CRC for
Water Sensitive Cities

DUBBO REGIONAL COUNCIL

NSW GOVERNMENT | Office of Environment & Heritage

Splash Network

LOCAL GOVERNMENT NSW

Using trees to mitigate the urban heat island effect

Dubbo Urban Heat Island Amelioration Project

Reducing the impact of heat waves in urban areas

Case Study

Prepared by Cooperative Research Centre for Water Sensitive Cities, January 2019.

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

The context

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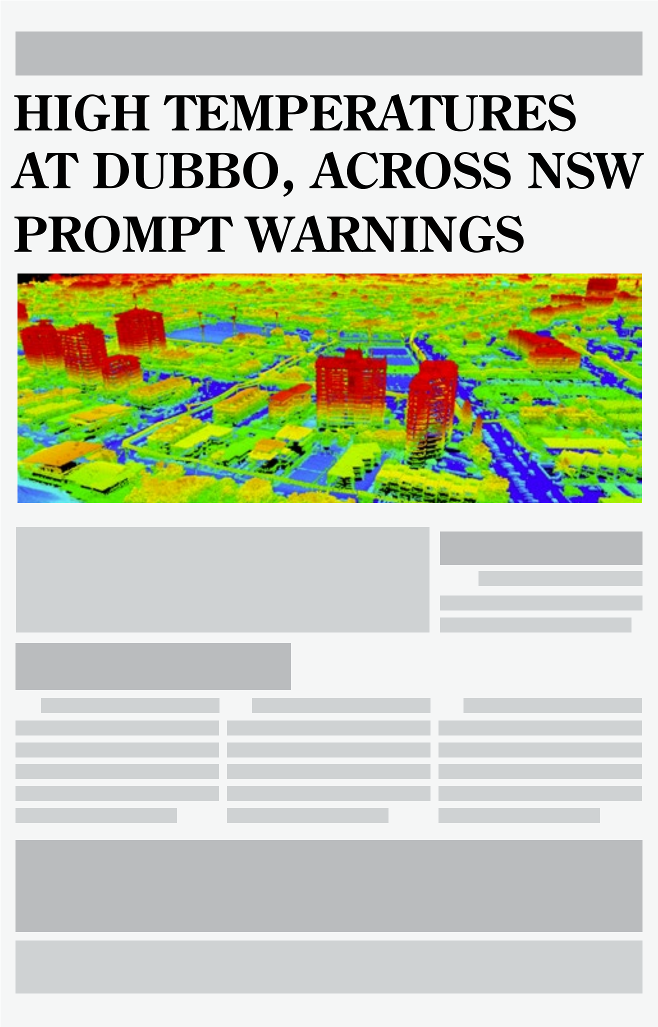
Introduction



Urban development, to cater for a growing urban population, replaces natural vegetated landscapes with roads and buildings. These impervious (hard) surfaces absorb heat but do not store water, leading to higher urban temperatures known as the 'urban heat island (UHI) effect'.

Heat waves combined with higher urban temperatures increase the risk of heat related illnesses and mortality in our cities (Nicholls et al., 2008). CRC for Water Sensitive Cities (CRCWSC) research showed the UHI in Adelaide and Melbourne is enhanced during heat waves (Rogers, Gallant & Tapper, 2017). Headlines such as "Hottest month on record", "Heatwaves hit town" are becoming all too familiar.

As a society, we are recognising the harsh reality of temperature increases associated with climate change. Increasing global temperatures, increased frequency and intensity of heatwaves and increased urban development means more people will be at risk of heat related illnesses and heat related mortality. Heat related illness includes dehydration, heat cramps, heat exhaustion, heat stroke and worsening of existing medical conditions such as heart disease, diabetes, or kidney disease (NSW Ministry of Health).

Urban planners must consider effective measures for planning our cities, to minimise the heat-health risks, using a variety of active and passive design measures that are also affordable (Tapper et al., 2016).

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Click here for media headlines from Daily Liberal (Dubbo's local newspaper).
https://www.dailyliberal.com.au/story/5153974/summer-turns-up-the-heat-more-hot-weather-coming-dubbos-way/

Climate Sensitive Urban Design (CSUD) aims to mitigate high urban heat and adapt to extreme heat events through planning and landscape design alternatives that create attractive, sustainable, and thermally comfortable cities (Coutts et al., 2013).

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One of the most cost-effective solutions to mitigate high urban heat, and to adapt to extreme heat events, can be as simple as improving and promoting the coverage of green spaces within our cities (Figure 1). Increasing vegetation, especially trees, is an effective approach for reducing urban heat through evapotranspiration and shading.

Protecting, maintaining and growing street trees requires a long term investment from local governments. But, local governments often have limited resources and competing priorities, so trees must be planted and maintained in a way that delivers the greatest benefits for their cost investment (Coutts & Tapper, 2017).

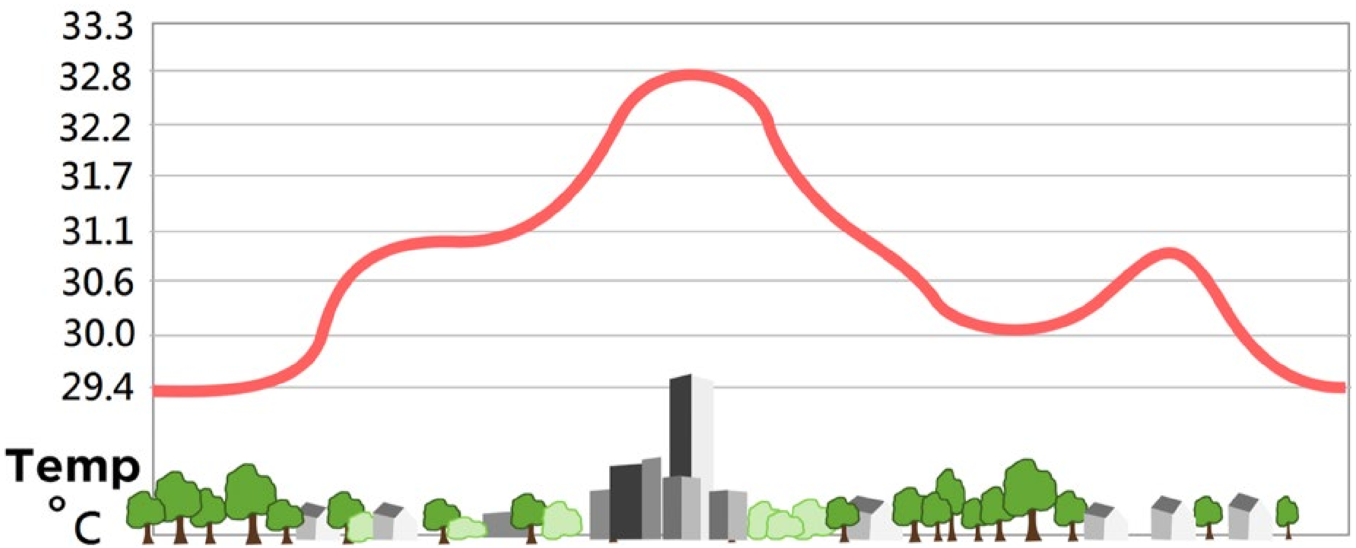

Figure 1: Urban heat island profile
Source: Adapted from http://www.crh.noaa.gov/

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Project location

The regional city of Dubbo is located on the New South Wales western plains, 388 km west of Sydney (Figure 2). It is a major regional city servicing many of the smaller nearby country towns and is also a major transit hub for people travelling from Melbourne to Brisbane.

Figure 2: Dubbo
Source: https://www.google.com/maps

Project area

The Dubbo Regional Council Local Government Area (LGA) is 7,536 km^2 and is home to approximately 51,050 people. The City of Dubbo (Figure 3) is one of the state's largest inland regional centres, servicing a catchment area of more than 130,000 people beyond its own population base. The main industries or land uses include traditional rural industries, educational facilities, professional, government and retail services, a growing internet technology sector, boutique enterprises and services associated with road, rail and air transport.

The Dubbo LGA is located within the Macquarie–Bogan catchment, which is part of the Murray Darling Basin. This catchment—covering 74,800 km^2—is regulated by two major water storages: Burrendong and Windamere Dams. The Macquarie River runs through the catchment. Dubbo's main sources of potable water supply include the Macquarie River (typically 70%) and bore water (typically 30%) (Dubbo Regional Council[1]).

[1] https://www.dubbo.nsw.gov.au/Our-Region-and-Environment/Natural-environment/water-waterways

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Climate

Dubbo's climate is characterised by hot summers and cool winters that attract frosts. The average annual rainfall is 588 mm. On average, January is the wettest month although rainfall is distributed relatively evenly over the year. Dubbo's mean maximum temperature reaches 33°C in January. Consecutive days over 38°C are becoming more common in summer. The mean daily minimum temperatures vary from 2.6 to 17.9°C (Bureau of Meteorology, 2017).

Climate change projections from NSW and ACT Regional Climate Modelling (NARCliM) predict climatic extremes will be exacerbated over the next 60 years (Figure 4). Maximum temperatures are projected to increase by 0.7°C in the near future and by 2.1°C in the far future. Spring and summer will experience the greatest changes in maximum temperatures, with temperatures increasing by 2.5°C by 2070.

The region experiences 20–30 hot days every year (when temperatures exceed 35°C) and this number is expected to increase. The number of cold nights (temperatures fall below 2°C) is projected to decrease (AdaptNSW, 2014).

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Figure 3: Birch Avenue, Wheelers Lane
Source: Dubbo Regional Council

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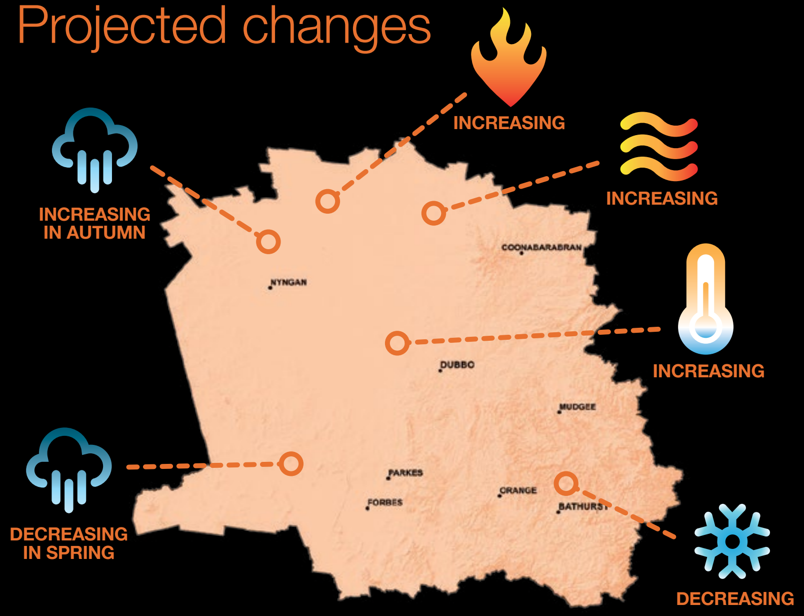
Projected changes



Projected **temperature** changes

Maximum temperatures are projected to increase in the near future by 0.4 – 1.0°C	Maximum temperatures are projected to increase in the far future by 1.8 – 2.7°C
Minimum temperatures are projected to increase in the near future by 0.5 – 0.9°C	Minimum temperatures are projected to increase in the far future by 1.5 – 2.6°C
The number of hot days will increase	The number of cold nights will decrease

Projected **rainfall** changes

Rainfall is projected to decrease in spring	Rainfall is projected to increase in autumn

Projected **Forest Fire Danger Index (FFDI)** changes

Average fire weather is projected to increase in summer, spring and winter	Severe fire weather is projected to increase in summer, spring and winter

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Figure 4: Climate change projections for the Dubbo Region
Source: AdaptNSW, 2014

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Project description

Providing thermal comfort for the many residents and visitors to the Dubbo central business district (CBD), particularly in the harsh summer months, is a priority for Dubbo Regional Council. And it is challenging in the face of projected rising temperatures and more hot days. But, research by the CRCWSC and others shows strategically placing vegetation, especially trees, can improve human thermal comfort.

The CRCWSC's *Trees for a cool city* guidelines highlight three factors for identifying high priority neighbourhoods at risk of heat related illnesses and mortality (Coutts & Tapper, 2017). The intersection of areas with a high heat exposure, a high vulnerable population (such as the elderly), and behavioural exposure (where people are outside and active), are priority areas for implementing cooling strategies (Figure 5).

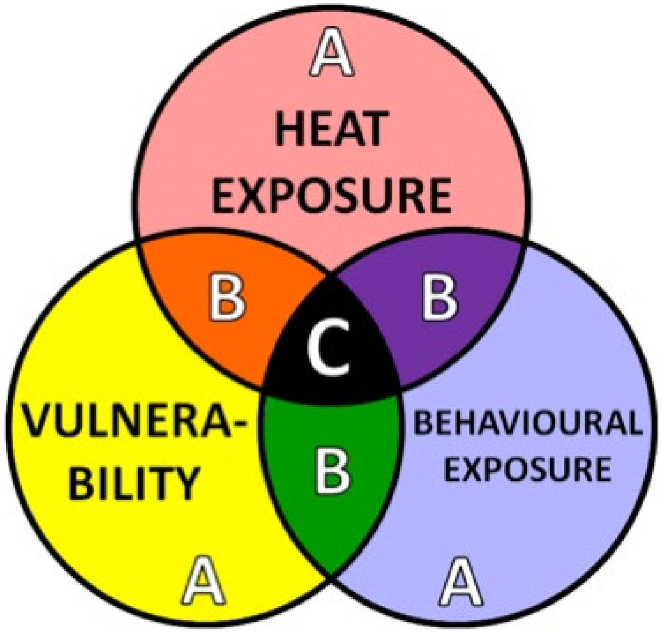

Figure 5: Identifying priority areas for cooling strategies
Source: Coutts & Tapper 2017

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Dubbo Regional Council is committed to increasing the urban tree canopy within the CBD via the Dubbo Street Tree Masterplan, which guides improvements to the quality and extent of the urban forest canopy. The masterplan identifies Bultje Street as being a high priority (Priority 1) for increasing urban canopy. It has high heat exposure and high pedestrian traffic.

The Dubbo Heat Island Amelioration project is located in a section of Bultje Street between Darling Street and Brisbane Street (Figure 6). This area is a key health and medical precinct, including specialist health practitioners who service Dubbo residents as well as nearby regional areas. It receives a large number of elderly visitors, who are among the most vulnerable to temperature extremes.

Figure 6: Canopy cover in Bultje Street before the amelioration project
Source: Dubbo Regional Council

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Before the amelioration project, this area of Bultje Street had a canopy cover of only 163 m^2 or as calculated by i-Tree Canopy, 2.8% of the total area. The project increases Bultje Street's existing tree canopy by up to 300% by planting street trees (Figure 7). It increases the shading of the asphalt surface significantly, reducing the ambient heat trapped and retained within the streetscape. Over time, the trees will also decrease ultraviolet (UV) exposure to pedestrians.

The project also uses water sensitive urban design to capture stormwater runoff from the nearby streets, to provide a passive and non-potable source of water for irrigating the trees. Providing an alternate source of water is essential for dry climates like Dubbo's.

Because Bultje Street is part of the original village of Dubbo, council's intent is to use plants that maintain the heritage value of the precinct. To achieve this aim, Council replaced the existing *Brachychiton populneus* (kurrajong) with *Zelkova serrata* (Japanese Elm) 'Green Vase' cultivar. It grows to a height of approximately 14 m, with a canopy width of 10 m. Although not native to Australia, it maximises shade in the warmer months and solar access in the winter months. Its shape and structure minimises the risk of damage to the branches by vehicles. And it is extremely hardy and adaptable to the urban environment tolerating heat, air pollution and periods of drought.

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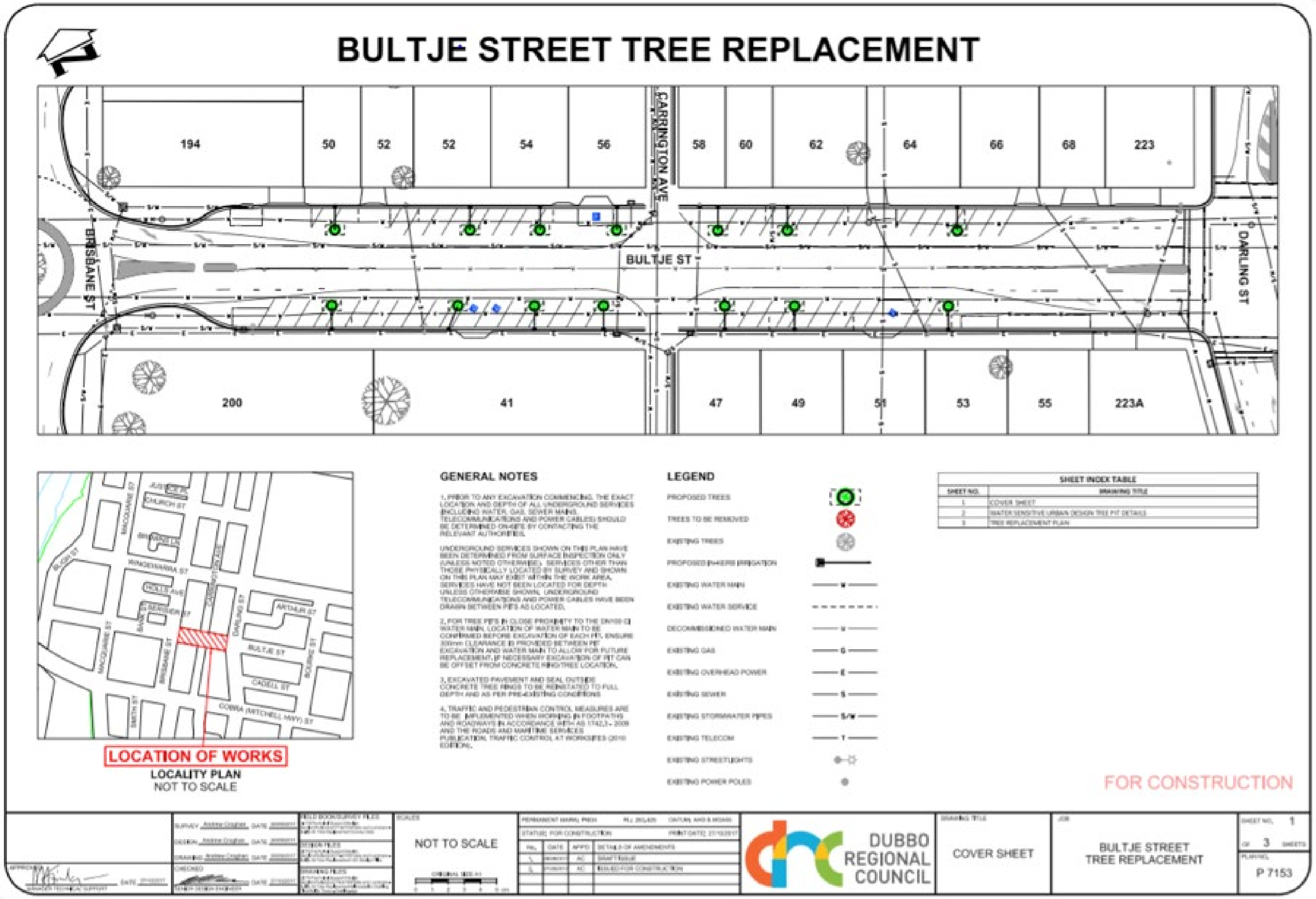

Figure 7: Tree planting within Bultje Street
Source: Dubbo Regional Council

The drivers

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The drivers

The Dubbo region is hot and projected to get hotter. The CBD, like many other precincts, is subject to the UHI effect. Dubbo Regional Council is committed to increasing the urban tree canopy, to mitigate heat and to adapt to climate change.

Improve local amenity and community resilience to climate change. The masterplan incorporates current best practice urban tree management. It also links the key benefits of street tree planting to climate change adaptation and community health and wellbeing.

Reduce ambient summer temperatures by increasing shading to road and footpaths. Research shows increasing an urban forest canopy by as little as 20% can reduce ambient temperatures by 3–4°C (McPherson, 1993). The CRCWSC's TARGET model shows the expected ambient summer temperatures within Bultje Street before and after the tree planting (Figures 11 and 12, below).

Reduce the risk of heat exposure and related illnesses and mortality to vulnerable communities. Elderly people, particularly those over 75 years of age, disproportionally experience illness and deaths from heatwaves. Trees moderate the environmental parameters that influence human thermal comfort and heat stress through evapotranspiration and by providing shade (Berry et al., 2013, Middel et al., 2014).

Reduce the risk of UV exposure to users of the Bultje Street precinct by increasing canopy cover by 300% over 15 years. Providing shade can reduce overall exposure to UV radiation by up to 75% (Parsons et al., 1998).

Reduce heating and cooling energy costs to occupants of buildings along Bultje Street. Urban street trees are an important component of climate sensitive urban design, because they can reduce building energy requirements (Donovan & Butry, 2009). A Californian study showed one large tree with a canopy cover of 7 m^2 created annual cooling savings between 3–8% annual per dwelling (McPherson & Simpson, 2003). Tree planting can significantly reduce peak load energy demand, which can become critical during heatwaves.

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Figure 8: Dubbo city centre
Source: Dubbo Regional Council

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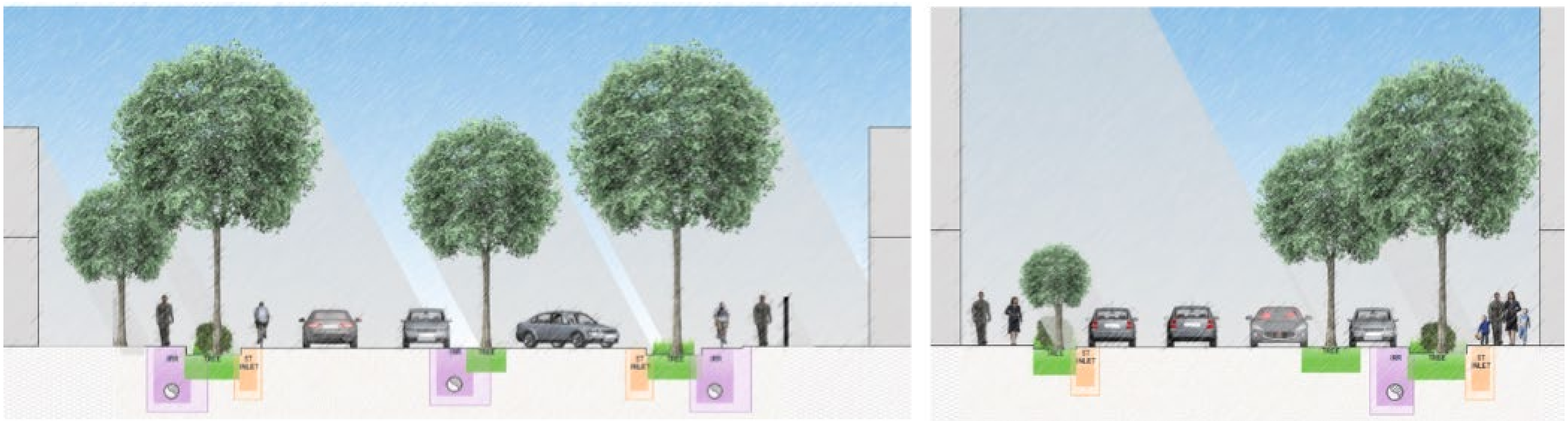
Increase longevity of local road infrastructure. Shading by large canopied trees protects asphaltic surfaces from UV damage and can reduce pavement fatigue including cracking, rutting and shoving. A 30-year trial in California found an unshaded segment of a road required six reseals over the trial period, compared with an identical shaded section (small canopy) that required only five reseals. A third section with a large canopy cover required only 2.5 reseals. Shade from the third section was estimated to save $US7.13 million over 30 years (McPherson & Muchnick, 2005).

Reduce and /or delay stormwater peak flows and nutrient loads. During large storm events, one large canopied tree can intercept between 190–380 L of rainfall (Xiao et al., 1998). It can slow the flow of water into the Macquarie River, reducing flash peak flows and erosion impacts. In addition, the trees have been planted within tree pits (Figure 9). These water sensitive urban design features capture stormwater, to passively water the tree and act as a biofilter to remove nutrients (phosphorus and nitrogen) preventing discharge to the Macquarie River.

Figure 9: Tree pits provide passive watering for trees
Source: Coutts & Tapper, 2017



The innovations

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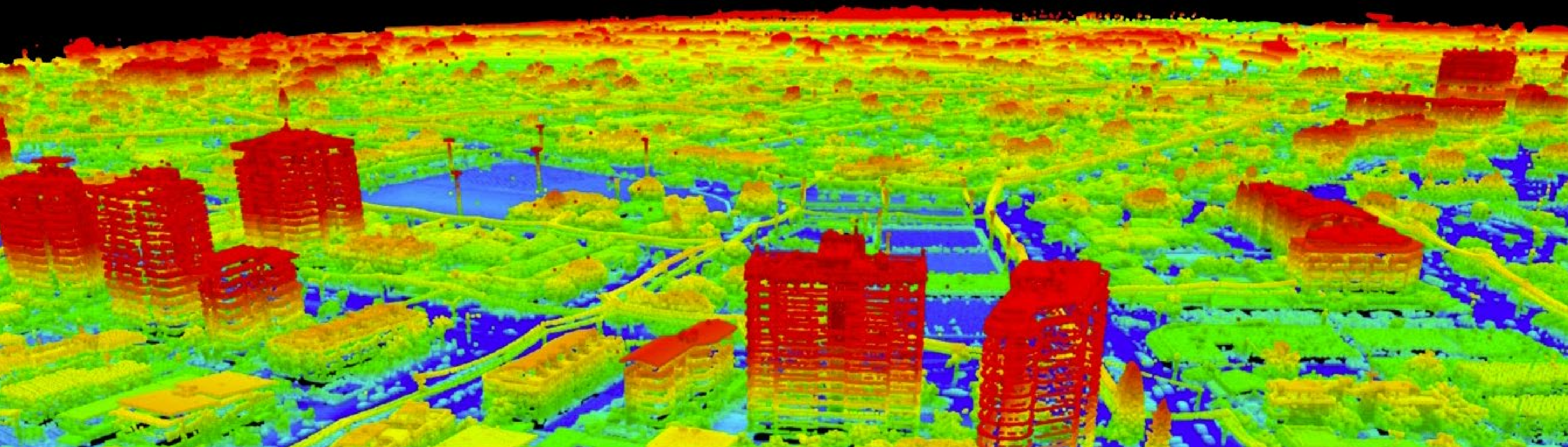
The research

CRCWSC research explores how green infrastructure and water sensitive urban design—at the household through to the neighbourhood scale—can modify the urban climate and reduce the impacts of the UHI. According to Coutts et al. (2013), these climate sensitive urban design (CSUD) measures can create attractive, sustainable and thermally comfortable cities that mitigate high urban heat and provide adaptation to extreme heat events. Urban street trees and canopies are an important component of CSUD (Donovan & Butry, 2009).

The literature also explains that to maximise their cooling benefits, trees must be considered as part of the urban design and strategically placed within the streetscape (Figure 10). Many factors can influence the effectiveness of street trees and urban canopy for mitigating the impacts of UHI, such as canopy density (Streiling & Matzarakis, 2003) and tree arrangement (Spronken-Smith & Oke, 1998). Street orientation and urban geometry (the layout of the streets) can also enhance or negate the influence of increased tree cover in certain urban landscapes (Lindberg & Grimmond, 2011b). Urban design known as 'canyon geometry' can also affect the effectiveness of urban tree plantings. Zutter (2018) describes an urban canyon as the basic urban surface unit comprised of the walls of adjacent buildings, the ground (street) between, and the air volume enclosed within. Coutts et al. (2015) demonstrated street trees were more effective at reducing the daytime temperatures in wide, open streets where building shade was absent.



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The CRCWSC's *Trees for a cool city* (Coutts & Tapper, 2017) guides practitioners about factors to consider when strategically planting trees, to gain the optimum benefits from a cooling and climate adaptation perspective.

A range of urban greening options are available including trees, open space, green roofs and green walls (vertical gardens). While all greening options can play a role in cooling the urban environment and mitigating UHI, trees are particularly effective because they provide cooling through transpiration and shade. Shade is important during warm sunny conditions for human thermal comfort. Unless trees are incorporated as part of the landscape design, open space and green roofs will not provide human thermal comfort. Trees are an effective solution to urban cooling and heat mitigation for a number reasons:

- Tree species can be selected to best fit with the local climate and environment.
- Trees provide multiple benefits including reduced stormwater volumes, air quality benefits, carbon uptake and storage, habitat, energy savings and amenity.
- People have a greater connection to and understanding of trees.
- Trees are relatively low maintenance in comparison to green roofs and walls.

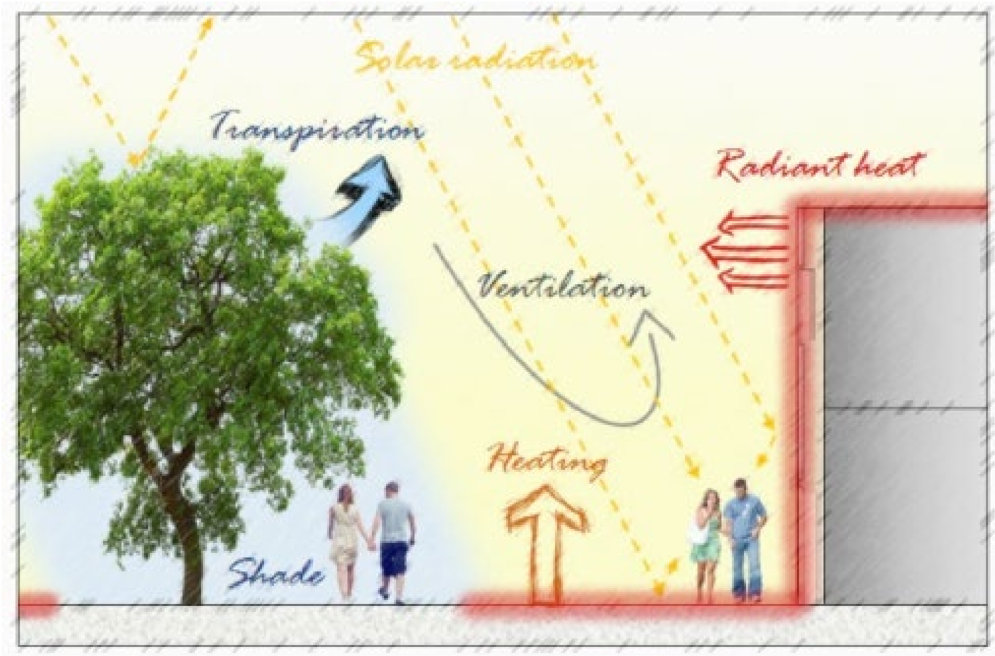

Figure 10: Factors that influence the effectiveness of trees
Source: Coutts & Tapper, 2017

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The tools

Two key tools demonstrate the benefits of the Dubbo Heat Amelioration Project.

The i-Tree software program from the United States Department of Agriculture (USDA) Forest Service provides urban and rural forestry analysis tools. Practitioners can use this tool to report on individual trees, lots, neighbourhoods, cities, and states. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link urban forest management activities with environmental quality and community liveability. i-Tree provides baseline data that can demonstrate value and set priorities for more effective decision making for urban tree plantings.

Council used the i-Tree Canopy Tool to determine canopy cover in Bultje Street before the project started. The tool indicated canopy covered 2.8% of the total area.

TARGET is an urban microclimate model, that specialises in the street-scale, to help practitioners better understand microclimatic conditions. It is one of a suite of CRCWSC tools developed to address aspects of small-scale design, and to derive optimal strategies for the implementation of water sensitive urban design.

The Bultje Street tree replacement project was modelled in TARGET to quantify and help visualise the UHI effect benefits of the proposed project. The tool uses satellite imagery and meteorological data to simulate extreme heat events, assigning land surface temperature (LST) and air temperature estimates to a GIS-based grid. In this way, it can create 'before' and 'after' scenarios.

Using climate information about Dubbo's hottest three-day period on record (10–12 February 2017), council used TARGET to model the heat effects before and after new trees were planted. Specifically, council modified the base land surface map: changing the cover type to tree canopy where the replacement trees were expected to grow (based on the expected canopy size of the tree to be planted); and changing the cover type to asphalt where existing trees were to be removed. Figures 11 and 12 show the contrasting grid-base maps of land temperature, with the future tree canopies providing significant cooling around the road reserve and surrounding landscape.

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Bultje Street, Dubbo – Before tree planting

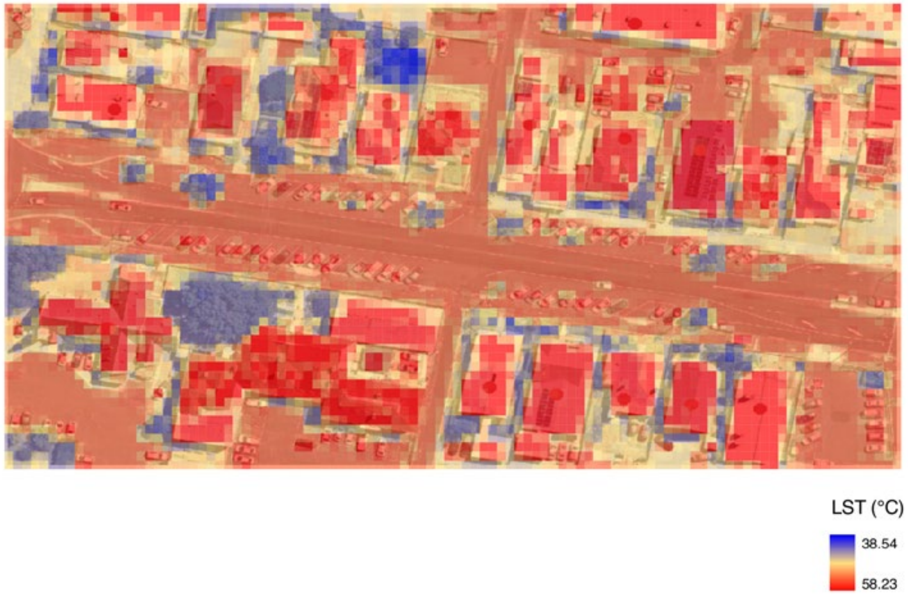

Figure 11: Bultje St – land surface temperatures before tree planting

Bultje Street, Dubbo – After tree planting (modelled LST)

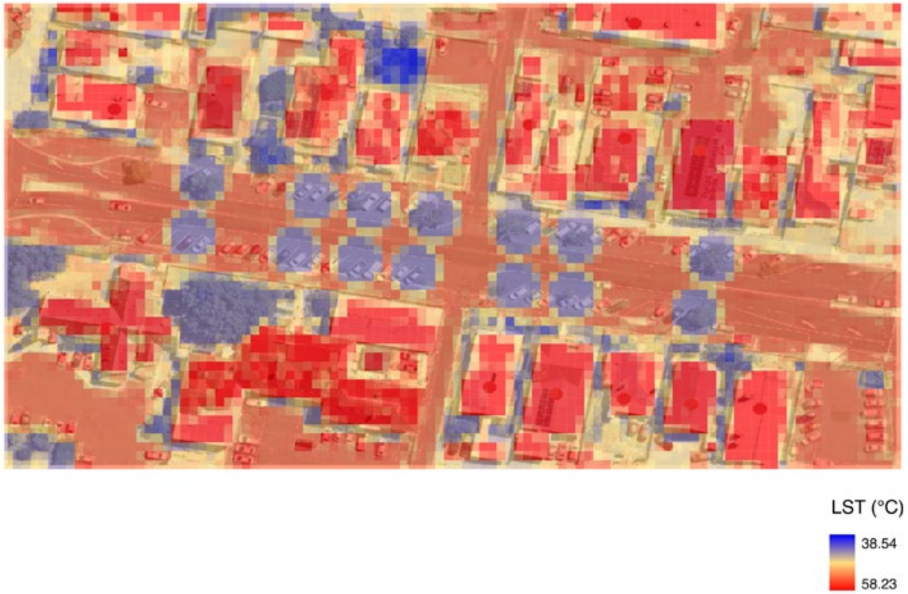

Figure 12: Bultje St – land surface temperatures after tree planting

The outcomes

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The outcomes

This urban heat amelioration project is expected to reduce Bultje Street's LST during heatwaves: from 58°C near hard surfaces including buildings, roofs and asphalt to 38°C under and near tree canopies. The tree pits also provide a stormwater function by reducing water quantity and pollutant loads discharging to the Macquarie River. In this way, strategic planting of trees within the urban landscape can benefit the local community and environment in many ways.

Figure 13: Mitchell Highway Blueridge
Source: Sydney Water

The lessons

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The lessons

The project stakeholders identified several lessons for others considering implementing a similar project:

- Local government funding is limited and resources are in high demand. Collaborating across council and leveraging stormwater and road infrastructure engineering projects with open space and urban greening projects can provide significant benefits and costs savings for a council.
- Collaboration across council can often solve multiple problems. Working together rather than in traditional silos allows valuable funding and resources to be combined and leveraged to solve multiple problems. At the same time as the trees in Bultje Street were being replanted, additional road infrastructure works enabled effective and efficient tree pits and stormwater drains to be installed. These works also alleviated localised stormwater issues by reducing runoff volume and velocity and pollutant discharge to the Macquarie River.
- Do not underestimate the value of planting a single tree within the urban area, because the benefits can increase significantly.
- Be strategic about tree placement, because some locations will yield greater benefits than similar planting in other locations.
- Water security is important. When planting street trees to cool your urban environment, be sure to include a water sensitive urban design structure to capture water to passively water the new plantings.
- Tree species selection is crucial. Not only will the tree species you select need to withstand current climatic conditions, they must also withstand future climatic conditions which are likely to be more extreme.

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More information

You can find more information about this project at:

- Dubbo Regional Council
- Bureau of Meteorology
- Adapt NSW
- CRC for Water Sensitive Cities

Figure 14: Dubbo city centre
Source: Dubbo Regional Council

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References

Bureau of Meteorology 2017. *Climate statistics for Australian locations*, http://www.bom.gov.au/climate/averages/tables/cw_065070.shtml.

Adapt NSW 2014. *Central West and Orana Climate change snapshot*, Office of Environment and Heritage.

Berry, P. & Cheng, J. 2013. 'Health co-benefits and risks of public health adaptation to climate change: a review of current literature', *International Journal of Public Health*, 58 (2), pp. 305–311.

Coutts, A.M., Harris, R.J., Phan, T., Livesley, S.J., Williams, N.S.G. & Tapper, N.J. 2016. 'Thermal infrared remote sensing of urban heat: Hotspots, vegetation, and an assessment of techniques for use in urban planning', *Remote Sensing of Environment*, 186, pp. 637–651.

Coutts, A.M. & Tapper, N.J. 2017. *Trees for a cool city: Guidelines for optimised tree placement*, Cooperative Research Centre for Water Sensitive Cities.

Coutts, A.M., Tapper, N.J., Beringer, J., Loughnan, M. & Demuzere, M. 2013. 'Watering our cities: The capacity for water sensitive urban design to support urban cooling and improve human thermal comfort in the Australian context', *Progress in Physical Geography*, 37, pp. 2–28.

Donovan, G.H. & Butry, D.T. 2009. 'The value of shade: Estimating the effect of urban trees on summertime electricity use', *Energy and Buildings*, 41, pp. 662–668.

Lindberg, F. & Grimmond C.S.B. 2011. 'Nature of vegetation and building morphology characteristics across a city: Influence on shadow patterns and mean radiant temperatures in London', *Urban Ecosystems*, 14 (4), pp. 617–634.

McPherson, E.G. 1993. 'Evaluating the cost effectiveness of shade trees for demand side management', *The Electricity Journal*, 6(9), pp. 57–65.

McPherson, E.G. & Muchnick J. 2005. 'Effects of street tree shade on asphalt concrete pavement performance', *Journal of Arboriculture*, 31(6), pp. 303–310.

McPherson, E.G. & Simpson, J.R. 2003. 'Potential energy savings in buildings by an urban tree planting programme in California', *Urban Forestry & Urban Greening*, 2, pp. 073-086.

Nicholls, N., Skinner, C., Loughnan, M. & Tapper, N.J. 2008. 'A simple heat alert system for Melbourne, Australia', *International Journal of Biometeorology*, 52, pp. 375–384.

Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M. & Williams, N.S.G. 2015. 'Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes', *Landscape and Urban Planning*, 134, pp. 127–138.

Parsons, P., Neale, R., Wolski, P. & Green, A. 1998. 'The shady side of solar protection', *Medical Journal of Australia*, 168(7), pp. 327–330.

Rogers, C., Gallant, A. & Tapper, N.J. 2017. 'Is the urban heat island exacerbated during heatwaves in southern Australian cities?', *Urban Climate*, Submitted.

Spronken-Smith R,A. & Oke, T,R. 1998. 'The thermal regime of urban parks in two cities with different summer climates', *International Journal of Remote Sensing*, 19, pp. 2085–2104.

Streiling, S. & Matzarakis, A. 2003. 'Influence of singular trees and small clusters of trees on the bioclimate of a city—a case study', *Journal of Arboriculture*, 29, pp. 309–316.

Thom, J.K., Coutts, A.M., Broadbent, A.M. & Tapper, N.J. 2016. 'The influence of increasing tree cover on mean radiant temperature across a mixed development suburb in Adelaide, Australia', *Urban Forestry & Urban Greening*, 20, pp. 233–242.

Xiao Q., McPherson E.G., Simpson J.R. & Ustin S.L. 1998. 'Rainfall interception by Sacramento's urban forest', *Journal of Arboriculture*, 24(4), pp. 235–244.

Zutter, H.N. 2018. *Urban canyon geometry: how variations influence sky view factor, air and surface temperature*. ResearchGate.

About us

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) was established in July 2012 to help change the way we design, build, and manage our cities and towns by valuing the contribution water makes to economic development and growth, quality of life, and the ecosystems of which cities are a part.

The CRCWSC is an Australian research centre that brings together many disciplines, world renowned subject matter experts, and industry thought leaders who want to revolutionise urban water management in Australia and overseas.

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