Urban greening for improved human thermal comfort

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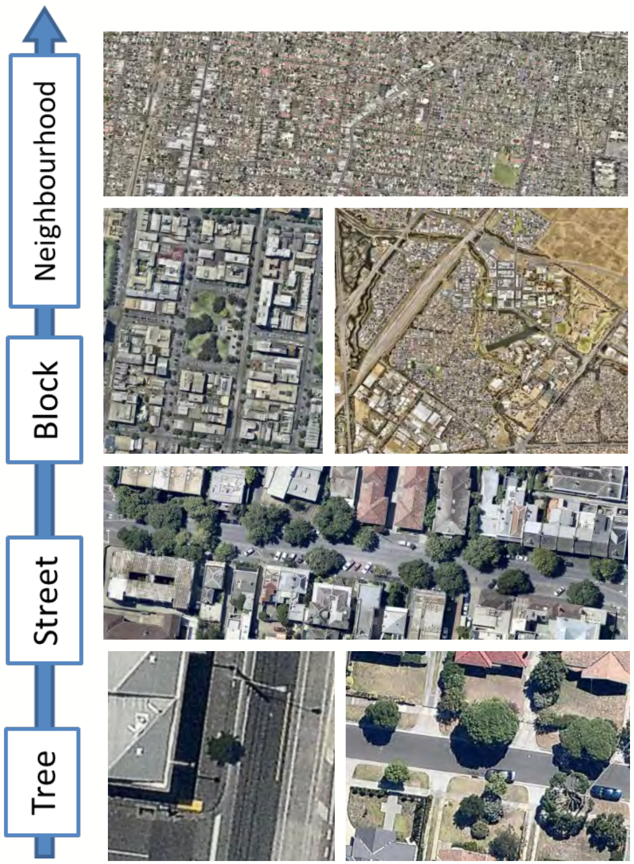
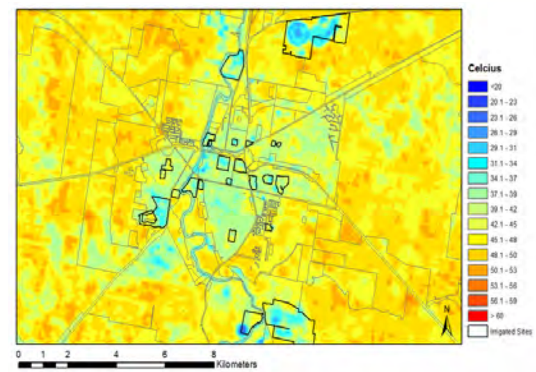
Research questions

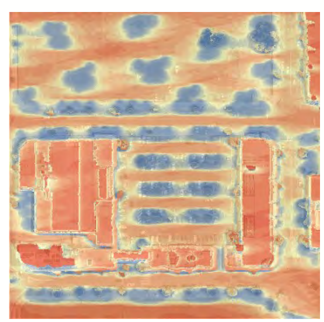
- How effective are storm water harvesting technologies, tree cover, green infrastructure and WSUD in improving urban climates **at a range of scales**?
- What are the key configurations required to reduce temperatures to save lives under heat wave conditions and to enhance human thermal comfort and liveability?



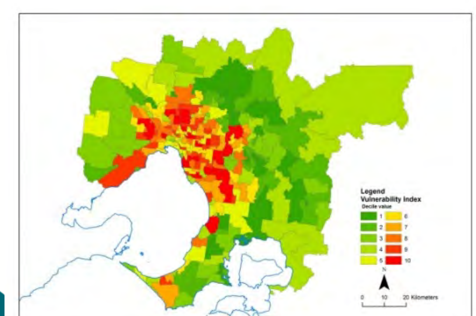
Observations



Remote sensing



Modelling



Database mapping

Cities

Trees must be part of the solution

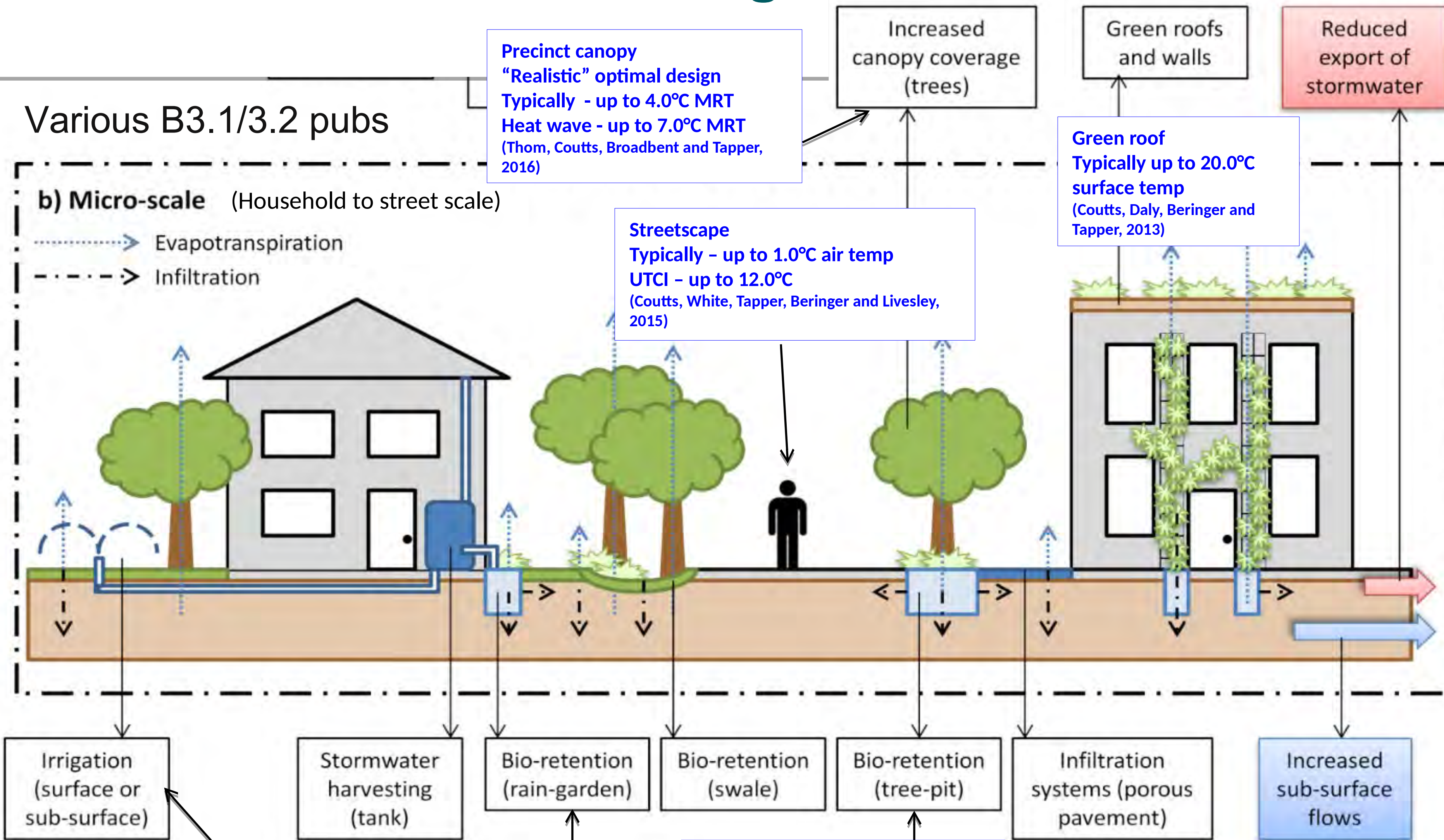
- They provide shade, reducing *mean radiant temperature*
- They access water from deep layers of the soil
- Diversity of species allowing more tailored greening options
- They deliver multiple benefits
- People just 'get' trees

Norton, Coutts et al (2015)

UGI	Green open spaces	Trees	Green roofs	Vertical greening
Shades canyon surfaces?	Yes, if grass rather than concrete	Yes	Shades roof, not internal canyon surfaces	Yes
Shades people?	Yes, if treed	Yes	No, only very intensive green roofs	No
Increases solar reflectivity?	Yes, when grassed	Yes	Yes, if plants healthy	Yes
Evapo-transpirative cooling?	Yes, with water No, without water	Yes (unless severe drought)	Yes, with water when hot No, without water	Yes, with water when hot No, without water
Priority locations	• Wide streets with low buildings – both sides • Wide streets with tall buildings – sunny side	• Wide streets, low buildings – both sides • Wide streets, tall buildings – sunny side • In green open spaces	• Sun exposed roofs • Poor insulated buildings • Low, large buildings • Dense areas with little available ground space	• Canyon walls with direct sunlight • Narrow or wide canyons where trees are unviable

Summertime WSUD Cooling

Various B3.1/3.2 pubs



Precinct canopy
"Realistic" optimal design
Typically - up to 4.0°C MRT
Heat wave - up to 7.0°C MRT
(Thom, Coutts, Broadbent and Tapper, 2016)

Streetscape
Typically – up to 1.0°C air temp
UTCI – up to 12.0°C
(Coutts, White, Tapper, Beringer and Livesley, 2015)

Green roof
Typically up to 20.0°C surface temp
(Coutts, Daly, Beringer and Tapper, 2013)

Botanic Garden Irrigation
Heat wave – up to 3.5°C air temp
(Lam, Gallant and Tapper, 2017)

Rain-garden
Summer conditions
Surface temp – to 25°C
Air above and downwind (1 diameter) – up to 1.5°C
(Shu and Tapper, 2017)

Single tree
Typically – up to 1.2°C air temp below canopy
UTCI – up to 7.0°C below canopy
(Coutts, Moore, Thom, Tapper and White, 2017)

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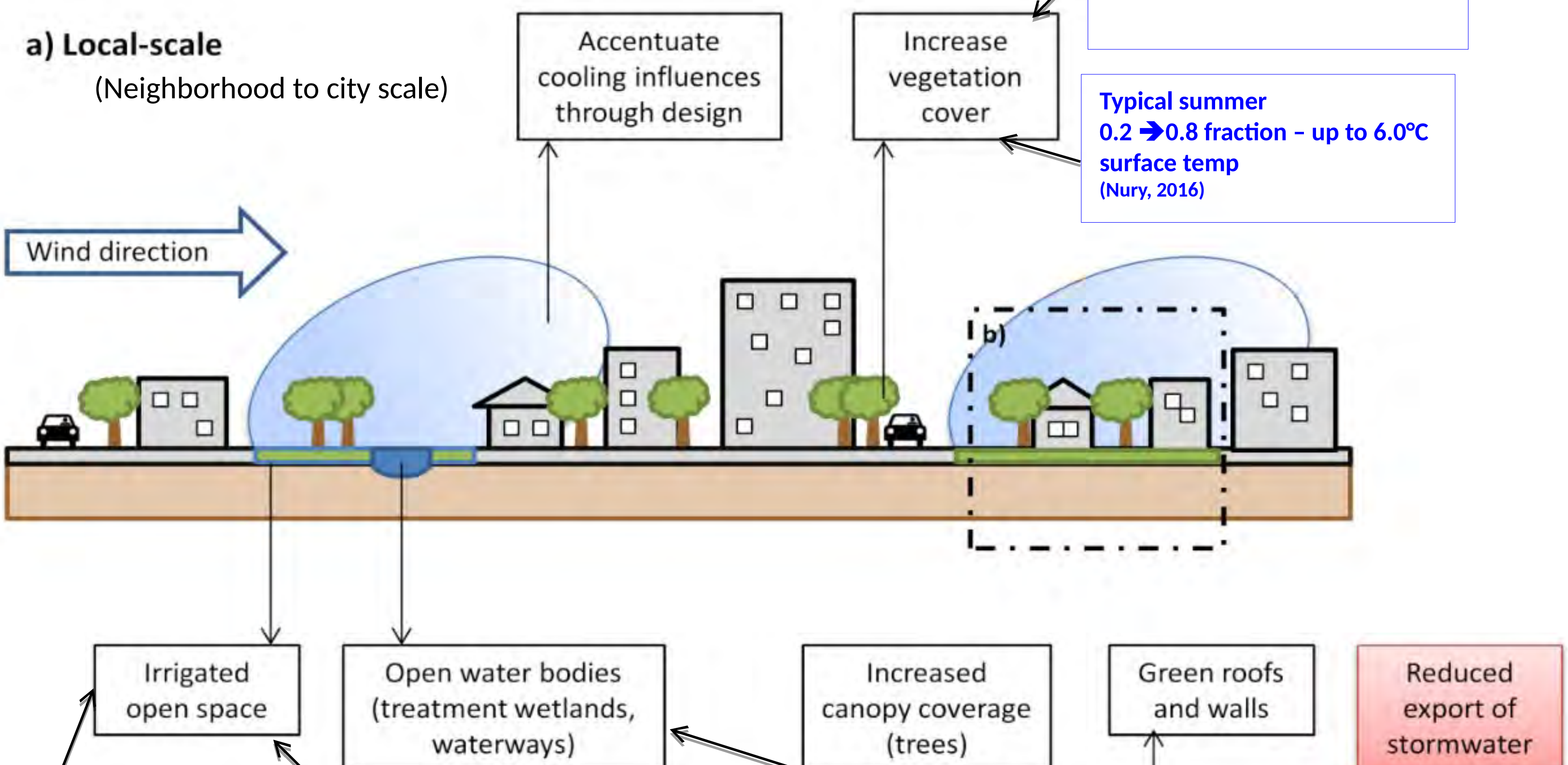
Summertime WSUD Cooling

Various B3.1/3.2 publications

Heat wave
10% - ~0.2°C air temp
100% - up to 1.0°C air temp
(Jacobs, Gallant and Tapper, 2017)



Typical summer
0.2 → 0.8 fraction – up to 6.0°C surface temp
(Nury, 2016)

Suburban heat wave
Low/mod irrigation - ~0.5°C air temp
Very heavy irrigation - up to 2.5°C air temp
Up to 20°C surface temperature
(Broadbent, Coutts, Tapper and Demuzere, 2017)

Park cooling
Typical – light irrigation ~1.0°C air temp
UTCI - up to 10.0°C (Motazedian, 2016)

Typical summer
~1.0°C air temp above and downwin
(1 diameter)
(Broadbent, Coutts, Tapper and Demuzere, 20

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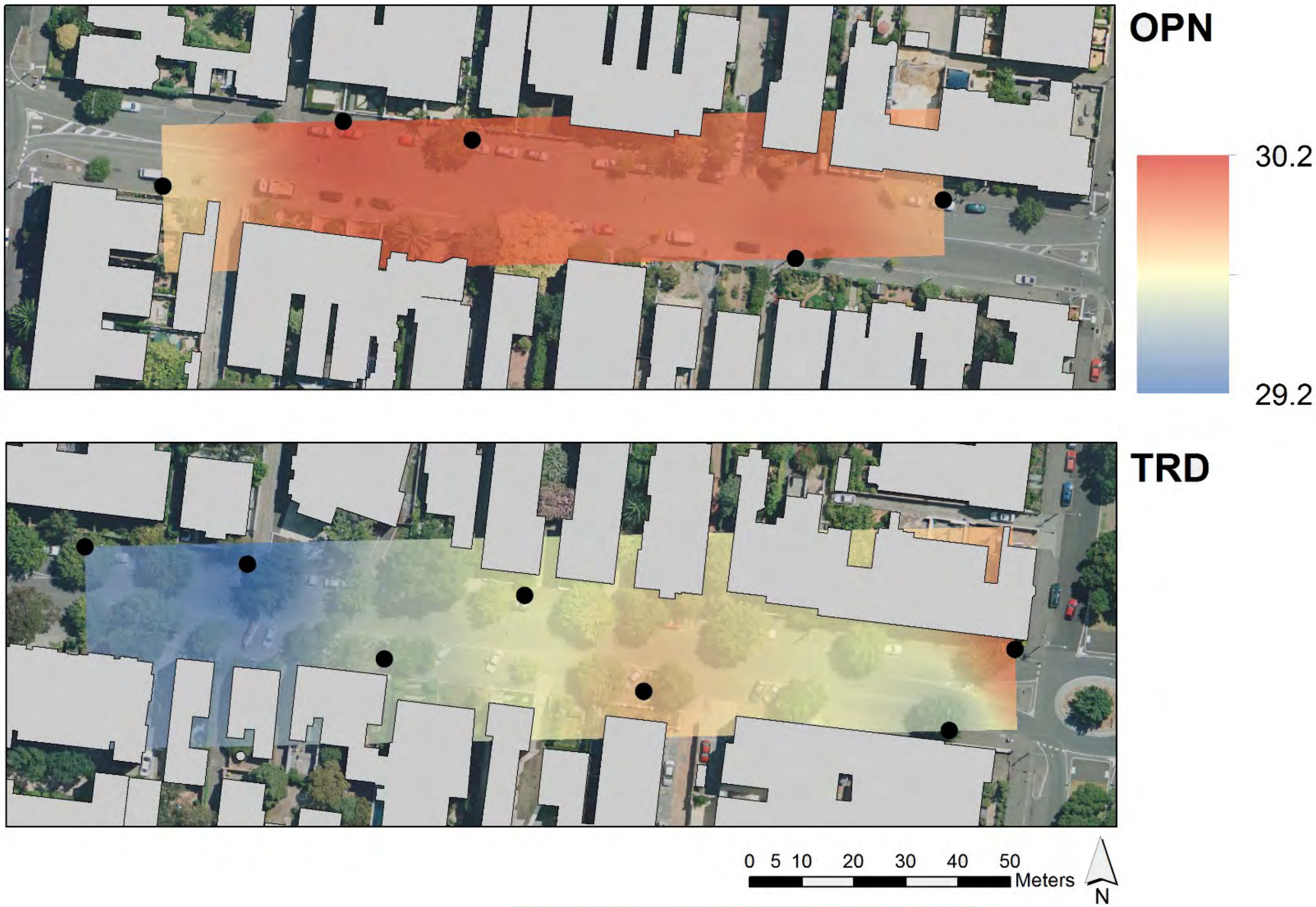
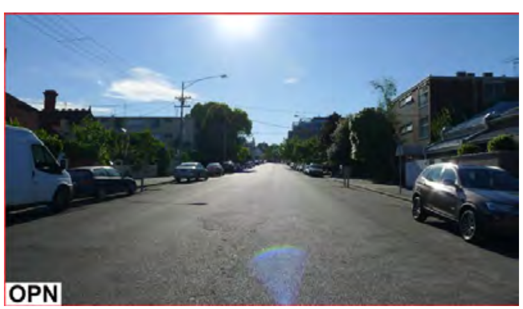
Street tree cooling



- OPEN street vs. a TREED street
- Average daytime air temperature
- 4-12 March 2013
- 9 consecutive days exceeding 32 °C
- Differences of up to 3.1 °C among the seven stations in TRD



Coutts, et al (2015)

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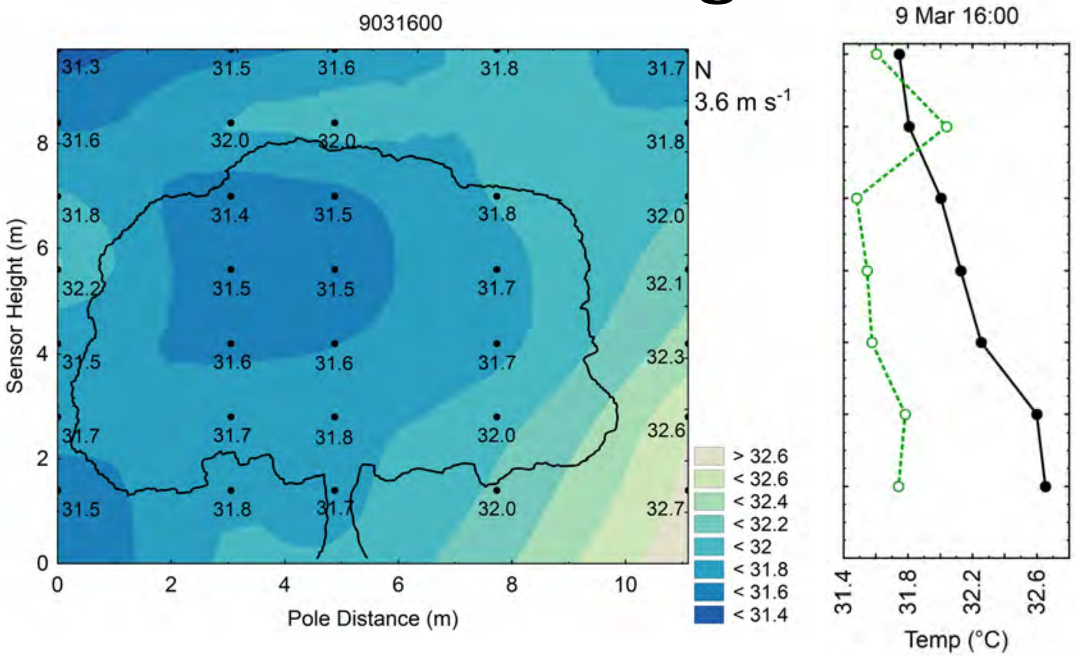
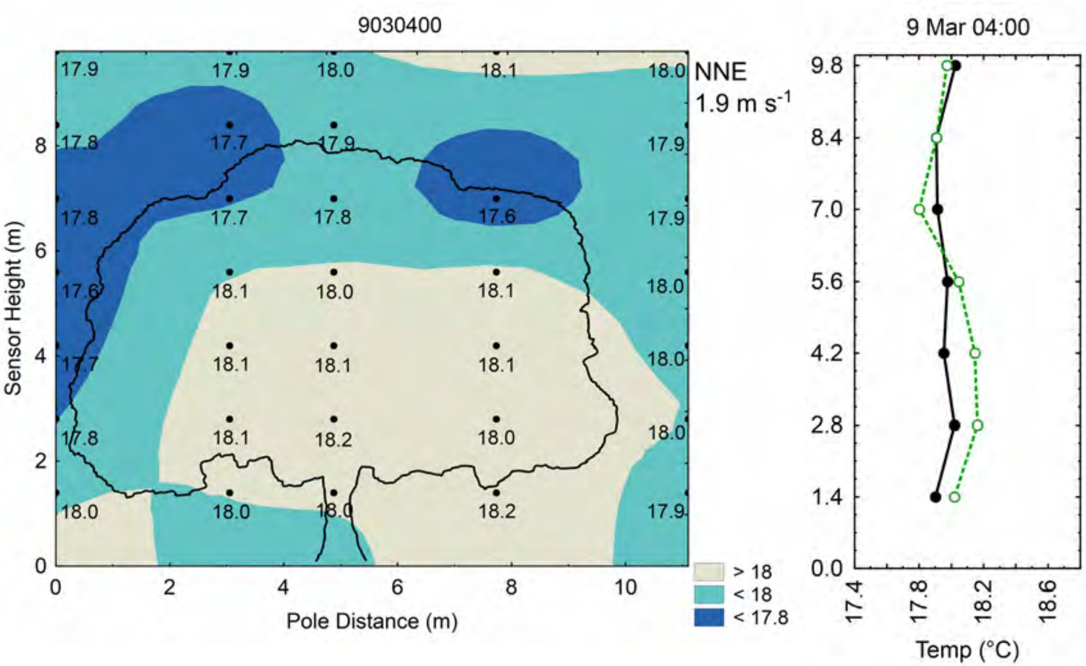
Isolated tree cooling



- Micro-scale cooling from shading
- Transpiration will add to local scale cooling
- Up to 1.2 °C difference at 1.4 metres
- Large improvements in human thermal comfort



- Slightly warmer below canopy at night of up to 0.4 °C
- Radiation trapping and emission below canopy
- Longwave cooling at canopy surface

Coutts et al (2016)

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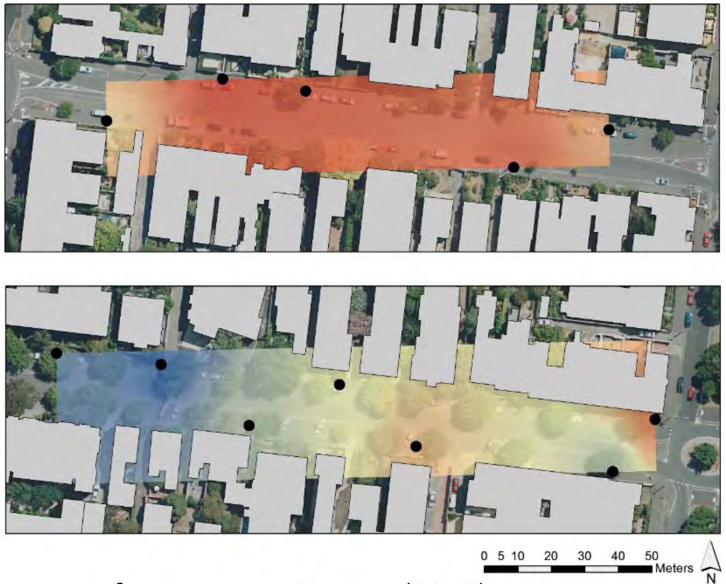
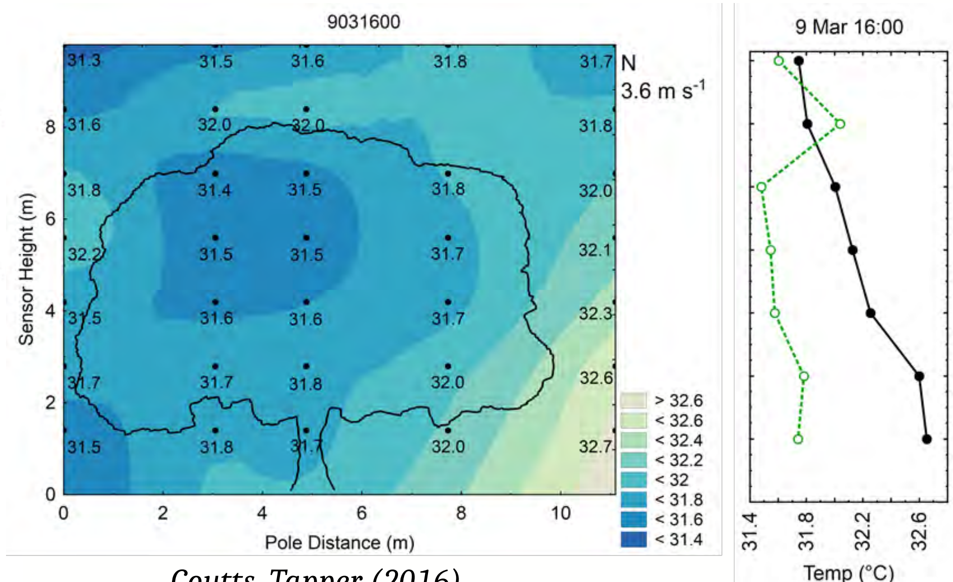
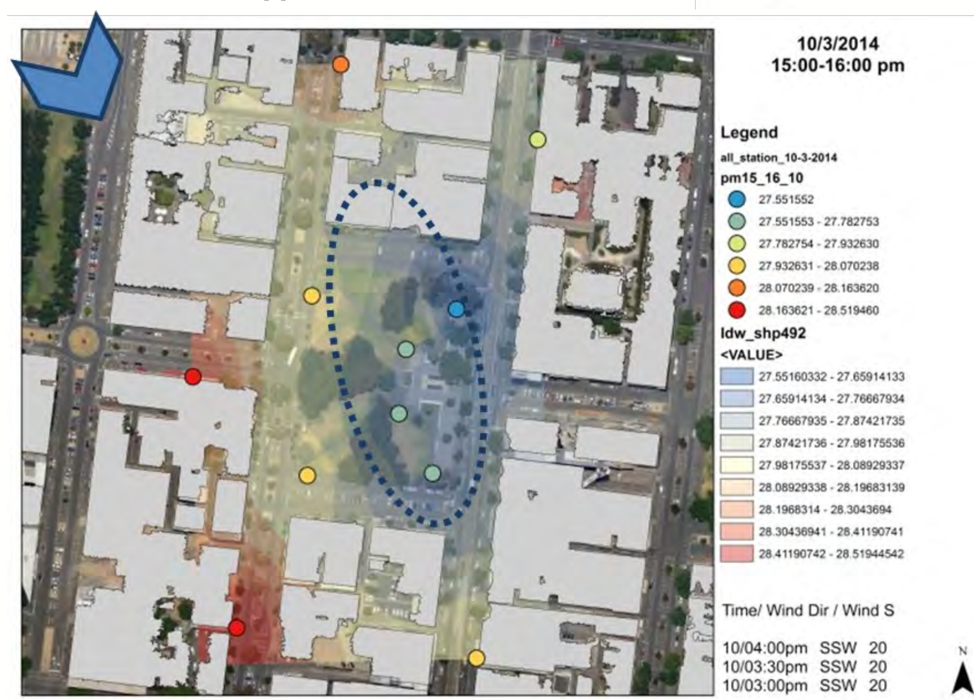
Reduce micro-scale air temperature



Coutts, Livesley, Beringer, Tapper (2015)



Coutts, Tapper (2016)



- Reductions in air temperature during the day
- Downwind cooling limited: Greening must be distributed widely
- Cooling variable in complex urban environment:
  - Type of greening
  - Urban geometry
  - Meteorology
  - Etc

Motazedian (2015)

Reducing heat-health costs with trees

- Economic benefit of street trees – City of Monash
- Street trees only (private veg left unchanged)
- Also valued carbon uptake and storage, air quality and stormwater

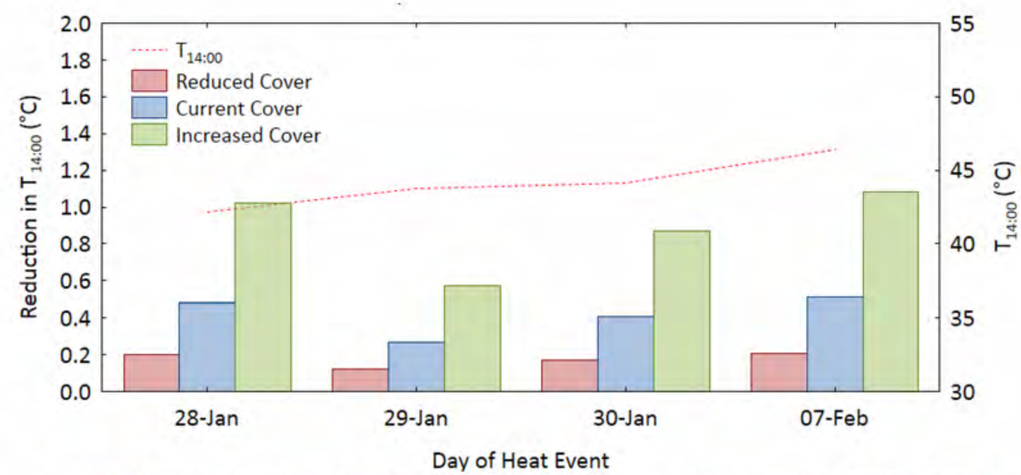
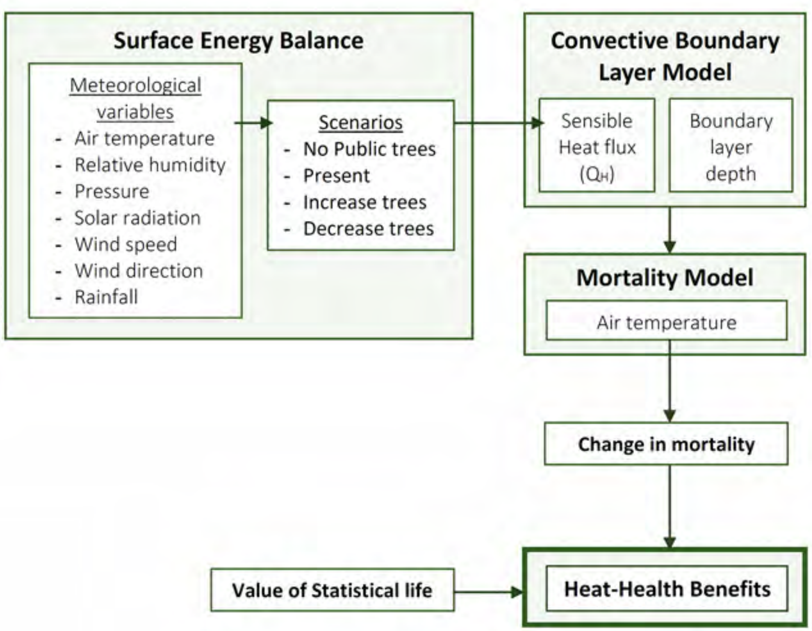


Figure 4.12: Illustrates the change in temperature ($T_{14:00}$) attributed to three tree cover scenarios: (i) the current tree population, (ii) a 50 % reduction in public trees, and (iii) a 100 % increase in public trees (left axis). $T_{14:00}$ measured at Moorabbin Airport on the four most extreme days of the 2009 heatwave is displayed on the right axis.



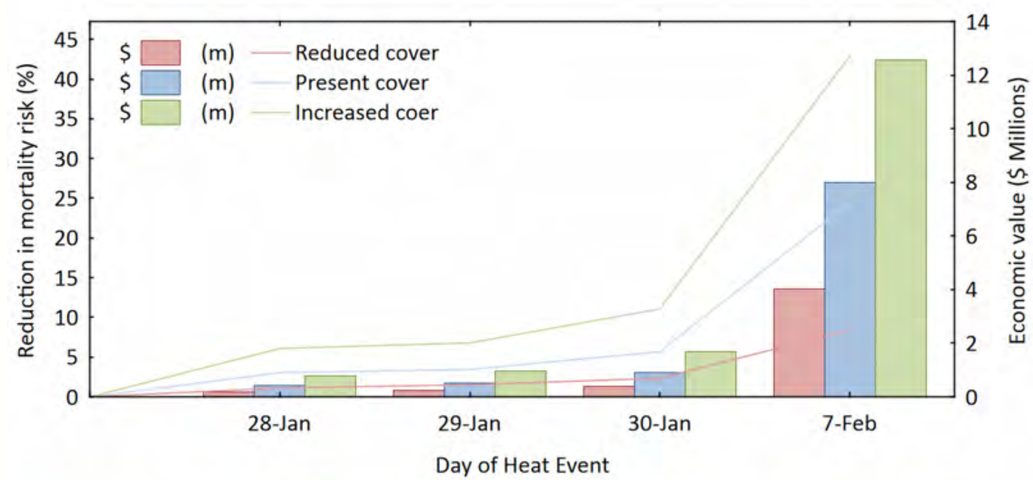


Figure 4.13: Illustration of the reduction in predicted mortality (ΔM) during an extreme heat event (left axis). Here canopy cover scenarios are: (i) present tree population, (ii) increased tree population, and (iii) reduced tree population. The associated economic value ($) is indicated in bars for each scenario (right axis) based on the recommended VSL for Australian policy analysis ($ 4.2 million) (Australian Government, 2014).

Thom (2015); Thom, Coutts and Tapper (2016)

City of Melbourne, 2012

Water and trees

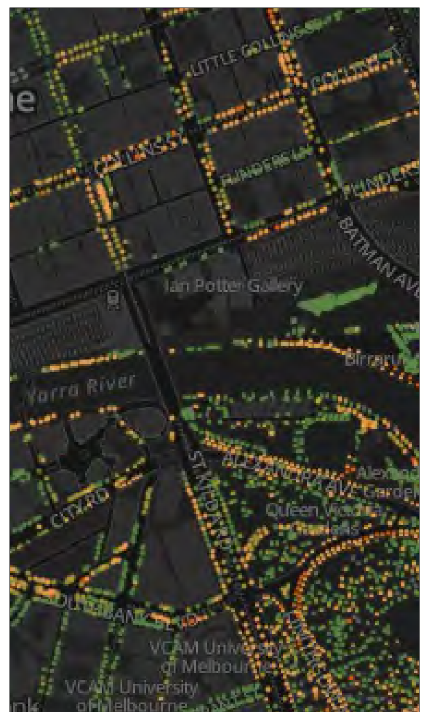
Trees can be extremely beneficial for urban climate BUT:

- They must have full canopies to provide shade
- Be actively transpiring to provide evaporative cooling

A lack of water compromises this

(Whitlow and Bassuk, 1988):

- Low soil water availability:
    - High stormwater runoff
    - Drought
    - Water restrictions
    - Reduced infiltration:
        - Hydrophobic soils
        - Compacted soils



City branches out to replace drought-hit trees

Dewi Cooke
May 11, 2010

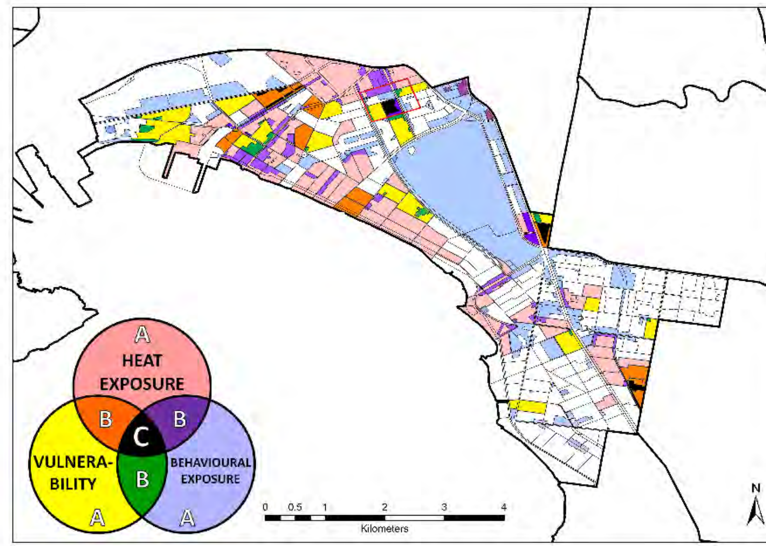
Comments 17

Extreme weather and the ravages of time have left many of Melbourne's trees in need of replacement. *Photo: Justin McManus*

MELBOURNE will look to such countries as Spain, Chile and the US for replacements of thousands of drought-ravaged trees

Key interventions

- Existing street trees should be protected & maintained
  - Passive and active irrigation in built up areas
  - Maintain healthy canopies for shading
- More trees should be planted
  - Prioritise canopy cover in areas of high solar exposure
  - Highly localised benefit so trees must be distributed
  - Tree species should be diverse
  - Water should be supplied
- ‘Right tree, right place’
  - Consider light, water availability, climate, etc



Norton, B. A., Coutts, et al 2015.

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Prioritising tree placement

- **Wide open streets** should be targeted as they are exposed to larger amounts of solar radiation during the day (Norton et al., 2015).
- **East-west oriented streets** were targeted as they are exposed to more solar radiation during the day (Ali-Toudert and Mayer, 2006).
- **North facing walls** (in the Southern Hemisphere) in east-west streets , and **west facing walls** to provide shading from the afternoon sun when Ta peaks.
- Trees should be **clustered together** - more effective at reducing Tmrt than isolated trees (Streiling and Matzarakis, 2003) and can help protect them from intense radiative loads (Oke, 1988).
- Employ a **'Savanah' type landscape** arrangement (as suggested by Spronken-Smith [1994] in relation to urban parks) of **clustered trees** interspersed **with open areas** to provide daytime shading while allowing nocturnal cooling and ventilation (Spronken-Smith and Oke, 1998)

Thom, Coutts et al 2016

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Limiting heat health impacts

Thom (2015)

- Economic benefit of street trees – City of Monash
- Mortality benefits ($)
- Street trees only (private veg left unchanged)
- Also valued carbon uptake and storage, air quality and stormwater

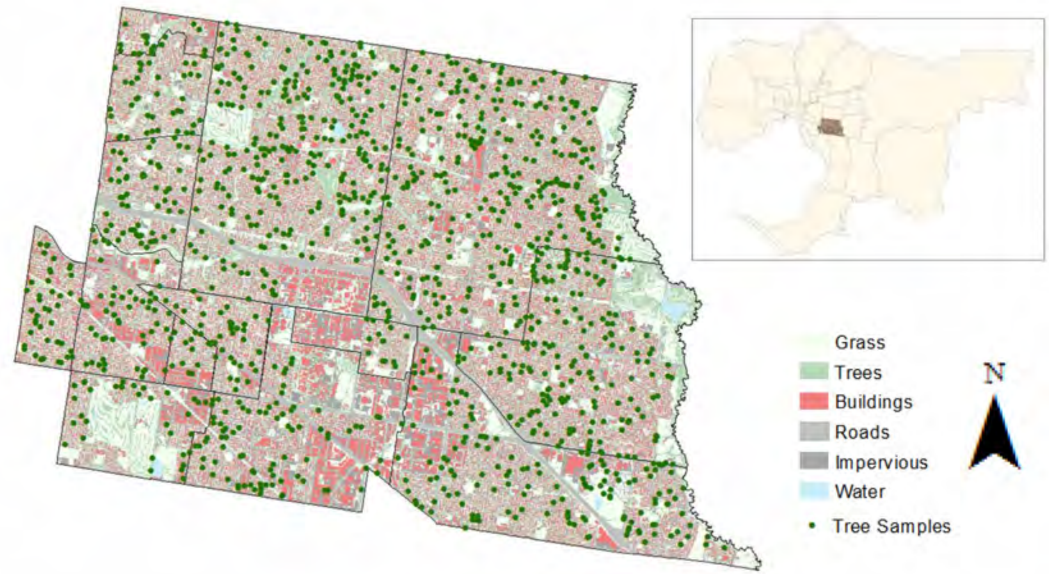
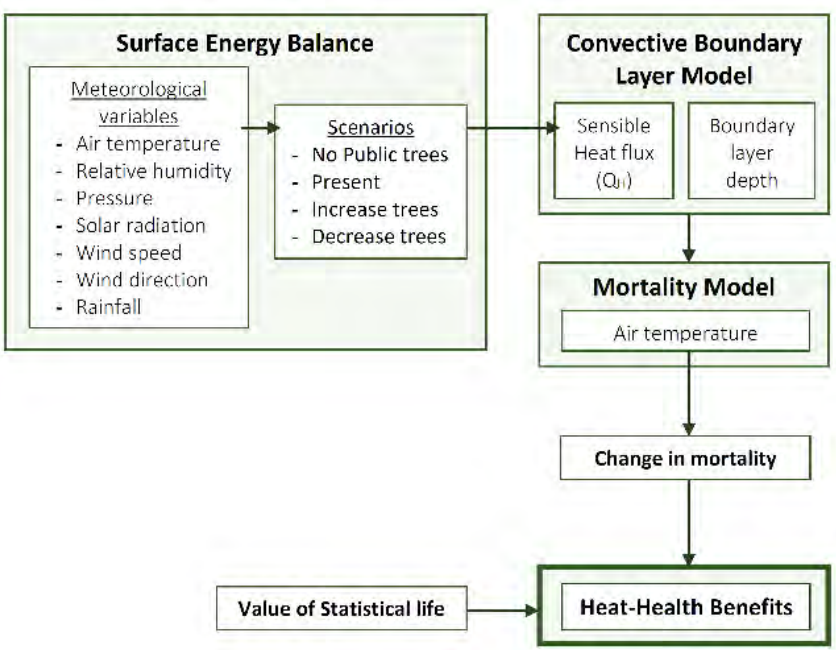
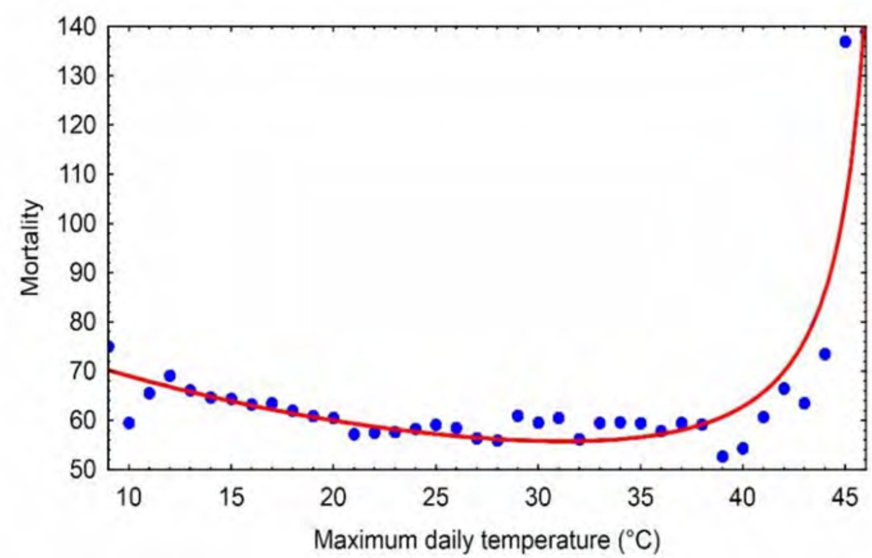


Figure 3.6: Street trees selected by stratified random sampling process (1 284) for field measurement in the City of Monash, Melbourne. Associated land cover around sample trees is illustrated.





Limiting heat health impacts

Thom (2015)

Scenarios

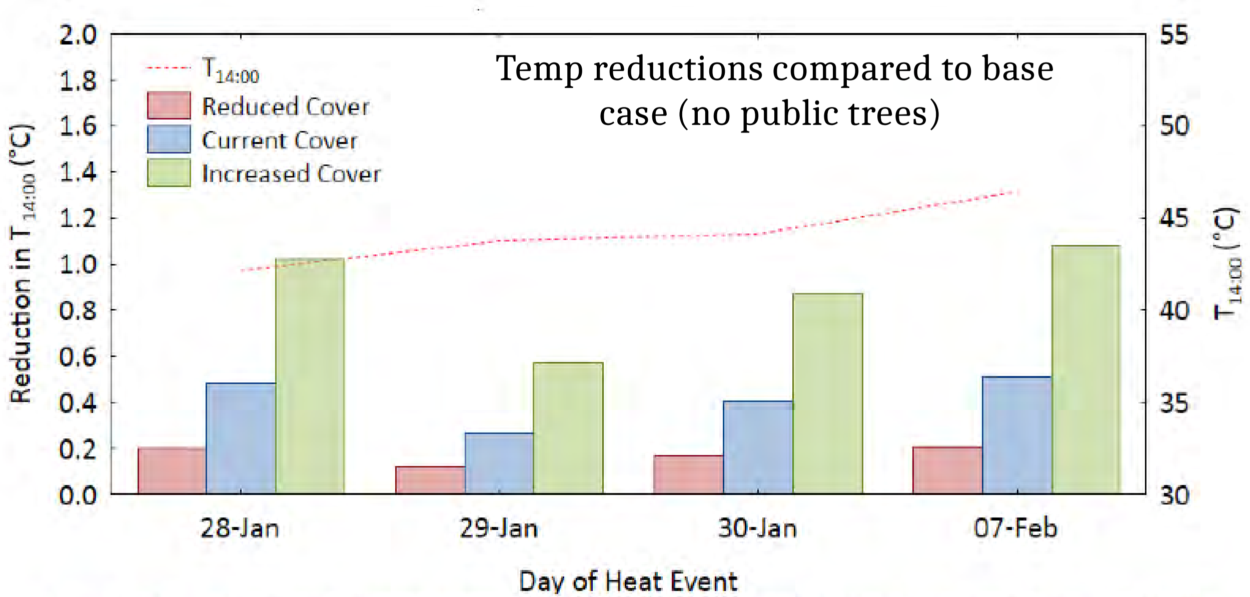
- No street trees (base case) (17%)
- Current street trees (24%)
- Less street trees (20%)
- More street trees (32%)

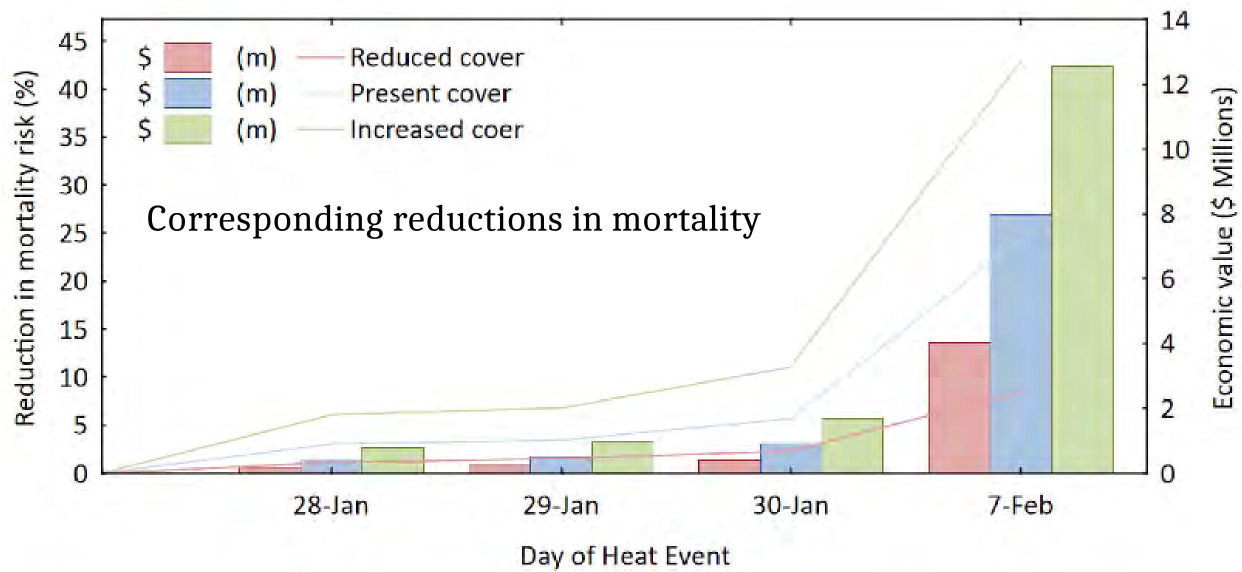
Mortality benefits over 4 day period:

- Current tree cover delivers ~0.5°C benefits = $9.78 million
- Doubling of cover provides a further ~0.5°C benefits (~1.0°C total over base case) =$16.01 million

Total value of current urban forest

- **$12.85 million**





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