# WHICH PLANT WHERE? SPECIES SELECTION FOR URBAN GREENING

**Leigh Staas and Michelle Leishman**

Centre for Smart Green Cities
Department of Biological Sciences, Macquarie University, NSW, 2109

## Abstract

Australia is a highly urbanized nation and the success of our cities will depend on how we adapt and design our urban regions to deal with population growth and future environmental change. Green infrastructure is an asset that is integral to the way our cities function, providing ecosystem services to their inhabitants through local climate regulation, pollutant reduction, storm water management, thermal comfort, improved human health and wellbeing, as well as aesthetic and biodiversity benefits (Tzoulas et al. 2007a, Taylor & Hochuli 2015, Davies & Corkery et el., 2017). While green infrastructure can contribute to the liveability of a city through its economic, social and environmental benefits, the success of an urban green space is not always realised. Incorrect species selection can result in considerable cost to public and private realms, especially if there are low survival rates or perceived co-benefits are not integrated into the design (Staas et al. 2017). Further, time pressures and low budgets often lead to inclusion of poor quality plant stock based on availability rather than suitability for the site. Notably, the tools and resources for plant selection vary from state to state and are generally used for specific purposes based on the organisation. There is no one tool that planners, practitioners and specifiers can use to support plant selection in urban regions across Australia. The *Which Plant Where* project will develop a database to allow decision makers to use location-specific factors for optimal plant selection. The online tool will be underpinned by rigorous research and industry knowledge, with the aim of expanding the diversity of plants to create living cities.

## Urbanisation

Two-thirds of Australia's population are living in our capital cities and our population is expected to increase to 36.8 million by 2061 (ABS). Urban intensification and expansion is changing the shape and composition of our urban matrix and influences the microclimates we experience within cities. Changes of microclimates are complex and can be manifested in increased temperatures, as well as changes to wind patterns, humidity and rainfall (Grimm et al. 2008, Davies & Corkery et. el 2017). In addition our cities are dominated by hard or impermeable surfaces such as buildings, rooftops, footpaths and roads, creating issues of increased stormwater runoff as well as increased temperatures due to the urban heat island effect. The urban heat island effect is created when heat is trapped due to the thermal mass of highly urbanised areas, resulting in significantly higher temperatures compared to peri-urban or rural areas (Oke 1982, Sharifi and Lehmann 2014). Studies demonstrate that the urban heat island effect in highly urbanised areas can increase temperatures by 2 - 12 degrees C (Voogt, 2003).

Urban heat island effects will be compounded by climate change and will continue to impact our cities. Over the last five years Australia has experienced increasing record breaking temperatures in the summers of 2012/13, 2013/14 and 2016/17 (Climate Council 2017). In just 90 days of 2016/17, more than 205 temperature records were broken around Australia (Figure 2 – 2016/17 Angry Summer). The relationship between heat and mortality has long been recognised (Haines et al., 2006), with heatwaves resulting in the deaths of more Australians that any other natural hazard (Chen 2013). Heatwaves contribute to the deaths of over 1000 people aged over 65 each year (Osmond, 2017) and this number is expected to rise with an aging population.

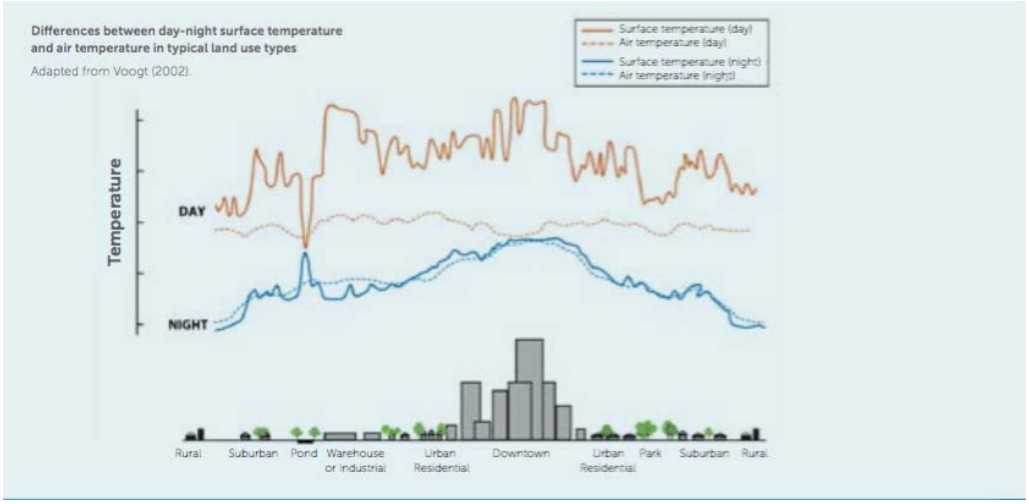


**Figure 1** - Differences between day-night surface temp and air temp in typical land use types (Osmond & Sharifi 2017)

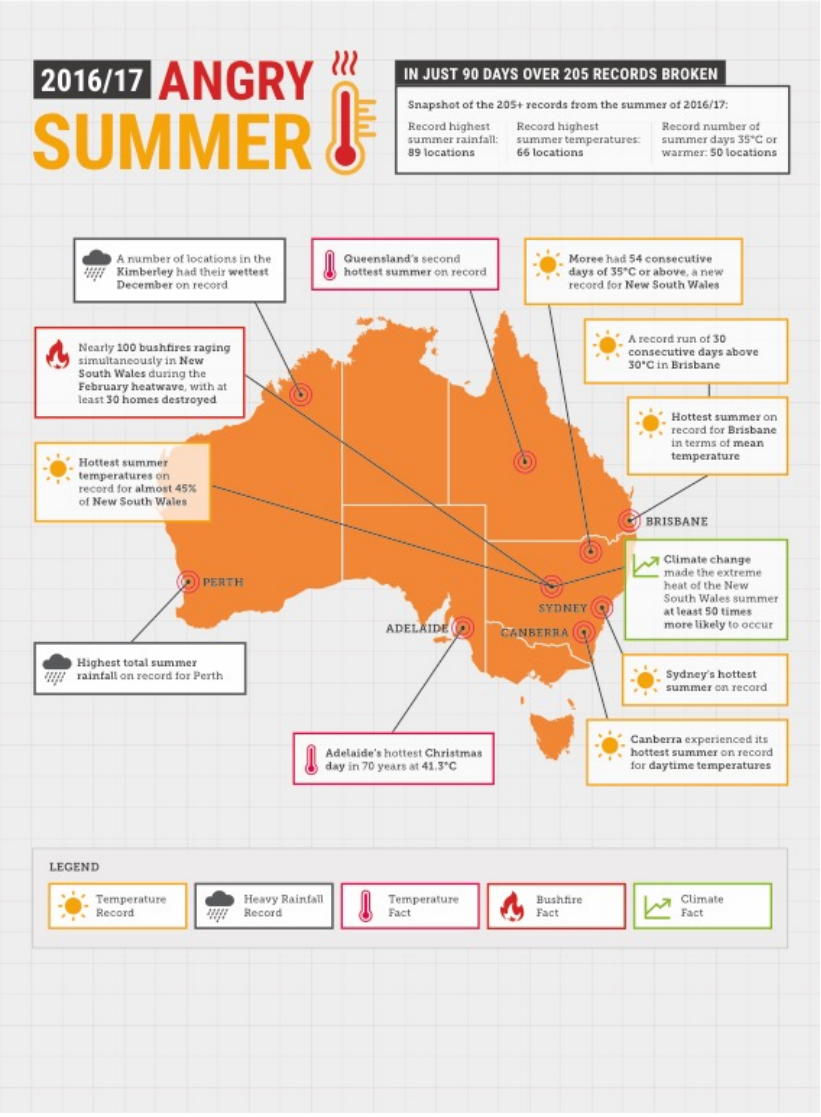


**Figure 2** - 2016-2017 Angry Summer (Climate Council 2017)

Urban development significantly modifies hydrological systems in urban areas. Changes to the natural environment, such as creek channelization, increased impervious surfaces and topographic modification, result in changes to the quantity, speed and direction of storm water (Barbosa et al. 2012, Davies et al. 2017). As urbanisation continues, and impervious surface cover increases, flash flooding and increased levels of urban stormwater runoff become more likely (Walsh et al. 2012). Given that the majority of Australian cities are situated on or near watercourses, stream health will become compromised (Walsh et al. 2007). Stormwater quality is affected by pollutants such as solids, heavy metals, nutrients, pathogenic microorganisms and organic micro-pollutants (Barbosa et al. 2012).

## Green infrastructure

Urban greening plays a significant role in contributing to temperature regulation in urban areas and can moderate and cool the microclimate through shading and evapotranspiration by humidifying the air. Informed selection and strategic placement of trees and green infrastructure can provide dense canopies to reduce the urban heat island effect and reduce air temperatures by between 2°C and 8°C (Pitman & Ely 2015, Norton et al. 2015, Davies & Corkery et. el. 2017). Based on the relationship between the ambient weather conditions and heat related mortality rate, it is estimated that a 10% increase in surface reflectivity from urban vegetation coverage can result in an average 7% reduction in mortality during heat waves (Kalkstein et al. 2014).

Several types of green infrastructure have emerged for the purpose of stormwater management including raingardens, bioswales and green roofs. Much research has gone into the impact of different design considerations, including plant performance, that affect water management outcomes of these spaces (Berndtsson 2010). Green infrastructure has been a popular solution for water management due to its multifunctional capacity (Lovell and Taylor 2013) – e.g. vegetated water retention basins can also be places for recreation or social meeting places within cities.

> Green infrastructure is the network of green spaces and water systems that deliver multiple environmental, economic and social values and benefits to urban communities. These benefits include health and wellbeing, cooling the environment, mitigating flooding, improving air quality and enhancing biodiversity and ecological resilience.

The co-benefits of green infrastructure are increasingly being realised and there is increasing evidence that supports green infrastructure as a means for mitigating the impacts of climate change. In order to maximize the economic and social return of our natural assets there needs to be an integrated approach to planning, design, construction and maintenance phases of urban greening. A key issue for the development and implementation of successful green infrastructure is the suitable selection of plant species. Many urban plantings have low survival (Monterusso et al. 2005, Durman and Rowe, 2007, Thuring et al. 2010) or poor performance (MacIvor and Lundholm 2011), resulting in reduced outcomes for green infrastructure.

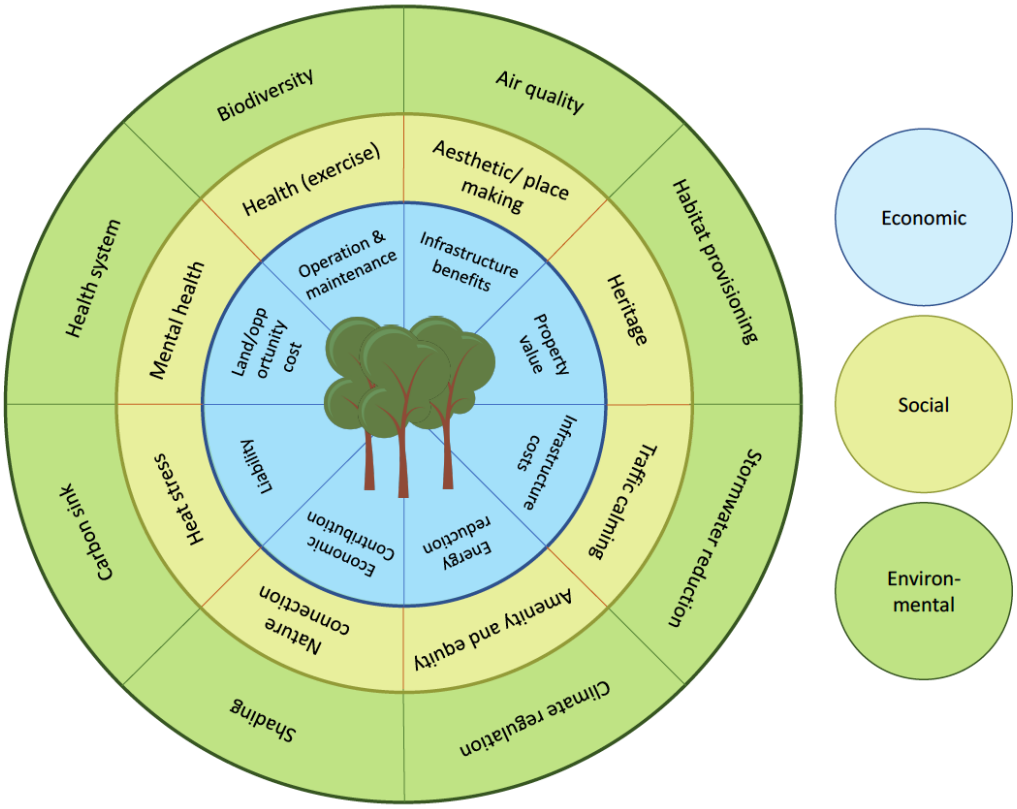


**Figure 3 -** Economic, social and environmental benefits of green infrastructure

## Which Plant Where project

The Which Plant Where project (WPW) is a five-year program that brings together a consortium of researchers, government agencies, industry partners, nursery and turf growers to facilitate sustainable green cities across Australia. Throughout the life of the project, selected species will undergo rigorous testing in laboratories and in real-world settings across Australia, with the aim of creating confidence for growers and practitioners about which plant they should use where, when and why.

As part of our research agenda and consultation, the research team will:

- identify climatic tolerances and traits of the selected species and build spatial maps of suitable areas for planting under current and future climates.
- assess success and failures of urban plantings across a range of contexts and regional areas.
- assess the selected species for heat and drought tolerance in the context of soil and moisture availability.
- combine the research data obtained into an online interactive tool with supporting guidelines to guide species selection for urban plantings across Australia

## Stakeholder engagement

The success of this project requires collaboration across sectors and the project team has undertaken intense consultation with key stakeholders. A national roadshow was held during the beginning of 2017 to promote the project, engage with stakeholders, receive guidance on industry needs and to ensure our project remains relevant to the needs of the nursery and turf industries. Workshops were held in Melbourne, Adelaide, Brisbane, Perth and Sydney. These workshops attracted over 111 people from 86 organisations, bringing together a diverse group of stakeholders including nursery and turf growers, practitioners, developers, landscape planners and designers, as well as state and local government representatives.

## Key findings from the roadshow workshops

Plant selection decisions for urban spaces are complex and continually influenced by multiple factors depending who is making the selection. There were however consistent themes that arose in every workshop and the most common factors influencing species/plant selection for an urban space include:

- Professional experience
- Nursery stock availability
- Cost
- Ongoing maintenance considerations
- Site location and size - often competing against existing services/infrastructure (e.g. water, sewerage, power lines), the built environment and limited land availability
- Aesthetics such as “order” and/or “uniformity”
- Plant size, shape, form and purpose - windbreaks, shading, biodiversity, health and wellbeing, crime prevention
- Master plans of a local council
- Current trends and cultural values

Numerous successful urban spaces were identified in all major cities, most of which was attributed to correct species selection, well thought out planning, good site condition and preparation and ongoing maintenance regimes. Inversely, participants identified that if there is a disconnect between the design, construct and maintenance process, success of an urban green space is either limited or may lead to failure. There are various points at which failure becomes imminent:

**Tender phase:** cost of the initial design may be too expensive and selected plants are replaced with cheaper lower quality plants.
**Construction phase**: removal of good quality top-soil, soil compaction, restricted growth space.
**Planting phase:** availability of stock in nurseries, wrong soils used, species/plant substitution due to overspend on project.
**Maintenance phase**: in the past, plantings were generally watered for the first year. This is now being extended to up to 3 years to ensure the plants survive.

It is important to note that the success or failure of an urban green space is not necessarily defined by whether a species survives or not, but rather if the right plant has been used for the context of the site. Many participants highlighted that a site could be deemed unsuccessful if the species selected does not provide multiple benefits. For example, shrubs planted along roads may be successful if measured by survival, but unsuccessful if success is measured in terms of providing enough shading for temperature mitigation.

Workshop participants also identified ongoing tensions that arise during this decision making process, for example the competition between grey infrastructure and green infrastructure, the lack of professional knowledge during the construction phase and the difference between aesthetically pleasing species for the public versus council maintenance requirements. This too can influence species selection and success of a site.

All workshop participants agreed that demonstration sites provide an outstanding opportunity for collaboration and engagement, including trialling of different species to measure performance in the landscape. They are also an important part of public education and engagement. There should be a focus on the site, its use and its overall function. When asked to identify what would constitute a good demonstration site, the following attributes were suggested:

- Street trees and urban forest
- Urban open space and parks
- Urban renewal sites
- New housing development sites
- Transport corridors, including roads, rail and nature strips
- Green roofs and walls
- Scientific complexity vs aesthetic
- Passive irrigation and water sensitive urban design

Participants of the workshops were asked about the tools and resources they use for species selection in urban spaces. Some of the most common tools that are used include:

- Google
- Websites such as PlantSelector+, iTree,
- Australian Plant Society (Australia)
- Specifying Trees
- Books, including international, national and local
- Local council list
- Expert advice
- Nursery websites
- Local guides and fact sheets

Notably there was no one tool that was used for plant selection and more often than not tools and resources varied from state to state. This demonstrates the need for an online tool that can be used across Australia.

## Which Plant Where project outline

The Which Plant Where project is a consortium of researchers from Macquarie University, Western Sydney University and NSW Office of Environment & Heritage, working with Hort Innovation Australia. The project consists of three separate but interlinking modules that form the evidence-base for the development of an online species selection tool for urban green spaces.

**Module 1: Species attributes and climatic tolerance**

To be able to predict which species will be most resilient in urban settings we need to understand both their traits and climatic tolerances. Plant traits are the physiological, phenological, and morphological adaptations which underpin their ecological strategies and performance. For example, leaf size and plant growth form can determine the amount of shade provided by a street tree, whilst also being a useful indicator of the potential water use needs in drier environments. This illustrates how we might use the traits of species to filter potential horticultural species to specific urban settings, providing a data-driven process for deciding where to put which plant, and why.

It is equally important to understand how the suitability of species may change across different climate zones. Species adapted to warmer, wetter environments may have reduced survivorship or performance in dry or cold environments. We will use bioclimatic and hybrid species distribution/physiological models to understand the extent of the climatic tolerances of species under both current and future climate scenarios. These models use data on the occurrence of species from herbarium collections and, where available, growth trials to build a spatial map of the potential distribution of a species.

**Module 2: Successes and failures**

Understanding and learning from past plantings in a variety of environments is critical. We will collate information on successes and failures from urban greening projects from across Australia. We will also develop field testing sites for a range of plant species and environmental conditions. Understanding what contributes to success or failure of urban plantings will enable the identification of good practice for species selection and planting.

**Module 3: Heat and drought tolerant species and soils**

Plants in urban environments face a range of unique stresses, and thus a thorough understanding of plant tolerance to environmental stresses such as heat and drought is critical for successful urban greening. In this module we will use a systematic screening approach using a combination of glasshouse and field trials for a wide range of species to assess plant species suitability under a variety of environmental and planting conditions and develop a predictive framework based on plant attricutes.

**Bringing it all together – development of a Species selection online tool**

The final output of this project will be to create an interactive online tool that will guide species selection for urban plantings across Australia. The tool will build on research data obtained throughout the life of the project in Modules 1, 2 and 3. Stakeholder engagement will ensure that the needs of the end-users are understood and incorporated. The online tool will support decision making for species selection for planting within urban spaces under current and future climates. The tool will include site characteristics and natural distribution, tree appearance, ecosystem services, required management activities, risks and interferences and will also include such things as

- urban site conditions (space, microclimate, soil conditions, water supply and light regime)
- biodiversity and ecosystem services aspect (diversity, native vs exotic, wildlife interactions)
- human requirements (shading, health and wellbeing, management, risk).

The development of this tool will be an important contribution to the facilitation and enhancement of urban green space across Australia, providing multiple benefits for human health, ecosystem services, biodiversity and the liveability of our urban areas.

## References

Angry Summer 2016/17: Climate Change Super-charging Extreme Weather by Professor Will Steffen, Andrew Stock, Dr David Alexander and Dr Martin Rice.

Barbosa, A. E., Fernandes, J. N., & David, L. M. (2012). Key issues for sustainable urban stormwater management. Water Research, 46(20), 6787-6798.

Berndtsson, C. J. (2010) Green roof performance towards management of runoff water quantity and quality: a review. Ecological Engineering, 36, 351-360.

Chen, D. (2013) Greening City - mitigate heat stress with urban vegetation, Report for Horticulture Australia Limited, CSIRO.

Davies, P., Corkery, L., Nipperess, D., Barnett, G., Bishop, M., Hochuli, D., Hose ,G., Joei, C., Lin, B., Keane, A., Osmond, P., Pelleri, N., Staas, L., Threlfall, C., Van den Berg, F., & Wilkinson, S. (2017) Blueprint for Living Cities: Policy to Practice. National Green Infrastructure Network

Durhman, A. K., Rowe, D. B. & Rugh, C. L. 2007. Effect of substrate depth on initial growth, coverage and survival of 25 succulent green roof plant taxa. Hortscience, 42, 588-595.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J. G., Bai, X. M., & Briggs, J. M. (2008). Global change and the ecology of cities. Science, 319(5864), 756-760.

Haines, A., Kovats, R.S., Campbell-Ledrum, D., Corvalan, C., (2006) Climate change and human health: impacts, vulnerability and public health. Public Health, 120 (7), 585-96.

Kalkstein, L. S., Sailor, D., Shickman, K., Sheridan, S., & Vanos, J. (2014). Assessing the health impacts of urban heat island reduction strategies in the District of Columbia.

Pitman, S. D. and M. E. Ely (2015). Green infrastructure as life support: Urban nature and climate change. Transactions of the Royal Society of South Australia 139(1), 97J112.

Monterusso, M. A., Rowe, D. B. & Rugh, C. L. 2005. Establishment and persistence of Sedum spp. and native taxa for green roof applications. Hortscience, 40, 391-396.

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, 127-138.

Sharifi, E., & Lehmann, S. (2014). Comparative analysis of surface urban heat island effect in central Sydney. Journal of Sustainable Development, 7(3), 23-34.

Staas, L., Beaumont, L., Leishman, M. (2017) Which Plant Where: What we heard: documenting the stakeholder workshops.

Macivor, J. S. & Lundholm, J. 2011. Insect species composition and diversity on intensive Green Roofs and adjacent level-ground habitats. Urban Ecosystems, 14, 225-241.

Oke, T. R. (1982), The energetic basis of the urban heat island. Q.J.R. Meteorol. Soc., 108: 1–24.

Osmond, P. (2017) Guide to Urban Cooling Strategies, Low Carbon Living CRC

Taylor, L. & Hochuli, D. F. (2015) Creating better cities: how biodiversity and ecosystem functioning enhance urban residents' wellbeing. Urban Ecosystems, 18(3), 747-762.

Thuring, C. E., Berghage, R. D. & Beattie, D. J. 2010. Green roof plant responses to different substrate types and depths under various crought Conditions. Hort Ecology, 20, 395-401.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., James, P. (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landscape and Urban Planning, 81, 167-178

Walsh, C. J., Sharpe, A. K., Breen, P. F. & Sonneman, J. A. 2001. Effects of urbanization on streams of the Melbourne Region, Victoria, Australia. I. Benthic Macroinvertebrate Communities. Freshwater Biology, 46, 535-551.

Tzoulas K, Korpela K, Venn S, Yli-Pelkonen V, Kaźmierczak A, Niemela J, James P (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review, *Landscape and Urban Planning* 81, pg 167-178