South East Water

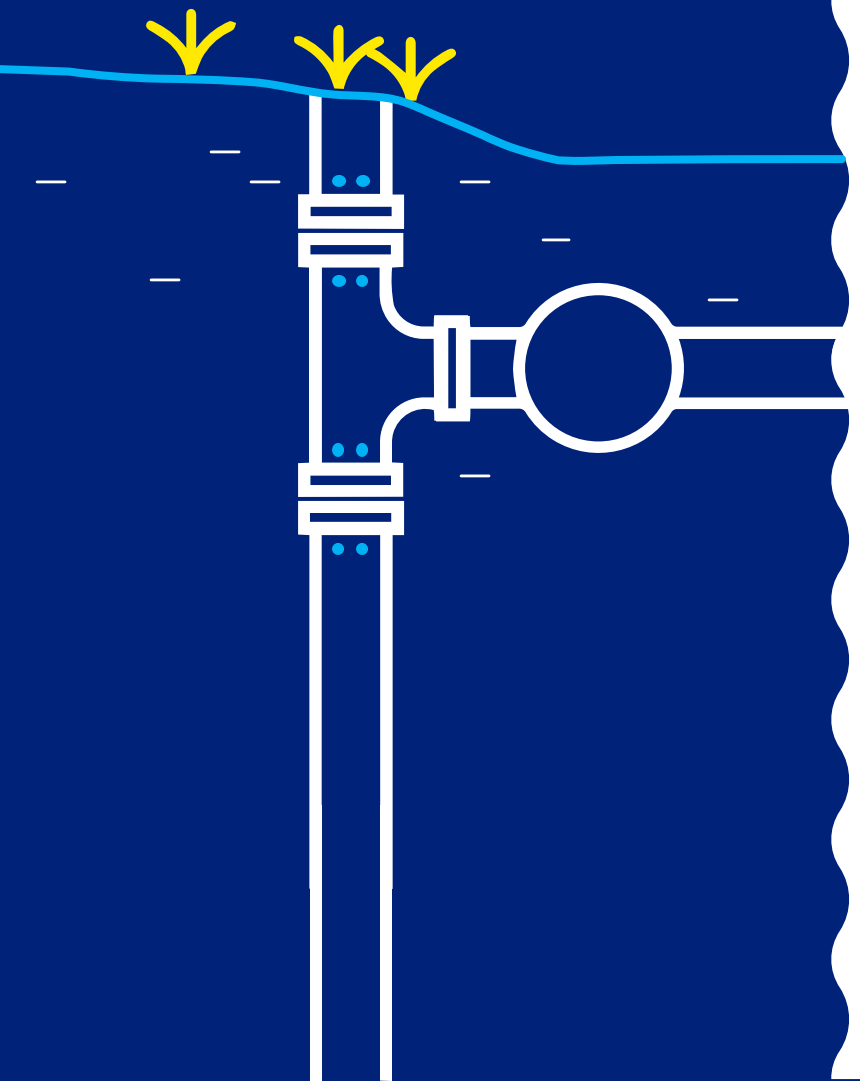
THE UNIVERSITY OF MELBOURNE

Water: enabling resilience and urban cooling

ABP Resilience Roundtable October 2023

Dr David Bergmann South East Water
Dr Kerry Nice University of Melbourne
(Pui (Paul) Kwan Cheung University of Melbourne)

Purpose



We set out to demonstrate that smart IoT irrigation and misting systems can contribute to cooler and greener residential environments.

We believe that cooler surrounds leads to lower housing energy costs, healthier people, and happier communities.

Leveraging the SEW OneBox® control system and using the SEW house at Aquarevo, and our partnerships with UoM and WSCA we set out to see what was possible.....

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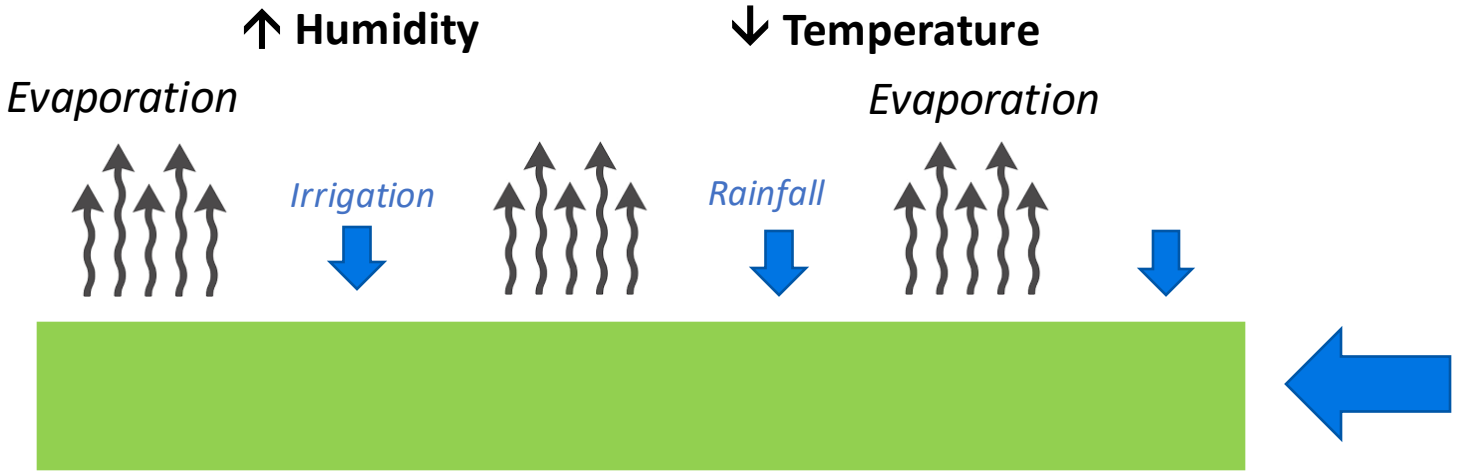
Cooling with Smart Irrigation – *the concept*



- Replenish soil moisture by irrigation and/or rainfall
- Based on real-time sensor feedback and rainfall forecast information.
- Evaporation provides the air moisture conditions to maximise cooling opportunities

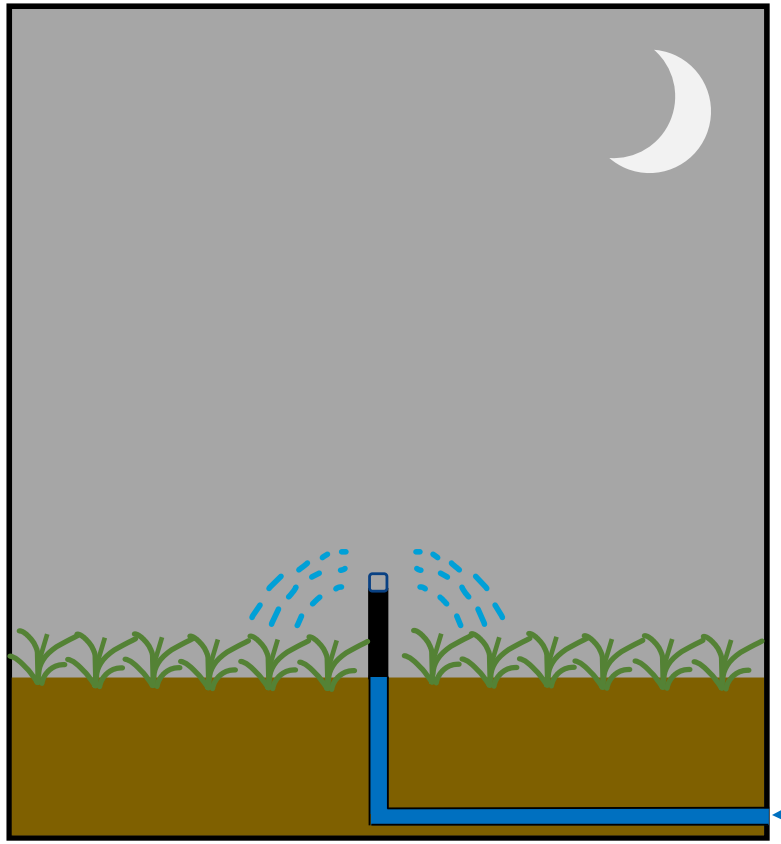

AQUAREVO
LYNDHURST


The Aquarevo House – March 2022


The Aquarevo House – March 2022

Irrigation for cooling green spaces is different

Irrigation for plant health:
1. Irrigate by **night**
2. Maximise **water use efficiency**



Potable water

Irrigation for cooling green spaces is different

Irrigation for plant health:
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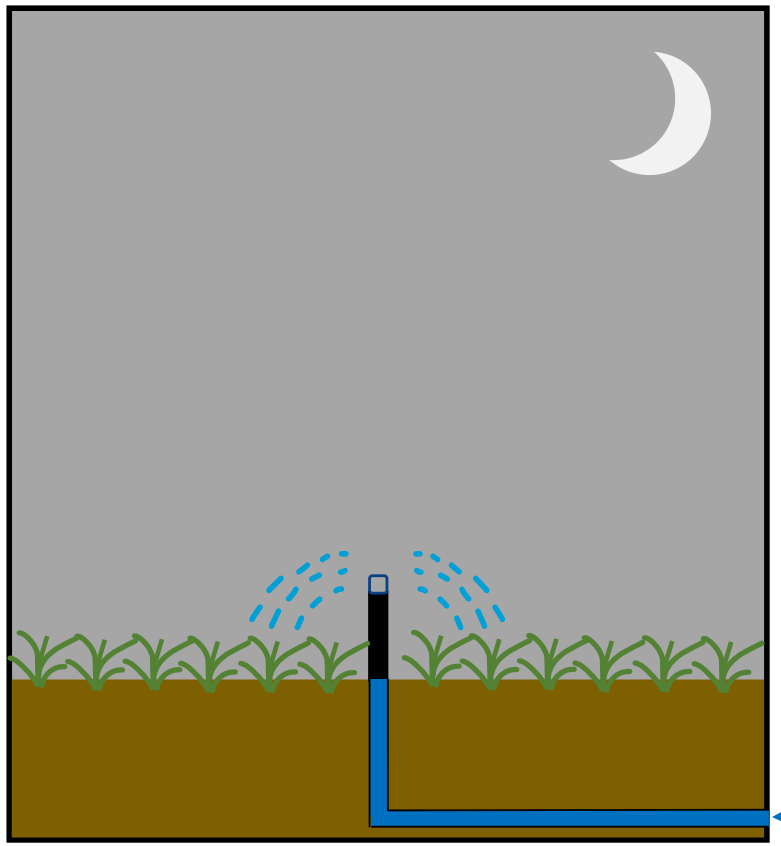
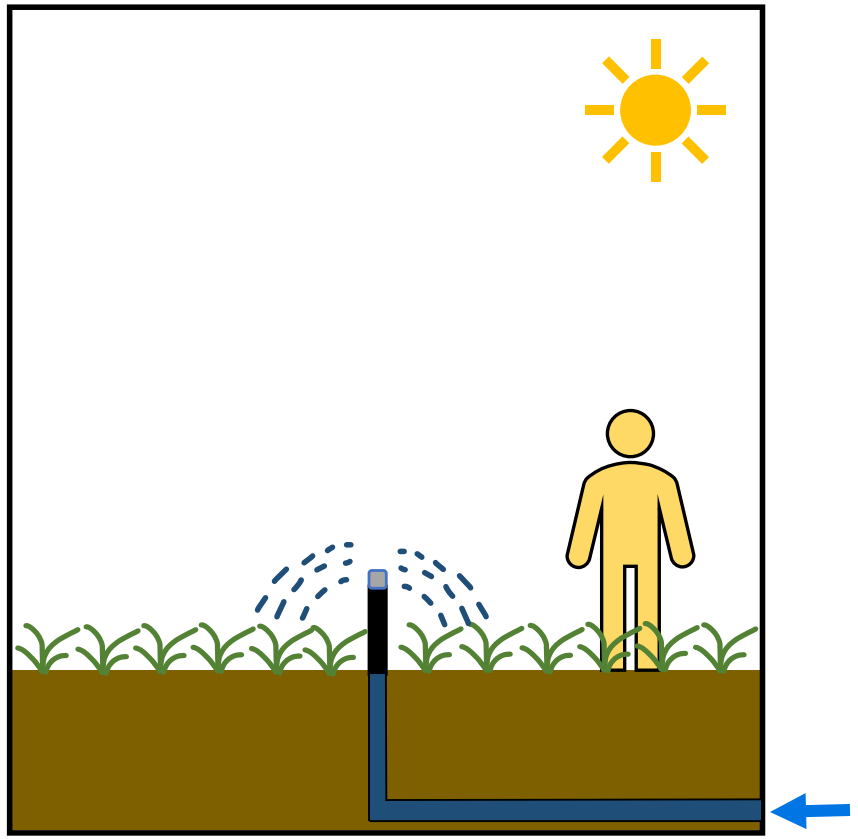


Potable water

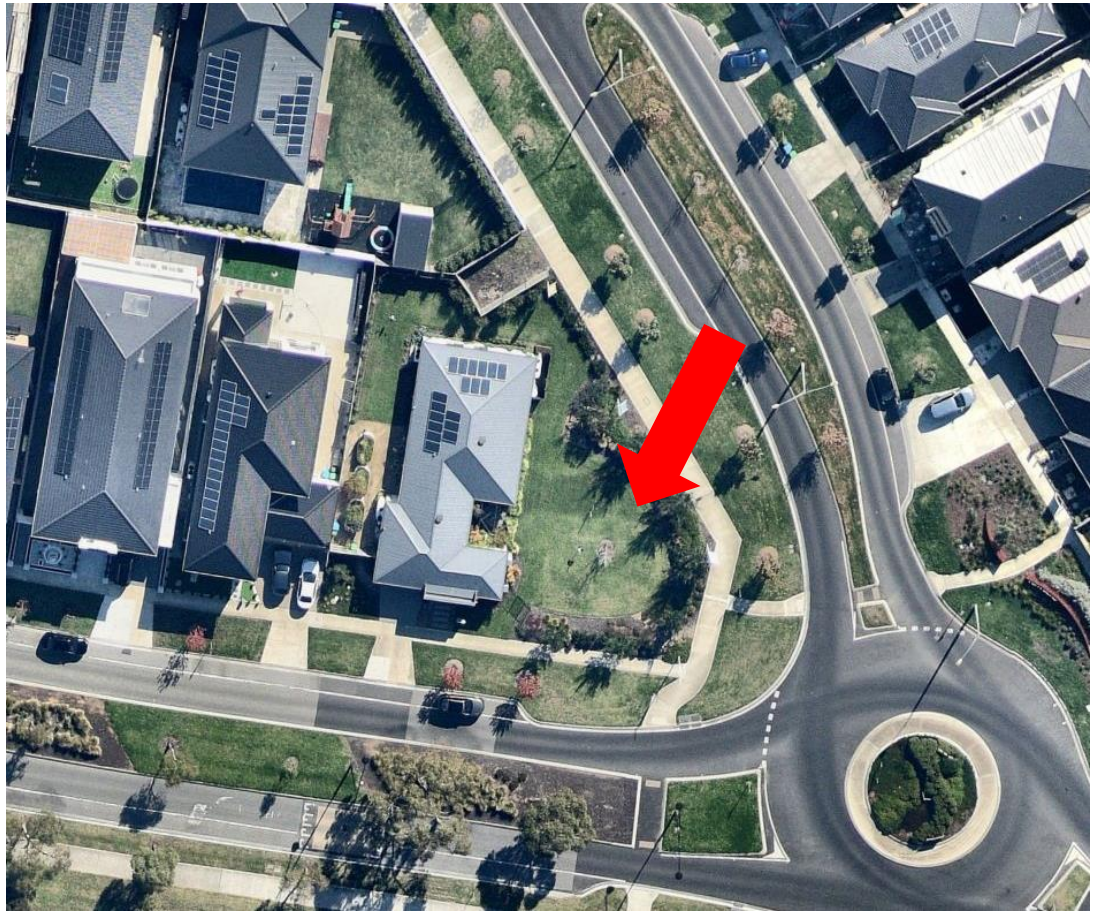
Irrigation for cooling green spaces:
1. Irrigate by **day/night**
2. Maximise **evaporation** and **transpiration**



Rainwater/ recycled water

Pui Kwan Cheung, Kerry Nice, Stephen Livesley, Irrigating urban greenspace for cooling benefits: the mechanisms and management considerations, Environmental Research: Climate, 2022.

At Aquarevo



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At Burnley Campus

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Irrigation cooling experiment at Burnley Campus

Hypothesis

Multiple daytime irrigation can provide a stronger cooling benefit for turfed backyards without using more water.

Irrigation treatments

1. **Reference:** Unirrigated
2. **Single night-time:** Irrigated 4 mm at 01:00-01:23am = 4 mm/day
3. **Single daytime:** Irrigated 4 mm at 13:00-13:23pm = 4 mm/day
4. **Multiple daytime:** Irrigated 1 mm at 12:00-12:05, 13:24-13:29, 14:00-14:05, 15:00-15:05pm = 4 mm/day

Same amount of water delivered at different times of the day

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Irrigation cooling experiment at Burnley

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Irrigation method

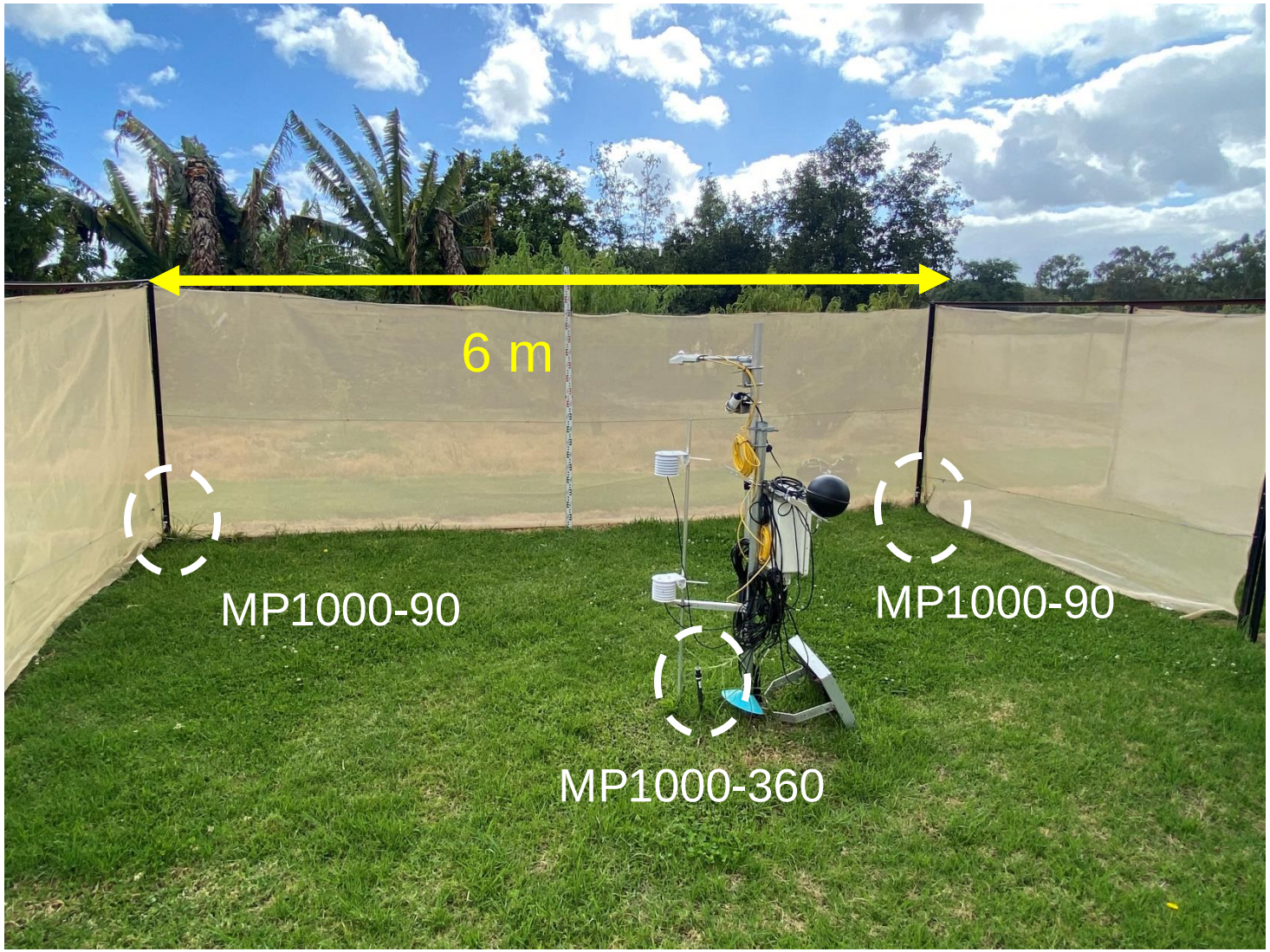
1. Hunter MP1000-360 × 1 at the centre,

   Hunter MP1000-90 × 4 at the corners

2. Operating pressure = 280 kPa

Microclimate measurements

1. Air temperature (1.1 m)
2. Turf surface temperature
3. Human thermal comfort (1.1 m)



Irrigation cooling experiment at Burnley – Results

x-axis = time of day
y-axis = air temperature of irrigated turf – air temperature of unirrigated turf
= 28°C – 29°C (example)
= –1°C (= irrigation has a cooling effect, example)

Single night-time:
Irrigated 4 mm at
01:00-01:23am
= 4 mm/day

Single daytime:
Irrigated 4 mm at
13:00-13:23pm
= 4 mm/day

Multiple daytime:
Irrigated 1 mm at 12:00-12:05, 13:24-13:29,
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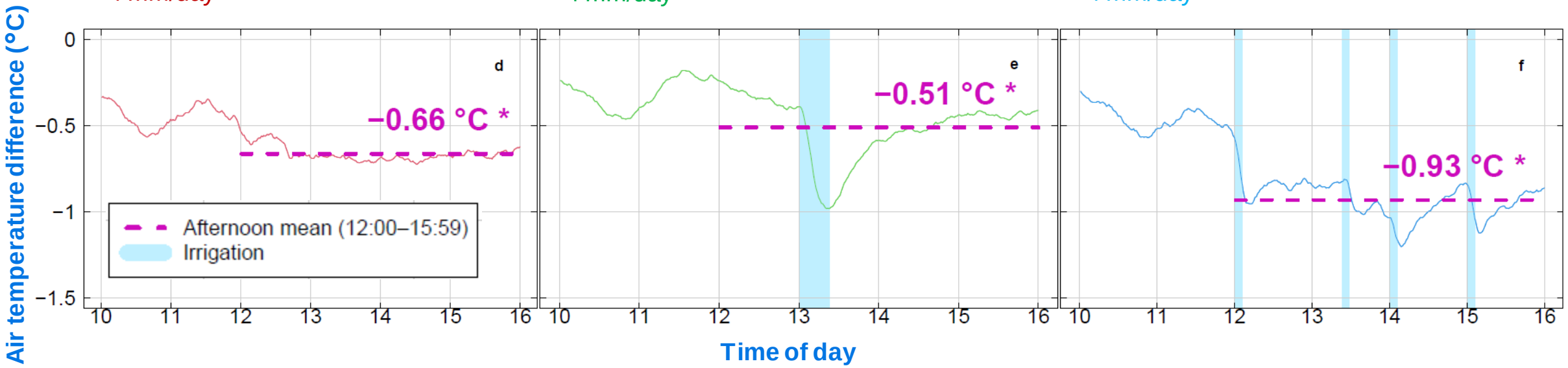

Pui Kwan CHEUNG, Irrigating urban green space as a cooling strategy – impacts on surface energy balance and microclimate, PhD thesis, 2023.

Irrigation cooling experiment at Burnley – Results

Air temperature

1. Some cooling effects in the morning.
2. Afternoon cooling effects were significant.
3. Afternoon cooling effect of multiple daytime irrigation (D4), –0.93°C, was significantly stronger.

➢ Smarter irrigation schedule can provide stronger cooling benefits without using more water.

Single night-time:
Irrigated 4 mm at
01:00-01:23am
= 4 mm/day

Single daytime:
Irrigated 4 mm at
13:00-13:23pm
= 4 mm/day

Multiple daytime:
Irrigated 1 mm at 12:00-12:05, 13:24-13:29, 14:00-14:05, 15:00-15:05pm
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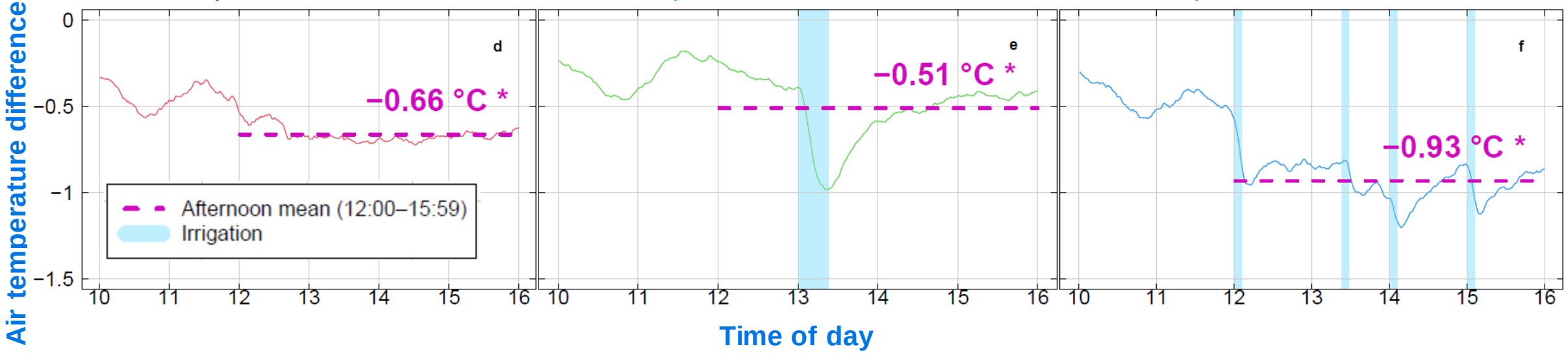
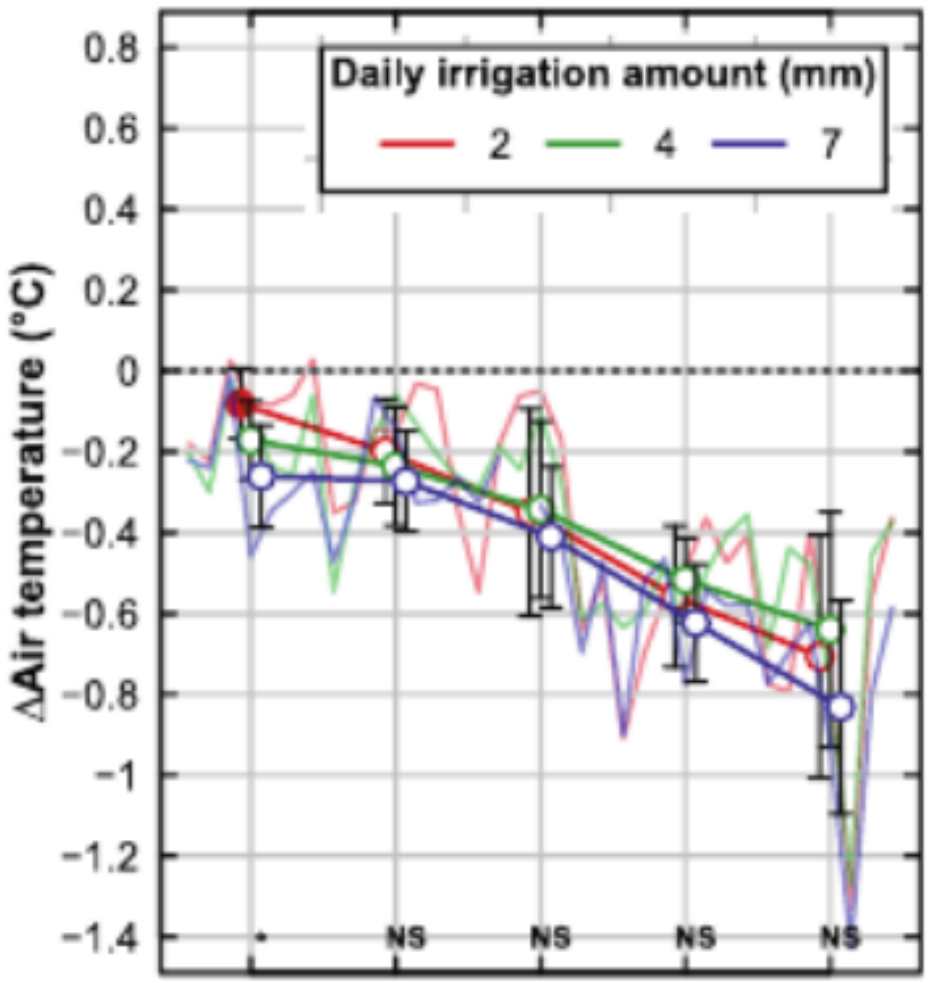


Pui Kwan CHEUNG, Irrigating urban green space as a cooling strategy – impacts on surface energy balance and microclimate, PhD thesis, 2023.

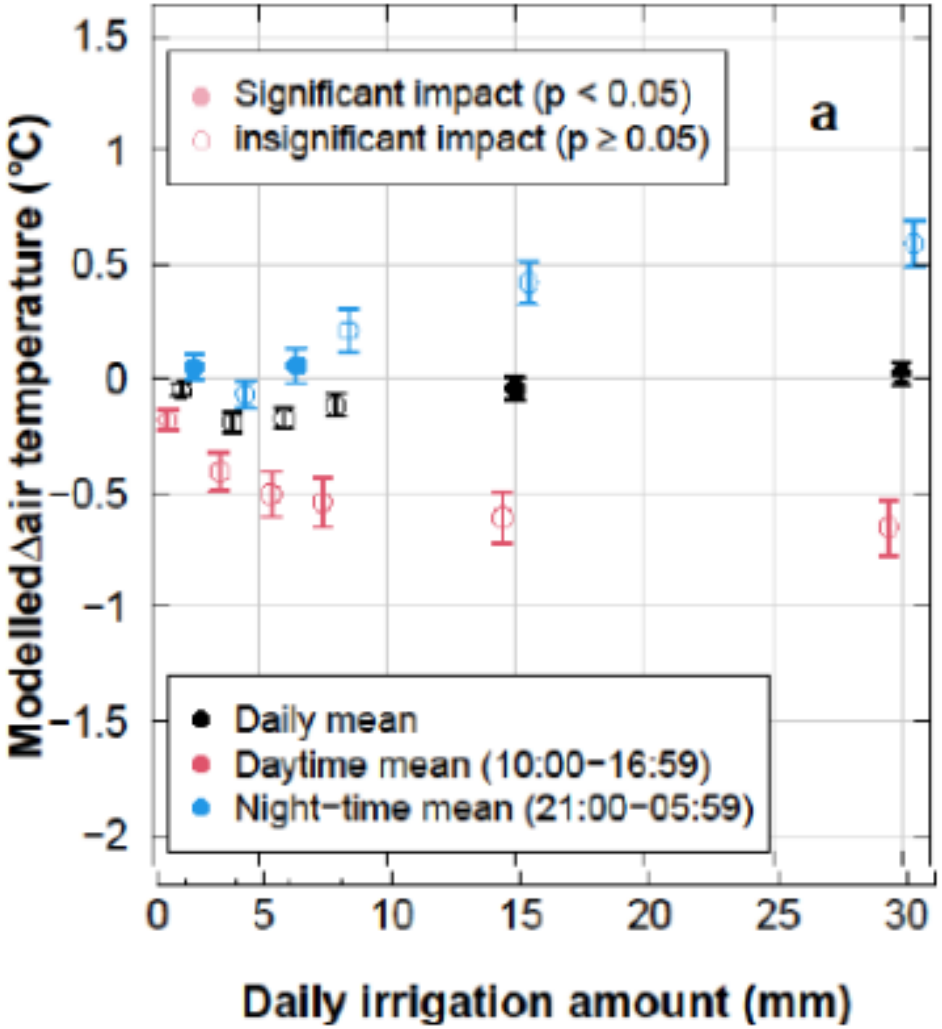
Warming can be seen as soil moisture dries out in the unirrigated plot



Impacts of irrigation on daytime (10:00–16:00) means. Differences between irrigated plots and unirrigated control plot across 6 weeks.

Pui Kwan Cheung, C.Y. Jim, Nigel Tapper, Kerry A. Nice, Stephen J. Livesley, Daytime irrigation leads to significantly cooler private backyards in summer, Urban Climate, 2022.

Cooling levels plateau when reaching reference evaportranspiration, ~4 mm/day in Melbourne



Modelled impacts of different daily irrigation amounts (2, 4, 6, 8, 15 and 30 mm)

Pui Kwan Cheung, Naika Meili, Kerry A. Nice, Stephen J. Livesley, Identifying the optimal irrigation amount for cooling urban green spaces in summer, Urban Climate (Under review)

Tree shade vs irrigation

Tree shade

Irrigation (1 mm × 4 = 4 mm/day)

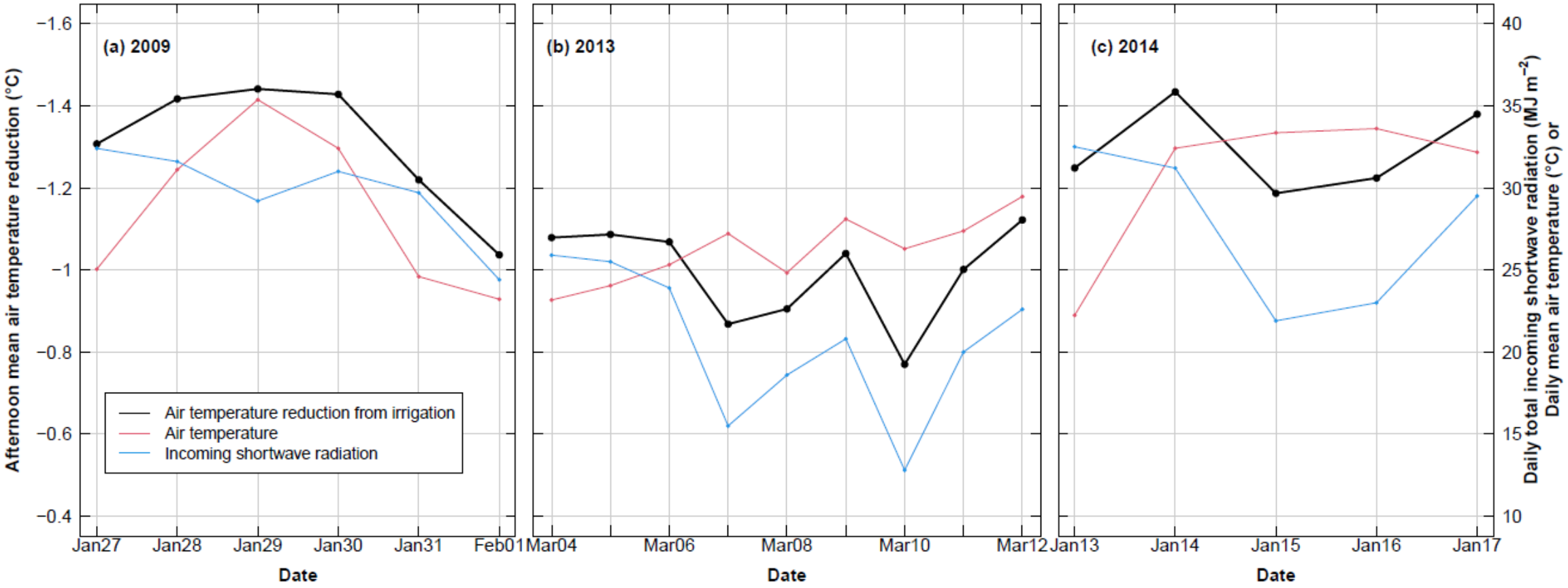
Cooling effect on air temperature in the afternoon (°C)

–1.5 to –0.7

–0.9

Sanusi, R. et al. (2017). Microclimate benefits that different street tree species provide to sidewalk pedestrians relate to differences in Plant Area Index. *Landscape and Urban Planning, 157*, 502-511.

Potential cooling during heatwaves using irrigation



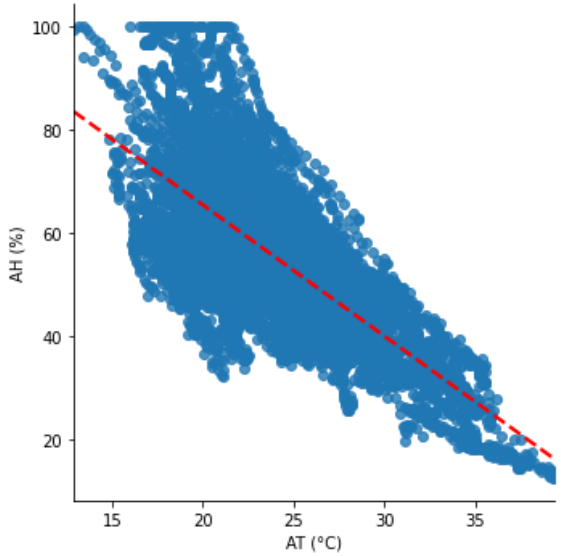
The predicted afternoon (12:00–15:59) mean air temperature reductions from irrigating urban green spaces during the three most recent heatwaves in Melbourne in (a) 2009, (b) 2013 and (c) 2014.

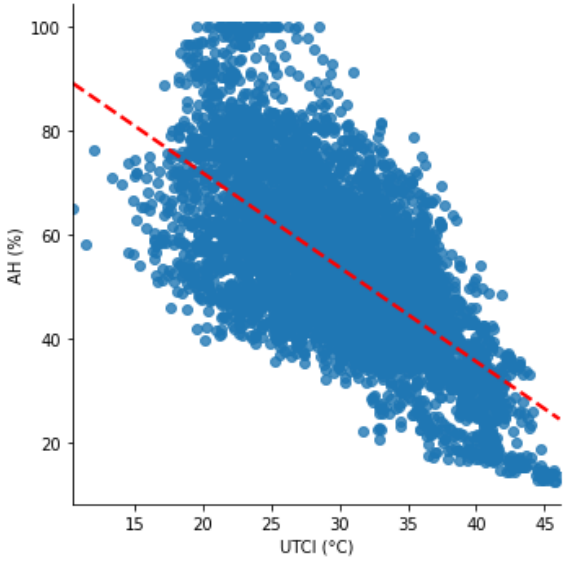
Warmer conditions (i.e. more available energy) means greater amount of water can be evaporated and increase the amounts of cooling

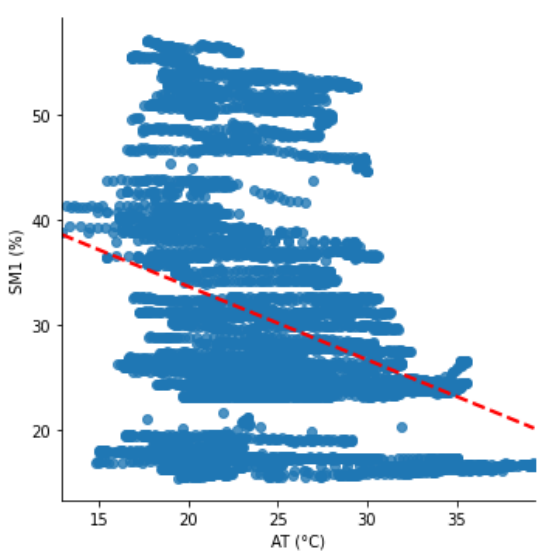
Pui Kwan CHEUNG, Irrigating urban green space as a cooling strategy – impacts on surface energy balance and microclimate, PhD thesis, 2023.

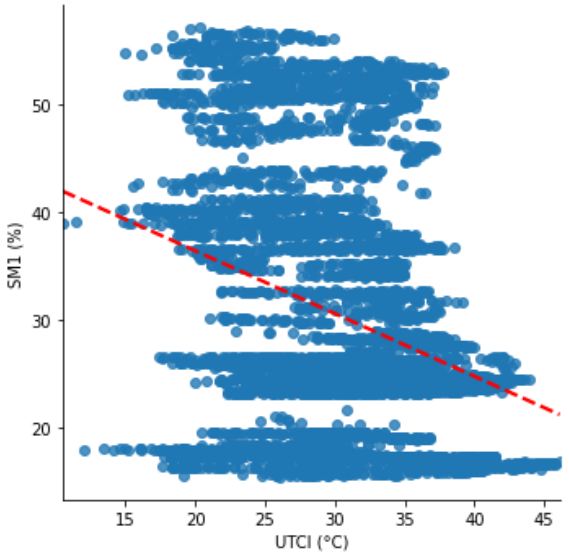
Replicating the conditions at Aquarevo House

- Moderate correlation (0.35) between Ambient humidity and Soil Moisture – Irrigation increasing humidity
- High correlation (-0.72) between Ambient temperature and Ambient Humidity – Irrigation reducing temperature
- Low correlation between Ambient Temperature and Soil Moisture









Correlations Between Environmental Parameters at Aquarevo House Node 0 (9am to 5pm)

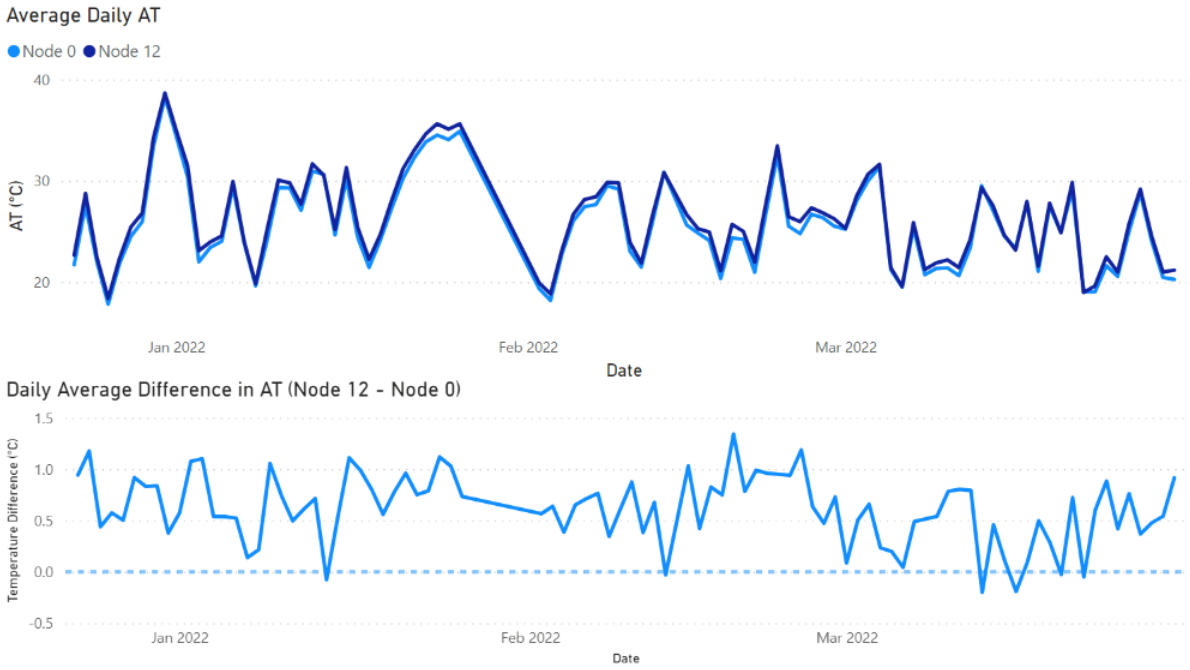
Node 0 is in the fenced backyard area where wind is less likely to blow away the cooling plume

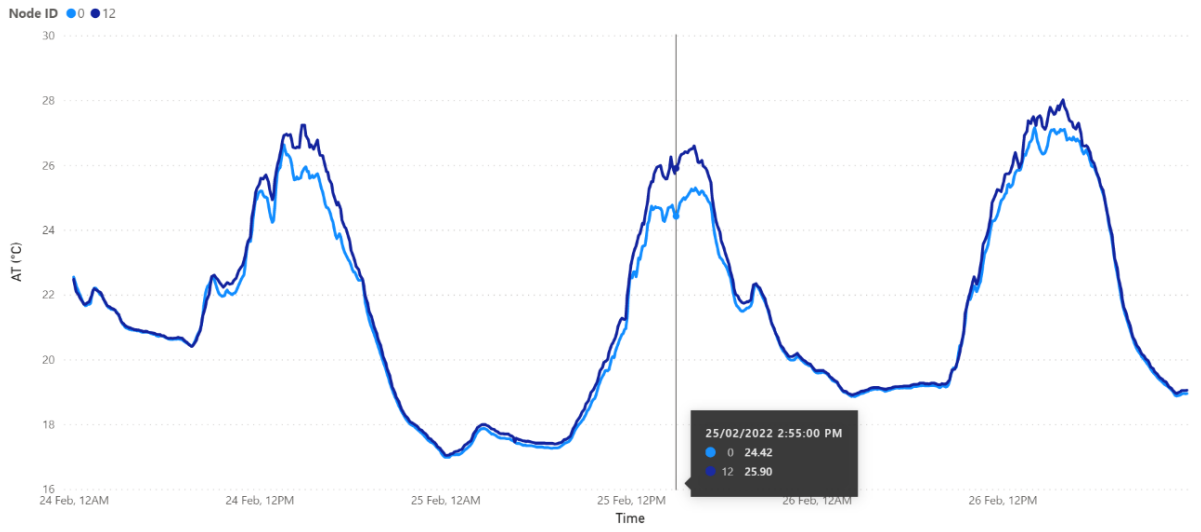
Node 1 show similar correlations

Impact of Not Having a Turf: Node 0 vs Node 12

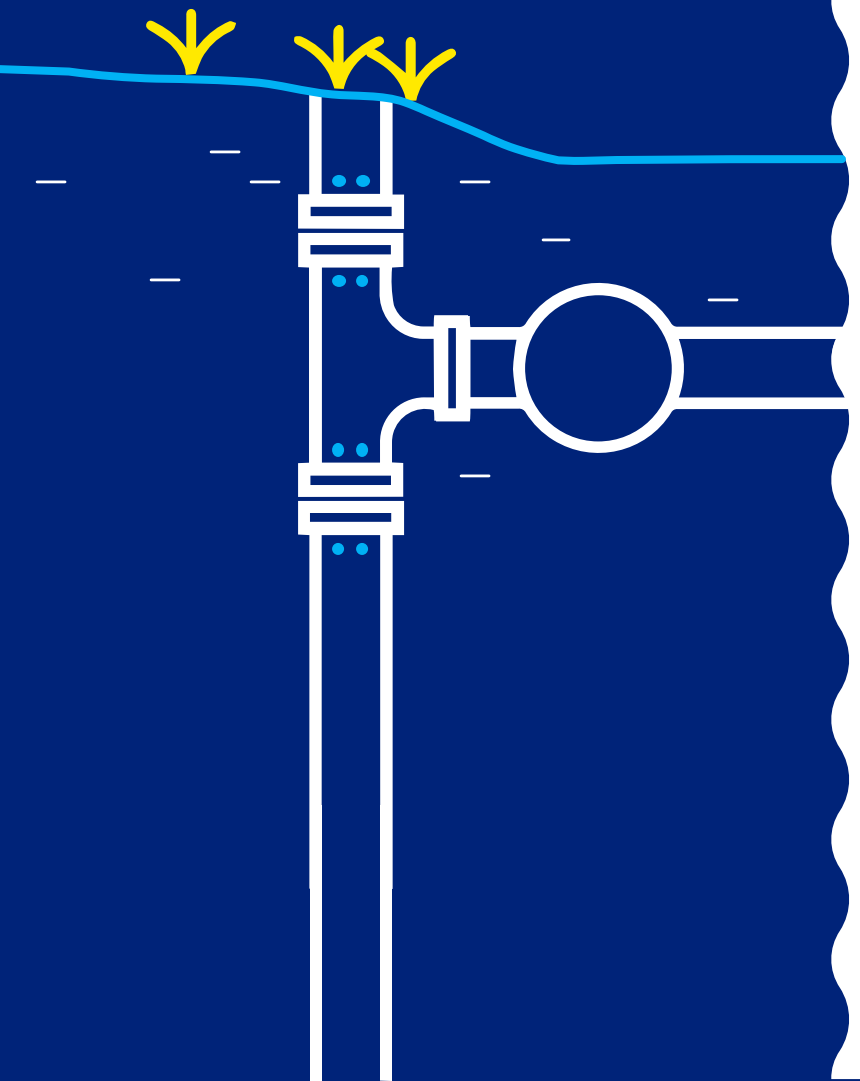
- Node 12 is in the gravel area and node 0 in the lawn area, both within 10m distance
- Both nodes have the sun directly above them between 1pm and 4pm
- Node 12 with no turf almost always has a greater ambient temperature compared to Node 0

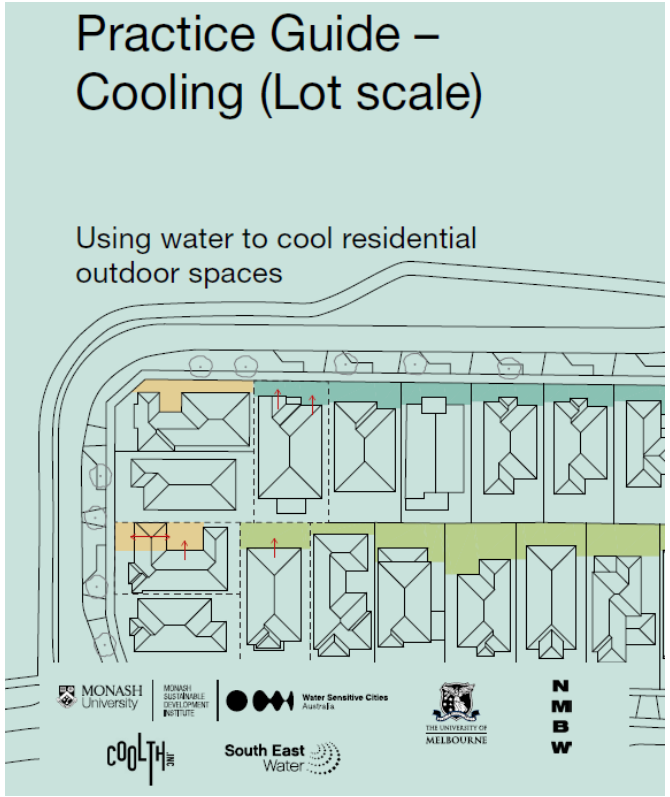
Aquarevo House





Guidance





This practice guide showcases good design for cooling outdoor living spaces using water, plants and architecture. The guide was developed by South East Water, University of Melbourne, Water Sensitive Cities Australia, NMBW Architecture and Coolth Inc.

Our aim is to raise awareness of cooling using water, providing both public health and environmental sustainability benefits. This guide focuses on the places where these cooling benefits are needed most: outdoor areas around our homes. It introduces evidence-based cooling principles and outlines practical ways to achieve good design.

https://wscaustralia.org.au/publications

https://wscaustralia.org.au/wp-content/uploads/2023/09/Cooling-guide-230927.pdf

Synthesis of urban cooling research to enable cooling at the lot scale

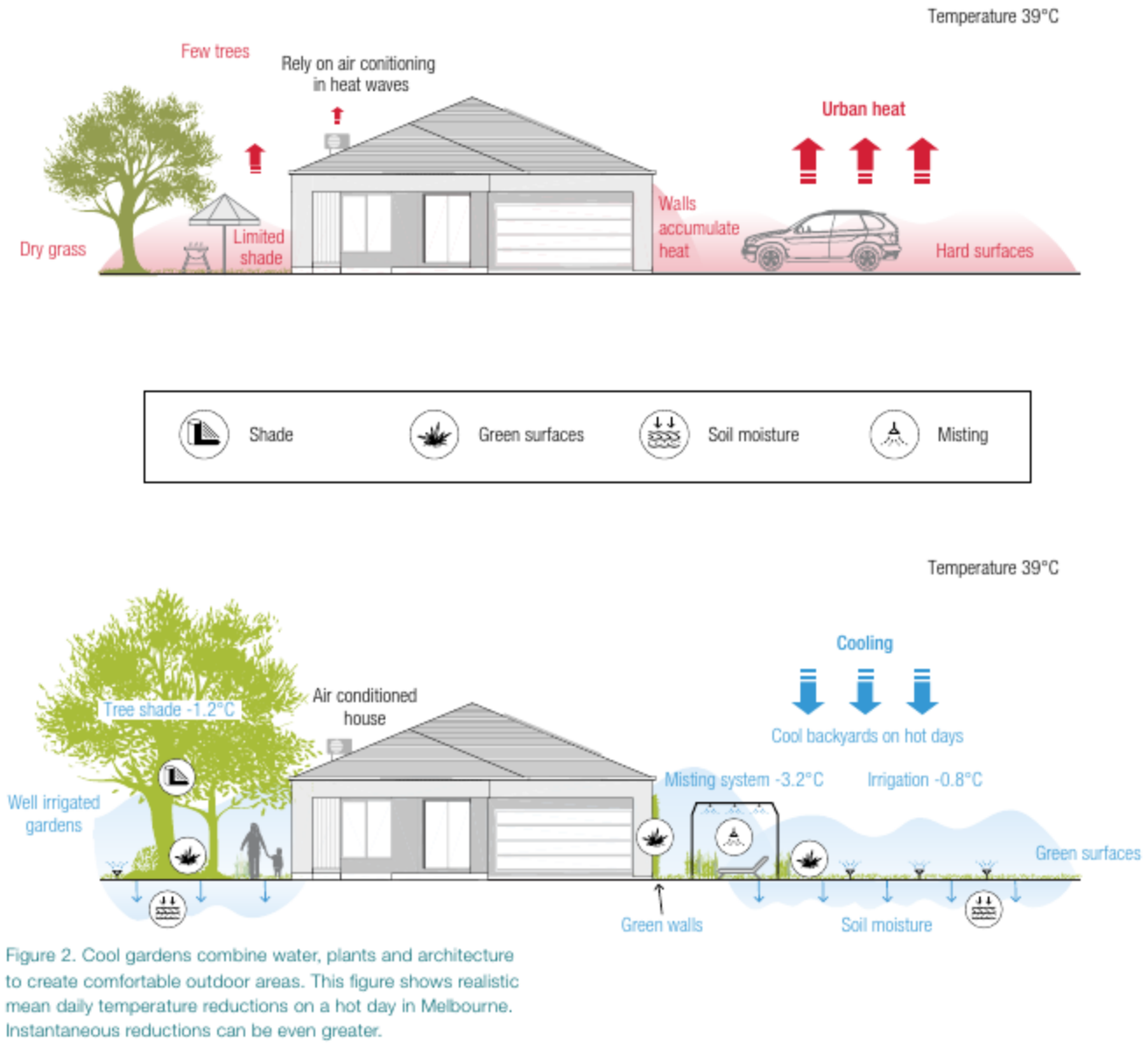
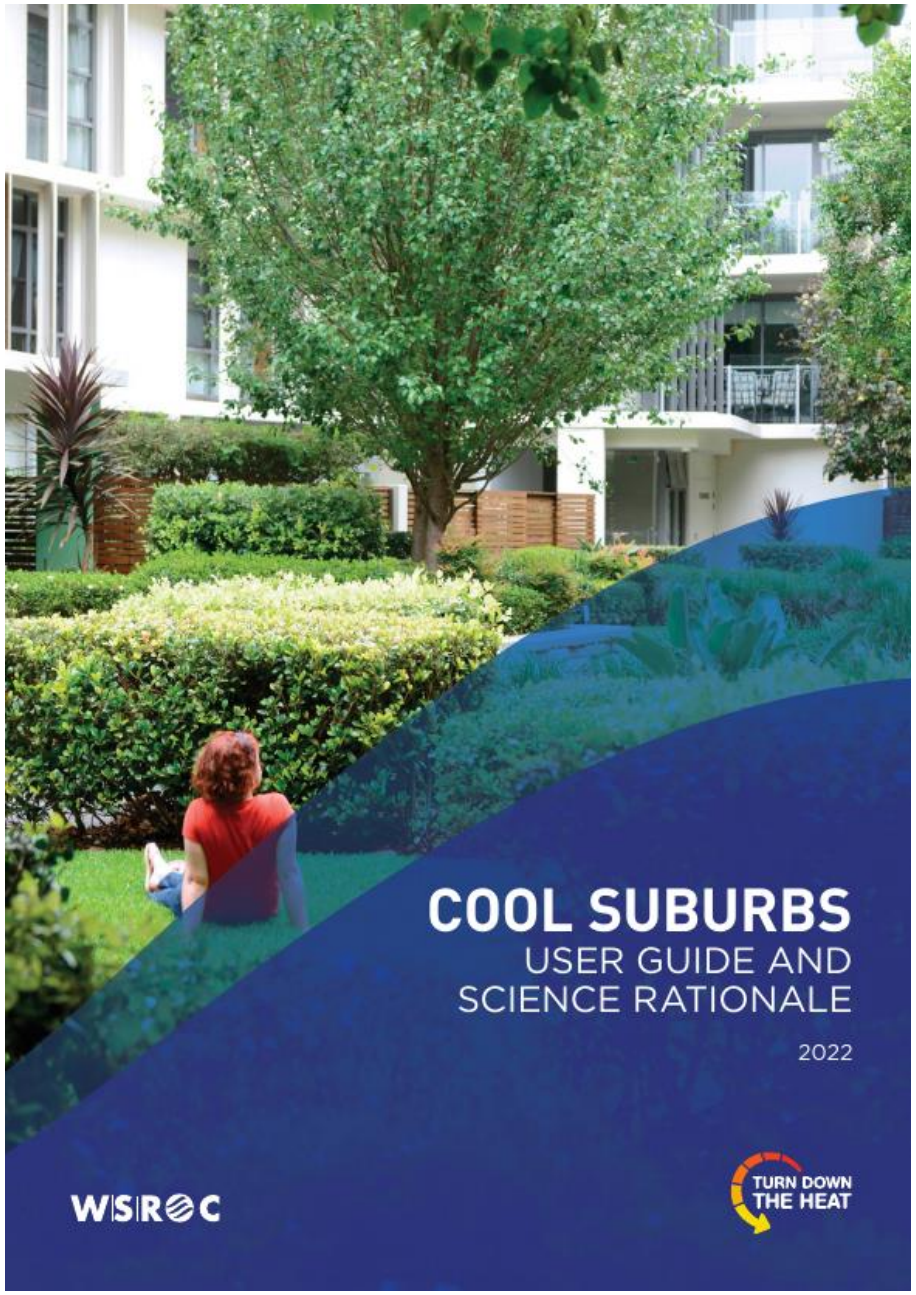


Figure 2. Cool gardens combine water, plants and architecture to create comfortable outdoor areas. This figure shows realistic mean daily temperature reductions on a hot day in Melbourne. Instantaneous reductions can be even greater.

Cool Suburbs Framework



TURN DOWN THE HEAT

Cool Suburbs is a heat resilience rating and assessment tool for urban planning and development.

Visit **coolsuburbs.com.au** for more information

The need for the Cool Suburbs Tool was identified as a priority action under the *Turn Down the Heat Strategy and Action Plan* (2018). The Turn Down the Heat Strategy was developed by 55 organisations across greater Sydney to create cooler, more resilient communities.

Cool Suburbs is also a flagship action under the *Resilient Sydney Strategy* (2018).

The Cool Suburbs project is a collaboration between WSROC, Resilient Sydney and the Greater Sydney Commission.

Cool Suburbs has been developed by Edge Environment in collaboration with the CRC for Water Sensitive Cities, Hydrology and Risk Consulting (HARC) and Kinesis. The project was supported by an expert science panel, consisting of: Monash University, Melbourne University, University of NSW, Western Sydney University.

This project has been assisted by the New South Wales Government and supported by Local Government NSW.

South East Water

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Water: enabling resilience and urban cooling

ABP Resilience Roundtable October 2023

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Selecting the most suitable plants for cooling

Table 2. Plants that help cooling, and how they might be used in a cool garden design

Botanical name	Common name	Yard type	Sun/shade	Day/night cooling
Trees				
Acer palmatum	Japanese Maple	F B		
Cercis canadensis	Eastern Redbud	F B C		
Cornus florida	Flowering Dogwood	F B C		
Corymbia ficifolia	Flowering Gum	F B		
Cupressus leylandii	Leylandii	F B C		
Magnolia grandiflora	Southern Magnolia	F B		
Fruit Trees				
Citrus latifolia	Tihiti Lime	F B C		
Citrus limon	Lemon 'Lisbon'	F B C		
Citrus x sinensis	Orange 'Navel'	F B C		
Prunus persica 'Nectarine'	Nectarine 'Fantasia'	F B C		
Prunus persica 'Peach'	Peach 'Anzac'	F B C		
Prunus domestica subsp.	Plum 'Damson'	F B C		
Shrubs				
Eutaxia microphylla	Common Eutaxia	F B C		
Hardenbergia violacea	Purple Coral Pea	F B C		
Lampranthus deltoides	Deltoid-leaved dew plant	F B C		
Murraya paniculata	Orange Jessamine	F B C		
Pittosporum Tenuifolium	Black Matipo	F B C		
Portulacaria afra	Elephant Bush	F B C		
Syzygium paniculata	Backyard Bliss	F B C		
Syzygium smithii	Lilly Pilly	F B C		
Viburnum tinus	Laurustinus	F B C		
Westringia fruticosa	Native Rosemary/ Grey	F B C		

Botanical name	Common name	Yard type	Sun/shade	Day/night cooling
Ground Cover				
Aptenia cordifolia	Heartleaf Iceplant	F B C		
Carpobrotus modestus	Inland Pigface	F B C		
Chamaemelum nobile	Roman Chamomile	F B C		
Dymondia margaretae	Silver Carpet	F B C		
Galium odoratum	Woodruff	F B C		
Isotoma axillaris	Rock Isotome	F B C		
Kleinia mandraliscae	Blue Chalksticks	F B C		
Mentha requienii	Corsican Mint	F B C		
Ophiopogon japonicus	Mondo Grass	F B C		
Sagina subulata	Irish Moss	F B C		
Sedum spurium	Caucasian stonecrop	F B C		
Soleirolia soleirolii	Baby's Tears	F B C		
Zygophyllum billardieroi	Coast Twin-leaf	F B C		
Raingarden Plants				
Baloskion tetraphyllum	Tassell Cord Rush	F B C		
Carex appressa	Tall Sedge	F B C		
Ficinia nodosa	Knotted Club-Rush	F B C		
Kniphofia 'winter cheer'	Red Hot Poker	F B C		
Limonium perezii	Sea Lavender	F B C		
Poa sieberiana	Grey Tussock-Grass	F B C		

Design typologies for cooling at the lot scale

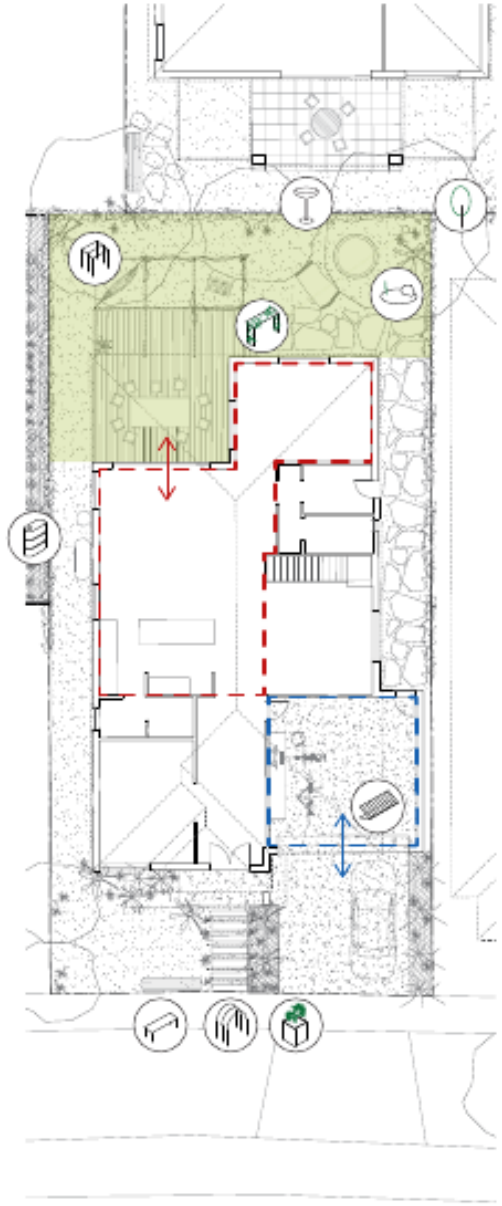


Figure 7. Cool backyard typology

A cool backyard

We use our backyards in many different ways: gardens, growing food, children's play areas and outdoor kitchens.

Adding cooling might be a matter of enhancing an existing garden area so it can be used on hot days. For example, adding a misting system and a hammock to a pergola creates a relaxed outdoor living area for summer.

In many backyards, a shade tree is the central cooling feature. You can use water systems to help the tree grow quickly, stay healthy and provide evapotranspiration for cooling. The cool area can be extended by adding smart irrigation systems to irrigate the lawn surrounding the tree.

If a tree is not an option (e.g. Figure 7), a cool backyard area can be created by adding features such as a trellis, arbour, green walls or well-watered garden beds. These features can complement overhead misting systems added to an existing outdoor entertainment area, along with well-irrigated gardens to cool the surrounding ground surface. These cooling features make the entertainment area more enjoyable on hot days, and help shield the walls of the house from the sun's radiant heat.

A cool courtyard

The cool courtyard is designed as both an outdoor entertaining area and a transition area connecting to the multipurpose garage (blue dashed line in Figure 8) and the internal living areas (red dashed line). This maximises the available living area on hot days, removing the need to escape the heat indoors.

The design uses suitable shade trees along the boundary or in pots and planters, and overhead structures to create shade. Surface areas are broken up with a mix of garden beds to minimise hard surfaces that absorb heat. Green walls and misting systems complement the cooling effect.

Other areas around the house can be used for food gardens in planter boxes or to locate rainwater tanks to enhance sustainable living, providing a sustainable water supply for irrigation systems. Misting systems should always be connected to the household mains water supply, for health reasons.

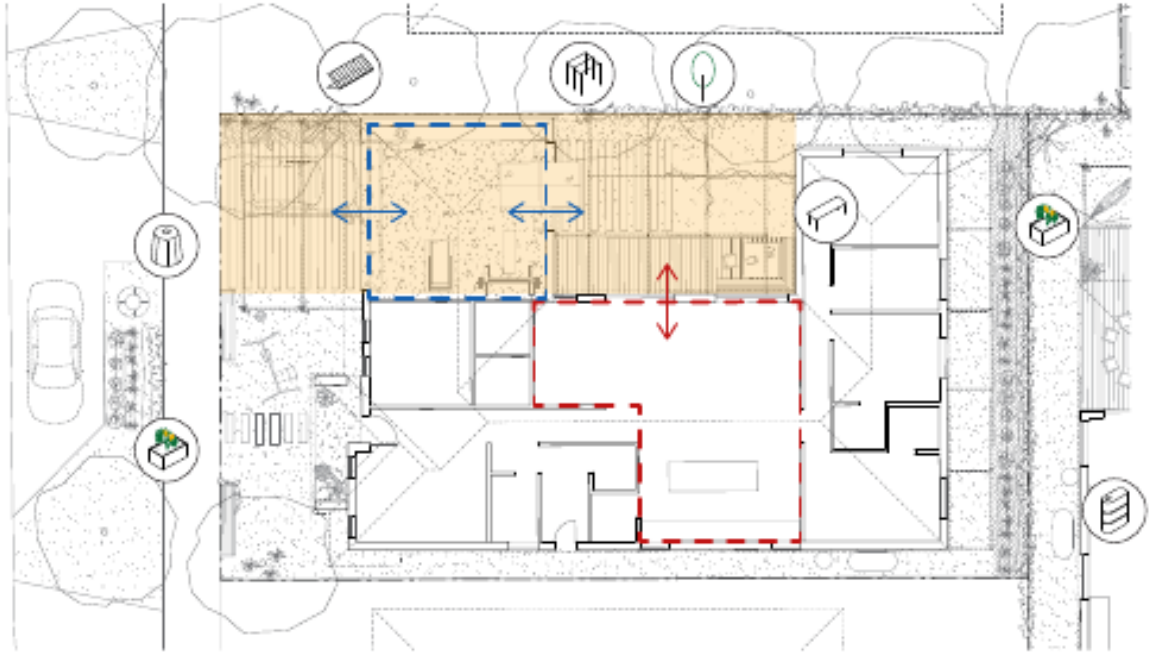
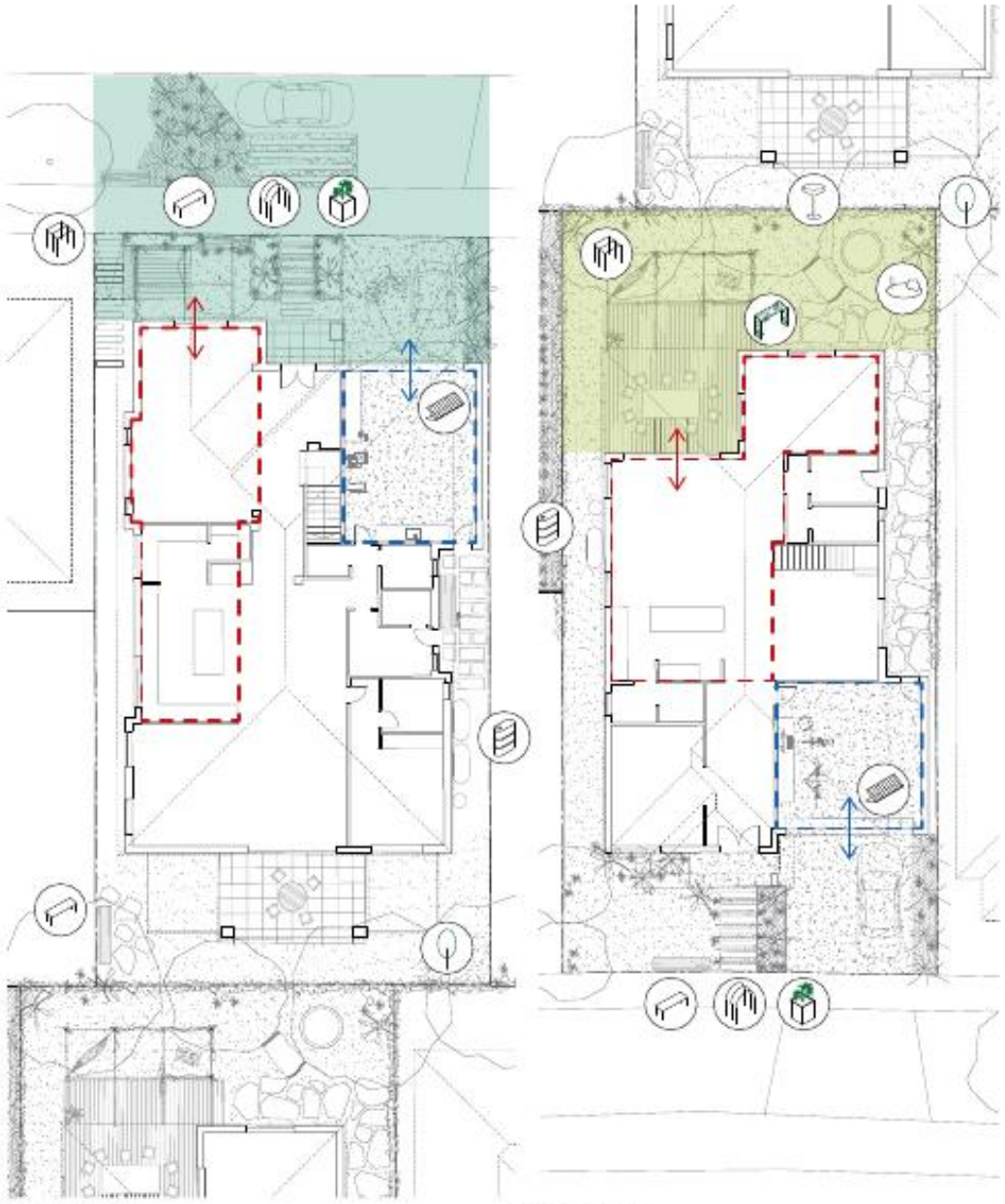


Figure 8. Cool courtyard typology

Practical designs for cooling at the lot scale

Some ways to combine the cooling strategies are shown in the following cool garden examples. Each example:

- shows a cool garden designed for a different location on a block, based on a typical house design found in new suburban developments, following step 1 in this guide
- suggests cool garden designs, created by following steps 2–5 in this guide
- highlights the opportunities to connect these cool garden spaces with living spaces inside the house to increase the comfortable living areas available on hot days.



TYPE A -Frontyard

TYPE B -Backyard

Type of outdoor spaces based on orientation

Front yard

Backyard

Courtyard

Relationship building between spaces

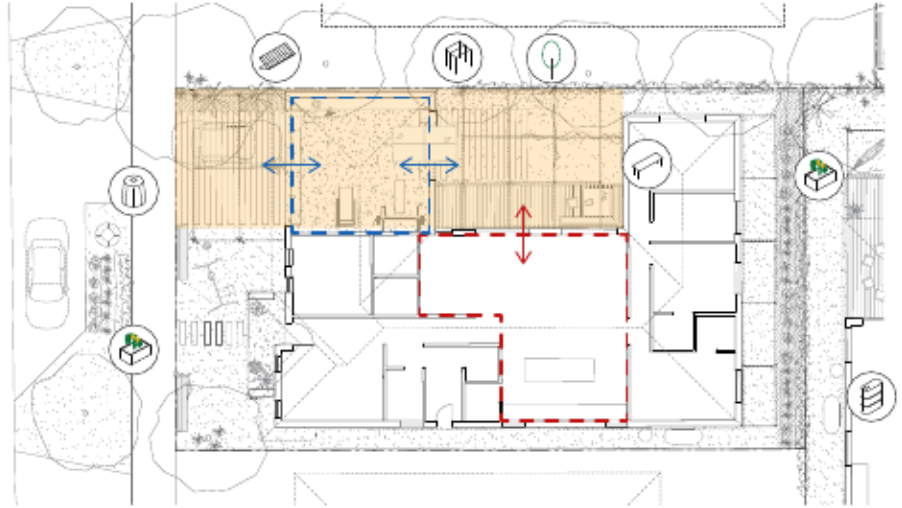
Your outdoor space complements an internal living space, whether it is the dining, living/lounge, kitchen or combination they work together in unison

Garages more than a storage space

Garage has direct access to the street, which presents a significant opportunity for an efficient and economic conversion to an accessible, multi-purpose space

Features to add to enhance cooling

01. Pergola frame with misting + planting
02. Arbour frame with misting + planting
03. Timber bench seat
04. Planter boxes
05. Compost bins
06. Water tanks
07. Retrofitting the garage
08. Shade tree
09. Habitat
10. Downpipe diversion
11. Raingardens
12. Green walls and green roofs



TYPE C -Courtyard

N

0 2 4 10

Framework for designing precinct scale cooling strategies

Table 3. Credits and their relationship to the resilience framework.

MEASURES (CREDITS)	REDUCE	ADAPT		RESPOND
		THRIVE	SURVIVE	
Category 1: Urban Design				
UD1: Wind paths	X	X	-	-
UD2: Wind buffering/filtering	X	X	-	-
UD3: Street canyons	X	X	-	-
UD4: Green and blue open space	X	X	-	-
UD5: Retention of existing tree canopy	X	X	-	-
UD6: Water sensitive urban design	X	X	-	-
Category 2: Cool Streets				
CS1: Shade	X	X	-	-
CS2: Irrigation	X	X	-	-
CS3: Cool and/or porous pavements	X	X	-	-
Category 3: Cool Parks				
CP1: Shade	X	X	-	-
CP2: Irrigation	X	X	-	-
CP3: Cool and/or porous pavements	X	X	-	-
Category 4: Cool Homes				
CH1: Site coverage	X	X	-	-
CH2: Site shade	X	X	-	-
CH3: Site irrigation	X	X	-	-
CH4: Passive cooling	-	X	-	-
CH5: Cool roofs	X	X	-	-
CH6: Cool and/or porous pavements	X	X	-	-
CH7: Alternative energy supply	-	X	X	-
Category 5: Cool Buildings (Non-Residential)				
CB1: Site coverage	X	X	-	-
CB2: Site shade	X	X	-	-
CB3: Site irrigation	X	X	-	-
CB4: Passive design	-	X	-	-
CB5: Cool roofs, green roofs and green walls	X	X	-	-
CB6: Cool and/or porous pavements	X	X	-	-
CB7: Alternative energy supply	-	X	X	-
Category 6: Innovative New Technology				
INV1: New technologies	X	X	-	-
INV2: Data collection	-	X	-	X
Response Checklist				X

3.3 CALCULATING THE RATING

The CST uses a point scoring system that reflects each Credit's relative impact on the following urban heat metrics (having regard to both day and night-time impacts):

- Neighbourhood air temperature;
- Street /allotment air temperature; and
- Street /allotment scale thermal comfort

Credit points and impact scores for each Credit are shown in Table 5.

Table 5. Summary of credits and available points and impact scores.

CATEGORY / CREDITS	CREDIT POINTS	* IMPACT SCORES 0 = NO IMPACT, 3 = HIGHEST IMPACT						*TEMPORAL IMPACT SCORES 0 = NO IMPACT, 3 = HIGHEST IMPACT		
		NEIGHBOURHOOD AIR TEMP.		LOCAL AIR TEMP.		LOCAL THERMAL COMFORT		SHORT-TERM (0-10YRS)	MID-TERM (10-20 YRS)	LONG-TERM (20+ YRS)
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT			
Urban Design Credits:										
UD1: Wind paths	3	1	1	1	1	3	3	2	2	2
UD2: Wind buffering/filtering	2	1	1	1	1	2	2	1	2	2
UD3: Street canyons	4	3	3	3	3	2	2	2	2	2
UD4: Green and blue open space	8	3	3	3	3	2	2	2	2	2
UD5: Retention of existing tree canopy	7	3	3	3	3	3	1	2	2	2
UD6: Water sensitive urban design	6	2	2	2	1	2	1	1	2	1
Cool Streets Credits:										
CS1: Shade	6	3	0	3	1	3	0	1	2	2
CS2: Irrigation	4	2	1	2	1	2	0	1	2	2
CS3: Cool and/or porous pavements	5	2	1	3	1	2	1	2	1	1
Cool Parks Credits:										
CP1: Shade	6	3	1	3	1	3	0	2	2	2
CP2: Irrigation	6	3	1	3	1	2	1	1	2	2
CP3: Cool and/or porous pavements	3	2	1	2	1	2	1	2	1	1
Cool Homes Credits:										
CH1: Site coverage	2	2	1	2	1	2	1	2	2	2
CH2: Site shade	3	2	1	3	2	3	1	2	2	2
CH3: Site irrigation	1	2	1	1	1	2	1	2	2	2
CH4: Passive cooling	2	0	0	0	0	3	2	2	2	2
CH5: Cool Roofs, green roofs and green Walls	3	2	2	2	1	0	0	2	2	2
CH6: Cool and/or porous pavements	1	1	0	2	0	2	0	2	2	2
CH7: Alternative energy supply	3	0	0	0	0	3	3	2	2	2
Cool Buildings Credits:										
CB1: Site coverage	3	2	1	2	1	2	1	2	2	2
CB2: Site shade	3	2	1	3	2	3	2	2	2	2
CB3: Site irrigation	1	2	0	1	0	2	1	2	2	2
CB4: Passive design	2	0	0	0	0	3	2	2	2	2
CB5: Cool envelope (including green roofs/walls)	2	3	3	2	2	2	2	2	2	2
CB6: Cool and/or porous pavements	1	2	1	2	1	2	1	2	2	2
CB7: Alternative energy supply	3	0	0	0	0	3	3	2	2	2
Innovative New Technology Credits:										
INV1: New technologies	5	2	2	2	2	2	2	2	2	2
INV2: Data collection	5	2	2	2	2	2	2	2	2	2

* Impact scores are for regular hot summer conditions (max day temperature < 37°C) and not for extreme heat conditions (max day temperature >37°C)

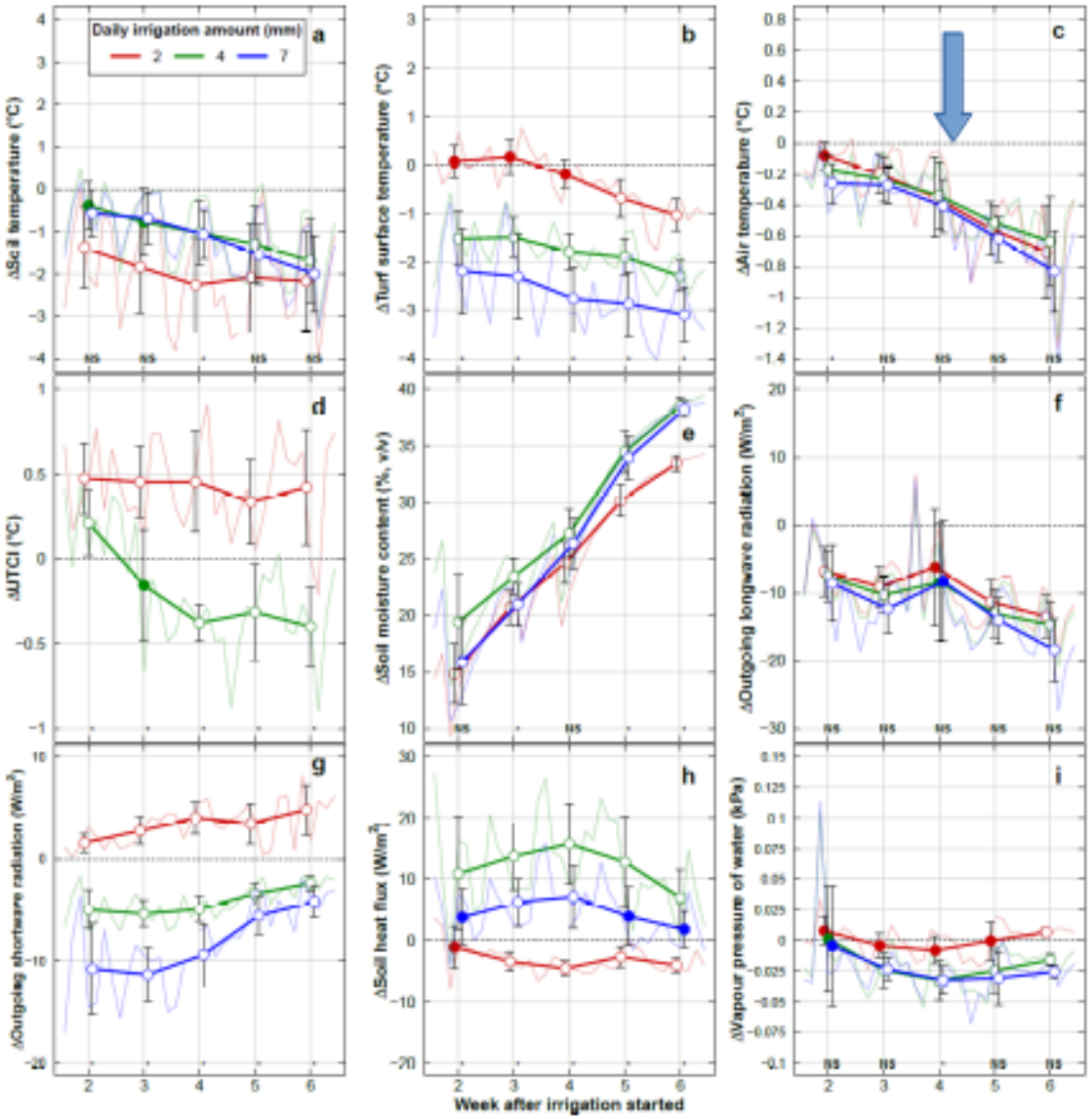
Example: How to best utilise vegetation shading to improve thermal comfort

COOL STREETS

CREDIT: CS1: SHADE	
Credit Outcome	Shade and evapotranspiration provided by street trees reduces local surface temperatures and improves local Human Thermal Comfort.
Credit Points	6
Credit Criteria	At least 75% of the development's streets must have greater than 30% tree canopy cover at maturity. *This credit is only available if Credit CS2 is also satisfied*
Guidance	• Trees have the greatest cooling effect when they are positioned to shade hard surfaces during the hottest times of the day. • Street tree planting recommendations: > E-W streets: both sides of street with priority to southern side > N-S streets: prioritise eastern side of street > Non-cardinal (i.e. do not follow North-South-East-West orientation) streets: prioritise predominant sunny side of street • Tree species selection to suit in-situ soil conditions and resilience to high heat stress. • Use deciduous trees for areas near indoor spaces that require light and solar access in winter. • Use evergreen trees for areas that will benefit from year-round shade. • A heterogeneous canopy (variety of suitable tree species) is preferred to increase the urban canopy roughness through different tree heights and foliage types. • It is important that a complete canopy cover is not present, as regular breaks in the canopy are required to support nocturnal cooling. • Selection and placement of street trees for shading of pedestrians should consider peak-use times (e.g., after school finishes) to ensure shade provided minimises pedestrian's solar exposure during summer months.

Figure CS1-1 Likely suitability of street tree design responses for common streetscapes (source: Victoria Government Department of Environment, Land, Water and Planning)

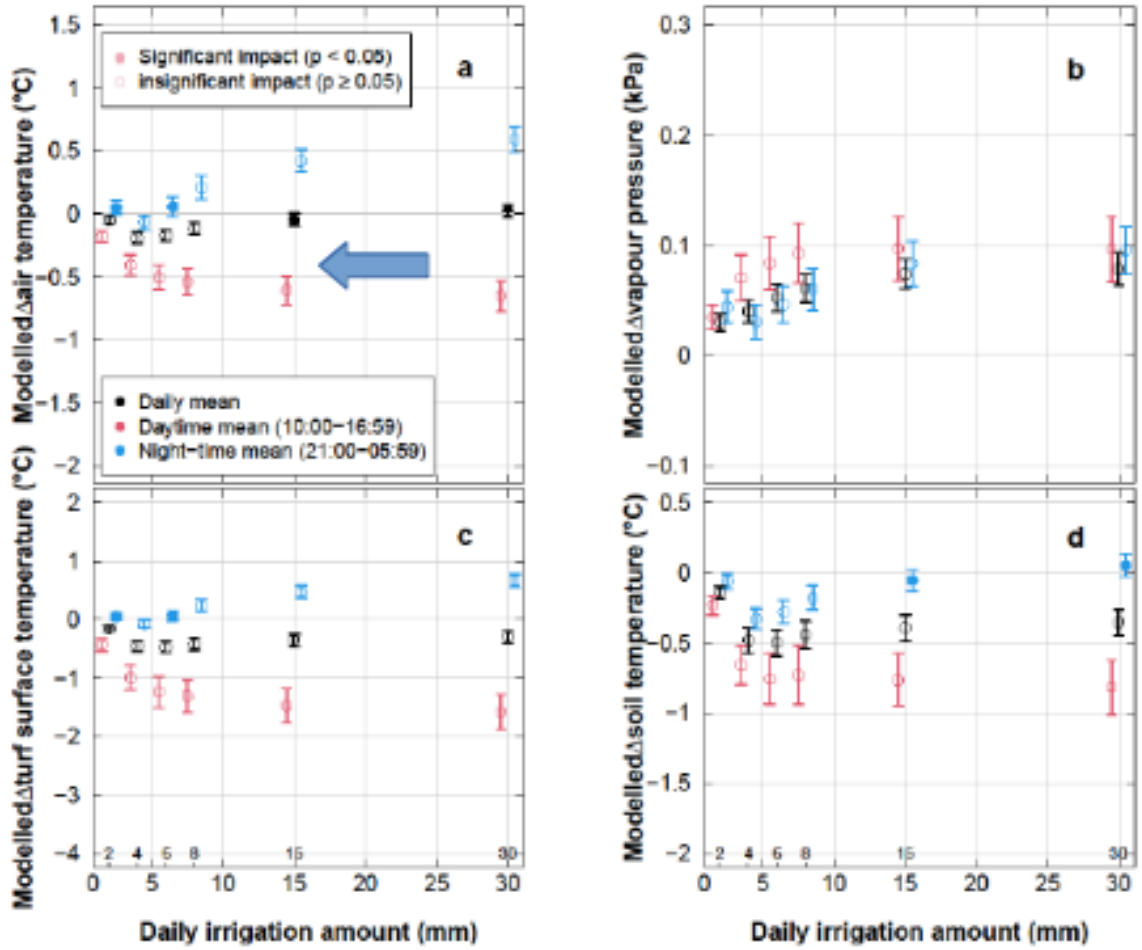
Irrigation amounts and cooling magnitudes



Impacts of irrigation on daytime (10:00–16:00) means.

Pui Kwan Cheung, C.Y. Jim, Nigel Tapper, Kerry A. Nice, Stephen J. Livesley, Daytime irrigation leads to significantly cooler private backyards in summer, Urban Climate, 2022.

Warming can be seen when soil moisture dries out (left). Cooling levels plateau when reaching reference evaportranspiration, ~4 mm/day in Melbourne (right)



Modelled impacts of different daily irrigation amounts (2, 4, 6, 8, 15 and 30 mm)

Pui Kwan Cheung, Naika Meili, Kerry A. Nice, Stephen J. Livesley, Identifying the optimal irrigation amount for cooling urban green spaces in summer, Urban Climate (Under review)