THE UNIVERSITY of ADELAIDE

Trees for Urban Streets

A multi-criteria guide to select street trees in Greater Metropolitan Adelaide

April 2023

Beta+

make history.

We acknowledge and pay our respects to the Kaurna people, the traditional custodians whose ancestral lands we gather on. We acknowledge the deep feelings of attachment and relationship of the Kaurna people to country and we respect and value their past, present and ongoing connection to the land and cultural beliefs.

This guide provides literature-based selection criteria for street trees and includes a list of 100+ trees to be used in the context of Greater Adelaide metropolitan area, South Australia

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ENVIRONMENT INSTITUTE

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Linked to this document:

Tree selection tool (spreadsheet)	Tree selection tool (app)	Feedback link (google form)

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Preamble

We are currently on the edge of the greatest crisis humanity is likely to face – global climate change. While much has been said about this and there is no doubt that public concern is growing, there is equally no doubt that it currently feels like we are doing too little too late. The next few years will define our future as a species. What can we do about this? The options are easily summarised:

- we can find ways to mitigate climate change – this is the gold star approach but it will also be the most complex and expensive by far and will probably not work quickly enough on its own;
- we can do our best to adapt to climate change so that the worst impacts are reduced in their ferocity – this is something we must achieve if for no other reason than to buy time for mitigation strategies to be developed and employed; and
- we can invest vast amounts of time, effort and money in trying to escape planet Earth and develop new communities on other moons and planets – this is the coward's response to the issue and is more likely to create new problems than to solve existing ones.

Adelaide is a city that is especially vulnerable to climate change. Many years ago, the visionary George Goyder travelled extensively through South Australia and developed a guide to where grain cropping was likely to succeed and as a result, we have the remarkable "Goyder's Line" which is now a well-known marker of the division between southern parts of the State with reliable long-term rainfall and the majority of the State where it is not. It is no secret that Goyder's Line is moving southwards as climate change impacts and this does not exclude a major change in the climate of our capital city. The immediate protection we can provide to the city of Adelaide is to increase the vegetation cover and to do this with species of trees and shrubs that will be best suited to future climates. This is a deceptively complex challenge, since it is both difficult to predict the impact of climate change precisely and it is also difficult to be sure about the response of any plant species to changing climates in Adelaide.

This guide makes an excellent start to that process and will be a valuable aid to anyone interested in planting for the future of their city and for the greater goal of planet-wide climate adaptation. Much more research is required to provide hard data to continually improve the process, but this guide provides a baseline for that research. Not many years ago, climate change was an issue for adults to consider when thinking about the future of their grandchildren. Now it is an issue that is already hitting hard and is only going to grow to a potentially catastrophic level while we develop appropriate responses. We have no time to waste.

Professor Robert S. Hill

September 28th 2022

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Disclaimer

The authors would like to acknowledge that:

- The information and data presented in this document and its associated tool are collected from creditable peer-reviewed sources internationally. There is much room to localise this data in future research and development projects.
- The data from literature is rigorously and critically reviewed to provide a collective list of selection criteria for street trees and the list of 100+ street trees for Greater Metropolitan Adelaide.
- There are emerging criteria such as climate change resilience, extreme heat tolerance, urban heat mitigation capacity and adaptability of street tree species to upcoming infrastructures that are not included in this document due to shortage of fine-scale data in the existing literature. These criteria may be subject to future research and development.
- Trees physiological adaptation and biological aspects are out of the scope of this document. This is a decision support tool for practitioners, planners and authorities to find appropriate street tree species based on desired/recommended selection criteria and avoid unsuitable species with low tolerances and high risks in urban areas.

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Criteria Definitions

Selection criteria	**Drought tolerance**	The ability of tree species to endure prolonged dry periods mostly during summer.
	Storm tolerance	The ability of trees to endure severe wind conditions.
	Frost Tolerance	The recognised ability of tree species to endure prolonged cold periods and lower temperatures below 4 degrees C.
	Salinity Tolerance	The recognised ability of tree species to endure certain levels of salt in the soil water.
	Endurance in urban settings	Tolerance to urban disturbances and constraints such as cutting off tree roots, soil compaction or excessive pruning.
	Prone to pests or disease	Known pests or disease currently observed impacting tree species health and growth.
	Allergenicity	The recognised ability of the tree to trigger abnormal immune response, over-reaction, cause physiological function disorder or tissue damage.
	Weed Potential	Tree species that invade native communities or ecosystems, causing major modification to species richness, abundance or ecosystem function.
	Regulated under powerlines	Trees that may not be planted in proximity to certain public powerlines as per the regulated list (2010) in the Electricity Act.

Descriptive data	**Origin**	Indigenous: local to the area (local provenance), Native: local to elsewhere in Australia, Exotic: not from Australia originally.
	Height	Tree height at maturity in metres assuming typical soil and water conditions.
	Width	Trees crown diameter at maturity assuming typical soil and water conditions.
	Canopy shape	The natural form or shape of the tree.
	Evergreen or deciduous	Trees with seasonal or all year around foliage.
	Longevity	The expected life span of a tree in an urban environment.
	Potential to gain legislative status	Species with the potential to gain legislative status in the future, having its circumference at 1 metre height greater than 2 metres for regulated trees and 3m for significant trees).
	Pruning needs	Relates to the frequency and extent of pruning required for a tree to be managed in an urban environment such as footpath and road clearances.
	Water needs	The amount of irrigation required for a healthy growth of tree species.
	Shade	Describes amount of shade provided by tree at maturity.
	Important habitat for fauna	Trees that provide nesting and shelter opportunities for native birds, mammals and insects as well as food sources in flowers, fruit and seed.

Trees and sustainable development goals (SDGs)

The unprecedented number of climate extremes in the 21st century have presented ever growing urban settings with the emerging challenge of our time: to maintain and enhance sustainability and liveability in the built environment. Adopted in 2015 and in response to the global nature of development challenges, the United Nations (UN) outlined 17 goals spanning the three pillars of sustainability, commonly known as the Sustainable Development Goals (SDGs). The benefits that trees provide can help cities and communities to meet 15 of the 17 internationally supported UN SDGs (see Table 1for details).

Current climate change estimations indicate a likely 2-4°C rise in temperature with an increased likelihood of extreme hot weather by 2100. Trees are highlighted as countermeasures to urban overheating in the recent literature. They provide shade and evapotranspiration in the built environment, provide habitat for wildlife, reduce stormwater runoff, capture and store carbon dioxide and contribute to better air quality. They re-introduce nature into our cities, thereby contributing towards mental and physical health of local communities.

In the context of warming of the urban environment, trees have been shown to reduce the urban heat island (UHI) effect. Urban greenery is shown to reduce the UHI effect by up to 2-4°C in outdoor spaces, thus serves as an effective countermeasure to the UHI effect. Street trees provide cultural associations between people, community, and trees. They tell stories about the development of a city and neighbourhood. They are part of the urban fabric that makes a successful place.

Planting new and maintaining existing urban trees are not without challenges and restrictions. The selection of species may be affected by the site restrictions including underground and overhead infrastructure services. For example, pruning the trees planted underneath overhead powerlines can be costly and aesthetically severe. This may result in smaller trees with inadequate canopies be planted along streets which new technologies may void the need for overhead powerlines in the near future.

Some trees develop roots that may affect the ground surface and underground infrastructures, while some trees drop seeds and branches that can have impact on the safety of people and vehicles nearby. Not all types of trees are suitable to all soil types, and with increasing occurrences of unpredictable weather patterns and extreme heat, they can be severely affected, struggle and die prematurely in urban settings.

Table 1. Overview of the benefits of urban trees and their relevance to the corresponding United Nations Sustainable Development Goals (SDGs) (*Turner-Skoff & Cavender 2019*)

Benefit of urban trees category	Corresponding United Nations Sustainable Development Goals	Scientific benefits of trees
	Health and social well-being	
Trees promote physical and mental health for urban residents. They support community ties and reduce crime rates	*Goal 3: Good health and well-being* *Goal 11: Sustainable cities and communities* *Goal 16: Peace, justice, and strong institutions*	- Reduce pollution - Improve physical and mental health - Strengthen community ties - Increase physical activity - Decrease aggression and violence - Reduce crime
	Cognitive development and education	
Trees increase a student's ability to succeed in school	*Goal 4: Quality education*	- Improve student performance - Reduce stress - Increase concentration - Reduce symptoms of ADD/ADHD - Increase attention - Increase self-discipline
	Economy and resources	
Trees are good for the economy and they reduce energy bills. They provide many resources, such as food, to a community	*Goal 1: No poverty* *Goal 2: Zero hunger* *Goal 7: Affordable and clean energy* *Goal 8: Decent work and economic growth* *Goal 10: Reduced inequalities* *Goal 12: Responsible consumption and production*	- High return-on-investment - Support tourism - Increase home prices and rental rates - Reduce energy use and bills - Promote food sustainability - Provide resources and firewood
	Climate change mitigation and habitat	
Trees mitigate the Urban Heat Island effect and store and sequester carbon. They are important for habitat.	*Goal 3: Good health and well-being* *Goal 13: Climate action* *Goal 15: Life on land*	- Reduce Urban Heat Island effect - Store and sequester carbon - Provide critical habitat
	Green infrastructure	
Trees are important forms of infrastructure, especially for storm water management	*Goal 3: Good health and well-being* *Goal 6: Clean water and sanitation* *Goal 9: Industry, innovation and infrastructure* *Goal 11: Sustainable cities and communities* *Goal 12: Responsible consumption and production* *Goal 14: Life below water* *Goal 15: Life on land*	- Manage storm water - Reduce pollution - Protect life on land

Project aim and objectives

Urban greenery enhancement is being actively promoted as an important planning tool with intertwined environmental and social benefits. Currently there are a handful of databases on street trees used by urban planners, local government, transport planners, landscape architects and other stakeholders invested in urban development and management. These databases are either descriptive or do not comprehensively address relevant aspects that impact the growth and life of the trees in urban settings. While existing online plant selection tools such as Best Plants and Plant Selector offer a quick guide for choosing suitable plants for various situations, they do not focus on street trees. They also do not provide enough information on tolerance of trees to drought, salinity, frost or required maintenance. For example, at present, there is only one salinity tolerant tree listed by Best Plants (Sublime, *Acmena smithi)*.

Based on a multiple-criteria approach, this research aims to comprehensively explore aspects related to the selection of urban street trees and develop a database for the **Greater Adelaide Metropolitan area**. The database is intended for professional designers and policy-makers in landscape architecture, urban planning, design and management.

The main objectives include:

1. To provide literature-based criteria for selection of best-fit street trees
2. To develop a filterable database of urban street trees for the Greater Adelaide Metropolitan area
3. To develop a multiple-criteria tool to be used by planners and managers to select appropriate species

We have developed a comprehensive matrix, covering relevant criteria for selection of urban street trees for the context of the Greater Adelaide Metropolitan area. This matrix consists of a wide range of criteria in two broad categories of selection criteria, and is linked to descriptive information of tree species.

- The selection criteria assist selection of street trees, based on their ability in dealing with various climatic, spatial and soil conditions.
- The descriptive data provide information of the selected species related to their natural characteristics, such as shape, size (width and height), amenity, type, growth and development patterns.

Tree Selection Criteria

The selection criteria are divided into eight sub-criteria, including: (1) ability to withstand drought, (2) ability to cope with salinity stress, (3) ability to withstand frost, (4) longevity, (5) allergenicity, (6) known pests, (7) weed potential, and (8) maintenance and management requirements.

To understand all aspects of selection criteria and enhance their relevance to the planning and management of urban street trees, we have reviewed existing literature on each criterion from a broader international perspective into a more specific context of Australia. Through an extensive review of academic literature, archival documents, government reports and online databases, the following sections present a discussion of how each selection criterion is conceived in theory, policy, and practice. Such review helps ascertain the extent of the existing knowledge regarding selecting resilient urban trees in response to a range of climatic and spatial forces, such as drought and salinity stress, or based on the potential health and environmental risks they may pose, such as allergenicity and weed potential.

Drought tolerance

Driven by climate change, drought severity and longevity has increased significantly across the globe. The impact of global warming impacts is gradually leading to pervasive decline and dieback of several vulnerable trees. Drought kills tree species in a density-dependent manner by affecting their chemical defence system and nutritional quality. To minimize drought-induced tree mortality and help adapt urban greenery to climate change, long-term solution should be prioritised for low-maintenance landscapes.

Different tree species have different reactions to extreme dry and hot conditions during summer heatwaves in South Australia. Attempts have been done to use genetic engineering techniques to improve resistance of trees to high-temperature stress. Assembling tree species with different leaf phenology (timing) and physiological characteristics reduces competition and facilitates resource acquisition, productivity and water efficiency of the plant.

A list of 60 drought resistant native species in the US suggests a set of useful guidelines on selecting drought resistant trees:

- *Select native trees* as they are better adapted to local soil, moisture, climate, and pest conditions.
- *Select early to mid-successional species*, those that colonize old fields, new soil areas, and disturbed sites (such as pines, black locust and elms), use water more effectively than late successional species or climax species (such as sugar maple and beech).
- *Select proper canopy type*. Trees with multilayered crowns having many living branches and leaf layers (such as oak, ash, gum and hickory) are more water-efficient than those trees with leaf canopies.

- *Select proper crown shape*. Tall trees with cone or cylinder-shaped crowns tend to be more resistant to dry conditions. Trees with deep, upright crowns are more effective in water use than those with flat, wide-spreading crowns.
- *Select small-leaved or small, deeply lobed leaved trees* (such as linden, elm, ash and willow oak) as they are more easily cooled and have better water use efficiency than trees with larger leaves (such as sycamore, cottonwood and basswood).
- *Select proper foliage reflection*. Broadleaved trees reflect more light than conifer species, therefore have better water efficiencies.
- *Select upland versus bottomland species*. Upland species are usually more drought tolerant than bottomland species.

The influence of climatic extremes and drought on urban trees has been well discussed in Australia. The process of chronic decline and dieback of eucalypt during drought-related die-off periods are studies in Eastern Australia. Meanwhile, major European deciduous tree species in Melbourne, such as *Ulmus procera*, *Ulmus L.* and *Platanus acerifolia*, are shown to be sensitive to climate change. Areas at risk of drought-induced tree mortality across South-Eastern Australia are highlighted. For example, Adelaide Advanced Trees (AAT) provides landscape architects with a guide to help choose varieties of drought tolerant trees in South Australia. Some of the popular varieties of hardy trees listed by AAT include *Corymbia ficifolia* (Baby Orange), *Eucalyptus cladocalyx* (Vintage Red), *Callitris gracilis* (Southern Cypress), *Callistemon* (Bottle Brush), *Brachychiton acerfolius* (Illawarra Flame Tree), and *Hymenosporum flavum* (Native Frangipani).

Salinity tolerance

Salinisation of land and water is regarded as a major threat to native species, ecological communities, and functioning ecosystems. Salt can cause damage to plants at all stages of growth and development. Salinity stress has three fold effects: (1) it reduces water absorption, (2) causes an imbalance in ion homeostasis and (3) leads to toxicity.

- The most common type of soil salinity is naturally occurring salinity associated with land with saline sub-soil, such as coastal marine plains and salt lakes. Approximately one-third of Australia (29 million hectare) consist of naturally occurring saline land.
- Another type of soil salinisation is known as secondary salinisation, induced by human activity. It is resulted from changes to the groundwater balance. Secondary soil salinisation may occur in irrigated and non-irrigated dryland areas.

In Australia, dryland salinity associated with shallow groundwater has been reported as a major form of land and water degradation in Western Australia, South Australia, and Victoria, and to a lesser extent in New South Wales, Tasmania, and Queensland. Additionally, urban soil salinity caused by deicing (removing frost) of streets and sidewalks with sodium chloride is considered to be a major contributor to the poor state of health and dying of street trees in regions with the cold winter season

There is a voluminous literature on exploration of tree species reaction and adaptation to saline conditions and on the ability of certain tree types in mitigating salt stress. For example, it is revealed that *Pinus leiophylla* has the regeneration potential in response to salinity, but very high salt concentrations can induce severe physiological impairments and promote the formation of adventitious shoots in its seedlings. The analysis of the salinity sensitivity of eight urban trees native in European and North America results in ranking them in three categories of (1) the least sensitive species (e.g. *Quercus rubra* and *Acer campestre*), (2) medium sensitive species (e.g. *Platanus xhispanica*, and *Gingko biloba*), and (3) very sensitive species (e.g. *Tilia xeuchlora* and *A. platanoides*).

Under the National Dryland Salinity Program, the Parliament of the Commonwealth of Australia (2004) outlines the nation's salinity problem, highlighting scientific perspectives presented in the evidence for the soil salinity processes.

A CSIRO publication provides a guide to selecting native salt-tolerant Australian trees. A South Australia study discusses the salinity tolerance and sensitivity of plant species within the Adelaide Park Lands. In Western Australia, a guide is provided for selecting salt tolerant plants for non-saline, slightly saline, moderately saline, very saline, and extremely saline sites. The Wagga City Council provides a useful booklet on water wise and salt tolerant plants, listing over 28 small trees (e.g. *Acacia acuminata*, *Agonis flexuosa* and *Eucalyptus macrandra*) and 13 large trees (e.g. *Allocasuarina leuhmannii*, *Brachychiton populneus* and *Eucalyptus astringens*) that are tolerant to salt stress.

Frost tolerance

Frost is common to Southern parts of Australia where the ground and ambient air cool through the loss of heat to the atmosphere reaching below 0°C (for fresh water). This occurs mostly under clear sky and calm weather. Frost originates on the ground and moves upwards onto objects. The most common form of frost in Australia is called white (or hoar) frost. This frost is seen on tree branches and may impact tree function and lead to limb death. As a result of frost, air bubble may form within the water conducting tissue of the tree with the potential to expand to the entire column of water and block water supply within the tree tissue (embolism). Another way that frost can damage plant tissue is through freezing of cells, adversely impacting photosynthetic capacity.

Timing is the crucial aspect regarding frost impact on deciduous trees. Timing of leaf unfolding during spring is a trade-off between minimising the potential for damage from frost and maximising the length of the growing period. When trees experience frost during winter then this has a low impact on trees. However, if frost occurs after the weather has warmed in spring, this may harm the tree as it may have lost its freezing resistance.

Frost tends to occur more in regions of higher elevation, as such may occur in the Adelaide Hills as warm and cool weather occurrence become more interspersed during winter and spring in the context of climate change. This increased risk of frost damage during spring. During autumn, deciduous trees form their buds for the following spring then enter dormancy. The signals for this dormancy are the day lengths and ambient temperatures. Species that open their buds earlier in spring tend to be more frost resistant than those have their spring flush later.

For example, increased freeze-thaw events has shown to increase the number of embolisms in *Picea abies (Norway spruce)*, likely due to the decrease in water availability to the plant as the water is freezing inside the plant tissue and not available for the plant to use. *Cornus florida (flowering dogwood)* tree is adversely impacted by both embolism in wood tissue and internal cell damage as a result of the thawing of ice crystals.

Some trees will be able to acclimate some traits to local conditions and be more likely to survive in frost conditions. An experiment on the deciduous tree *Quercus lobata (valley oak)*, demonstrated that these trees adapt to local frost conditions in terms of their timing of bud burst. One method to select for more frost damage resistant tree species is to choose individuals with narrow water conducting vessels, these narrow vessels allow for fewer opportunities for gas bubbles to form and subsequent plant tissue death.

Longevity in urban settings

A common street tree is expected to live for 50 years and longer. However, a US Department of Agriculture study indicates only 10% of trees live to grow longer than 25 years in CBD (downtown) areas. This suggests an average life expectancy of 19-28 years for street trees, based on typical annual mortality of 3.5-5.1%. Health, growth rate, size, and ultimate longevity of street trees can be impacted by site conditions, microclimates and proximity to urban infrastructures.

Environmental and physiological factors may influence tree survival too, yet infrastructures, development and maintenance practices can accelerate tree lose in the built environment. Research and practice indicate that compacted soil layers and impervious surfaces can reduce soil water, aeration, and root growth. In addition to limiting rooting space, the replacement of damaged or worn urban infrastructures (such as road and pathway surfaces) can cause significant mechanical injury and loss of stability, especially in instances where existing structural roots are severed near the trunk for trenching, road expansion, or curb replacement.

Newly planted trees tend to die at a higher rate than established trees. Young tree loss may result from inadequate watering, incompatibility with environmental conditions at the planting site, improper planting practices, or even vandalism during the establishment phase. Much of the mortality associated with newly planted, street trees (40-50mm trunk diameter) occur 1-2 years after installation. Yet, tree loss linked to transplant failure may occur even after 5 years of re-planation phase. Once established, mortality rates generally decrease until trees grow larger and overly mature.

Apart from short-term survival of newly planted street trees, their long-term longevity can be impacted by construction practices near trees. Street trees directly adjacent to these development activities may experience 5% greater mortality than nearby control trees. An increase in the tree lawn width (distance between the curb and sidewalk) has shown to have positively correlation with greater tree survival and growth rates.

Allergenicity

Trees are symbols of health; however, exposure to allergens from some tree species can trigger symptomatic health reactions, including allergic rhinitis, asthma and eczema. The most common tree allergens are pollen grains emitted during the stage of reproduction in flowering plants (angiosperms). In the southern hemisphere, tree pollination usually occurs in late winter to early spring. In Europe, the prevalence of tree pollen allergy is estimated to be 5% to over 50%, mainly generated by Birch (*Betulaceae*) in north, central, and Eastern Europe, and by Olive (*Olea europaea*) as also cypress (*Cupressus*) in the Mediterranean regions.

Not all allergens are associated with the pollination of flowering trees. In some species (e.g. *Platanus* or London Plane Tree), hairs from leaves can cause a range of allergies particularly during pruning activities. In a few tree species (e.g. *Cupressus sempervirens*), direct contact to trunk resins can trigger similar health problems.

A 1-10 allergenicity ranking scale for over 3,000 plants is being used by the United States Department of Agriculture. In Europe, the allergenic potential of 20 most-frequent urban trees in six Mediterranean countries is published , suggesting 5 species (i.e. *Acer negundo*, *Fraxinus excelsior*, *Populus alba*, *Taxus baccata*, and *Ulmus minor*) with high allergenicity ranking and 2 species (i.e. *Cupressus sempervirens*, and *Platanus*) with very high ranking.

Guidelines to design low-allergy green spaces include:

- Increase plant biodiversity,
- Ensure moderate, controlled introduction of exotic flora,
- Control of invasive species,
- Avoid massive use of male individuals of dioecious species (avoid botanical sexism),
- Choose species with low-to-moderate pollen production,
- Adopt appropriate management, maintenance and gardening strategies to ensure removal of opportunist and spontaneous species,
- Avoid forming large focal pollen sources and screens by respecting planting distances,
- Obtain expert advice when selecting suitable species for each green area, and avoid fostering cross-reactivity between pan allergens,
- Establish specific local authority by-laws ensuring that sufficient time is available for the design and planning of urban green spaces.

In Australia, the relationships between bioaerosol exposure to London Plane Tree and allergic sensitization is studied in inner-urban Sydney, indicating pollen emitted from the Plane Tree constitutes 76% of total pollen, with high concentrations during the period of August-November. A cross-sectional study in South-East Queensland suggests *Eucalyptus* (gum tree) as a major allergen for children with asthma. and *Melaleuca quinquenervia,* in coastal regions. Daily total pollen counts for both tree and weed pollen in Adelaide includes 10 tree species that may produce aeroallergens, including Ash tree, Birch, Cypress, Eucalyptus, Fruit tree, Olive tree, Pinus, Plane tree, She-Oak and Wattle.

Pest or disease

The ability of tree species in dealing with health threats posed by pests is of great importance to urban service providers. Pathogens, such as bacteria, fungi, viruses, and helminths, coupled with arthropod herbivores, such as insects and other invertebrates, cause widespread damage to natural plant ecosystems on an annual basis.

Pathogens usually access the plant interior either by penetrating the leaf and root surface directly or by entering through natural openings or wounds in the plant. Arthropod herbivores attack all parts of the plant resulting in lower yields, deteriorating growth condition and, if sever, death of the.

The resistance of tree species to herbivores and arthropod pests varies significantly depending on the molecular, morphological and physiological characteristics of the host plant. It can be described in a variety of mechanistic levels, including parasite- and race-specific resistance, age-related (ontogenetic) resistance, organ-specific resistance and acquired or induced resistance.

Genetic engineering of plants (the selection of genes to genetically engineer into plants to protect against) can enhance resistance against fungal pathogens. A strategic framework for using resistant trees underlines six steps in developing and deploying resistant trees

- initial description of the focal system and programme objectives
- exploring resistance in natural populations
- developing resistant trees
- propagation of resistant material for field deployment
- practical deployment of resistant trees
- monitoring of resistant trees.

In Australia, under the National Priority Plant Pests, there is a list of 42 common plant pests and diseases, including insects and pathogens. A notable example is Xylella (*Xylella fastidiosa*) as the most dangerous plant bacteria worldwide, putting over 350 plant species at risks such as wine grapes, olives, and nut trees. Over the past few years, a variety of digital identification tools and databases have been also developed to support the identification and mitigation of pests. The most notable examples include the image databases of the US Centre for Invasive Species and Ecosystem Health – CISEH and the Pests and Diseases Image Library – PaDIL – in Australia. However, the existing databases and regulatory-based documents do not necessarily specify certain types of trees based on their ability in dealing with pests.

Weed potential

Weeds are plants that are have an impact on agriculture, horticulture and native ecosystems. They are plants growing where they are not wanted or have a negative impact on their surrounding environment. Weeds are considered a threat to biodiversity. The impact of weeds is likely to increase with climate change as native and agricultural biomes change in terms of plant physiology, nutrients, water and temperatures. In terms of weed potential, the aim is to avoid planting tree species that have the potential to become weeds in South Australia.

Invasion risk is predictable and higher for ornamental plants than for agricultural purposes. Food crops tend to have high maintenance requirements so are less likely to become weedy than ornamental plants that are often chosen as they have lower horticultural maintenance requirements and as such, may thrive as a weed. While street trees provide many benefits beyond ornamental, for this purpose, they would be considered as such.

Main concerns to consider when planning for whether a plant may become weedy are:

- Native range: the plant's native and known potential distribution, climate envelope and weediness of the tree species in other parts of the world. If there is predicted overlap with these aspects and any Australian ones, then the tree is considered to be potentially weedy.
- Undesirable attributes: resistance to herbicides, potential for regrowth from pruning, long-lived propagules
- Biology and ecology: these are the attributes that contribute to the capacity of the species to reproduce, spread and persist

In addition to pathogens and herbivores, putative exotic trees can also have significant impacts with high levels of mortality and damage. This is largely owing to the increasing international trade in plants and plant material as well as climate change which altogether facilitate the spread of organisms and create novel threats to various native tree species. An example is Melaleuca (*Melaleuca* *quinquenervia*) which is native to Australia, New Guinea, and New Caledonia and was first introduced into the United States in the early 1900s for landscaping and swamp drying purposes sloughs. This exotic tree is known to invade several wetland habitats such as sawgrass marshes, wet prairies and aquatic sloughs across the US.

In South Australia, some weeds are regulated under the Landscape South Australia Act 2019. The Department for Primary Industries and Regions South Australia (PIRSA), lists policies for individual weed species either declared (considered a threat to primary industries, native ecosystems and public health and safety) or undeclared under the Act. Some of these weeds are trees, for example, the Aleppo pine and Willow, and are considered unsuitable for planting in South Australia. A report compiled following a workshop commissioned by the Australian Weed Committee detailed the development of the Weed Risk Assessment (WRA) system. This system has since evolved into a system where seeds are assessed prior to import into Australia and accepted by the Australian Quarantine and Inspection Service (AQIS) only if the species is on the current "permitted seeds list" rather than not on a "prohibited list".

Maintenance

Improper maintenance of street trees leads to fewer benefits from urban greenery. Street trees require maintenance during planting, removal and treatment as well as regular-periodic maintenance including pruning, irrigation, pest and disease management and street cleaning.

In South Australia, SA Power Networks are one of the largest utility foresters as they are the state's only energy distributor and governed by Electricity (Principles of Vegetation Clearance) Regulations 2021. These regulations require SAPN to keep high voltage powerlines free from street tree foliage and branches and low voltage powerlines free from woody material. This provides a safety buffer from events such as fire caused by powerlines being broken by trees or damaged powerlines sparking and causing fire in the trees.

In parallel, while much tree pruning occurs above ground, tree roots have damaged underground infrastructure in the past and SA Water – South Australia's Government owned water distributor, provides advice for South Australian homeowners to plant appropriate trees for their area.

Councils in the Greater Adelaide area in South Australia generally water trees during the hot and dry months for three years after planting to assist with establishment. Street trees that are established using stormwater control measures – stormwater is guided towards establishing trees using engineering solutions – are able to grow up to twice as much as their counterparts without any stormwater control.

Furthermore, the type of urban green space is an influencing factor in determining the right tree. Litter decomposition and kerb type and maintenance requirements and frequency vary for tree species. Deciduous species are more likely to require clean up during autumn mostly, whereas evergreen species that require some clean-up all through the year.

Evergreen trees can provide shade all-year-round but they may also shed plant material continuously and can screen out winter sunshine. Deciduous trees can cool in summer and let full sunshine through in winter. They are associated with the autumn shedding of leaves which can be a problem for stormwater systems and maintaining clear streets and footpaths.

The cost to maintain a deciduous Jacaranda in the City of Mitcham is $40.50 per year versus $47.95 per year annual cost for an evergreen South Australian Blue Gum. This highlights the difference in cost to trim the trees and repair the footpath and kerb damaged by roots.

Another litter fall factor to consider is the time taken for litter to decompose if it is not swept. Trees that produce litter that takes longer to decompose are best planted in areas with impermeable, artificial ground surfaces, thus, if the litter is not swept up immediately, nutrients are less likely to enter the stormwater system and cause downstream eutrophication. On the other hand, fast decomposing litter is best in areas where the nutrients can go straight back into the ground, such as on a nature strip or park.

Descriptive street tree information

Tree information such as origins, shape, canopy spread, leaf density and potential height are vital when specifying street trees. The origin of a plant may be a factor when seeking to maintain or support local landscape or heritage.

- Street trees can facilitate biodiversity in urban settings. Tree hollows are often used by native fauna but may take more 60-100 years to form and it is unlikely that many trees will reach that duration of life unless adequately management.
- Species selection is also influenced by the actual amount of space available, such as the width of the street verge and vehicle cross overs.
- The origin of a plants may also be a factor when seeking to maintain or support local provenance or choosing a plant at local nurseries.

Descriptive tree information for Greater Metropolitan Adelaide is well established and can be accessed in the Botanic Gardens of South Australia's Plant Selector tool.

Street trees for biodiversity

Adelaide is located on borders of one of Australia's 15 biodiversity hotspots, the Southern Mt Lofty Ranges. Biodiversity is not just beneficial for fauna but also for humans, with cardiovascular disease reduction in more biodiverse street tree neighbourhoods. Street tree selection and composition can play an important role in biodiversity. Although all kinds of tree species may provide a degree of habitat and food for fauna, native species are particularly beneficial and often have very specific benefits that introduced species cannot provide. The structure and shape of trees can also support different kinds of species.

Street trees are often planted as monocultures and in straight avenues for urban legibility and aesthetic effect. There is increasing evidence that street tree species selection has an important role to play in biodiversity with some species favoured over others. Likewise, by combining larger street trees with other species of understory planting or smaller bushier tree species, different types of birds can be catered for. The size of trees is often important to reduce the effects of urbanisation on fauna such as birds. Large trees can reduce noise and other disturbing urban phenomena creating healthier environments for both humans and fauna.

By planting trees in groves or groups, continuous canopies can support a range of arboreal creature such as marsupials. Some of the most important tree species for habitat, are not always suitable for residential streets. For instance, the river red gum, *Eucalyptus camuldensis*, is suitable for park side streets but due to its size and tendency to drop branches, should not generally be planted in residential streets. However, this tree is one of the great character trees of Adelaide, providing identity and a wealth of biodiversity benefits to all kinds of animals. Indigenous species are also significant for Kaurna people and form part of their cultural landscape and history.

Genetic biodiversity is a consideration in ensuring the longevity of tree species in the long term. Traditionally many street trees have low genetic biodiversity due to their horticultural propagation methods.

Street trees for climate resilient futures

"It's an intriguing premise: what if we could reduce the severity of global climate change by planting hundreds of billions of trees to remove excess carbon from our atmosphere?" (Alan Buis, NASA).

Concentrations of building mass and insufficient greenery in cities are extensively highlighted to contribute significantly to human-made heat stress in the built environment and the formation of the urban heat island (UHI) effect. A recent projection of the impact of potential increases in tree canopy in Adelaide CBD to mitigate the CSIRO climate change scenarios (RCP 2.6, 4.5 and 8.5) for 2030 and 2090 indicate a promising 1-3°C air temperature reduction by having 30% tree canopy by 2090, preventing 140,000 tone CO_2e to be released into the atmosphere in Adelaide.

	By 2030 (°C)			By 2090 (°C)		
	Min	Max	Mean	Min	Max	Mean
RCP2.6	0.2	0.9	0.5	0.3	1.4	0.7
RCP4.5	0.3	1.0	0.6	1.1	2.4	1.6
RCP8.5	0.5	1.2	0.8	2.5	4.8	3.8

Projected mean temperature change in three representative concentration pathways (RCP) scenarios in Australia for 2030 and 2090 compared to 2010

Scenario	Tree canopy	Permeable landscape	Hard landscape	Precedent	Winter temperature variation at precinct scale (°C)	Summer temperature variation at precinct scale (°C)
SC1 (existing)	15%	20%	65%	Art Centre Plaza Adelaide CBD	N/A	N/A
SC2 (Improved)	20%	30%	50%	Adelaide CBD + Parklands	-0.8	-1.6
SC3 (Ideal)	30%	30%	40%	South East of Adelaide CBD + Parklands	-1.0	-3.0

Heat resilient scenarios for urban surface cover transformation in Adelaide (these temperature projections are based on the assumption that the mean temperature changes are translated directly to equivalent hot summer conditions).

In addition to reduced energy demand, carbon emissions and urban heat mitigation significant health, biodiversity and flood prevention benefits are reported worldwide as the result of trees.

We are now in that stage of climate change.

We need to plant the right trees in the right location with the right conditions.

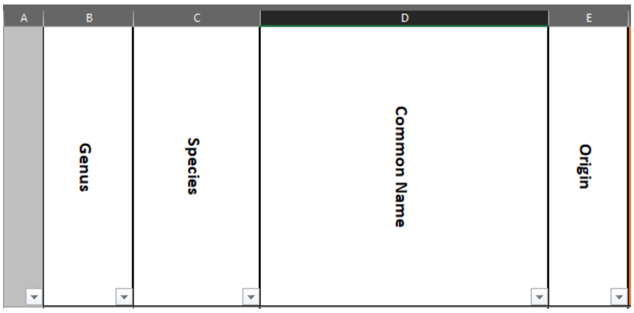
How to use the multi-criteria street tree selection tool

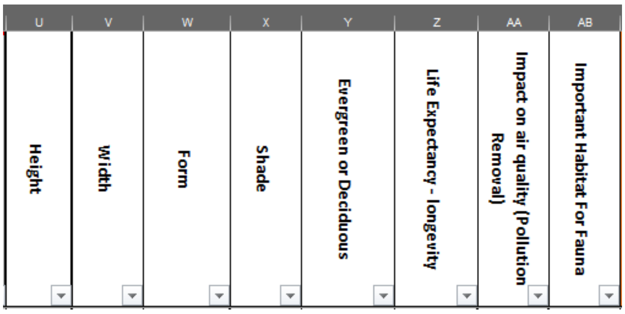
The Beta+ version of the multi-criteria street tree selection tool is now available to download, usage and feedback.

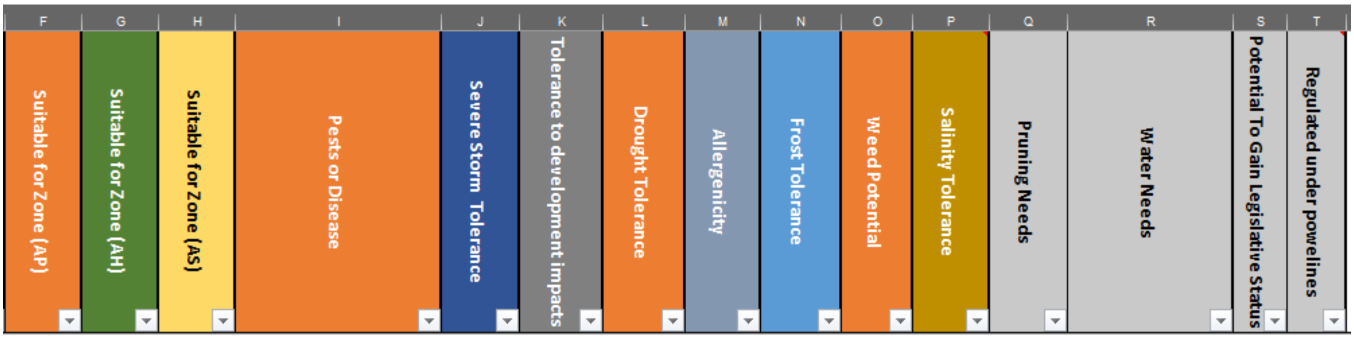
Tree selection tool (spreadsheet)	Tree selection tool (app)

Instruction to use the tree selection tool (spreadsheet):

1. Download the tool file on your computer.
2. There are 3 worksheets in the tool:
   - Instructions to use the tool
   - Master Datasheet gives the main dashboard to filter and select street trees based on desired criteria.
   - Attribute Definitions describes criteria definitions, unit and range.
3. There are 125 street trees in the tool – some are marked brown! due to low tolerance and/or high risks and are not recommended as street trees in Adelaide metropolitan area.
4. In Master Datasheet there are 3 column sets:
   - The white calls on the left are related to street tree names and origins.
   - The coloured cells on the first row are related to key selection criteria.
   - The white cells on the right are related to descriptive information of the trees.







5. Make a strategy for your search. For example, if you are prioritising suitability for specific climate zones, drought tolerance, salinity or which factors are the most/least important in your project.
6. Click on the filter sign – triangle – on the first-row cells.
7. Start from the most important selection criteria in your project.
8. Uncheck <Select All> and filter the tree list based on high/medium/low tolerance of your section criteria.
9. The list will be filters with reduced number of trees based on your first section criterion.
10. Continue the same process by adding more selection criteria filters until you get to 3-10 street trees left in the list.
11. No inspect the remainder street tree descriptions and decide which one the bast match to your project.

Always have a list of a few trees – not just one tree

Double check the trees seasonal changes and other information at

*the **Botanic Gardens' Plant Selector tool***

The aim of this tool is not to give you only one option but a manageable evidence-supported options

Run your final list through a trusted arborists before making the final decision

Feedback link

(google form)

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