Ngā Pou a Tāne – the National Māori Forestry Association vociferously protested. What a remarkable situation. Here we had environmental non-governmental organisations fighting for native forests only, while some Māori were proclaiming their exotic forests as taonga and evoking rights under Te Tiriti o Waitangi – the Treaty of Waitangi to protect them. Presumably achieving social agendas was the main reason behind that. However, this focus also reflects the priorities set out in one of the best-known Māori proverbs:

> He aha te mea nui o te ao?
> He tangata, he tangata, he tangata.
>
> What is the most important thing in the world?
> It is people, it is people, it is people.

It's not the first time I have noticed tensions between Māori and western-influenced conservation ideals. Counterintuitively, it is Māori who are often the more willing accommodators of introduced species and of their consequences. I assume this reflects cultural differences in construing and valuing nature in our landscapes; Māori thinking of themselves and their actions as part of it – and not necessarily a desecration. Kaitiakitanga (guardianship) isn't angling at some unattainable pre-human state of purity.

Rob McGowan, a trustee of Tāne's Tree Trust, interprets the Māori word 'mauri' as the web of life-sustaining relationships and connections between all things and that allow us, both humans and Papatūānuku (Earth mother), to thrive. He is more concerned about healing the land by restoring a functional ecology than about whether all the plants serving that purpose are purely native. It's the relationships that are important. Similarly ethnobiologist Dr Priscilla Wehi seems to suggest that, when dealing with invasive alien species, and when eradication is impractical, indigenous philosophies could 'create new, shared space by centring relationships, fulfilling responsibilities and realising justice' (Wehi et al, 2023).

There is an honesty associated with this approach and a useful pragmatism too. Moreover, it seems that Te Tiriti doesn't preclude accepting introduced species and hybrid landscapes. Indeed, it may even be the conceptual basis to legitimising them.

I'm not going to take this idea any further. It is a matter for experts and much wider debate. The key question posed here is simply whether reforming delusional/popular environmental ideals and adopting an alternative concept of nature, perhaps more like the Māori one, could help us come to terms with our bogeymen – the weeds? Because come to terms with them we must – somehow. It's a matter of mental health. Mine at least!

Mental health

The main idea of this section follows a fine vine of suspicion down into the understory. Like a fishing line tangled in kelp, it might be unsound and break. But I'm not claiming it to be science or anything more than relating my own troubled thoughts and experience. It tugs in this direction; that priming an eco-warrior with fears and for warfare is bad for his brain. His sniper's eye will reinforce neural pathways that do see, in fact, the enemies are everywhere and even more than before. And his creaking knees know there will be no end to this war on weeds. Repetitive exposure to such negativity is adversely affecting his happiness, while others blissfully enjoy the very same landscape.

Symptoms of his affliction commonly include an up-then-down, joy-then-frown emotional pattern. For example, when driving around the countryside, it frequently goes like this:

> 'Wow, that's quite nice [Romantic bucolic scene].' – Oh-oh,
> Yo-yo, 'Shit! Look at all the bloody ginger there!'

Other situations involve more prolonged stress. For example, when he is visiting new friends for the first time, they proudly show off their extensive gardening activities. His face sets a mild smile and a compartment of brain somehow keeps conversation going, masking his quiet despair at what he sees – another malignant cell in his beloved country. He feels bad about being such a serious killjoy. His soldier's eye keeps spotting the enemy, and wishes he could instead be that happy and fun person. Pour the wine please.

While this is a personal malaise, shouldn't we be questioning to what extent popular environmentalism has shaped this thinking? Environmental author Bill McKibben (2006) posits, 'All we can do is make it less bad than it will otherwise be' (cited in Marris, 2011, p 55). What an inherently negative and dystopian worldview. Is this feeding anxiety to our kids, and depression in my generation? Surely, doubts should dog all dogmas, especially if they are based on fear, propaganda, discrimination, negativity, romanticism and doomsday forecasts, as the war on weeds is.

I feel it is time for its reform.

*

Some inspirational environmentalists, such as the late Jane Goodall, say we have a responsibility to remain 'stubbornly optimistic'. As a pessimist, I totally agree. When confronted with a hopeless situation, it is the heroic course and choice. However, where does the brain fit into this? Should we remain stubbornly deluded about winning an unwinnable war and restoring an imaginary 'nature' unsullied by human history? Or should our stubborn optimism be channelled somewhere else, somewhere more effective, and where could that be?

My personal experience suggests we need to create a less problematic and more positive popular environmental paradigm. One that can accommodate history, Te Tiriti, constant change and unpredictability. One that knows our ignorance and the dangers we pose, yet still allows us to be part of nature, and take up heroic roles for her protection and regeneration. One that fosters positive language, positive thoughts and hope.

Intuition is my compass here. And I feel like I'm on the cusp of something.

Figure 3. In some pine forests, native understories are regenerating quite well – including seedlings of native canopy trees – but they are not without weed species too (image by author, 2023).

Novel ecosystems

I promised this essay would end optimistically because I do see dots and trails on the horizon, flightpaths of hope to follow. Ideas and terms such as 'novel ecosystems' (Hobbs, Higgs and Hall, 2013), continuous cover or 'close-to-nature' forestry, regenerative agriculture and adaptive management. And papers such as 'A nature-positive future with biological invasions' (McGeoch et al, 2024). These collectively orientate in a new general direction to reconceptualise nature and its practical management. Heads and beaks swing further away from the shoulder. Language veers slightly from nostalgic 'restoration' toward the more open-ended idea of *regeneration* and resilience.

Hinewai Reserve on Banks Peninsula is an example of early inklings. In theory, it was nothing new, just basic forest succession 101. But it proved that working with gorse rather than fighting it can be a successful strategy. This is a small but fundamental mindset shift from all-out-war mode. Mentally, I imagine it was also a far more positive and healthy perspective for the hands-on manager, Hugh Wilson. After more than 30 years, he has neither burnt out nor been defeated – but the gorse has been.

Such ideas can be translated to other situations. A local example for me relates to a Māori whānau (family) trust. A failed pulp-industry venture left their whenua (land) with 50 hectares of wattle forest. These wattles are aggressive weeds and an anathema to the trust's kaitiakitanga. Bulldozing them and replanting with natives was their desire. While I sympathised, I certainly couldn't recommend it. Obliteration now, no matter how intense the rage or weaponry, is simply unachievable. The wattles would resprout thick as a wheat field and quickly choke out any natives planted. But this is a story of hope, where preposterously (again), I'll forecast that one day this whānau may look back at this weed predicament even as a kind of blessing.

My confidence sprouts from observation and theory. From the roadside, their forest is a total monoculture of wattle – an exotic invader. However, within the forest, amongst the leaflitter on the floor, and between the many shrub weeds of the sub-canopy, there is already a multitude of native plant seedlings regenerating. Tōtara, pūriri, tānekaha, taraire, makamaka and even kauri seedlings, along with nīkau, patē and ferns, all appear quite healthy. The wattles are providing a 'nurse-cover' role that would otherwise be performed by natives such as kānuka. Nothing suggests the natives won't chug on up through the understories. This is just the simple and well-accepted process of forest succession. Nothing ground-breaking here. Just the balance of time.

Contentiously, I'll speculate that the wattles even offer some distinct advantages. They are nitrogen fixers, adding fertility to the impoverished gum-land soil. Their wispy crowns let plenty of light in to allow regeneration and seedling growth. Furthermore, the wattles have a much shorter life-expectancy than kānuka. Muscular natives such as tōtara, kauri and pūriri will have no trouble elbowing their shoulders up through the wattles and they will develop clean straight boles as a result. Shade from a mixed native–exotic understory will preclude the regeneration of wattles and ensure a successful transition from a wattle infestation to a new and predominantly native forest.

The significant words in the above sentence are *new* and *predominantly*. While eventually the wattles will mostly be displaced by natives, they still won't be eradicated. They'll always be scrounging around the fringes like a pack of bony dogs, pouncing into any gaps and disturbances such as slips. Nevertheless, working *with* rather than warring *against* these weeds is undoubtedly the only pragmatic option. However, coming to terms with this new and one day *predominantly* native forest, and its novel successional pathways, will require a more accepting and less war-like mindset. Furthermore, maintaining the conceptual dichotomy of native or exotic forest will become increasingly confounding. But isn't that exactly what we are clutching on to so desperately – me included? And probably you too.

My wattle example above is all too conveniently clear-cut and tidy. It still inadequately accommodates weeds that pose a more serious threat to forest succession. However, I only promised an optimistic ending – not a refined solution. The above is encouragement for brave helmspeople to set sail again, to extrapolate beyond the present and popular constellation of 'nature' in Aotearoa New Zealand, to pursue promising currents and to fish up new philosophical bedrock from these murkied waters.

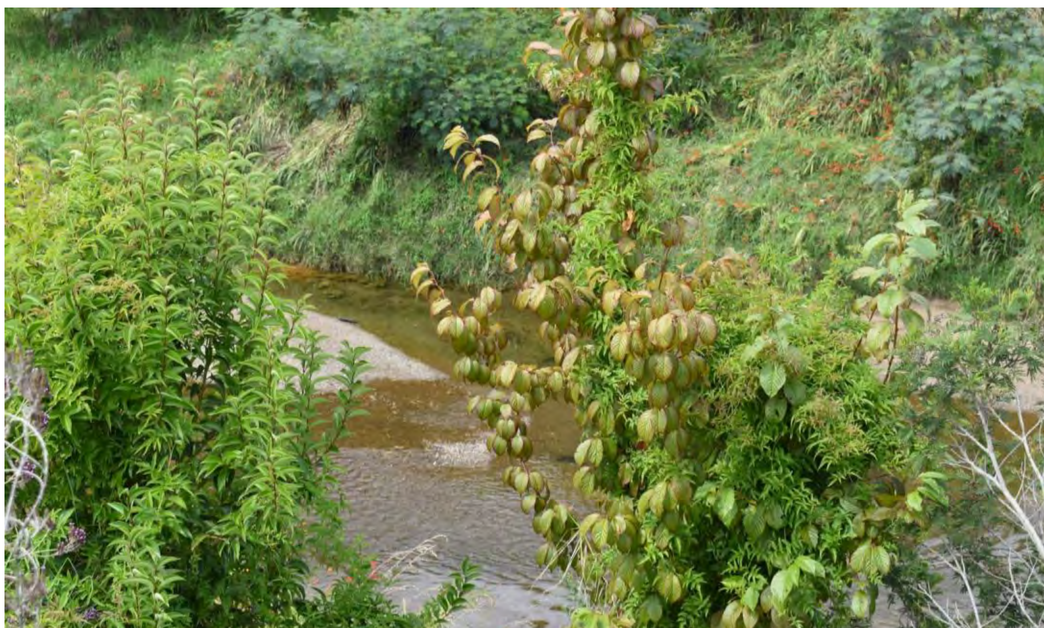

Figure 4. What do we see? The Kaeo riverbed infested with weeds or lush with nature? When neither eradication of environmental weed species nor restoration to native forest in such areas is tenable, coping with this reality requires a new and more robust concept of nature (image by author, 2025).

*

I contend that critically evaluating how any such new paradigm deals with weeds in Aotearoa New Zealand will be a useful stress test of adequacy. But this should not be done with a narrow ecological lens. A new environmental paradigm will be an evolving social and cultural construct, and even very indirect and spurious angles of examination, such as congruency with the social sciences, ethics and potential effects on mental health and landscape enjoyment, could all be useful polish.

Ultimately, the war against insurmountable weed problem that is coming to rural Aotearoa New Zealand will be won or lost within our minds.

It's time to weigh the anchors.

About the author

Paul Quinlan lives in the Far North of Aotearoa New Zealand. He is a trustee of Tāne's Tree Trust, convenes the Northland Tōtara Working Group and is a technical advisor with Trees That Count. In these roles he is a promoter of native forest establishment and its sustainable management. He is a qualified landscape architect and a registered member of the New Zealand Institute of Landscape Architecture and the New Zealand Institute of Forestry.

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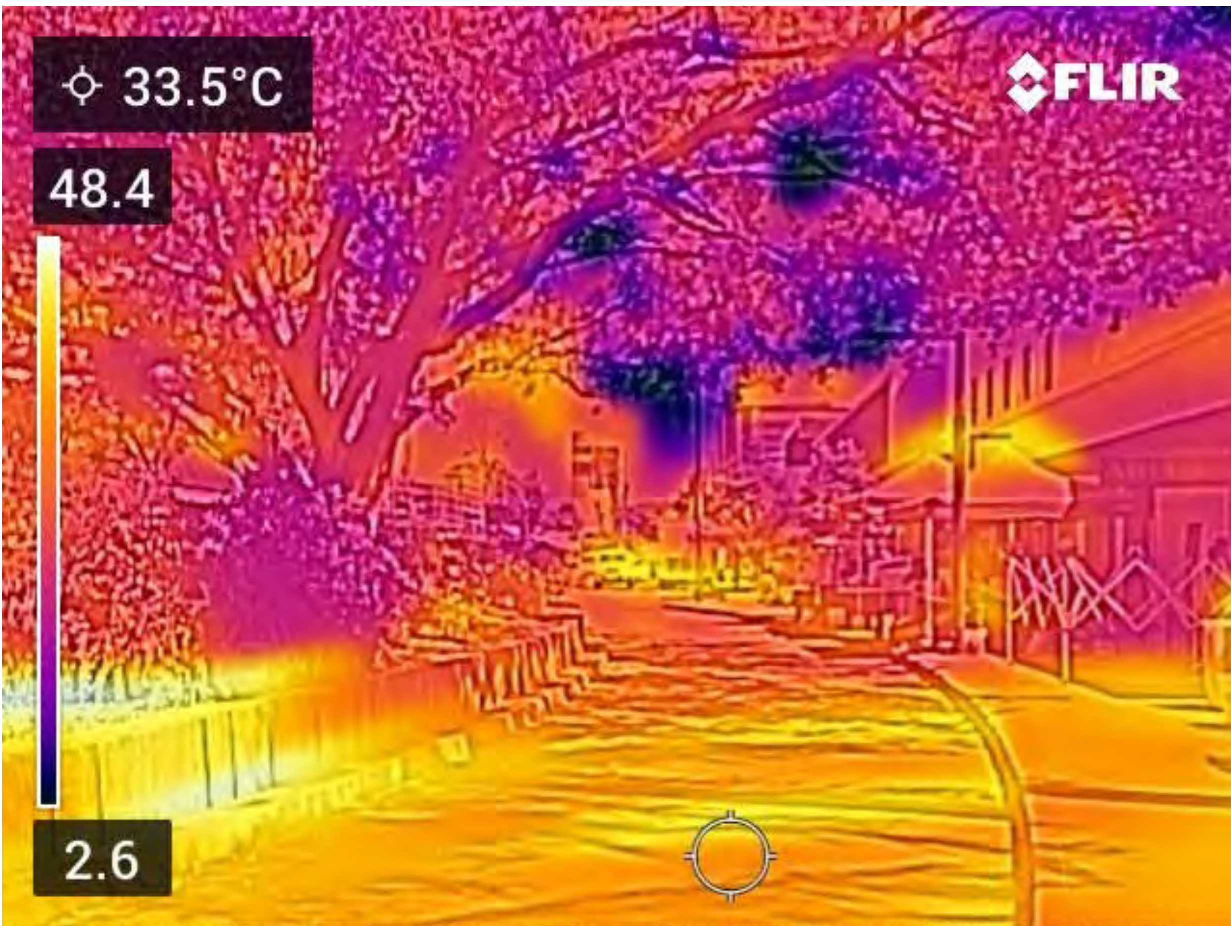

Urban form, materials, vegetation and the resulting urban microclimates (image by Jiawei Fu, 2022).

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.

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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urban microclimate; outdoor thermal comfort; heat stress; climate-responsive design; built environment; urban comfort

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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.

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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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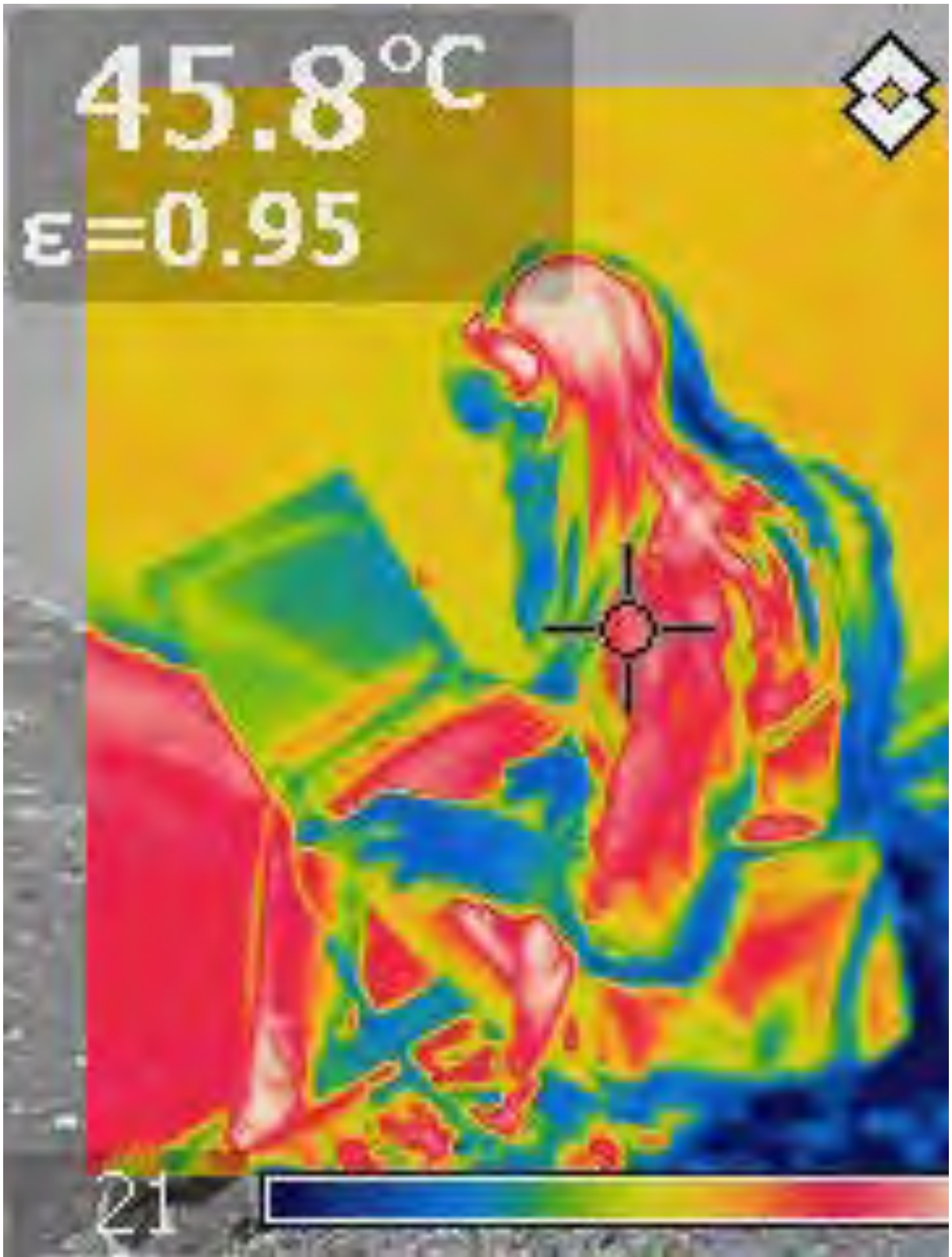

Thermal image of a student working (image by Wendy Walls, 2024).

Turning up the heat: reflecting on a decade of teaching landscape climate design

Jillian Walliss and Wendy Walls

When a landscape digital design practice emerged in the 2000s, it offered an unprecedented ability to engage with invisible atmospheric conditions. With big data and new software tools, dynamic systems could be integrated directly into design processes. Since 2015, the University of Melbourne landscape programme has explored these new design potentials in studio and electives focused on heat. The same decade has seen deeper acceptance of the climate crisis, more accessible and extensive data sets and more advanced software, yet student outcomes are no more sophisticated or innovative. Reflecting education and research practice, and drawing on student work and critical theory, this paper discusses conceptual difficulties in engaging with non-linear digital design processes. Interest in atmospheric theoretical framings and technological applications has been replaced by passive solutionism and linear design thinking, or 'problem-solving'. Centrally, conceptions of simulation as offering an understanding of atmospheric behaviours have shifted to a belief in control; an attitude mirrored in practice with problematic results. As the artificial intelligence era begins, the implications for landscape architecture practice are critical. The increasing reliance on technology to accurately model 'reality' allows complex algorithms to decide the future of cities, diminishing, if not erasing, the role of creativity and design.

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Atmosphere and the digital turn (2015–2020)

In the early 1990s, architecture theorist Mario Carpo (2013) described architecture's first digital turn and the potentials of digital technology to shift ways of designing. Key to this was the emergence of parametric modelling, which foregrounded relational decision-making and the potentials of computationally supported complexity in design processes.

Although it happened substantially later, landscape architecture also experienced a digital turn focused on design practice. This turn has been documented in a suite of publications in the mid-2010s, such as *Landscape Architecture and Digital Technologies* (Walliss and Rahmann, 2016b), *Responsive Landscapes* (Cantrell and Holzman, 2016), *Codify: Parametric and Computational Design in Landscape Architecture* (Cantrell and Mekies, 2018) and *Dynamic Patterns* (M'Closkey and VanDerSys, 2017).

For landscape architecture, the digital turn offered possibilities of new computational design investigations that escaped the constraints of static representational techniques such as mapping, diagramming and the plan. Whereas static techniques offer 'a visual representation of information and position the designer to respond to what is already known or what can be visually discerned', working with data and simulation facilitated:

> time-based investigations in which change is implicit through the active composition of behaviours and relationships. In this new context, the designer adopts an experimental process, establishing interdependencies and relationships between information, phenomena and systems across micro and macro scales. Rather than prescribe solutions, these research-driven design methodologies present 'a controlled discovery,' offering productive techniques for engaging with the unpredictability of climate change. (Walliss and Rahmann, 2016a, pp 41–42)

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design pedagogy, landscape architecture, digital, AI, climate design

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Importantly, the emerging non-linear digital design processes were supported by design theorists such as Lally (2014) and Rahm (2014), who described ways of understanding and designing through intensities, gradients and change. Also influenced by earlier design theory incorporating systems such as the work of ecologist Gregory Bateson, these critical understandings of variance are described by Keith VanDerSys (2014) of PEG studio as uncovering 'a difference that makes a difference', identifying conditions, behaviours and forces of the greatest degree of change in which to intervene.

This period was therefore not about modelling reality, but instead about accessing enough information to identify what computer scientist Chris Leckie defines as a 'high value' problem. He comments that our unprecedented access to data demands a level of critical thinking, requiring us to move from a vast amount of data to 'pick out the interesting or unusual events that are worth exploring and then filter them down' (Leckie, 2013).

For landscape architects engaging with questions of atmosphere and thermal conditions, the distinctions of identifying difference and high-value problems, as opposed to absolute or controlled outcomes, are critical to engaging with the generative design opportunities of data and digital tools. These framings also demand rigour in the critical thinking of the designer as to how they interrogate and apply data-driven information to the design process.

A landscape architecture master's thesis project (Toh, 2015), which aimed to modify the extremely humid streetscape of Singapore's premier shopping street Orchard Road, offers a clear demonstration of how this critical thinking leads to a novel design response. Research sourced from scientific journals highlighted the negative effects of traditional linear street tree planting, in that the practice increased air temperature (due to the reduced wind speed), as well as having the potential to raise humidity levels through tree coverage.

Working parametrically with Grasshopper as a Rhino plug-in, with inputs of small and big data, it was possible first to optimise tree placement for maximum shade but uninterrupted airflow. In a second phase, this new street tree-planting scheme was reconsidered in conjunction with the different albedo effects of paving colour to further increase air circulation along the street. Central to the Grasshopper definition was a matrix of weightage that placed more value on certain effects than others in different locations. Lighter-coloured pavers were placed under trees to achieve the effect of drawing air away from the trees, while darker shades of pavers were placed nearer to the road to encourage air movement towards the centre, aiding in its dispersal.

Through simulation and parametric tools, it was possible to derive the most thermally comfortable path that emerges from the aggregates of these design strategies. After adopting this optimum path as the foundation for street design, further design interventions can be introduced to enhance pedestrian comfort along it (figure 1). These include the programmatic use of the space and the location of street furniture and gathering points.

Shifting away from the stable equatorial Singaporean climate, the second landscape thesis project centred on the climatic extremes of the Daxing District of southern Beijing (Yu, 2016). Focusing on the everyday residential environment, the project aimed to work across multiple scales to reduce resident exposure to pollution by leveraging the combined effects of site planning, open space design and materiality. Beginning with a Geographic Information System (GIS), the plug-in Airflow Analyst and data accessed from a Beijing monitoring station (made available by a visiting Chinese professor), the optimum configuration and heights for standard Chinese residential buildings were explored. Decisions were premised on encouraging favourable pollution-dispersing northern wind speeds to be maintained between 7 and 10 metres per second, minimising the problematic southern winds that funnel pollution into the site and maximising solar access for residential buildings (figure 2).

Importantly, the move into more detailed design investigations was not a linear progression. Once the configuration of the buildings was established, a different question drove the next set of design decisions, beginning by investigating which times of year and times of day result in the highest pollution exposure. This bringing together of two temporal scales – the yearly pollution fluctuations with the 24-hour cycle of Chinese life – revealed

that while air pollution reaches its highest levels during winter nights (when people are largely inside), the daytime pollution levels are much lower in winter than in summer. Here we see how making decisions around maximums differs from understanding the relationship between fluctuating pollution levels and people's day-to-day behaviours.

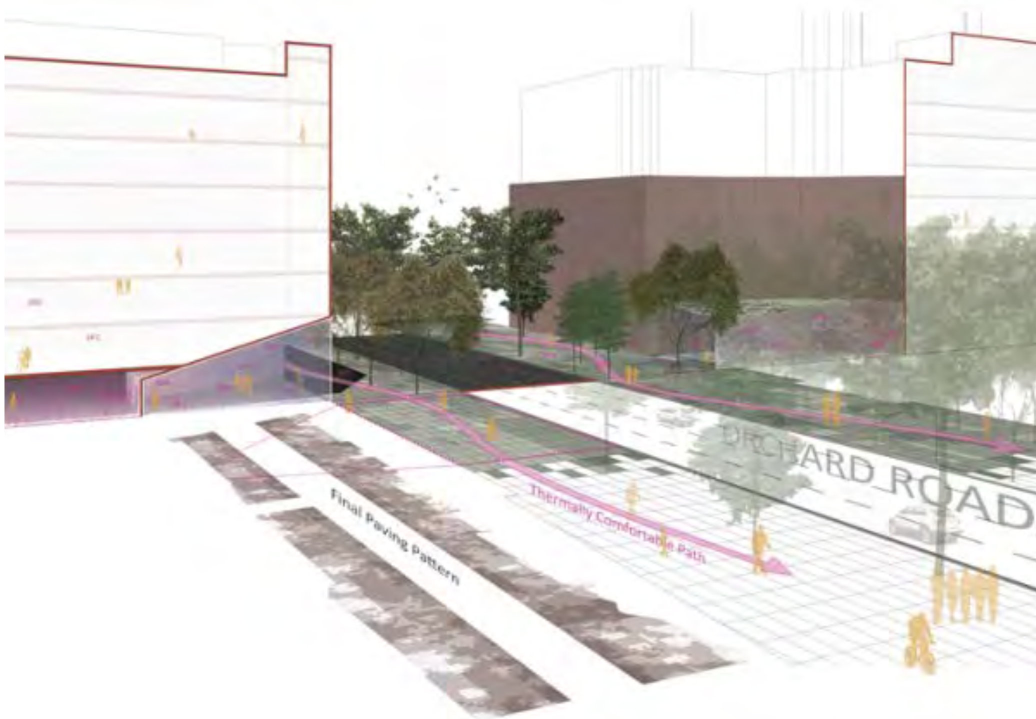
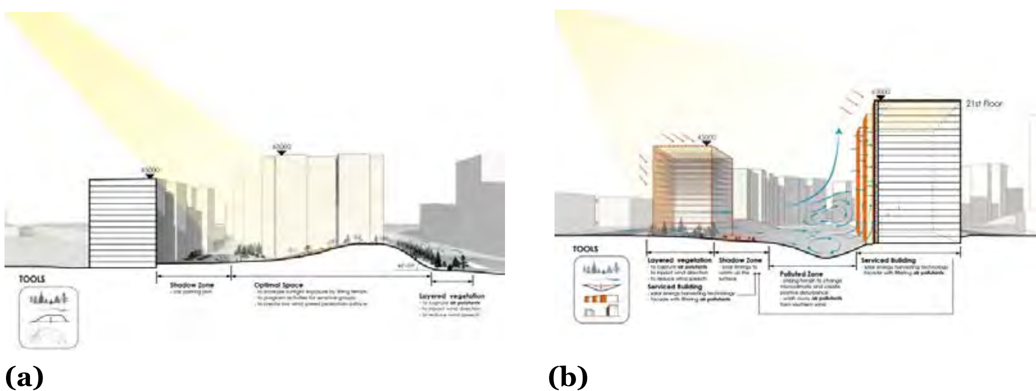


Figure 1. Defining a thermally comfortable path for pedestrians along Orchard Road, Singapore (image by Jason Toh (2015)).



(a) **(b)**

Figure 2. **(a)** Open space design for *Polluted City: A Meteorological Driven Design Approach for Beijing*. **(b)** Explanation of design with wind flows. (Images by Junya Yu, (2016))

This observation, which can be considered 'the difference that makes a difference', formed the basis for establishing an open-space strategy based on 'warming' winter spaces primarily by inserting a large mound to maximise exposure to winter sun. This space was also designed to perform well in summer. Functional uses such as car parking were placed in less healthy areas of the site, while in the most polluted areas, spaces were designed for no habitation and acted as pollution traps incorporating smart pollution-diminishing materials in the façades.

These urban-scale projects demonstrate how both master's students used data to understand and reveal behaviours and relationships – not to find a singular solution. This same thinking guided design outcomes in smaller-scale design interventions delivered as part of the multidisciplinary elective Designing for Heat.

In this subject, students were tasked with analysing real-time data collected on-site using i-button temperature sensors. In one case, students discovered an anomaly in climatic behaviours, where the air temperature at certain locations would drop for a short period despite the overall trend of rising temperatures. The cause of this temperature drop was never fully established. However, the observation prompted further investigations into the potential for material effects to interrupt the building-up of heat, acting to 'reset the external spaces' (figure 3) and thereby preventing spaces from reaching maximum temperatures (Bessabava and Szumer, 2015).

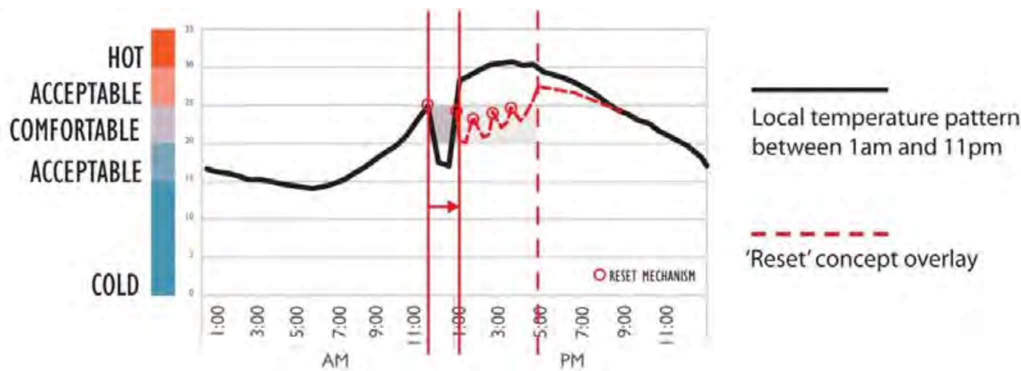
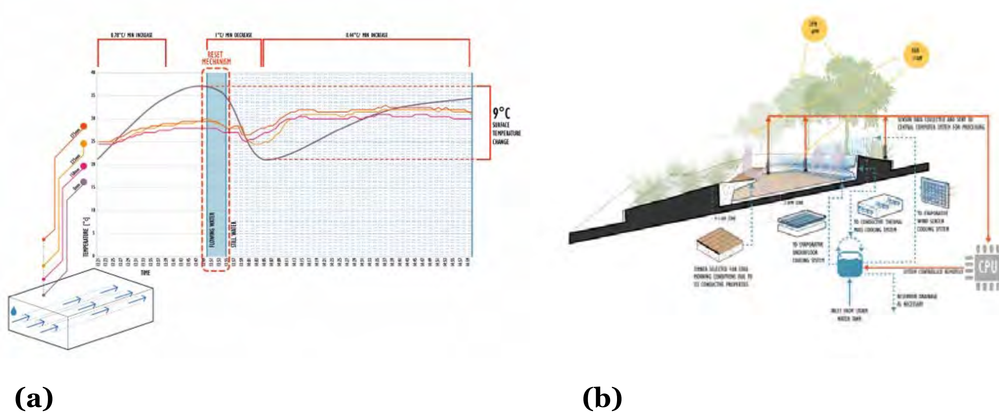


Figure 3. Diagramming the progressive build-up of heat over time and the anomaly effect of a sudden temperature decrease. This is shown against the proposed 'reset' concept of concurrent temperature drops (image by Bessabava and Szumer (2015)).

The students used this performative trait as a lens to investigate thermal behaviours of different surface materials such as concrete, brick, steel, timber and vegetation. In a series of physical experiments, the students explored the potential for 'resetting' the material behaviour using passive cooling techniques in response to conduction, convection and radiation. The insights from the physical tests were further explored using computational fluid dynamics (CFD) simulation and parametric environmental modelling (figure 4) to enhance the potential comfort levels at a material scale at strategic locations within a site, without the need to cool down the entire outdoor space.



(a) **(b)**

Figure 4. **(a)** Diagram of data capture from material tests exploring the reset mechanism. **(b)** The design of 'Reset Pods' as thermally responsive systems. (Images by Bessabava and Szumer (2015))

These three student projects highlight how the use of data and simulation supported by scientific research leads them to constantly redefine the problem. In no way are the simulations offering the solution. Instead, the designers are curating the process, developing greater insights through each exploration and gaining more knowledge about where they can have agency and impact. This ability to define the point of intervention

(spatially and temporally) is particularly important when engaging with dynamic atmospheric conditions such as heat and pollution. Given the complexity of climate change, it is impossible to directly affect the extremes of these phenomena, which are tied to broader global concerns like global emissions and deforestation. However, working as designers, it is possible to tactically interrupt, heighten or minimise different aspects of these conditions as they play out at the scale of a site, materials and human experience. Through abstraction of environmental processes, behaviours and relationships, computational tools offer a transition between the macro and the micro scales, transforming the notion of atmosphere as constraint to a perceivable material space.

It is important to note that in these cases, the students themselves scripted the project models and parametric tests. In doing so, they had to properly understand the parameters and behavioural rules they were dealing with. These earlier projects were delivered at a time when digital tools were novel in the landscape curriculum. While computer-aided design and 3D modelling were commonly used, plug-ins, real-time data and simulations were only beginning to emerge. In this context, these tools offered no easy processes or simple results so students who wanted to employ them were forced to be proactive. Thus, these examples offer insight into a generation of students who were curious about design, processes and technology and were prepared to push their thinking and technical skills beyond the limitations of the current tool set.

Since then, however, this critical and design-focused positioning of the role of data and digital tools has been changing in two ways. First, these data and tools have become easier to obtain and now permeate design decision-making and operations. The rapid arrival of integrated artificial intelligence (AI) technology has brought new workflow efficiencies that require less attention from the designer than in the earlier period, when, for example, designers were required to engage with scripting. The second change is that landscape architecture has increasingly aligned itself closer to science, manifesting as a problem-solving attitude. The ongoing concerns of climate change, urbanisation and resource depletion further encourage a solution-focused approach for disciplines like landscape, which includes taking up the epistemological position and 'repeatable' methodologies of science in design. The combined effect has been to disengage with parametric (relationships and behaviours) design and become more reliant on a linear cause-and-effect solutionism. Notably, these attitudes are encouraged by data and technology tools when the designer steps back from a critical position.

The seduction of accuracy (2020–2025)

Thinking about the developments of digital technology and architecture in the 2000s, Carpo (2017) identifies a second digital turn that reframes the digital as 'tools for thinking'. He writes:

> the unprecedented power of computation … favors a new kind of science where prediction can be based on sheer information retrieval, and form finding by simulation and optimization can replace deduction from mathematical formulas.

In contrast to using data to find 'the difference that makes a difference' or to identify high-value problems, exploring simulations through a reductionist process of cause and effect sets up very distinctive conditions for how we approach thinking in design.

For example, a paper discussing the work outlined in the previous section for a special edition of *Landscape and Urban Planning* was rejected due to the lack of scientific methodology. The paper argues for the value of the relative and tactical approaches to thermal sensation employed in the examples of design processes. Despite the paper explicitly setting up a theoretical position, qualitative methods and case study examples of designing with thermal performance in external sites, the reviewers looked instead for an explicit quantification of material performance. Reviewer 2 writes:

> The authors failed to explain exactly what microclimatic consequences each design alternative might bring about and what the underlying mechanisms are. The research was not able to answer to what extent timber regulates the surface heat gain and consequent thermal sensation in the morning sun as compared with concrete and other materials.

Similarly, reviewer 3 rejects the paper because:

> The paper does not elaborate on any of the author's own quantitative research work, but mainly discusses some problems and others' practices.

This example highlights the underlying assumptions in data-driven work that solutions, as designed outcomes, can be gained directly from quantitative research. Despite the extreme dynamism of external environments and the near impossibility of reducing a complex open system like the shifting thermal conditions of a landscape site, it is still assumed that with enough data and simulation power, it is possible to quantitatively derive a clean solution.

This acceptance of solutionism, and its reliance on simulation and data are closely tied to a desire for absolute accuracy and control. These attitudes are best exemplified by the increasing popularity of digital twins. These kinds of models are premised on flows of detailed data aimed at replicating real-world conditions under the assumption that it is possible to capture data on all aspects of a site. Such models are built on claims that information itself is neutral or objective and can be cleanly synthesised into a precise version of the real thing. This creates a kind of paradox in data-driven modelling because even highly detailed models struggle to reproduce the social, cultural and messy unplanned characteristics of real space (Cureton and Dunn, 2021; Gram-Hansen, 2017).

While often driven by a moral position of addressing the urgent questions of climate change and urbanisation, the reliance on reduction reveals a diminishing of critical thinking on how we are establishing the question in the first place (see, for example, Holmes, 2020; Lickwar and Oles, 2015). These shifts in thinking and attitudes are increasingly evident in student work, which demonstrates that they are no longer critical in their design processes and struggle to work with incomplete data. It is an outlook most often revealed in their passive acceptance of what the computer, data or AI tool offers as an answer.

Is this because the generation of digital natives has not known a non-digital design process? Does the easy access to data produce a submissiveness to it? Students seem increasingly reluctant to move beyond the accessible archive of quickly googled site facts and satellite images. Rather than expanding investigations, data richness has constrained the process of site 'discovery', which is central to landscape architecture. More so, these attitudes have extended into design exploration, where students continue to look for the easiest and quickest outcome, rather than engage with the difficulties, complexities and long journey of design.

For example, environmental simulation software is still challenging for design students. While these tools are far more accessible and applicable in design work than they were 10 years ago, many of these programs still require considerable time and effort to run. Among these are CFD simulations, which are mathematically complex and require greater computational power than more common design software. Running simulations requires careful attention to the model parameters, geometry or mesh creation and scale of the intended results. Even then, simulations may not offer the detail or resolution that students would like. Although the results of exploratory testing can still offer useful feedback into a design process, students will often spend time trying to perfect a simulation to make it 'more accurate' in order to find an answer, rather than engage with the ongoing process of defining parameters and adjusting the model as part of a design exploration.

This fixation with accuracy (along with the notion that the computer has the answer) has permeated through students' learning attitudes and into practice. Within the Designing for Heat intensive subject, which runs over four weeks, students are required to work fast and rapidly test ideas for influencing atmospheric performance through design.

Despite extensive design theory and discussion about the role and limitations of the tools, students are increasingly obsessed with the software working ‘properly’ under the assumption the answer lies in this result – rather than looking for behaviours or understanding how the results might inform a design exploration.

The emergence of this attitude can be tied to multiple factors. In contrast to the earlier workflows, which required students to actively script (including understanding the limitations of modelling), the arrival of more user-friendly tools can encourage a more passive assumption that tools will offer the answer. In addition, it is well documented internationally that the COVID-19 interruptions had a huge impact on higher education, including by shifting the role that university plays in students’ lives, which led to a drop in learning engagement (Burki, 2020; Guppy et al, 2022; Sharma and Alvi, 2021; Yang et al, 2024). Reduced engagement can also manifest in looking for the easy answer. From our own observations of teaching across this period, we estimate that our students are producing 30 per cent less work than pre-COVID cohorts.

For example, a quick design exercise asked students to consider a bridge structure on campus, specifically thinking about conditions of heat and the resulting atmosphere around, above and below. When one group’s attention was drawn to the shade occurring under the bridge, their response (figure 5) was to build another bridge above the initial bridge to ‘shade the hot area’. Even with the environmental simulations highlighting the relative diversity of thermal conditions across the landscape scale of the site, the students were only able to identify the hottest part (on top of the bridge) and propose to ‘fix’ that. When questioned about the recursive nature of the problem, meaning that it would not be resolved no matter how many layers of new bridges they added, the students continued to attempt to fix the heat with a shade shelter, rather than engage with the existing and deeper shade found under the bridge.

Figure 5. Student design work on heat showing interventions with a shade shelter on top of a bridge structure (image from Designing for Heat intensive subject, 2023).

This attitude of using the simulation only to identify problems is mirrored in many student responses when working with environmental conditions. Often students emphasise solutions involving object placement, even when faced with fallacies of logic.

In a further example from the Designing for Heat intensive, a group re-drew the wind and solar simulation results as diagrams expressing how they would like the air and light to move (figure 6). In this case, the students were frustrated with the simulation results not ‘working properly’, meaning they could not get the CFD simulation to interact with their proposed geometries in the way they wanted and so they reverted to a diagram depicting something entirely different to the CFD results. These kinds of diagrams are not unique to students and are colloquially known in environmental design as ‘arrows of hope’.

In this example, warm air is shown moving down the proposed chimney structures while cool air moves upwards, which simply ignores the laws of physics. Here the approach to the simulation tool is based on desiring detailed results in a specific area. When these do not show what is expected, the students turn away from the simulation entirely. In doing so, they also fail to examine or interrogate the simulation for what it does show – where wind effects occur at a different scale, or how the design might respond to the emergent or surprising discoveries.

Figure 6. Student design showing air flow moving up and down proposed chimney structures (image from Designing for Heat intensive subject, 2023).

These student responses highlight some of the most worrying attitudes and thinking about data, tools and the role of design. While we also have recent examples of better work, the cases presented here clearly illustrate the trend in student attitudes and approach to learning. Perhaps most troubling within this trend of perceiving design as only problems and solutions, and the concurrent setting aside of common sense (bridges on bridges and cold air moving upwards), is the lack of curiosity about the relationships and behaviours that are at work in designing with thermal conditions. Wind simulations are imperfect and it is acknowledged that inaccuracies arise when working with digital CFD, particularly in the open system of an outdoor environment (Tominaga et al, 2023). Whereas trained environmental engineers can achieve precise and detailed results, accuracy is more limited for designers engaging with CFD tools. Despite this, CFD can still offer important insights into wind behaviours and interactions that are otherwise difficult to grasp. Such simulations, alongside other data and tools for solar intensities and energy effects, can reveal atmospheric effects as a tactile and rich material for design if understood as tools for discovery and exploration, not just simple answers.

These are not new ideas. Forty-six years ago, Lisa Heschong (1979) published *Thermal Delight in Architecture*, calling on designers to engage with thermal diversity and difference. Because of data and simulation tools, these effects of fluctuating thermal effects have never before been more tangible to designers. Yet we are seeing little interest in thermal delight or atmosphere as material from our students, particularly in comparison to an earlier generation.

In many ways, this experience accurately reflects Gartner's well-known hype cycle of technology (figure 7). That is, the initial expansion of data and simulation tools towards design represents a major 'peak of inflated expectations', only to be followed by a 'trough of disillusionment'.

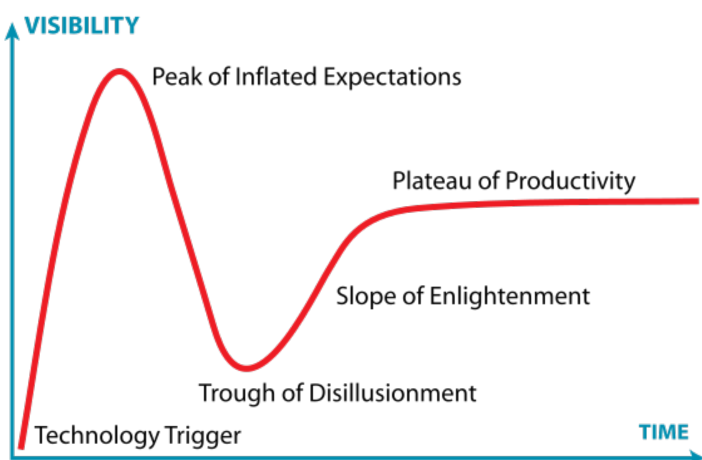


Figure 7. Gartner's hype cycle of technology diagram (image by Jeremykemp at English Wikipedia is licensed under CC BY-SA 3.0).

If the hype cycle continues in its usual course, technology users interrogate the tools more closely and rebuild them towards a 'plateau of productivity'. But are we on the upward slope of enlightenment? The constant move towards efficiencies, more data, AI shortcuts and 'hacks' suggests not. Instead, the rise of technology seems to be affecting a work ethic towards thinking less, not more. In explaining this phenomenon, Sun-Ha Hong (2020) suggests:

> The pursuit of machinic objectivity calls on human subjects to know more than they reasonably can, and in their failure to keep up, defer to new institutional arrangements of recessive and opaque technologies. (p 181)

These effects are becoming better documented in research on higher education and pedagogy, and on the major impact that AI is having on education. While some write on the opportunities of AI for advancing learning tools, scholars are also noting the negative effects on intellectual development over time (Asio and Gadia, 2024; Chan and Hu, 2023; Gimpel et al, 2023). A particular concern is for the development of holistic competencies, including creativity and critical thinking, when students presume they can bypass these independent cognitive skills with AI shortcuts. For example, in their systematic literature review on the effects of AI on students' cognitive abilities, Zhai, Wibowo and Li (2024) explain:

> students in research and education might depend too heavily on AI-generated content, neglecting the development of their ideas and original thought processes. This dependency can foster complacency, making students less inclined to engage deeply with the material or develop essential problem-solving skills. (p 31)

The damage that this attitude could have on design education is potentially vast, challenging the very premise that design is an exploratory and open-ended endeavour.

Conclusion

Landscape architecture is faced with a daunting future. External environments are at extreme risk under climate change effects of heat, drought, human demands and weather events. Designing into this uncertain future demands both rigour and curiosity. Simulation tools and data offer designers immensely valuable insight and information, but they cannot provide a straightforward answer to immeasurably complex questions. In other words, having more data will not in itself translate into a solution. As Cureton and Dunn (2021) explain:

> The abundance of 'real' data arguably is not a direct correlate for improved design, nor can it remove the unpredictable or 'black swan' events of near, middle, and far futures ... Modelling closer to reality doesn't necessarily translate to making better spaces, and the designer's role is most critical here. (p 247)

Here lies the rub. The seduction of data accuracy lures designers and students into believing that the world can be replicated and controlled. But in that struggle for the perfect digital 'model' or accurate simulation, the understanding of the real world as incomplete, messy and unexpected is overlooked. As landscape architects, we should know this best, because the external world is in constant flux. Designing into dynamic landscape systems and environmental processes presents major conceptual and physical differences from the controllable indoor environments that heating, ventilation and air conditioning engineers and architects work with. Yet our more recent generation of students is failing to understand this difference.

Where does this leave design educators? First, it highlights the need for our design processes to work across the physical and digital worlds. Unlike the selective factors driving the digital model, the physical site is the ultimate 'proof of concept' bringing together the complex factors that underpin landscape. 'Digital twins' will only ever engage

with a small fraction of the landscape condition. Second, in the rapidly unfolding era of AI it is becoming clear that critical thinking is the number one skill to encourage in our students. In terms of technology, this translates into developing understandings of what is 'in the black box', meaning what values, algorithms and parameters are driving the solution. And finally, this paper is a warning to not be enticed into chasing unattainable precision at the expense of design as a critical and creative practice. Rather, it is important to consider the value of these tools as a pursuit of possibilities. As Simone de Beauvoir wrote in 1948, science fails when it is consumed by the 'quest to attain and capture being', but it finds truth as 'free engagement of thought'.

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The layered urban fabric of Beijing, where the expansion of multi-level municipal roads reflects accelerating urbanisation and squeezed green spaces (image by Yanhan Li, 2025).

LANDSCAPE
REVIEW

Cooling strategies using thermal alliesthesia: a complementary approach to enhancing greenway walking comfort

Yanhan Li, Liang Li, Wenqing Wang, Lanxi Yang and Gillian Lawson

A favourable thermal environment along urban greenways supports public health and sustainability. In dense built-up areas, limited land availability makes it difficult to rely solely on high-quality green spaces for continuous greenway development. Planners are attempting to increase tree canopies along municipal roads, even under less than ideal conditions. The key challenge is how to improve thermal comfort for those walking along these road corridors. Combining a literature review and field investigation, this paper introduces thermal alliesthesia as a perspective that complements physical design. Existing strategies to improve thermal comfort in greenways focus on enhancing static environmental quality. In contrast, 'thermal alliesthesia' emphasises how changing subjective perception can shape thermal experience. The thermal alliesthesia effect can be triggered by variations in the physical environment. Taking Beijing's Second Ring Road Greenway as a case study, this paper proposes route planning and landscape design for urban greenways as strategies to elicit this effect. It describes the detailed design of a representative section of the greenway to demonstrate how this concept can be applied. This approach is adaptable across climate zones, provided designers develop flexible, site-specific solutions. The findings offer practical insights for greenway planning and design in complex urban contexts.

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Introduction

Climate change and heatwaves have become pressing issues globally. Human activities are major contributors to the urban heat island (UHI) effect (Grimmond, 2007), particularly through vehicle emissions and heating, ventilation and air conditioning systems (Chen et al, 2019; Hsieh, Aramaki and Hanaki, 2007; Ribeiro et al, 2021). In response, key strategies to mitigate the UHI effect have focused on reducing reliance on motor vehicles for short trips and minimising heat generated by inefficient air conditioning (Caprì et al, 2016; City of Los Angeles, 2019; Ruefenacht and Acero, 2017). In this context, outdoor walking is increasingly recognised as an effective measure to alleviate urban heat. It is promoted as an important form of non-motorised transport in the United Nations Environment Programme's (2021) *Sustainable Cooling Handbook for Cities*.

Greenways, as linear corridors connecting dispersed green spaces in urban areas, provide important locations for walking (Horte and Eisenman, 2020; K Liu et al, 2016). In particular, as accessible and low-cost locations for walking, greenways can help mitigate social disparities in opportunities for physical activity (He et al, 2021). Accordingly, in China, the development of urban greenways is actively promoted to enhance the public health benefits available through walking.

Environmental quality significantly influences walking behaviour (Qiao and Yeh, 2023), with thermal conditions playing a critical role in people's decisions for or against walking (Audate, Romaric Da and Diallo, 2024; Baobeid, Koç and Al-Ghamdi, 2021). However, in major Chinese cities, the scarcity of land resources makes it challenging to develop greenways on land with desirable landscape and ecological functions, leading planners to repurpose existing municipal roads for greenway construction (Z Liu et al, 2019). For example, in the high-density city of Shenzhen, 56.5 per cent of greenways consist of public infrastructure such as footpaths, trails and motorised roads (ibid), meaning greenways in urban built-up areas often alternate between renovated road segments and

high-quality green spaces such as parks. In other high-density cities such as Singapore and New York, urban greenway projects have shown that integration with existing infrastructure is feasible (Gan, 2017; TJ Zhang and Li, 2013), underscoring the importance of prioritising environmental quality during renovation. Realising this potential calls for strategies that meet traffic efficiency requirements while also achieving urban greening and thermal comfort goals.

Currently, many countries and regions have developed policy responses to urban heat. In the Asia–Pacific and Oceania region, northern Australian cities such as Brisbane, Darwin and Cairns face significant heat exposure risks and challenges to walking comfort. Australia has developed a number of action guidelines to address urban heating over the past decade (Osmond et al, 2017; Western Sydney Regional Organisation of Councils, 2021). In recent years, Aotearoa New Zealand has also focused on urban cooling and climate change, adopting several related policy measures (Auckland Council, 2020). These strategies provide comprehensive solutions, such as land use, landscape design, and urban energy consumption.

In urban planning and design, widely adopted heat-mitigation strategies include modifying vegetation, urban geometry, water features and surface materials to achieve certain positive outcomes (Osmond et al, 2017; Western Sydney Regional Organisation of Councils, 2021). Current strategies to improve the thermal environment of greenways primarily focus on optimising landscape design and recommending appropriate times to use them. However, even though walking is a linear, dynamic process, current strategies tend to treat greenways as static and singular spaces. Moreover, due to spatial constraints, existing recommendations for optimising greenways may not apply readily to already constructed greenways in high-density urban areas. In this context, the concept of the 'thermal alliesthesia' effect provides a valuable supplementary perspective, with its emphasis on enhancing thermal comfort by enriching people's dynamic perceptual experience when they are walking.

Pedestrians moving through urban environments experience varying microclimatic conditions, such as changes in wind, solar radiation, and shading. These variations create a more complex thermal experience than stationary activities (J Li, Niu and Mak, 2022; Zhao et al, 2024). While traversing different microclimates, pedestrians experience diverse thermal perceptions and trigger physiological adaptation over short periods (Dzyuban et al, 2022). Moreover, they may experience the 'alliesthesia' effect, subjectively perceiving thermal overshoot before they adapt physiologically (J Li, Niu and Mak, 2023). Research on thermal alliesthesia by Richard de Dear's team at the University of Sydney has provided important theoretical foundations for such applications. The alliesthesia effect associated with transient thermal perception in non-steady-state thermal environments is currently being investigated (Huang et al, 2020). It has been recognised that this phenomenon has the potential to improve walking thermal comfort.

Accordingly, this paper first summarises recent research on enhancing greenway thermal comfort, and then reviews the concept and development of the thermal alliesthesia effect. Using the Beijing Second Ring Road Greenway as a case study, this paper explores strategies for applying this effect to improve thermal experiences while walking in urban greenways. It also describes the design of a representative section of the greenway to demonstrate how this effect can apply in practice. Finally, the paper discusses the potential of the thermal alliesthesia effect in improving the thermal comfort of walking across different regions.

Approach

This paper reports on a study that began with a review of the literature on research into greenway thermal comfort and the thermal alliesthesia effect in building environments. The second part of the study involved a field investigation of the Second Ring Road Greenway in Beijing. Experiential surveys were carried out on 14 selected days in summer, late spring and early autumn from 2022 to 2025. These seasons were chosen as they

represent periods of high heat exposure and were most relevant for studying thermal conditions for walking. The survey was conducted at times when pedestrian activity was at its peak, mainly during daylight hours. The surveys covered the full walking route and its connected open spaces to document spatial characteristics and user behaviours. Mapping techniques were then applied to show the current features of the greenway and identify potential areas of concern. Finally, targeted optimisation strategies were proposed based on the thermal alliesthesia effect.

Findings and insights

Current research for enhancing greenway thermal comfort

Scholars have extensively examined factors promoting the use of greenways and strategies to improve them, focusing on connectivity (Z Li et al, 2024; B Xie et al, 2023;), the built environment (He et al, 2021) and amenities (Chi and Lin, 2019). In comparison, thermal comfort has received far less attention.

Existing studies mainly emphasise the role of meteorological factors in thermal comfort while walking and they suggest corresponding design strategies. Li Li and colleagues (2013) explored the impact of 16 surface-material and environmental combinations in Guangzhou's greenways. Their results showed that water-permeable brick, tile, arbours and water were effective for cooling greenways. Later, Lin Liu and colleagues (2022) evaluated the effects of tree density and roadway width on greenway microclimate using ENVI-met simulations and proposed corresponding design strategies. Yuankui Li and colleagues (2024) examined thermal comfort while people were undertaking mild activity in shaded spaces outdoors in hot regions. Based on their finding that thermal stress on greenways was higher during the day and comfort improved at night, the researchers recommended evening use of greenways.

However, these strategies face limitations in urban built-up areas. For example, it is not always feasible to modify footpath widths or adjust tree density along existing municipal roads. Users who rely on greenways for last-mile commuting may lack the flexibility to choose their walking times and may consequently be exposed to higher thermal stress during hotter periods of the day. In addition, current urban planning and design approaches for greenways may pay insufficient attention to how environmental variations influence the walking experience within linear spaces. Therefore, further development of current strategies is needed to better guide planners on effective ways of converting municipal roads into greenways.

The concept and research progress of the thermal alliesthesia effect

Cabanac (1971) coined the term 'alliesthesia', derived from the two words 'esthesia' (referring to sensation) and 'allios' (meaning changed), as a way to describe a shift in sensory pleasure. In the field of the built environment, 'thermal alliesthesia' describes the phenomenon in which an individual already experiences a deviation from their thermal set point, and external thermal stimuli either correct that deviation so that the individual perceives it as pleasurable (positive alliesthesia) or exacerbate the deviation so that the individual perceives it as unpleasant (negative alliesthesia) (Huang et al, 2020; Lai et al, 2020). These studies address variations in thermal perception due to meteorological stimuli such as temperature and wind speed (J Li et al, 2022; Zhao et al, 2024), and the changes in thermal comfort resulting from variations in thermal sensation (S Liu et al, 2021).

Research on this phenomenon began in indoor thermal environments. Richard de Dear's research group systematically studied the physiological and psychological mechanisms of thermal alliesthesia induced by thermal variations (de Dear, 2011; Parkinson, 2016; Parkinson and de Dear, 2017; Parkinson, de Dear and Candido, 2016; Schweiker et al, 2020). Building on this work, they proposed a personal environmental control (PEC) system that applies this phenomenon to interior spaces, aiming to enhance occupant satisfaction while reducing energy consumption (Parkinson, 2016).

Outdoors, current studies primarily focus on characterising changes in thermal perception during dynamic activities in urban open spaces, where microclimatic conditions fluctuate frequently (J Li, 2022; S Liu et al, 2021; Y Zhang et al, 2020). Some of these studies consider thermal alliesthesia during walking activities (J Li et al, 2023; Peng et al, 2022; Vasilikou and Nikolopoulou, 2020; Y Xie et al, 2022). The main aims of such research are to confirm that thermal alliesthesia occurs and to assess its impact on thermal comfort and people's willingness to exercise outdoors. These studies are typically conducted along a continuum of urban settings with complex variations, such as streets, waterfronts and campuses, including both outdoor and semi-outdoor spaces (Dzyuban et al, 2022; J Li et al, 2023; Peng et al, 2022).

Studies show that variable thermal exposures can improve thermal comfort while walking (Dzyuban et al, 2022; J Li et al, 2023). The research of Dzyuban and colleagues (2022) in a hot desert climate provided strong evidence of thermal alliesthesia, with spikes in pleasure ratings triggered by minor reductions in physiological equivalent temperature (PET). The most significant changes in thermal perception occurred at microclimatic transitions, rather than at extreme temperatures. Similarly, a climate chamber study simulating outdoor conditions revealed that the instantaneous thermal sensation significantly decreased for individuals moving from prolonged sunlight exposure to shade, compared with the experience of those remaining continuously in the shade (Zhao et al, 2024). Peng and colleagues (2022) found that, despite the average air temperature along urban walking routes being 3 degrees Celsius higher than in suburban areas, individuals reported feeling less thermally bored and more willing to remain for longer in the inner city. The researchers attributed this finding to the more frequent occurrence of thermal alliesthesia effects from cooling and warming transitions.

These findings indicate that an individual's subjective thermal perception is shaped by comparisons with prior experiences, and the overall thermal experience throughout a walk is shaped by the accumulation of successive transient thermal perceptions. Therefore, consciously creating frequent thermal alliesthesia offers a promising strategy for enhancing the thermal experience of walking along a greenway. This does not imply that urban planners should ignore environmental design improvements; rather, it highlights the potential to strategically use this psychological process to achieve more cost-effective outcomes.

A case study of Beijing's Second Ring Road Greenway

Beijing's Second Ring Road was completed in 1992 as the city's first urban expressway. For many years, it shaped both the spatial structure and the traffic system of China's capital city. Since 2015, parts of the surrounding space have been redeveloped into the Second Ring Road Greenway. The pedestrian route of the greenway extends for about 80 kilometres across four administrative districts, linking moat-side roads, riverside green spaces, and urban infrastructure (figure 1). This marks a broader transition from speed-oriented infrastructure to people-centred, ecological and cultural functions (L Li, 2014; Y Li, 2016).

In 2024, the North Moat River connectivity project removed eight breakpoints along the waterfront path, gradually improving continuity. However, challenges remain. Some roadside land is underused, and in certain locations pedestrians on the greenway cannot easily connect to footpaths in the adjacent urban road system.

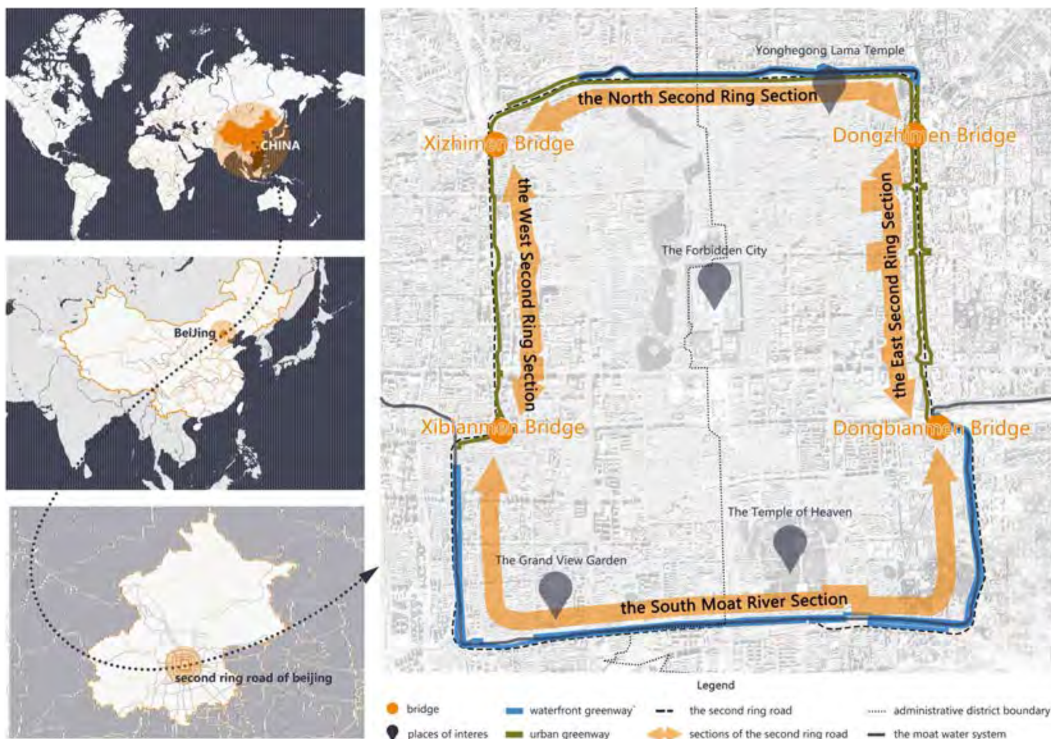


Figure 1. The geographical location and the sections of the Second Ring Road Greenway (image by Yanhan Li and Lanxi Yang, May 2025, adapted from the official website of the Beijing Municipal Forestry and Parks Bureau).

Analysis of the current conditions

The North Second Ring section includes both a waterfront greenway and an urban greenway (figure 2). The waterfront greenway has complex topography, with variations in path width and green space area, connecting a series of themed parks and providing flexible walking routes and diverse landscape experiences. In contrast, the urban greenway consists mainly of shaded walkways and rest areas but suffers from repetitive design and a monotonous landscape character. It reduces both thermal comfort and recreational appeal.

In the South Moat River section, waterfront walkways are provided on both sides of the moat. In some sections along the embankment crest, the greenway route is limited to the municipal road footpaths, while others lack pedestrian pathways altogether. The connectivity between waterfront walkways and embankment-top pedestrian paths or linear parks is poor due to significant elevation differences and insufficient stairs or ramps. The result is to restrict pedestrian access, limiting route flexibility and the overall richness of the walking experience. In addition, the landscape beside the long waterfront walkway lacks spatial and visual variation.

In contrast, the West Second Ring section benefits from broader green spaces adjacent to municipal roads, forming linear parks with varied spatial configurations. The section incorporates themes such as finance and historical Beijing character, offering diverse spaces with a rich range of functions, including shaded walkways, sunlit paths, tree-lined plazas and open squares.

The East Second Ring section features recreational walkways and themed open spaces. On the west side, the walkway widths vary and shading is generally sufficient, with node spaces ranging from open plazas to shaded areas. The northern segment of the east side is densely vegetated, providing ample shade, while the southern segment allows intermittent sunlight through the canopy. Pedestrian overpasses connect both sides.

Figure 2. Current conditions of the Second Ring Road Greenway (image by Yanhan Li and Lanxi Yang, May 2025).

Optimisation strategies

International practices provide useful insights for overcoming such constraints. Singapore's Park Connector Network illustrates how underutilised land – such as drainage buffers, roadside reserves, and spaces beneath viaducts – can be transformed into accessible green corridors with minimal need for new land acquisition. The original spatial conditions of these sites, combined with their redesign, create diverse environmental settings for greenways. The network thus could introduce varied spatial experiences that optimise the thermal alliesthesia effect for pedestrians. This approach demonstrates how strategic reuse of land and the reconfiguration of existing infrastructure can create routes that enhance walking comfort.

Targeted strategies are proposed for each segment of the greenway based on current conditions of the Second Ring Road Greenway. These strategies demonstrate the practical application of the thermal alliesthesia effect in greenway planning and design (see figure 3 for a visual summary).

1. North Second Ring section

To address the monotonous landscape of the urban greenway in this section, diversified design strategies are recommended. Small open plazas with a few trees can create sunlit leisure spaces, while denser planting of broad-leaved trees can establish enclosed, tranquil zones. Shading panels on rest pavilions or pergolas, designed for Beijing's seasonal solar angles, can both provide shade in summer and allow for sunlight in winter. These approaches enrich spatial layering and offer varied thermal experiences for pedestrians.

Localised microclimates along the riverside greenway can be further optimised through strategic planting and micro-topographic adjustments to improve the walking experience. For example, refined planting strategies can be adopted by selecting tree species with varying forms and canopy sizes, combined with a range of planting densities.

2. South Moat River section

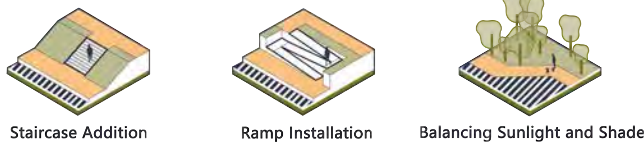
Drawing on Singapore's green corridor development experience, roadside reserves and river buffer zones can be fully utilised to enhance the design. In sections with both a waterfront walkway and an embankment-top pedestrian path, more stairs and ramps should be added to enhance vertical connectivity. Clear signage and pavement design can help guide pedestrian flow in a logical manner, enhancing both navigational ease and walking comfort.

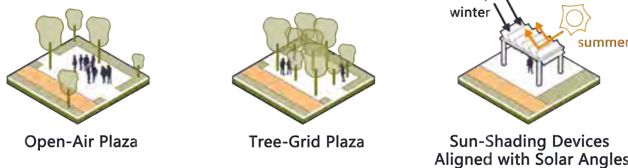
In sections with only the waterfront walkway, microclimatic design should consider the river orientation and topography. Sparsely foliated vegetation can be selectively planted in sunlit, well-ventilated areas to reduce shading and allow direct sunlight, balancing sun and shade. Additionally, vertical greening elements can be introduced in certain areas so that shading and plant transpiration improve the vertical thermal environment.

3. East and West Second Ring sections

Without changing the overall layout, it is still possible to improve the landscape quality of existing themed pocket parks. High-albedo or permeable paving materials can reduce heat absorption, and misting fans and dynamic water features like fountains help heat to dissipate through air movement and evaporation.

For the northern segment of the greenway on the west side of the East Second Ring Road, where dense canopy cover creates heavily shaded conditions, selective pruning at appropriate locations may be considered to introduce greater variation in light exposure.





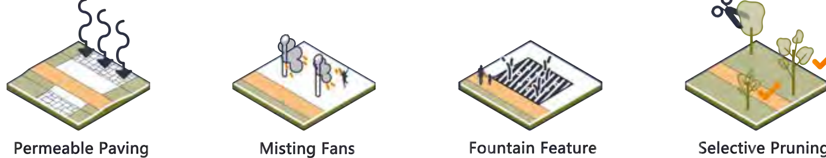


Figure 3. Targeted optimisation strategies using the thermal alliesthesia effect (image by Yanhan Li and Lanxi Yang, May 2025).

Pilot segment: Design informed by thermal alliesthesia

A representative segment of the greenway was analysed to demonstrate how thermal alliesthesia principles can inform design (figure 4). In the proposed design of this segment, the continuity along the municipal footpath, the in-park greenway path and the riverside walkway is enhanced. The route is structured as a sequence of contrasting microclimates to deliberately elicit thermal alliesthesia during walking. In a typical 15–20 minute route, a pattern of alternating 'warm' and 'cool' is arranged: an urban footpath provides the initial warm baseline; a sunlit waterfront forecourt maintains brief radiant exposure; a shaded

under-viaduct passage offers rapid relief; an open lawn reintroduces gentle warmth; and a final grove provides shade. The goal is not to maintain a single 'best' temperature, but to create frequent changes in thermal stimuli during the walk to enhance the overall thermal experience. Other routes along this corridor likewise offer diverse conditions capable of inducing this effect.

Design interventions are directly linked to this mechanism. Permeable paving with low reflectance reduces re-radiation and establishes a controllable warm starting point. Shaded corridors beneath the bridge provide cooling. Planting density is varied to adjust the duration of shade, while open squares briefly restore mild warmth. New ramps and stairs connect the viaduct footpaths with the greenway, improving accessibility and allowing users to choose preferred thermal conditions. These measures maintain the primacy of physical improvements – vegetation, ventilation and materials – while using perceptual sequencing to amplify their benefits to the walking experience.

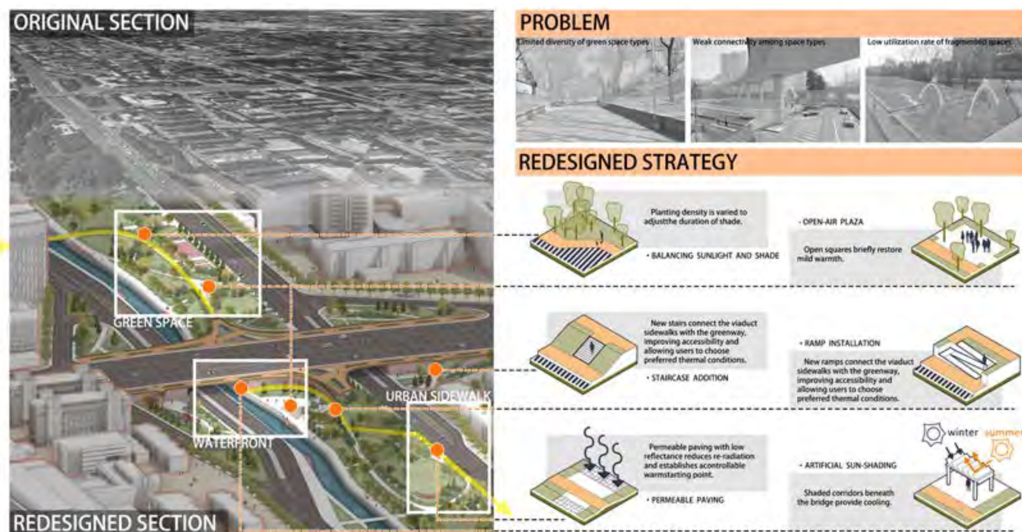


Figure 4. Pilot segment illustrating the application of the thermal alliesthesia effect in design (image redrawn by Yanhan Li and Lanxi Yang, adapted from a project of the research group, August 2025).

Implications

Applying thermal alliesthesia in urban greenway design

Greenways with high-quality environments such as parks tend to provide better thermal comfort (Beele et al, 2024; de Quadros and Mizgier, 2023; Norton et al, 2015). However, given that current trends in urban renewal emphasise sustainability and the optimisation of existing built environments (Almulhim et al, 2024), planners are increasingly exploring ways to integrate urban roads into greenway networks, including in areas with less favourable conditions, in particular poor drainage and narrow spaces. Improving these areas calls for innovative strategies, rather than strategies that rely solely on ideal locations.

In environments with varying microclimatic conditions, the dynamic thermal experiences along a route can contribute to a more nuanced and, at times, more satisfying thermal experience. Planners and designers should create greenway environments that introduce thermal alliesthesia by deliberately varying microclimatic conditions at a small scale, which in turn enhances pedestrian comfort and encourages greater greenway use.

Achieving these kinds of greenways requires introducing physical variations along the corridor, which can be accomplished through two strategies: route planning and landscape design. Route planning should incorporate contrasting landscape features – such as municipal streets and parks – to create thermal transitions. For longer greenway sections, the design should aim for varied landscapes to avoid repetitive design language, which might limit thermal alliesthesia.

Effective use of existing urban spaces, combined with landscape interventions, lays the foundation for high-quality greenway networks. In this process, integrating design strategies informed by thermal alliesthesia helps to capitalise on the psychological benefits of dynamic thermal comfort alongside physical improvements. This approach complements rather than replaces traditional landscape and infrastructure measures, offering a practical and cost-effective way to expand greenway networks in real urban settings.

Global applications of thermal alliesthesia in urban greenways

Growing awareness of urban heat has brought the issue to the forefront of the global planning and policy agenda. At the same time, many cities are advancing greenway initiatives that strengthen active transport networks while supporting public health, such as New York's recent Greater Greenways plan (New York City Department of Transportation et al, 2025).

Against this backdrop, acting on the opportunity to create thermally comfortable greenway environments becomes particularly important.

Supported by the case study of an existing greenway in Beijing, this paper proposes planning and design strategies to enhance thermal comfort by harnessing the thermal alliesthesia effect. This concept has broad international applicability. Introducing it to diverse environments requires flexible, location-specific solutions based on climatic characteristics, urban spatial forms and climate-responsive guidelines.

As a concept that complements physical design, thermal alliesthesia provides a new perspective to improve subjective thermal comfort for people walking outdoors. In this way, the effect has the potential to indirectly reduce motorised travel and support strategies for mitigating the intensifying challenge of urban overheating. This paper therefore recommends integrating this effect into frameworks for responding to heat globally.

Conclusions

A well-designed thermal environment along greenways can promote outdoor exercise such as walking, which benefits public health and sustainable urban development. In urban renewal, planners increasingly need to repurpose existing municipal roads and adjacent underutilised spaces as part of greenway systems, even under less than ideal conditions. Therefore, a key challenge is how to improve thermal comfort for pedestrians along these interwoven greenways. Meeting this challenge requires innovative design strategies.

Current strategies to improve thermal comfort in greenways focus on improving environmental quality. The thermal alliesthesia effect expands the potential strategies available by highlighting how changes in subjective perception have a role in shaping thermal experience. This effect can be induced by varying microclimatic conditions.

Using the Beijing Second Ring Road Greenway as a case study, this paper has explored specific methods of applying the thermal alliesthesia effect to improve thermal comfort in urban greenways. The main approach it recommends is to create diverse thermal environments through route planning and landscape design. A detailed design of a representative section of the greenway demonstrates how these strategies can be applied. Moreover, this approach can be adopted more widely across different places and climates, with designers developing flexible solutions suited to their given location.

The concept of thermal alliesthesia provides a valuable additional perspective on enhancing pedestrians' thermal comfort. It offers new insights for planners and designers into ways to improve greenways as community spaces for walking and other socio-physical activities.

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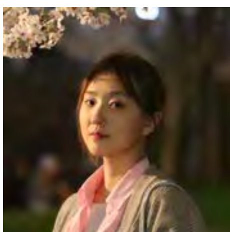

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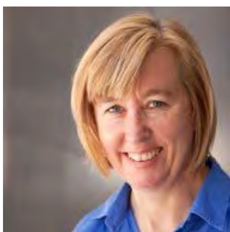

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Native Australian grasses planted as part of Project Cultivate in the Melbourne General Cemetery (image by author, May 2024).

LANDSCAPE
REVIEW

The future of a cemetery in a warming climate

Wendy Walls

This paper utilises the complex physical and cultural landscape of an inner urban cemetery in Melbourne to position microclimate materiality as a crucial contemporary design framework. Beginning with key concepts from design literature on the design potentials of heat, air and atmosphere, this theory-led framing suggests that small-scale fluctuations in temperature over time can offer insight into spatial and temporal diversity as qualities that can be leveraged through design. This position is further explored in the specific social and environmental context of the Melbourne General Cemetery. This case illustrates the relevance of microclimate materiality for landscape design in navigating urban pressures in our time of climate change – especially in complex sites where cultural, social and environmental values overlap.

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Introduction

The Melbourne General Cemetery, sited to the north of the Melbourne central business district, is a historically important and very large open space within central Melbourne. Although originally designed as a garden cemetery following nineteenth-century European design principles, over time the cemetery has filled with graves, transforming from open parkland as in its original vision to an intensive, multilayered and complex urban landscape.

The cemetery is now at a critical juncture as the site can no longer take new in-ground burials, which have been its primary source of income, resulting in a major impact on the cemetery's operating and maintenance models. Added to these economic challenges are the pressures of future planning and the value of large open spaces to urban communities in the context of climate change.

Melbourne is predicted to become hotter and drier, factors that also influence the quality of urban landscapes. Anticipating that this will lead to combined pressures related to funding, maintenance and future planning, the cemetery's horticulture team has trialled an innovative native grassland planting strategy called Project Cultivate. While this new planting strategy has been successful, local community groups who use the cemetery recreationally have agitated for an even more substantial site redesign towards addressing climate threats like urban heat.

This scenario involving a culturally valuable site with issues related to its maintenance, costs and community pressure in a warming climate exhibits a compelling, provocative and fundamentally difficult design challenge that is illustrative of the issues facing many urban cemeteries worldwide. In the Australian context, the example further highlights the need for conceptual frameworks and exploratory methods that can enable designers to address warming urban landscapes that are socially complex.

This paper proposes a design framing based on microclimatic materiality to describe and discuss the distinctive atmospheric and landscape qualities of the cemetery. The framing is intended to highlight the spatial and temporal diversity of the microclimate as a material condition, and as a way of viewing and responding to complex landscapes like the cemetery.

The paper is presented in two parts. The first presents recent literature on urban cemetery redesign and introduces the framing of microclimate materiality for navigating these kinds of intricate spaces. Part two gives a more detailed description of the Melbourne General Cemetery, its background, heritage, current condition, community involvement

KEY WORDS
design, material speculation, microclimate, landscape architecture, planting design

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and recent Project Cultivate. The site is an important example of where diverse landscape qualities and spatial influences create conflicting agendas, which impact on the potential for landscape design in a warming climate.

Part one: Design challenges and microclimatic opportunities

Cemeteries, while often meticulously designed in the first instance, are traditionally viewed as single-programme spaces with a primary design strategy that is assumed to be kept indefinitely. Further, governance and policy on cemetery sites are often decades old, reflecting the priorities and concerns of previous urban agendas but also limiting the options for introducing new design strategies into cemetery spaces. More so, until relatively recently, it has been rare for the maintenance plans or redesign of urban cemeteries to be included in the work of urban designers and planners at all (Bennett and Davies, 2015).

However, as cities come under the pressures of a warming climate, population growth and built density, cemeteries and their often-large open spaces are increasingly drawing attention for their potential to cater to new uses and multiple programmes. Whereas in the past, cemeteries have been perceived as separate from other social, community or environmental uses, they are increasingly identified as usable spatial urban resources. This is reflected in the growing body of global research on how older cemetery spaces can be redesigned and planned to address greater social and environmental concerns. For example, studies have considered the need for more community engagement and placemaking in cemeteries (Bachelor, 2020; Bennett and Davies, 2015; Grabalov and Nordh, 2022), or how cemeteries can have a role as ecological enclaves where the relative isolation of a site creates refuge for urban plants and animals (Anna and Ewa, 2020; McClymont and Sinnett, 2021). Much of this research engages with design strategies, such as succession planning, mixed-use design and transformative maintenance, that work towards a diversified programme and varied spatial uses.

However, ideas for doing more with cemetery sites also highlight some obvious tensions, such as how cross-programmed activities might conflict with spaces of mourning, traditions and perceptions of respect. For example, many cemeteries are physically divided by religion or cultural practices that may no longer reflect emerging community demographics or interests. The Melbourne General Cemetery, which part two will explore in more detail, was originally laid out in discrete religious denominations primarily indicating the customs of European immigrants. Over time, with new migration patterns and changing burial practices, this original layout and new burials have become intermingled. Yet, despite the unique new montage of stories, people and influences, the history and heritage of the site are still not fully representative of the current and growing community.

The inclusion and celebration of some buried in the cemetery, and the absence and exclusion of others, are reminders of the heavy influence of social norms, colonialism and wealth in countries like Australia. As historian Robert O'Shea (2011) writes:

> Despite its inclusive name and ecumenical foundation as a collaboration between various Christian denominations and the state, the Melbourne General Cemetery has consistently functioned as an exclusionary space … from the creation of the cemetery as the first burial ground in Melbourne with no allocated space for Indigenous burials, to the present, where interments are limited to expensive mausoleums. (p 82)

Although the size, environment and semi-public nature of cemeteries may appear to be a quick solution to offering more park-like environments in cities, these are still complex socially and culturally coded spaces. In addition to the importance of history and memorialisation are new emerging and critical questions about changing community attitudes (Grabalov and Nordh, 2022; Nordh et al, 2023; Rae, 2021). The premise of transforming cemeteries to become more diverse in their use and to enable multiple communities of people, plants and animals alongside existing traditions of remembrance

is not about just adding more to these sites, but rather is concerned with how to negotiate with spatial and social diversity (Greene and Walls, 2023; Hooper, 2020; Klingemann, 2022; Straka et al, 2022).

It may not be viable to retain cemetery landscapes for single programmes within the pressures of the contemporary urban environment. Yet introducing even more priorities, like environmental performance or social activation, only adds to the challenge of navigating between values and priorities of past, present and future uses.

This research poses a design theory-led position of microclimatic materiality as one framework (among many possibilities) for interrogating complex sites like cemeteries. Microclimates, as dynamic and temporal small spaces of light, air and temperature, offer a rich spatial diversity for designers to utilise for conceiving design opportunities in contested and layered spaces. Even more useful is how the behaviours and effects that inform microclimatic qualities can be aligned with other agendas like social use, environmental performance or cultural connections. Thermal effects, for example, are a strong driver of how people or animals use and enjoy outdoor spaces. When viewed this way, the transferable materiality of atmospheric qualities, including heat, are a creative medium that, in unison with landscape elements, designers can employ to respond to heightened social, cultural and environmental performance.

Lastly, a focus on microclimatic materiality in urban landscapes also invites a design conversation about working in the future climate of cities. Cities are increasingly hot environments due to the effects of thermally dense materials and the urban heat island, which are further compounded by the incremental temperature gains due to climate change (City of Melbourne, 2016; Osmond and Sharifi, 2017). Although the increasing threat of extreme heat in urban environments adds urgency to a focus on microclimate materiality, this is most often presented as a technical problem to be solved through a singular focus on cooling (Nice et al, 2024; Osmond and Sharifi, 2017; Wang et al, 2022).

Rather than presenting a solution-oriented approach, this paper focuses on the spatial and experiential potentials of microclimates. A design-led framing and deeper theoretical engagement with atmospheric effects are often ignored in the face of the urgent need to respond to climate change and warming cities. However, for designers interested in qualities of diversity and temporality, there are considerable opportunities underpinning the sensory condition of microclimates and their material effects. The final section in this part turns to design literature to expand on the theoretical context, which then frames the part two discussion of the example of the Melbourne General Cemetery.

Microclimate as design materiality

Atmospheric qualities, like temperature, air quality, humidity and light, are primary conditions that influence how both human and environmental communities use and enjoy physical spaces. The thermal zones of microclimates can invite users to linger, as gentle warm sunshine can on a winter's morning; or equally they can repel people and animals, such as when heat builds up to uncomfortable levels. Dynamic conditions also can lead to diversity in the way a space is used at different times. For example, the shifting and fluctuating temperatures of daily, diurnal and seasonal patterns create distinctive, yet ephemeral moments in time and space.

Throughout the twentieth century, work with environmental effects was most closely aligned with environmental and climate sciences, with a focus on measurement and quantification. This led to assumptions that atmospheric effects were conditions to be controlled or fixed, rather than a design materiality. Writing from a twenty-first century perspective, Roesler and Kobi (2018) explain:

> To look at the existing literature on microclimates (conceived as man-made artifacts) one gets the impression that this is still a purely scientific and technical subject which has little to do with architecture, landscape architecture or material culture in general. (p 16)

However, beyond viewing these conditions as environmental byproducts, a growing body of design theory recognises microclimates as a rich material palette, which can be harnessed and influenced through design (Lally, 2014; Rahm, 2014; Roesler, 2019).

This is particularly evident when sites and phenomena are viewed at a human scale, in the immediate space where a body might feel and experience but also react to local conditions. Whereas much urban climate research has focused on large-scale cooling such as addressing the heat island of whole suburbs or cities (Gao et al, 2022; Shao and Kim, 2022; Žuvela-Aloise et al, 2016), the framework of microclimate as design materiality emphasises the many and varied smaller-scale effects that emerge through the interactions of environmental forces with physical and material conditions.

These design ideas are found in recent writings from scholars like Silvia Benedito (2021) and design work by Phillipe Rahm (2023) and Sean Lally (2014), who have tested and explored the potential of atmospheric materials to form spatial design. These examples show how thermal conditions can be used to shape and direct human and environmental uses of a site. For example, the environmental potentials of relatively quiet, dark and cool spaces might inform future planting strategies, or knowledge of the influence of thermal diversity on interactions might highlight how social programmes work differently in the mornings compared with the afternoons. In this way, microclimates offer a mechanism for engaging with environmental and social diversity through use and experience. Further, the interactions of microclimate temperature, site and use are relational. Bodies and use respond to but also contribute to thermal effects. While a group may seek out space with relative warmth, they bring heat with them too, adding further microclimate variance that depends on people's actions and activity. Articulating these interwoven and temporal elements that influence microclimate allows us to understand temperature effects as environmental conditions, but equally how the materiality is 'shaped by cultural, social and political meanings' (Roesler and Kobi, 2018, p 13).

Thus, as a design-theory view for diversifying spatial qualities, arrangement and uses, microclimate materiality is valuable for interrogating the growing research and proposals related to the question of how urban cemeteries might offer greater social and environmental amenities. However, it is important to recognise that landscape microclimates begin from existing site and material conditions. Here, the distinct landscapes of cemeteries pose particular technical challenges that can contradict thermal management with traditional spatial elements. For example, in Victoria, Australia dark marble and stone are common for graves, but these materials absorb and hold heat from the sun. In addition, the norms of planting trees and shrubs are informed by heritage precedents, ongoing maintenance and new demands.

Certainly emerging research is looking to cemeteries as landscape solutions to urban cooling; for example, studies of cemeteries in German and Turkish cities found that densely treed cemeteries had a greater cooling effect than parks (Selim, Karakuş and Eyileten, 2023; Stumpe et al, 2024). However, the conditions in these locations do not necessarily reflect the distinctive landscapes of other cemeteries. Part two now turns to the unique site of the Melbourne General Cemetery to explore this theory more directly through a particular context and community and specific spatial qualities.

Part two: The Melbourne General Cemetery

The Melbourne General Cemetery (MGC) covers 43 hectares, equivalent to the area of the Melbourne Botanic Gardens. It is positioned next to the University of Melbourne, and amidst Melbourne's busy and densifying northern suburbs (figure 1). The physical size of the site makes it one of the most substantial pieces of open space in the inner-north of the city. It is a large and distinctive landscape that is much loved and enjoyed by its surrounding communities (Epstein, 2021; Saffer, 2022).

Figure 1. Aerial map of central Melbourne showing the central business district and the Melbourne General Cemetery 2 kilometres to the north (adapted from Nearmap, 2024).

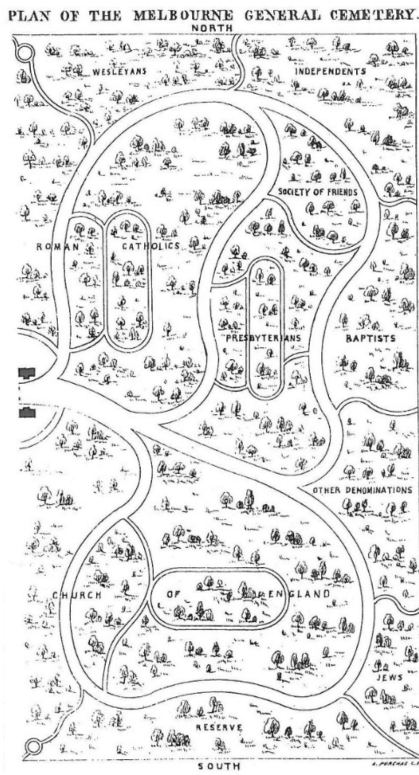
With the intention of designing a *garden cemetery*, the original plans included curving pathways and lawns in a spatial arrangement dividing European religious denominations (figure 2a). This underlying arrangement is an exemplar of romantic garden style, a significance reflected in the Victorian Heritage Register (H1788), which states:

> aesthetic importance due to the meticulous planning of architect Albert Purchas (1825–1909), and botanist Baron Ferdinand von Mueller (1825–1896) who were responsible for the formal and romantic layout of the cemetery and also the plantings of exotic and indigenous species of flora. (Victorian Heritage Database, 2024)

Since the cemetery opened in 1853, its landscape has evolved through many stages of planning, management, mismanagement and varied maintenance (Chambers, 2003; O'Shea, 2011; SMCT, 2024b). While the general shape of the early plan remains legible, the layout and historical markers of the garden style, like open grassy lawn and trees, have been removed over time as new graves have infilled the original layout (figure 2b).

The remaining distinctive heritage elements range from the small scale of the wrought-iron fence (1870s) to some mature trees planted in the late 1800s and a selection of monuments to famous characters like explorers Robert Burke and William Wills, billiards champion Walter Lindrum and several Australian prime ministers. Other than a memorial to First Nations chief Derrimut, there is a notable absence of Aboriginal Australian graves or memorials (Briskey, 2023; Edensor and Sumartojo, 2024).

Further to the site's elements of colonial heritage, the MGC has taken on several curious features like the iconic memorial to Elvis Presley (figure 3). Added into a Charles Robinette rock grotto in 1977, it is the only official monument to the singer outside of North America (Jones, 2000; Stubbins, 2018). However, beyond the individual moments, the MGC is the resting place of over 300,000 graves. Across this collection is a remarkable diversity of cultural and religious practices, made visible in the evolving memorial types and in their upkeep and care. Forming a symbolic timeline from the 1850s through to today, the details within the MGC offer extraordinary insight into Melbourne's colonial, post-war and migrant histories (Dwyer, 2023).



(a) **(b)**

Figure 2. (**a**) An early plan of the Melbourne General Cemetery 1854 (reproduced from Chambers, 2003). (**b**) The cemetery today shows the same distinctive, though adapted curvilinear paths (image by Nearmap, 2024).

Figure 3. The idiosyncratic addition of an Elvis Presley memorial to a Charles Robinette rock grotto (image by author, 2024).

Today the MGC is governed by the Southern Metropolitan Cemeteries Trust (SMCT). This trust operates nine of Melbourne's major cemeteries under a private not-for-profit board and trust structure, reporting to the Minister for Health (SMCT, 2024b). Management is further guided by legislation and rules that are specific to cemeteries in Victoria, Australia. For example, when a grave is purchased in Victoria, it is in perpetuity, meaning that the cemetery site must be planned for continued and ongoing care (O'Shea, 2011). This provision for continual preservation raises complicated questions for sites like the MGC. Until very recently, the primary income for maintaining the site has come from traditional in-ground burials. However, as the site has filled up over time, this revenue is no longer available. While there are options for other sources of funds, the removal of this source represents a major loss of maintenance income.

These intersections of heritage, ongoing maintenance and potential future uses of a very large and important piece of open space make a compelling case for thinking about long-term design in cities, particularly considering climate change predictions of more heat in the future (CSIRO and Bureau of Meteorology, 2022). Increasing temperatures add pressure to urban landscapes but also impact how human communities can continue to enjoy outdoor space. This tension is exacerbated in the MGC site, which is a remarkable and beloved community space but also a very hot environment (Miller, 2024). After the following three sections briefly elaborate on these key site issues, the final section in this part discusses the important Project Cultivate initiative and the future of the cemetery in a warming climate.

A remarkable landscape

Beyond its major monuments, the landscape of the MGC is unusual and engaging, though in many parts degraded. After 170 years of mixed governance, maintenance and planning, the landscape is a patchwork of graves, roads, paths and plantings. It has gone through well-known periods of mismanagement, including alleged embezzlement and reuse of space (Ibac, 2017; O'Shea, 2011; Stubbins, 2018). For example, in the 1970s unmarked graves were covered with a new layer of soil to create space to re-sell as private plots. Similarly, parts of the original roads were repurposed. Now lines of graves from the mid-twentieth century era cut through older areas, following the curve of the original garden cemetery roads (figure 4) (O'Shea, 2011).

The density of graves, patchwork of styles and rearrangement of lines create a strong sense of the uncanny throughout the site. This quality reflects in part the site's physical evolution over time but also the impact of long-term ownership and maintenance challenges. Graves are purchased in perpetuity and are nominally the responsibility of the family who owns them. However, in many cases relatives no longer tend to their plots and, with over 300,000 burials, institutional upkeep of individual graves is untenable (O'Shea, 2011). The current maintenance strategy for subsiding and damaged headstones is to lay them down once they become unstable, primarily as a safety precaution (figure 5). Despite this, the intermingling of distinctive spaces, materials and character is rich with surprise and even moments of delight. Small groves of trees, for example, contrast with the extensive stone and concrete (figure 6).

The cemetery site, with its unusual layout, varied materiality and large space to explore, has a rare contemplative quality in urban public space. It is a landscape that creates reflection not just by being a cemetery, which of course provokes thought, but through its curious mix of planned and unplanned form, formal and wild vegetation and the diversity of experience that can be found within the large and exposed, yet full landscape. Its contradictions and ambiguity make it special and its charm is well-loved by the surrounding communities (Saffer, 2022).

Figure 4. Grave plots bordering one of the old serpentine roads (image by author, 2024).

Figure 5. Unstable headstones are laid on the ground (image by author, 2024).

Figure 6. A grove of trees and a rare clearing within the Melbourne General Cemetery (image by author, 2024).

A community space

The cemetery is home to many memorials and graves of local families who regularly visit loved ones. It is also used by commuters, walking or on bicycles, as it easily connects the city with the northern suburbs. The SMCT (2024b) estimates around 200 people pass through each day.

In addition to these uses, the open space is valued by the residents of the surrounding suburbs of North Carlton and Princess Hill as a kind of parkland for light recreation. Because of its distinctive qualities, locals use it in ways that differ from their use of other local parks, playgrounds and sports fields. This particular engagement with the site intensified during Melbourne's famous COVID-19 lockdowns (2020–2021), when the cemetery became an essential and peaceful space for locals to spend time outside (Princes Hill Community Centre, 2022; Richards, 2021). That period also sparked recognition of the importance of the cemetery and the Save Our Cemetery residents' group who are focused on advocacy to local government and the SMCT for better upkeep of the site and its features (Epstein, 2021; Princes Hill Community Centre, 2022; Saffer, 2022; SMCT, 2024a).

An active 'friends' group also volunteers time for gardening and maintenance on new plantings, like Project Cultivate (discussed below). Beyond the formally organised events, known guerilla gardening practices of informal tending and planting take place around some of the older graves. Plants like rosemary, lavender and forget-me-nots have been added as indicative of traditional European cemetery vegetation, alongside garden cuttings of succulents and pelargonium, which grow well in the cemetery's relatively hot and dry microclimate (figure 7).

Figure 7. Garden plantings interspersed among graves (image by author, 2024).

These acts of informal guerilla gardening are far more prominent in the cemetery than in surrounding parks, offering some insight into the unique role of the cemetery as a community space. From the work of formal groups to the informal practices, the actions and use of the site reveal many layers of connection to and care of the site. But these also hint at the critical tensions over how to future-plan the site given its multiple community and maintenance interests. Clearly, there are divergent perspectives within the community about not only how the cemetery should look but also how people should be using the site. These tensions are further exacerbated by climate change predictions, including about how the site will look and perform in a warming climate.

A hot site

The material conditions of the cemetery can make the landscape a very hot site. The graves, roads and paths are hard surfaces of marble, concrete and asphalt (figure 8), which make up much of the terrain. While there are some remarkable old trees and shady groves like the row of peppercorn trees in figure 9, they are rare moments within the broader landscape.

Further contributing towards the climatic performance of the site is the highly complex subsurface. Even the existing groves and clearings, while appearing to be open landscapes, still include burials – some are entirely unmarked, while others are very old with minimal or semi-submerged headstones. The underground strata of graves in various states of decomposition have created a honeycomb of soil, materials and air pockets across the entire site. This is a major constraint on future design and heat management, especially the common method of mitigating heat with an extensive tree canopy as reflected in the City of Melbourne's target of achieving 40 per cent canopy cover by 2040 (City of Melbourne, 2012). In the MGC, creating a dense canopy simply is not a replicable option because it is impossible to plant new trees safely.

Figure 8. In some sections of the cemetery, almost the entire surface consists of marble and concrete (image by author, 2024).

Figure 9. A row of peppercorn trees (*Schinus molle*) in one of the few sections of open ground with canopy cover (image by author, 2024).

Despite these constraints on heat management through canopy cover, the community, including groups like Save Our Cemetery, would like to see more trees, more shade and more robust greening in the site. Recent campaigns to the local council have focused on the issues of heat and how people, plants and animals who share the cemetery will fare in the warming climate. Local resident Jane Miller (2024), writing to Melbourne's newspaper *The Age*, comments:

> just down the road from me is the Melbourne General Cemetery where decades of neglect and excessive use of herbicides have resulted in the creation of a heat island. At 43 hectares it is larger than the Royal Botanic Gardens yet estimates of tree coverage range from 8 to 18 per cent (the latter figure including trees outside the cemetery).

In the case of the MGC, the clear tensions between community, management and future planning present an important set of issues. The mix of ideals, visions and opinions about what the cemetery should look like and achieve reflects the issues facing cities in relation to climate change more generally. Of particular significance is how pragmatic concerns like funding and maintenance are balanced against competing community interests.

In 2023 the SMCT initiated a major planting strategy called Project Cultivate, which offers a striking and effectual response to some of these concerns. The final section in this part will briefly explain that project before reflecting on these site conditions against the framing of microclimatic materiality for design that engages with sites with concurrent social and environmental priorities.

Project Cultivate

Project Cultivate is a native grassland and meadow planting strategy applied to some of the older sections of the MGC. The project aims to eventually cover at least 15 per cent of the total site. Led by the horticultural assets manager, the initiative uses mulching and native plantings to create a better-performing ground condition. The mulch addresses the site's poor soil quality and helps in managing water runoff. Planted into the improved ground are native grasses and wildflowers, including kangaroo grass (*Themeda triandra*), wallaby grasses (*Rytidosperma* sp.), everlastings (*Chrysocephalum*) and native flax (*Linum marginale*). These plants will tolerate the hard growing environment but also pose minimal risk in the complex subsurface. In the unirrigated site, the new grasslands will also help to manage the site's microclimate and improve biodiversity. Initial pilot plantings have already greatly reduced maintenance costs and herbicide use as well as improving rainwater runoff (SMCT, 2024c).

The visual and sensory effect of Project Cultivate is to provide a remarkable play of delicate colours and textures of Australian grasses against the structures of old graves (figure 10). The aesthetic is both uncanny and beautiful, connecting with theory of melancholy in landscape design (Bowring, 2016). It is also an extraordinary project for how it engages with Australian plant material, simultaneously acknowledging the pre-colonial landscape before the cemetery was built and forecasting towards supporting the site in the future.

Figure 10. Project Cultivate grass planting between graves (image by author, 2024).

Project Cultivate is highly innovative – especially in the context of the cemetery and its maintenance demands. The work will greatly improve the ongoing environmental performance of the site; from urban animal habitat to water management. While the native planting offers much environmental and aesthetic value to the site, residual tensions remain between the community expectations and wants, heritage significance and how this landscape will perform in the warming climate. The low-level grasses cannot provide shade and, although the plantings create a much-improved ground condition with reduced ambient air temperature, there is little space for people to be part of this emerging new landscape.

The mechanism of planting itself has engaged with locals and community groups through a series of planting days (SMCT, 2025). Nevertheless, returning to the premise that older cemetery spaces can and should be redesigned to increase both social and environmental uses, the grasslands are not planned around ongoing community activities.

In large part, this omission has occurred because the project centres on the environmentally focused strategy applied across as much of the site as is viable. The questions about how heritage is preserved or how the values implicit in guerilla gardening are addressed remain outside of the project scope. However, in considering the future of complex sites like cemeteries and cities experiencing climate change, are single strategies enough?

In reflecting on the issues raised in this paper, I suggest they are not, and that designers must find ways to shape spaces where cultural, social and environmental values overlap. This does not mean to detract from the considerable value of Project Cultivate. It is

an effective strategy with environmental significance. More so, reflecting on Project Cultivate within the MGC context exposes just how challenging it is to work across concurrent and conflicting agendas. In this light, finding design strategies and approaches that can engage with diversity is more critical than ever before.

Here, the design theory of microclimatic materiality offers one useful perspective where design can engage with diverse sensory and spatial effects, rather than seek uniform solutions. Importantly, these framings open up site possibilities to engage with social use in concert with environmental performance. For example, quiet evening strolls in the cemetery are distinctly different from the experience of the intense heat of the middle afternoon. Morning community events can be planned in spaces of gentle morning sun. Walking routes and education spaces can be designed around cool zones. Equally, warm and hot spaces can be designated for those creatures (lizards and skinks) who like them most.

Most importantly, all of these uses can occur together – not all at once, but through the temporality of microclimate conditions. The physical characteristics of external space are a major driver of how people and animals will use and enjoy it, and the fluctuating microclimatic qualities of temperature, light and air are a primary materiality in producing special moments of inhabitation for bodies – human or otherwise. This is especially true in cities – like Melbourne – that experience a highly variable range of seasonal and diurnal conditions (CSIRO and Bureau of Meteorology, 2022).

Conclusion

In the broader sense, this paper asks, what are our cultures of and assumptions about designing in a warming climate? Answering this question goes beyond trying to fix urban heat with single interventions like mass plantings or tree canopy, to engage with strategies that allow designers to work across social, cultural and environmental concerns.

The cemetery, as a microcosm of the city, highlights many of these complexities as well as the tensions in introducing new uses or programmes to established sites. While the cemetery is often described as a single-programme site with an overarching layout, examining the space in more detail reveals considerable diversity in its qualities. These kinds of distinctions can be leveraged through design. Further, harnessing site microclimates with smaller fluctuations of warm to cool or hot and the many in-betweens offers a compelling and richer material palette for conceiving design. This brings questions of community and people into design thinking about environmental effects and offers a framing that begins to align microclimate behaviours with the other agendas of contemporary urban sites.

About the author

Dr Wendy Walls is a lecturer in Landscape Architectural Design at the University of Melbourne, Australia. Her research focuses on landscape design practice, theory and methods in working with heat in cities. This includes the role of landscape architecture in designing for the lived experience of a warming climate, which she explores through data-driven and digital design methodologies informed by eco-critical theory and material explorations.

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