Naturally Cooler Towns Project

Tree Species Selection and Planting Guidelines

February 2022

Contents

Introduction

The urban tree species selections for GMCA have been guided by the five principles of GMCA's Strategic Plan that support the vision of "*Our communities actively responding to climate change to help build a positive future*."

These principles are:

- Adapt to climate change.
- Mitigate urban heat island effects.
- Create water sensitive towns and urban areas.
- Create healthy ecosystems.
- Design our urban landscapes for community health, wellbeing and liveability.

Underpinned by these principles, the objectives of this tree species selection and planting guidelines document are to:

- Ensure urban forest diversification in age, species and health across the 16 local government and agency partners.
- Provide scientifically based criteria for selecting tree species for urban areas.
- Start to generate a resilient urban tree population better able to cope and adapt to environmental extremes and risk of pest and disease attacks.
- Nominate tree taxa suited to different geographic areas and/or uses.
- Ensure that nominated species are likely to survive and succeed in the face of predicted climate change.

The following information and species selections are for the urban areas, towns and villages, of the areas encapsulated within the Goulburn Murray Climate Alliance (GMCA). The selected tree taxa are intended for use in urban streets and parks and not for revegetation of rural lands, conservation sites or National Parks.

Climate change and urban trees

Trees are living organisms, with different species adapted to survival under particular environmental conditions. As climate change alters the environmental conditions experienced in a location, it is inevitable that it will impact trees growing in our cities and towns. We rely on these integral components of urban landscapes and ecosystems to deliver aesthetic and ecosystem services to our communities. The potential for decline threatens the ability of our urban forests to deliver these benefits. Maintaining and enhancing the health and resilience of trees is essential if urban forests are to continue producing beneficial services. Therefore, it is critical that we understand the implications for tree selection imposed by the changing climate.

Projected changes in climate present significant challenges for urban trees as they are already subject to high levels of physical change in their growing environment. The interaction of heat output from built infrastructure; climate-change related variability in rainfall and temperature regimes; and increasing urban drought severity and frequency is a principal concern for urban tree managers (Diamond Head Consulting Ltd., 2017).

There are two factors that influence tree selections for a changing climate. It is impossible to give precise predictions of the future climate, as all climate projections comprise certain bandwidths of possible future developments. Secondly, due to the high number of variables that dictate tree response to such conditions, it is unclear how particular species will respond to climate change in their area. Testing of stock needs to consider the breadth of conditions that each species can tolerate, effect of provenance on individual specimens' tolerance, and the enhancing or mitigating effects of the urban environment. The current lack of clarity around these characteristics presents an impediment to successful tree selection.

For this reason, large genetic diversity and large phenotypic plasticity (ability of an organism to change in response to stimuli or inputs from the environment) are desirable features in urban trees to be able to cope with a range of possible changes. The greater their ability to physiologically adjust to changing or stressful conditions is, the better.

Predicted broad changes to the Australian climate

CSIRO and the Bureau of Meteorology (2020) predict that over the coming decades Australia will experience the following changes that could impact on plant performance:

- Further increase in temperatures, with more extremely hot days and fewer extremely cool days.
- A decrease in cool-season rainfall across many regions of southern Australia, with more time spent in drought. Rainfall in Victoria has declined in most seasons over recent decades, with the greatest decreases in the cooler seasons.
- More intense heavy rainfall throughout Australia, particularly for short-duration extreme rainfall events.
- An increase in the number of high fire weather danger days and a longer fire season for southern and eastern Australia.

Importantly, the upper range of temperature results from the Victorian Climate Projections 2019 (VCP19) high-resolution modelling shows that a hotter future than that projected by the earlier Global Climate Model (GCM) data results is possible.

Ovens Murray Climate Projections 2019

- High confidence of increasing maximum and minimum daily temperatures. By the 2030s, increases in daily maximum temperature of 1.0 to 1.9°C (since the 1990s) are expected.
- Rainfall will continue to be very variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence), but with some chance of little change.
- Extreme rainfall events are expected to become more intense on average through the century (high confidence) but remain highly variable in space and time. It is expected that extreme heat days will increase from 20 days per year to 30-54 days per year
- By the 2050s, the climate of Wodonga could be more like the current climate of Forbes, NSW.
- The number of high fire days are predicted to increase by 60% by 2050 (or 11 more days per year)

Reference - Clarke, J.M., Grose, M., Thatcher, M., Round, V. & Heady, C. 2019. Ovens Murray Climate Projections 2019. CSIRO, Melbourne Australia. Updated 19th February 2020

Goulburn Murray Region climate predictions 2019

- High confidence of increasing maximum and minimum daily temperatures. By the 2030s, increases in daily maximum temperature of 0.9 to 1.8°C (since the 1990s) are expected.
- Rainfall will continue to be very variable over time, though is likely to decline annually but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn
- Extreme rainfall events are expected to become more intense on average through the century (high confidence) but remain highly variable in space and time. It is expected that extreme heat days will increase from 14 days per year to 23-40 days per year
- By the 2050s, the climate of Shepparton could be more like the current climate of Griffith, NSW.
- The number of high fire days are predicted to increase by 60% by 2050 (or 11 more days per year)

Effects of predicted climate change on plant growth

It is expected that reduced rainfall, increased temperatures and more extreme heat days, which all intensify the urban heat island effect, will:

- Reduce volumes of soil water
- Reduce recharge of soil water
- Increase duration and frequency of water deficit conditions
- Increase plant demand for water.

In urban areas this could potentially lead to widespread decline in tree growth in some species and an increase in tree mortality.

Temperature is often identified as a key factor with regard to the performance of trees in urban environments (Jenerette et al., 2016; Kendal et al., 2018; Burley, et. al., 2019). Along with temperature, water and nitrogen are usually the most limiting environmental factors for plant growth. Where temperature and nutrients are optimal, the quantity and quality of growth depends primarily on water supply. Water is the single most limiting essential resource for tree survival and growth. Water shortages severely damage young and old trees alike and predispose healthy trees to other problems. Prolonged drought conditions can lead to tree decline, inciting pest problems, and non-recoverable damage.

Therefore, the greatest risk to urban trees from climate change is the likely long-term change in soil moisture availability. This one factor threatens tree vitality, establishment success, summer canopy cover and annual growth. Scientific literature agrees that less precipitation, particularly during winter and spring, warmer temperatures and intensified urban heat island effect will increase evaporation, reduce plant available soil moisture, and reduce reservoir water supplies (Diamond Head Consulting, 2017). The trees within our urban forests are vulnerable to this risk because supplying supplemental water to individual trees which can be expensive and difficult to organise.

A predicted increase in heat waves and associated heat loading (the length of time the temperature exceeds a threshold), exacerbated by increases in hard surfaces, will place greater water stress on street trees. Regardless of appropriate species selections, there may be times when supplemental irrigation will be required to sustain the trees over extended heat events.

In urban environments, the availability of water is negatively impacted upon by impermeable built urban infrastructure. Impermeable surfaces can create or intensify drought conditions simply through preventing infiltration of rainfall and increasing surface run-off. In addition, through vastly reducing total evapotranspiration, urban infrastructure increases vapour pressure deficit (the difference between the saturation of the leaf and ambient environment), significantly increasing plant water use, intensifying urban heat, and increasing water loss from the remaining vegetation. Each of these factors may contribute to increasing frequency, duration and severity of water deficit stress experienced in urban environments (Schneemann, et al. 2019, Xu, et al, 2010).

The increased frequency and duration of water stress conditions and dealing with higher temperatures appear to be determinant factors for plant performance under climate change scenarios.

Selecting tree species for climate change

Ensuring that the next generation of trees is suited to the present and future climate is critical for building urban forest resilience. Species distribution modelling is complex and, at this point in time, limited data and tools are available to define future climate suitability for the wide diversity of tree species planted in urban forests. Further research and development of tools such as climate envelope modelling to assess climate suitability of urban forest tree species would benefit urban forest planners (Burley, et. al., 2019).

Long-term success of tree selection under a climate change scenario will be reliant on an increase in our knowledge of individual taxa's response. Effective plant selection is often limited by poor understanding of the physiological or morphological mechanisms that provide a plant with resilience (Wahid, et al., 2007), and/or how they might respond in cultivation or in varied microclimatic conditions. Equally, waiting to see what thrives and what struggles does not work in the commercial reality faced by most landscape managers.

A commonly used approach to determine future species suitability, especially in forestry research, is the use of bioclimatic envelope modelling, also known as species distribution, ecological niche models (Brune, 2016) or climate suitability models (CSMs, also termed species distribution models) (Burley, et. al., 2019). These models assume that climate, and particularly precipitation, broadly drives native tree species distribution and, in combination with soil (edaphic) factors, determines which introduced tree species can successfully grow in each area.

CSMs can be used to map the current distribution of suitable habitat for a species, identify suitable areas beyond the species' known occupied range, and assess how suitability may change under past or future climate scenarios (Baumgartner et al., 2018). However, the application of CSM models for species in urban areas is not common practice. (Burley et. al. 2019).

CSMs typically only consider macro-climatic variables. Obviously, other factors, such as microclimate, extreme weather events, edaphic conditions (soils), and phenotypic plasticity, will also influence the suitability of species for particular urban areas (Burley et. al. 2019).

Species selection can be fraught with problems because of the genetic plasticity of trees under different site conditions, which can lead to different characteristics or traits being expressed over different environments (phenotypic plasticity). Tree selections are often made without controlled testing, demonstration, and consistent reproduction. Tree selections are typically either reinforcing existing trees due to dominant landscape character (for better or worse), based on limited research provided from literature or growers, or are subjective in nature (Brune, 2016).

Process for tree selection for GMCA

Species-level data was compiled from a broad range of sources including horticultural texts and journal articles, commercial nursery websites, local and international botanic garden and herbarium websites, Council factsheets and databases, local and international Government department websites, University and research centre websites, Atlas of Living Australia (ALA), Analogous Explorer-Climate Change in Australia, and the Global Biodiversity Information Facility (GBIF) (Burley et. al. 2019). This information was used in conjunction with the personal experience and knowledge of the horticultural/arboricultural team undertaking the urban tree selection process.

Primary sources used to aid selections:

- Burley, H., Beaumont, L. J., Ossola, A, Baumgartner, J. B., Gallagher, R., Laffan, S., Esperon-Rodriguez, M., Manea, A., Leishman, M. R. (2019). Substantial declines in urban tree habitat predicted under climate change. *Science of the Total Environment* 685 (2019) 451–462.
- Hirons, A. D. and Sjöman, H. (2018) *Tree Species Selection for Green Infrastructure: A Guide for Specifiers*. Trees & Design Action Group.
- Kendal, D., Baumann, J. (2016). The City of Melbourne's Future Urban Forest. Identifying vulnerability to future temperatures. The University of Melbourne, Burnley Campus, School of Ecosystem and Forest Sciences.
- Schneemann, B., Brack, C., Brookhouse, M., Kanowski, P. (2019). Urban Forest Tree Species Research for the ACT. The Australian National University. College of Science /Fenner School of Environment and Society.

Drought and heat tolerance are the decisive criteria for the selected tree species, however there are several other factors that should be considered when selectin tree taxa for urban areas.

GMCA urban tree selection criteria

Fundamental criteria are the species ability to tolerate drought (extended dry periods) and heat (increases in the length, intensity and frequency of heatwaves in many regions). Selected tree taxa should be available in commercial numbers. However, some selections have been made where the taxa are known to be available in Australia and with planning can be contract grown by nurseries to commercial quantities. GMCA should coordinate with municipalities to enter into contract growing agreements with nurseries to ensure availability of less commonly planted tree species.

However, additional criteria are needed to choose a street or park tree. These criteria guide selection of the 'right tree for the right place'. They consider a trees suitability for being grown beneath power lines, in building shade, being pruned to allow vehicular and pedestrian movement, do not create onerous maintenance requirements, adaptability to waterlogged soils, and tolerance of soil compaction. Other considerations include the species' longevity, pathogen and pest susceptibility and manageability, effect on community health and allergies, low flammability (particularly on the peri-urban fringes), the degree and quality of shade cast, maintenance requirements and extent of tree litter produced. As a result, the tree species selected for the GMCA region are known to be adaptable to urban conditions using these criteria ten base criteria in order of importance:

1. Drought tolerance
2. Heat tolerance
3. Availability
4. Longevity
5. Ability to form a canopy (generally taller than 6 metres)
6. Low flammability, including fibrous or ribbony bark
7. Weediness (self-seeding)
8. Pathogen and pest susceptibility and manageability
9. Potential as allergen
10. Maintenance required and ability to be pruned
11. Tree litter (particularly fruit)
12. General urban tolerances, particularly soil conditions and appropriate space

There is no one perfect urban tree.

It is also important to understand that there is no one type of urban environment. The urban environment is a varied conglomeration of microclimates and heterogeneous soil conditions. Above ground or below ground site conditions can change dramatically within the space of a few metres.

Consequently, a site analysis of each planting site will aid appropriate tree selection.

The most successful strategy is to match the planting site limitations with the right tree for that site.

Native versus exotic

Urbanisation has dramatically altered the conditions to which Australian and indigenous trees have adapted. Just because a plant is native to a site does not necessarily mean that the current site conditions are optimum for its growth. Few native soils mimic urban soils. Once a tree is planted in an urban environment, it ceases to be in its native environment.

Predicted climate changes may also reduce the ability of local indigenous species to perform well within the area. Increases in temperatures, an increase in the urban heat island effect and a reduction in soil moisture reserves during the hotter months will reduce the viability of indigenous species that have evolved with different environmental conditions.

Australian species from other localities and exotic species can make positive contributions to the landscape. In some cases, these species are better adapted to the conditions of the highly modified environment. They may have positive attributes and are able to fulfil specific landscape functions.

Many exotic deciduous species have the advantage of decades of selective breeding which ensures quality stock suited to urban landscapes, including drought and heat. They have developed form (canopy) shape to suit vertical or horizontal site constraints, are typically more pollution tolerant, and are generally more resilient to urban conditions. Australian native species can be selected based on their tolerances to hotter and drier conditions. Both natives and exotics have positive and negative attributes for use as street trees.

The focus should be on tree species adapted to a site and with acceptable characteristics relative to the desired purpose. Selecting the right tree for the site should be the most important focus to achieve the best and most sustainable landscape outcome.

The wrong choice of species, placed in inappropriate locations has little to do with tree selection, rather it is an indication of poor planning. In many instances, requirement is often confused with tolerance.

Remnant, indigenous and native vegetation has an important role to play in urban landscapes. The maturity of existing indigenous vegetation is impossible to replace, and the diversity of natural plant communities is difficult to replicate. Consequently, the preservation of existing natural and remnant vegetation is the most efficient way to incorporate biodiversity in urban landscapes.

The use of indigenous tree species in streets will have greater impact and benefit when used adjacent to open space that has significant remnant vegetation.

Deciduous trees and solar access

An important advantage of exotic deciduous trees (those that lose their leaves in winter) in an urban context is that can provide greater solar access to the streets and adjacent buildings through the winter months. Some natives are deciduous but generally in spring or early summer (an inheritance of their monsoonal origins). The red and white cedars (*Toona ciliata*, *Melia azedarach*) are the closest native trees Australia has to being winter deciduous, but both have a range of issues making them less than ideal for planting in urban centres.

Different types of trees can be selected on the basis of their growth habit, crown density and leaf retention to provide the desired degree of shading for various situations. Points to note include the following:

- Deciduous trees and shrubs provide summer shade yet allow winter access.
- Trees with heavy foliage such as planes and elms are very effective in obstructing the sun's rays and casting a dense shadow. Dense shade is cooler than filtered sunlight.

Trees with light foliage, such as most eucalypts, filter the sunlight and produce a dappled shade.

Fire retardant trees

Apart from the potential human tragedy and loss, bushfires often result in a temporary loss of landscape amenity. Following bushfires there is often apprehension by those directly affected about replanting trees adjacent to homes and other buildings.

The benefits of trees in our landscapes are significant and well documented. The use of fire retardant trees in areas prone to bushfires can not only add beauty to our gardens, but when selected and placed appropriately they can assist in safeguarding homes in the advent of a bushfire.

Trees with the best fire-retardant properties are those which have soft leaves with a high moisture content, smooth and non-peeling barks, and low volatility oils in their foliage. In general, this includes the majority of deciduous trees and some evergreens from the sub-tropics and rain forests. Trees that create or hold on to lots of dry dead branches and debris, have loose flaky bark, have dense, fine foliage with a low moisture content should be avoided.

All plants, whether they are exotic or Australian, will burn when subjected to sufficient heat. Different fire conditions have varying effects at different times on the same species. The tree selections made here will not guarantee safety in a bush fire. Instead, the following selection of trees, if correctly sited, can complement fire management plans for individual homes by serving as a wind break absorbing and deflecting radiant heat from the fire and acting as a barrier to flying sparks and embers.

Trees and landscapes must be part of a complete fire planning system and ongoing diligence in managing your site. Site management includes maintaining trees in a healthy condition, for example keeping soil moist, pruning out dead wood and cleaning up debris and leaf litter.

The following list is not definitive. Further information can be sought from the references listed below and from local authorities. Species known to have low flammability have been noted on the tree selection sheet.

The following trees could be used for specimen plantings. Planting of trees should take into consideration separation distances between buildings.

- *Acacia melanoxylon* (Blackwood). Tree will vary in size dependent on climate and soil type. 8-15 m in height.
- *Acer monspessulanum* (Montpellier Maple). Deciduous medium tree 8-10m.
- *Acer negundo* 'Sensation' (Variety of Box-elder Maple). Deciduous, broad domed, medium sized tree to 12-15m.
- *Brachychiton acerifolius* (Illawarra Flame Tree). Pyramidal tree 8-15 m in height.
- *Brachychiton populneus* (Kurrajong) Domed evergreen tree, 12-20 m in height.
- *Cupaniopsis anacardioides* (Tuckeroo). Broad-domed evergreen tree 8-12 m in height.
- *Lophostemon confertus* (Queensland Brush Box). Broad-domed evergreen tree 10-15 m in height.
- *Melia azedarach* (White Cedar). Broad-domed, deciduous tree. 8-15 m in height.
- *Quercus canariensis* (Algerian Oak). Large, broad domed tree. 20-25 m in height.
- *Stenocarpus sinuatus* (Firewheel Tree). Upright tree 8-14 m in height.

The following trees could form useful screens adjacent to buildings.

- *Acmena smithii* var. *minor* (Lilly Pilly). Small tree, bronzy new growth 3-6m
- *Acmena smithii* 'Hot Flush' (Lilly Pilly var.) Up to 3m with moderate growth habit and new reddish growth.
- *Eleaocarpus eumundii* (Eumundi Quandong). Moderate sized conical tree to 8-10m tall by 3m.
- *Elaeocarpus reticulatus* (Blueberry Ash)
- *Hymenosporum flavum* (Native Frangipani). Narrow tree to 10 m in height. Best used in clumps or groups.
- *Pyrus calleryana* ‘Capital’ (Callery Pear var.) Deciduous, columnar tree to 12m.

The following are varieties of Scrub Cherry (*Syzygium australe*) that could also be used as low screens.

- *Syzygium australe* 'Aussie Southern’ 3-4m
- *Syzygium australe* 'Elite' 3-5m
- *Syzygium* ‘Aussie Northern’ Compact to 4-5m

Trees damaged by bushfire that are close to buildings, driveways or other high target areas should be inspected by a qualified arborist to ascertain tree hazard and appropriate remedial works.

Some trees, although looking irreparable from external appearance, may recover.

GMCA Recommended Tree Species List

Small trees. Typically, 6-9 metres tall (some selections may grow taller under ideal conditions).

More details on tree selections can be seen in the GMCA - Urban tree selections spread sheet.

Species	Common name	Type category	Evergreen/ deciduous
Acacia pendula	Weeping Myall	Australian native	Evergreen
Acer monspessulanum	Montpelier Maple	Exotic broadleaf	Deciduous
Acer negundo 'Sensation'	Sensation Box Elder Maple	Exotic broadleaf	Deciduous
Acer platanoides 'Crimson Sentry'	Crimson Sentry Norway Maple	Exotic broadleaf	Deciduous
Allocasuarina littoralis	Black She-oak	Victorian native	Evergreen
Allocasuarina verticillata	Drooping She-oak	Indigenous to area	Evergreen
Angophora bakeri	Narrow-leaved Apple	Australian native	Evergreen
Callistemon 'Harkness'	Harkness Bottlebrush (Callistemon 'Gawler Hybrid')	Cultivar - Australian native	Evergreen
Callistemon viminalis	Weeping Bottlebrush	Australian native	Evergreen
Eucalyptus platypus	Round-leaved Moort	Australian native	Evergreen
Eucalyptus torquata	Coral Gum	Australian native	Evergreen
Eucalyptus viridis	Green Mallee	Victorian native	Evergreen
Ficus brachypoda 'BWNPOD Podium'	Podium Desert Fig	Cultivar - Australian native	Evergreen
Geijera parviflora	Wilga	Australian native	Evergreen
Koelreuteria paniculata	Golden Rain Tree	Exotic broadleaf	Deciduous
Koelreuteria paniculata 'Fastigiata'	Columnar Golden Rain Tree	Exotic broadleaf	Deciduous
Lagerstroemia indica x *L. fauriei* 'Sioux'	Sioux Crepe Myrtle	Exotic broadleaf	Deciduous
Lagerstroemia indica x *L. fauriei* 'Tuscarora'	Tuscarora Crepe Myrtle	Exotic broadleaf	Deciduous
Melaleuca bracteata	Black Tea-tree	Australian native	Evergreen
Melaleuca lanceolata	Moonah	Victorian native	Evergreen
Melaleuca linariifolia	Snow-in-summer	Australian native	Evergreen
Olea europaea 'Swan Hill'	Swan Hill Olive	Exotic broadleaf	Evergreen
Parrotia persica	Persian Witchhazel	Exotic broadleaf	Deciduous
Pyrus betulaefolia ‘Southworth' Dancer	Dancer Pear	Exotic broadleaf	Deciduous

Medium trees Typically 10-15 metres tall (some selections may grow taller under ideal conditions).

Species	Common name	Type category	Evergreen/ deciduous
Acacia salicina	Cooba, Native Willow	Australian native	Evergreen
Brachychiton acerifolius	Flame Tree	Australian native	Deciduous (variable)
Brachychiton populneus	Kurrajong	Indigenous to area	Evergreen
Brachychiton rupestris	Queensland Bottle Tree	Australian native	Deciduous (variable)
Callitris endlicheri	Black Cypress-pine	Indigenous to area	Evergreen
Corymbia eximia	Yellow Bloodwood	Australian native	Evergreen
Corymbia maculata 'ST1' Lowanna	Compact Spotted Gum	Cultivar - Australian native	Evergreen
Cupaniopsis anacardioides	Tuckeroo, Carrotwood	Australian native	Evergreen
Eucalyptus leucoxylon	Yellow Gum	Indigenous to area	Evergreen
Eucalyptus mannifera	Brittle Gum	Indigenous to area	Evergreen
Eucalyptus spathulata	Swamp Mallet	Australian native	Evergreen
Ficus rubiginosa	Port Jackson Fig	Australian native	Evergreen
Jacaranda mimosifolia	Jacaranda	Exotic broadleaf	Deciduous
Koelreuteria bipinnata	Chinese Flame Tree	Exotic broadleaf	Deciduous
Lagerstroemia fauriei 'Fantasy'	Fantasy Japanese Crepe Myrtle	Exotic broadleaf	Deciduous
Liquidambar styraciflua 'Oakville Highlight' (PBR)	Oakville Highlight Sweet Gum	Exotic broadleaf	Deciduous
Liquidambar styraciflua 'Palo Alto'	Palo Alto Sweet Gum	Moderate tolerance	Deciduous
Lophostemon confertus	Qld. Brush Box	Australian native	Evergreen
Melia azedarach 'Elite'	Elite White Cedar	Exotic broadleaf	Deciduous
Melia azedarach 'Lilac Lady'	Lilac Lady White Cedar	Exotic broadleaf	Deciduous
Pyrus calleryana 'Chanticleer'	Chanticleer Callery's Pear 'Glen's Form'	Exotic broadleaf	Deciduous
Quercus x *bimundorum* 'Crimschmidt'	Crimson Spire Oak	Exotic broadleaf	Deciduous
Quercus ilex	Holm Oak	Exotic broadleaf	Evergreen
Quercus lusitanica	Portugal Oak, Gall Oak	Exotic broadleaf	Semi-evergreen
Quercus palustris 'Pringreen'	Green Pillar® Pin Oak	Exotic broadleaf	Deciduous
Quercus suber	Cork Oak	Exotic broadleaf	Evergreen
Stenocarpus sinuatus	Firewheel Tree	Australian native	Evergreen

Species	Common name	Type category	Evergreen/ deciduous
Ulmus parvifolia 'Emer II' Allee®	Allee (PBR) Chinese Elm	Exotic broadleaf	Deciduous
Ulmus parvifolia 'InSpire'	'InSpire' (PBR) Chinese Elm	Exotic broadleaf	Deciduous
Ulmus parvifolia 'Todd'	'Todd' (PBR) Chinese Elm	Exotic broadleaf	Deciduous
Washingtonia filifera	California Fan Palm	Exotic palm	Evergreen

Large trees. Typically, > 15 metres tall

Species	Common name	Type category	Evergreen/ deciduous
Angophora costata	Smooth-barked Apple	Australian native	Evergreen
Brachychiton discolor	Lacebark	Australian native	Deciduous (variable)
Casuarina cunninghamiana	River She-Oak	Australian native	Evergreen
Cedrus atlantica 'Glauca'	Blue Atlas Cedar	Exotic conifer	Evergreen
Cedrus deodara	Deodar Cedar	Exotic conifer	Evergreen
Corymbia citriodora	Lemon-scented Gum	Australian native	Evergreen
Corymbia maculata	Spotted Gum	Australian native	Evergreen
Cupressus arizonica var. *glabra*	Smooth Arizona Cypress	Exotic conifer	Evergreen
Cupressus torulosa	Bhutan Cypress	Exotic conifer	Evergreen
Eucalyptus albens	White Box	Indigenous to area	Evergreen
Eucalyptus blakelyi	Blakely's Red Gum	Indigenous to area	Evergreen
Eucalyptus camaldulensis	River Red Gum	Indigenous to area	Evergreen
Eucalyptus largiflorens	Black Box	Indigenous to area	Evergreen
Eucalyptus melliodora	Yellow Box	Indigenous to area	Evergreen
Eucalyptus microcarpa	Grey Box	Indigenous to area	Evergreen
Eucalyptus polyanthemos subsp. *vestita*	Red Box	Indigenous to area	Evergreen
Eucalyptus rossii	Inland Scribbly Gum	Victorian native	Evergreen
Eucalyptus sideroxylon	Red Ironbark	Indigenous to area	Evergreen
Ficus macrophylla	Moreton Bay Fig	Australian native	Evergreen
Fraxinus pennsylvanica 'Cimmzam'	Cimmaron Green Ash	Exotic broadleaf	Deciduous
Fraxinus pennsylvanica 'Urbdell'	Urbanite Green Ash	Exotic broadleaf	Deciduous
Ginkgo biloba	Maidenhair Tree	Exotic conifer	Deciduous
Ginkgo biloba 'Princeton Upright'	Upright Maidenhair Tree	Exotic conifer	Deciduous
Livistona australis	Cabbage tree palm	Palm - Australian native	Evergreen
Phoenix canariensis	Canary Island Date Palm	Exotic Palm	Evergreen
Pinus brutia	Turkish Pine, Calabrian Pine	Exotic conifer	Evergreen
Pinus canariensis	Canary Island Pine	Exotic conifer	Evergreen
Pinus pinea	Stone Pine	Exotic conifer	Evergreen

Species	Common name	Type category	Evergreen/ deciduous
Quercus bicolor	Swamp White Oak	Exotic broadleaf	Deciduous
Quercus canariensis	Algerian Oak	Exotic broadleaf	Semi-evergreen
Quercus castaneifolia	Chestnut-leaved Oak	Exotic broadleaf	Deciduous
Quercus cerris	Turkey Oak	Exotic broadleaf	Deciduous
Quercus coccinea	Scarlet Oak	Exotic broadleaf	Deciduous
Quercus lobata	Valley Oak	Exotic broadleaf	Deciduous
Quercus macrocarpa	Bur Oak, Mossy-cup Oak	Exotic broadleaf	Deciduous
Quercus phellos	Willow Oak	Exotic broadleaf	Deciduous
Quercus schumardii	Shumard oak	Exotic broadleaf	Deciduous

Tree Planting Design Guidelines

Design principles for healthy trees

The following design principles are from *Trees for Cooler and Greener Streetscapes Guidelines for Streetscape Planning and Design*. The State of Victoria Department of Environment, Land, Water & Planning 2019.

To create greener and cooler urban areas, tree managers must create the space and conditions to grow large canopied, which contribute to the character and function of streets for decades to come. To help achieve this, the focus is on five design principles.

1. Supporting place-making

Good design speaks to the local context and leverages the opportunities to add to the character of the street and enhance its function and liveability.

2. Creating room to grow

Good design caters for the horticultural needs of the tree to allow it to reach full maturity and size. Solutions need to support large-sized urban trees (the larger the canopy tree the greater the benefits). Larger pavement openings generate larger, healthier trees with less conflicts. More soil (un-compacted rooting volume) supports larger, healthier trees. Where existing soil resources are available, they should be used (may need amelioration). Allow for drainage so sites do not become waterlogged.

3. Providing water

Good design provides water to a tree to support healthy growth, evapotranspiration for cooling, and can lead to improved stormwater outcomes.

4. Integrating urban infrastructure

Good design uses innovative thinking to integrate urban infrastructure that provides space for trees and enhances the functional role provided by trees. Solutions must be viable for below and above ground services access that can be realistically maintained. Strategic, cost-efficient design yields larger, healthier trees. Use the open planter system where space permits. Use fewer components, such as tree guards and grates. Invest in fewer trees per soil volume to increase the potential for each to reach maturity.

5. Ensuring longevity

Good design anticipates the long-term outcomes and future needs of the street.

Designing to mitigate the effects of UHI

Planting of urban vegetation for heat mitigation involves considering the following:

- Prioritising areas with high socio-economic disadvantage
- Prioritising areas where heat impacts are high e.g., areas that currently lack vegetation cover and are high in impervious surfaces
- Targeting area with high levels of pedestrian activity such as withing commercial and retail precincts, around community centres, schools, local shopping areas, public transport hubs, kindergartens, aged care facilities and along walking paths.

Key opportunities to mitigate urban heat by increasing urban green space and tree planting include:

- converting underutilised road space and establishing roadside plantings incorporating water sensitive urban design treatments.
- providing information, guidelines, and incentives for increasing vegetation in private open space, including garden areas, green roofs, walls and facades, in new developments and existing residential areas.
- protection for existing trees and urban green spaces.
- providing opportunities for community involvement in the ongoing planning, management, and custodianship of urban green spaces.

(Osmond and Sharifi, 2017)

Tree size matters

A strategically located large-stature tree has a bigger impact on conserving energy and mitigating the urban heat island effect than a corresponding quantity of smaller trees.

Larger trees do more to:

- Reduce stormwater runoff.
- Extend the life of street surfaces.
- Improve local air, soil, and water quality.
- Reduce atmospheric carbon dioxide.
- Provide wildlife habitat.
- Increase property values.
- Enhance the attractiveness of an area.
- Promote human health and well-being.

The bigger the tree, the larger the benefits and, ultimately, the better the community's quality of life.

While it is understood that large trees are not suitable in every street location, the aim should be to plant large-stature trees in as many appropriate places as possible while also creating the best possible site conditions, particularly soil, that maximizes space and allows for good growth and tree longevity.

Diversity

It is important that a diversity of trees, both in age and species, be maintained across urban areas to promote resilience to climate variability, resistance to insect pests and disease vectors and to assist with streamlined management resource allocation.

However, to have a sustainable urban tree population, selected tree taxa need to be adapted to growing in the heterogeneous nature of urban landscapes and streets.

Diversity is not a universal remedy for enhancing the survivability of urban tree populations. Street trees in particular are vulnerable to a host of environmental stressors (Quigley 2004), and diversity does not insure against the mortality associated with development, vandalism, changes to the growing environment, and poor maintenance practices (Steenberg et al. 2017).

Species diversity should be related to the diversity of site conditions and functional requirements on a community's streets, and not to pre-set ideas of the value of diversity per se (Richards, 1983). Because street planting sites are usually complexly stressed environments, generally only relatively few of the many species planted in a particular area prove broad and long-standing adaptation as street trees.

There are some tree species that are more resistant to harsh urban conditions and better candidates for survival (Roloff et al. 2009), which explains in part their abundance relative to other tree species and limits to some extent the choices available for increasing diversity (Richards 1993; Watson 2017). Most urban tree populations around the world are dominated by a relatively few species that have proven adaptable and useful under austere conditions.

Replacing tree species that are performing with untried new taxa may not provide the population stability being sought. Most of the additional species are unlikely to prove as widely adapted to the range of conditions already experienced by the older trees, and there is no reason to expect that they might be better adapted to predicted changes in these conditions. Risks of catastrophic disruption of the population by disease or insects, often unduly attributed to species, are best reduced directly by proper site selection, good planting and early care, and best management practices (Richards, 1983).

Establishing diversity targets should consider factors such as scale, land use and site characteristics. Set diversity goals as high as realistically possible but with the understanding that urban environments are typically difficult with limitations on the number of species that perform well, and those that do should not be replaced by underperforming or untrialled species (Watson, 2018).

The accepted level of species diversity will evolve based on the continuum of the dynamic nature of tree removal and replacement works taking into consideration the changes in species/variety availability, changes to environmental or planting sites and changes to community expectations (Richards, 1993).

The following factors will dictate species diversity:

- Existing landscape character
- Proven adaptability/tolerances and suitability of species
- Availability of selected tree species
- Personal and community preferences over time
- Ability to fulfil functional requirements.

Another facet of street tree diversity lies in the available planting sites throughout the city. Species diversity can be increased by improving planting sites that can support more species, such as incorporating passive irrigation initiatives. It may also include the development of new planting sites that allow planting of different species within an established avenue or landscape that could provide a highlight, such as within roundabouts, medians, or kerb outstands, allowing for additional aesthetic, while also providing diversity within the stand.

Tree age diversity within a population should also be a focus for renewal and planting programs. In street tree populations, stability depends primarily on the longevity of individual trees and enough numbers of successfully planted replacements. Good age diversity is essential for future population stability.

Diversity of age allows normalising of budgetary requirements (regulating expenditure).

Consider planting principles that improve spatial diversity at the local scale, such as:

- Planting a single species on a street but not planting that species in connected streets.
- Planting multiple species of similar form and appearance on a single street.
- Planting a high diversity of species in parks where growing conditions are easier.
- Planting trees with diverse life-expectancies and planting over a long period of time to promote age diversity.
- Planting trees of diverse genetic stock to promote resistance to pests and disease.
- Planting a diversity of species in layers (understorey to overstory) to promote vertical structure and biodiversity.

(Diamond Head Consulting, 2017)

Providing adequate space for trees

The further a tree is away from infrastructure the less likely damage will occur. Combined with this is the understanding that the smaller the size of the mature tree the narrower the planting site can be, within reason.

Table 1 can be used as a guide in the selection of appropriate sized species for planting areas. Larger trees could be considered for smaller sites only if engineering solutions, such as modified soil profiles and permeable pavements, were incorporated into the planting site.

Table 1. Planting area guidelines (Adapted from Gilman, 1997)

Total Planting Area (Lawn, island, or soil strip)	Planting strip width	Distance from trunk to pavement or wall	Maximum tree size at maturity
Less than 9.5m^2	1.0m to 1.3m	0.6m	Small (Less than 9m tall)
9.5m^2 to 18.5m^2	1.3m to 2.5m	1.2m	Medium (Less than 15m tall)
More than 18.5m^2	$>$ 2.5m	$>$ 1.5m	Large (Taller than 15m)

The potential for direct mechanical damage and upheaval is one factor in street tree planting. It is also necessary to consider the tree species, soil type and the proximity and design of structures.

Appropriate soil volumes

Urban soils are often highly altered from the natural state, and human activity is the primary agent of the disturbance. They generally have high vertical and spatial variability, modified and compacted soil structure, an impermeable crust on the soil surface, restricted aeration, and water drainage, interrupted nutrient cycling, altered soil organism activity, presence of anthropogenic materials and other contaminants, and altered temperatures. The loss of natural soil structure is one of the most important limitations to tree growth in urban areas (Stewart & Scullion, 1989).

Soil aeration is impacted by urban landscape features. In undisturbed, well-drained soil, oxygen and carbon dioxide contents can be near atmospheric levels close to the soil surface, decreasing most rapidly in the first 30 cm (Yelenosky 1963; Brady and Weil 1996). When not paved, vegetated and non-vegetated urban sites can be as well-aerated as forest stands (Gaertig et al. 2002). However, if topsoils are sealed or compacted, gas exchange between the soil and the atmosphere is interrupted (Gaertig et al. 2002). (Watson, Hewitt, Custic, Lo, 2014). The soil temperatures under sealed or paved root zones can also be up to 10^{0}C higher than adjacent unpaved areas (Watson, Hewitt, Custic, Lo, 2014). Higher soil temperatures will slow root growth.

The bulk density that limits root growth varies with soil texture. Urban soil means bulk density values of 1.6 g cm^3 have been reported, with individual values as high as 2.63 g cm^3

Table 2. General relationship of soil bulk density to root growth based on soil texture (NRCS Soil Quality Institute, 1999).

Soil texture	Ideal bulk densities (g/cm^3)	Bulk densities that may affect root growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
Sands, loamy sands	<1.60	1.69	>1.80
Sandy loams, loams	<1.40	1.63	>1.80
Sandy clay loams, loams, clay loams	<1.40	1.60	>1.75
Silts, silt loams	<1.30	1.60	>1.75
Silt loams, silty clay loams	<1.10	1.55	>1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	>1.58
Clays (>45% clay)	<1.10	1.39	>1.47

When trees are planted in paved areas, the limited root space available in planting pits will ultimately limit the size and longevity of the tree.

Trees need significant soil volumes of low compacted soil with suitable pore space, drainage, nutrients, and organic matter to provide for their long-term growth. There are many methods for attributing appropriate soil volumes for tree growth.

In this case a method developed by James Urban (2008) is used that is based on the crown projection method, which as a general guide recommends that root space should be 60cm deep within the projected crown area of a tree. The amount of soil required for trees of different sizes is depicted on Figure 1. As indicated on this graph, a large tree with a trunk diameter of approximately 40cm requires more than 28 cubic metres of soil to reach the size where it becomes a significant contributor to a healthy urban landscape.

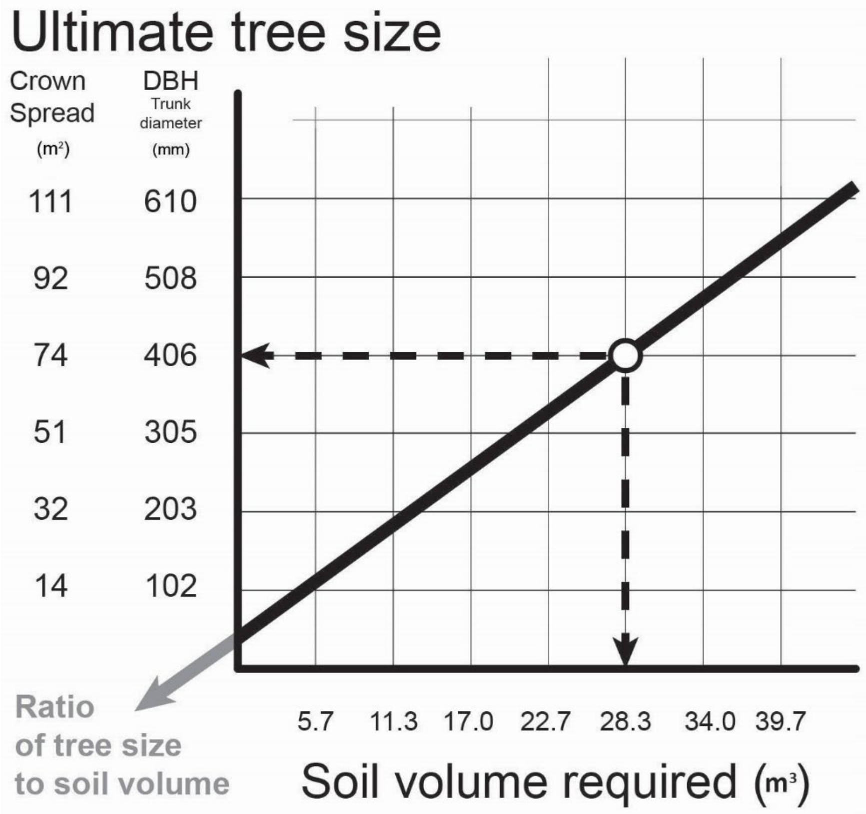

Figure 1. Soil volume estimator based on estimated tree size. (Adapted from Urban, 2008)

Soil volume estimation by Urban (2008) is reiterated by the University of Florida (2009) See Table 3. (Web (http://hort.ifas.ufl.edu/woody/urban_design.shtml)

Minimum soil volume required to support reasonably healthy trees can be summarised in the table below. This soil should be at least 0.9 m deep and must have a bulk density below the critical value (see Table 2) for the soil type. Rooting space needs to be wider if it cannot be 0.9 m deep. Place trees as far from hard surfaces as possible.

Table 3. Soil volumes reiterated by the University of Florida (2009)

Mature DBH (cm)	Soil volume (m^3)
30	20
40	28.3
60	48

Australian method for estimating soil volumes

Leake and Haege (2014) have also developed an approach to estimating appropriate soil volumes to sustain healthy tree growth - Soils Volume Simulator (SVS). The method can be seen at https://www.elkeh.com.au/soils/.

As part of the new Landscape Soils Handbook, Leake and Haege (2014) developed the SVS to assist towards not just sustainable, but regenerative landscape environments.

The first part of the SVS allows tree planting scenarios to influence recommended soil volume through 5 selections. Influencing factors on tree volume include:

- tree design size,
- climate,
- soil within the tree pit,
- maintenance including irrigation,
- design life (considering acceptability of tree stunting)

The soil volume calculations developed via the SVS are estimates from a combination of averages and ranges of scientific research results (as detailed in Leake and Haege, 2014, Appendix C) as well as published literature and combining soil testing experiments, observations, and experiences Leake and Haege (2014) have had and observed with different tree species. Leake and Haege (2014) acknowledge that calculating soil volumes will always be a non-precise science based on the multitude of organic influencing factors.

As an example, the following is the soil volume calculated when applying the influencing factors:

- Tree design size and height: 9-20 metres (tall tree, estimated 40+ cm DBH)
- Climatic growing conditions (particularly rainfall): is generally suited to the tree species selected (this is reliant on a rigorous tree selection process that factor matches the selected species to the site).
- Soil suitability within the tree pit: The soil quality and effectiveness will likely be tolerated by the tree species selected (again, as above, relies on good selection process)
- Maintenance: There will be no fertiliser applications, no mulch, no supplementary or passive (WSUD) irrigation design.
- Lifespan/Design (replanting) time: Minimal stunting of tree is acceptable and/or the design life of the tree is estimated between 36-99 years

Considering the above 5-factors, the total recommended minimum soil volume is **26.95 m^3**.

Caveat on calculating soil volumes

The soil volumes generated are estimates and should only be used to generate an order of magnitude as a guide or target volume. Calculating soil volumes will always be a non-precise science based on the multitude of natural and anthropogenic influencing factors.

Water, oxygen, mechanical resistance, temperature, soil reaction, cation exchange capacity, contaminants, and biology are soil factors that directly affect root growth. Water can be a dominant controlling factor, but all are interconnected. Altering one factor can affect the quality of the others, and management practices to improve root growth must consider the effects on all factors interacting together (Watson, Hewitt, Custic, Lo, 2014).

We have all observed trees growing in available soil volumes that are much less in volume than the commonly recommended soil volumes from the literature. For the most part, trees will stunt according to the volume of soil (and hence water and nutrients) available to them and yet still provide adequate function as a street tree (Leake and Haege, 2014).

When soil volume is restricted, soil quality becomes very important. High-quality soil and intensive maintenance can compensate for limited root space volume to a limited extent.

Planting near underground services

A trees mature size and mass, rate of growth (size change rate), and mechanical adjustments generated to remain structurally stable, all interact closely with available rooting volume, soil strength, and distance to infrastructures. Potentially large trees planted in small soil volumes will be quick to exert mechanical forces on surrounding infrastructures (Coder, 1998).

The size of the root plate, or the zone of rapid taper, does vary by genus and species. Using root plate or structural rooting distances as a minimum distance to infrastructure is possible. A Structural Root Zone (SRZ) comprises the area around the base of a tree where structural roots required to maintain the tree's stability in the ground are typically located. The SRZ is calculated using the formula provided in the Australian Standard *AS4970-2009 Protection of trees on development sites* (SRZ radius = $(D \times 50)^{0.42} \times 0.64$ where D = trunk diameter, in metres). Clark (2015) found that if you average the ratio between SRZ (radius) and stem diameter as displayed in AS 4970-2009 for trees with a trunk diameter (DBH) of between 0.4 m and 1.6 m you get a ratio of approximately 3.5 to 1. Hence, a reasonable approach would be to ensure that the trees selected are planted 3.5 times the mature trunk diameter away from a service.

BSI (British) Standards have also considered separation distances for trees and services. To avoid direct damage to drains, BS 5837:2012 recommends certain minimum distances at which newly planted trees and drains should be separated. These vary for different mature size trees (Table 3) and for shallow drains (e.g., sewer laterals) or deeper pipes (e.g., sewer mains). Biddle (1998) notes that as the likelihood of damage is often unpredictable, trees that are closer to pipes and drains than these recommendations should not automatically be suspected of causing damage.

Table 4. BS 5837 recommended minimum distances between new trees and drains to avoid direct damage. (Adapted from BSI, 2012).

Diameter of stem at 1.5 m above ground level at maturity	Drain installed <1 m deep	Drain installed >1 m deep
<30 cm	0.5 m	N/A
30-60 cm	1.5 m	1.0 m
>60 cm	3.0 m	2.0 m

Coder (1998) recognised that tree diameter (DBH) and distance of the stem to the infrastructure has been directly related to damage and goes on to state that once a tree has exceeded 20 cm (8 inches) in trunk diameter, the potential for damage increases exponentially (See Figure 2).

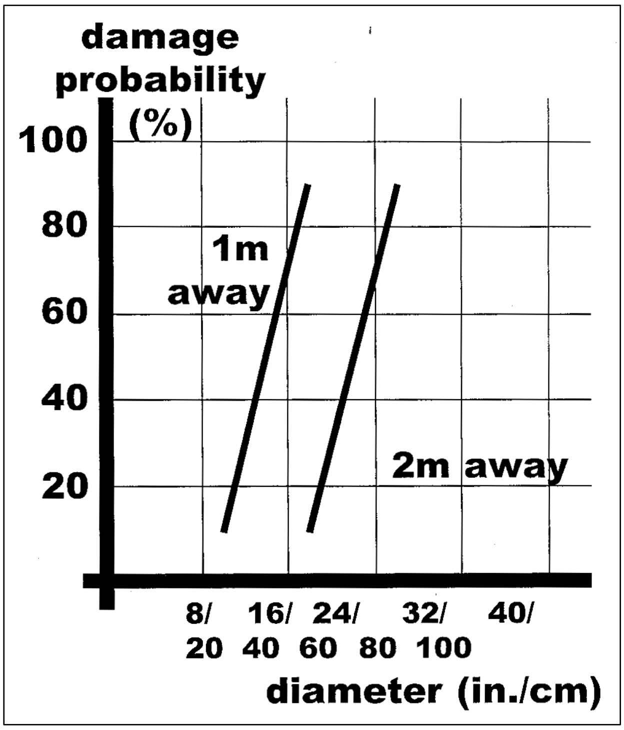

Figure 2. Correlation between tree size, distance from infrastructure and potential conflict (Coder, 1998)

Tree spacing

The optimum spacing of trees in the urban landscape is achieved by balancing aesthetic and environmental values with the physical form of the tree being used, and the carrying capacity of the site. In general, aim for the maximum amount of tree coverage that is attainable while respecting site constraints, visibility lines, utility requirements, and other important landscape elements. Spacing is considered on a site average scale, and preference is to match existing tree spacing.

Typically, street tree spacing is one tree per residential allotment, other than corner allotments, which equates to 12 to 15 metre spacing.

Where feasible endeavour to attain regular tree spacing so that the trees appear as a continuous linear element of the street. If using smaller statured trees, then decreasing the planting spacing (distances between individual trees) can achieve continuity and flow in the streetscape.

Spacing should also endeavour to provide the optimum canopy cover for the streetscape taking into consideration the specific site constraints within the street, such as planting site width or overhead services.

Street tree spacing should be determined by the expected mature size of the tree. All tree spacing should be a function of mature crown spread and may vary widely between species or cultivars.

Generally, trees should be planted with the following spacing:

- Small trees (5-7 metre height <6m crown diameter at maturity) should be planted 6 to 10 metres on centre.
- Medium trees (8-15 metre height. 6-11 metre crown diameter at maturity) should be planted 10-15m metre on centre.
- Large trees (>15 metre height, >11 m crown diameter at maturity) should be planted 15-20 m on centre.

Tree canopy size is a better measure of impact than the quantity of trees. In order to grow large, healthy trees, they must be planted at a distance wide enough to allow each tree the recommended soil volume.

Climate adaptation strategies for improving soil management

The following guidelines focus on the most important soil management strategies for supporting the growth of a healthy urban forest:

Maximize soil volume: Provide sufficient soil volume in the rooting zone (upper 1 metre of soil) for healthy tree growth. The recommended volumes should be developed from method developed by James Urban (2008) or Leake and Haege (2014). Larger volumes may be required under warmer, drier climates to provide greater soil water storage for urban trees under climate change. Solutions for load bearing footpaths or parking areas, such as trenches to connect soil volume, suspended pavements supporting soil volume below, structural cells and structural soils, should be used to increase soil volume in hard surfaced landscapes. In an established landscape it is difficult and costly to retrofit soil. Wherever possible, optimal soil conditions should be designed into the construction of new landscapes (Leake and Haege, 2014).

Prevent compaction: Prevent soil compaction during construction in areas for future tree planting by fencing off planting areas or laying down materials like mulch or matting where machine access is needed. In areas that are already compacted, aerate, rip or deep till soils prior to planting.

Increase water storage capacity and reduce water loss: Protect native soils and soil structure. Where importing soil, follow Australian Standards (*AS 4419:2018 - Soils for landscaping and garden use*. *AS 4454-2012 Composts, soil conditioners and mulches*.) to select soils or amend soil properties to optimize water-holding capacity while still allowing adequate drainage. Avoid amendments to soil that will be backfilled into a planting hole if they cause the soil texture to vary from the surrounding soil. Apply mulch to the root zone of trees to reduce water loss in the soil through evaporation.

Minimize competition at planting sites: Minimize competition for water in root zones. Roots of turf grass and other vegetation compete with tree roots for nutrients, light, oxygen, and water. Use mulch rather than turf grass below the dripline of trees as far as is practicable.

Minimize soil interfaces: Changes in soil texture create interfaces that can disrupt water flow and create waterlogged soils and perched water tables. Ensure that the entire root ball is within one soil type.

Preserve or improve soil quality: Maintain or create suitable soil conditions for trees to grow in. Retain and protect native soils (and soil structure) where possible as they typically have higher organic content, nutrients, water storage capacity, porosity and microbial activity than modified urban soils. Where stockpiling topsoil on development sites, it should be drawn from the A1 horizon. Do not invert soil layers/horizons (subsoils). Limit potential sources of soil contamination.

Passive irrigation of street trees

Increasing soil moisture and subsequently healthy vegetation will help reduce urban heat through evapotranspiration and shade.

Passive irrigation systems use gravity to direct stormwater from adjacent surfaces into the vegetated system. Water can be directed to these landscapes either at the surface (where water infiltrates vertically down through the soil) or through subsurface systems which can recharge soil moisture at depth where it can be accessed by plant roots.

There are several types of passively irrigated systems, including commonly used water sensitive urban design (WSUD) assets such as bioretention, swales and wetlands, which are vegetated systems designed to capture and treat stormwater.

Systems suitable for street trees include:

- Kerb entry connected to a perforated pipe that surrounds the planting area to allow storm water to irrigate the tree
- Infiltration trenches. An excavated channel in the ground that is filled with porous material and collects storm water runoff from hard surfaces. These trenches can be incorporated into permeable pavement systems.
- Sunken tree pit / raingarden - open
- Sunken tree pit - Grated
- Incorporating permeable surfaces, structural soils or structural cells into planting systems.

There are many technical guidelines that can be accessed to determine appropriate passive irrigation systems. See the Moreland City Council Passively Irrigated Street Trees Best practice guidelines / tech notes (2019) and Cooperative Research Centre for Water Sensitive Cities (2020). Designing for a cool city–Guidelines for passively irrigated landscapes. Melbourne, Victoria: Cooperative Research Centre for Water Sensitive Cities.

Passive irrigation of street trees using stormwater provides two key benefits in the urban environment:

1. Increased tree growth which in turn leads to increased ecosystem services such as helping to mitigate the Urban Heat Island Effect
2. Reduced volume and frequency of stormwater runoff which in turn helps to mitigate the Urban Stream Syndrome

Opportunities for incorporating passive irrigation into streets could occur during:

- Retrofit situations, such as replacement of declining or inappropriate trees or planting of new trees within established streets
- Capital works, such as opportunities arising from road or footpath reconstruction
- Civic projects, such as opportunities arising from high profile civic spaces or urban design projects

Typologies where passive irrigation are likely to be implemented within streets will need to be designed and approved by each Council. A collective best practice design guide could be developed.

Where possible, consideration could also be given to increasing the use of permeable pavements, in conjunction with tree planting, to increase the potential for cooling, while also passively irrigating the trees and recharging soil moisture.

Planting in nature strips

Relevant Australian Standards

Australian Standard	Description
AS 4373-2007 - Pruning of amenity trees (Pending Revision). Standards Australia	AS 4373 provides a guide for the pruning of amenity trees based on the widely accepted theories of compartmentalisation of decay/ dysfunction in trees (CODIT). Its aim is to encourage correct and uniform pruning practices. Council requires that pruning is undertaken in accordance with AS4373-2007. Failure to prune in accordance with AS4373-2007 is

Australian Standard	Description
	considered a breach of the Wollongong City Council's Tree Management Policy.
AS 4419:2018 - Soils for landscaping and garden use. Standards Australia	AS 4419 provides manufacturers with a set of requirements which will ensure that soils can support plant growth and to give users, such as growers, landscape architects and consumers, assurance of the suitability and quality of soils. AS 4419 sets out requirements and methods of test for general purpose soils, top dressing, topsoil and landscaping mixes, for domestic and commercial use, supplied in either bulk or bagged lots.
AS 4454-2012 Composts, soil conditioners and mulches. Standards Australia	AS 4454 specifies requirements for organic products and mixtures of organic products that are to be used to amend the physical and chemical properties of natural or artificial soils and growing media. It specifies physical, chemical, biological and labelling requirements for composts, mulches, soil conditioners and related products that have been derived largely from compostable organic materials and which meet the minimum requirements as set out in this Standard.
AS 2303:2018 Tree stock for landscape use. Standards Australia	AS 2303 provides criteria for those who grow, specify or purchase tree stock for landscape use. The use of such criteria enables quality tree stock to be identified, regardless of the production method used to grow them. It specifies the criteria for the assessment of above-ground and below-ground characteristics of various production methods for tree stock that are to be supplied for landscape use.

Understanding and improving site conditions is vital in order to support healthy growth and to encourage a diversity of species, some of which may not be ideally suited to urban environments (Watson and Himelick, 2013).

Planting and successful establishment of trees is predominately about managing air and moisture in the soil. Manage these correctly and trees will grow quickly following planting. Four of the most common causes of poor plant establishment are 1) planting too deeply, 2) under watering, 3) over watering, and 4) over-mulching.

Planting too deeply in compacted soil can also lead to very slow root development. Each of these problems can lead to extensive tree death, poor growth, or a slow decline after planting. If appropriate trees are planted at the right depth and they are irrigated properly, the planting has a good chance of success.

Newly planted trees benefit from providing larger planting holes. The depth of the root ball of the stock determines the depth of the planting hole. The depth of the root ball is measured from the bottom of the trunk flare to the bottom of the hole. The hole is to be dug slightly shallower than the root-ball depth.

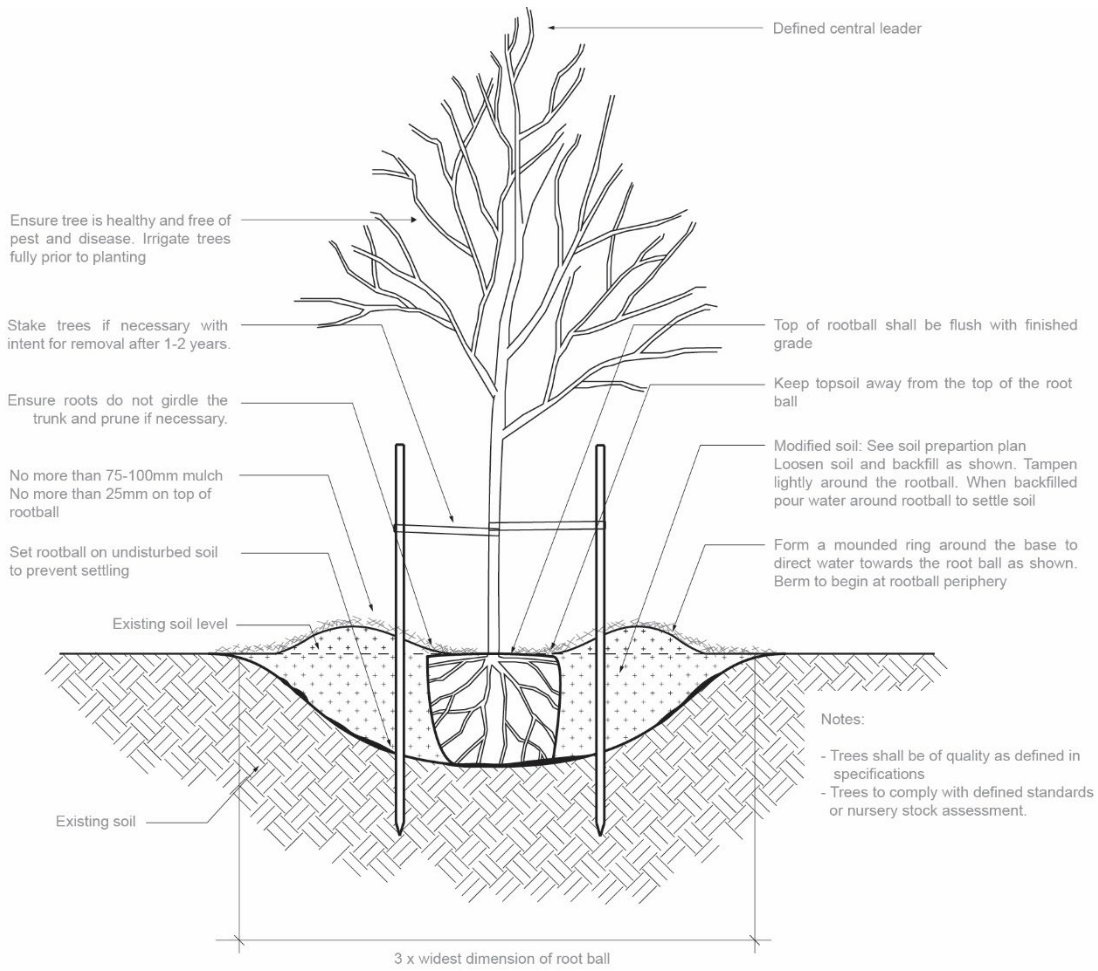

Figure 3. Indicative tree planting detail in a grassed/open space area.

Trees should be planted so that the top of the root ball is level or slightly proud of the natural grade of surrounding soil. Trees planted too deep can dry out more quickly as the generally finer texture of the surrounding soil placed over the root ball can draw and bind water preventing percolation through to the coarser substrate generally found in container medium. Planting too deep can also lead to the suffocation of roots preventing the natural exchange of gasses between the soil surrounding the roots and the atmosphere. This can be further exacerbated on poorly drained or wet sites where planting heights can be increased to 1/3 the depth of the root ball.

Planting holes should be dug with a diameter no less than 3 times the diameter of the root ball (or root spread). The hole should be dug with sloping sides and have a shape not dissimilar to that of a wok. This provides a greater volume of loose cultivated soil in which rapid root initiation can occur and as root growth generally proliferates closer to the soil surface, the shape is ideal and eliminates the need to dig to the full depth of the root ball for the diameter of the hole.

Seasonal considerations for planting

- Trees establish more readily in autumn than in spring or summer.
- With autumn planting, the period when concentrated attention must be given to trees will be shorter than in spring or summer.
- Trees planted in spring, particularly late spring, are trying to establish as they enter the driest time of the year.

- In the case of spring or summer plantings, longer after-care maintenance and greater monitoring are essential.

Tree planting procedure

Root ball Preparation

Above Ground Container Stock

- The root balls of good quality container stock generally require little in the way of preparation before planting. Always inspect the root ball following removal from the container to ensure there are no circling roots. Where circling roots are encountered, the sides of the root ball can be shaved to remove circling roots. In addition to eliminating potential girdling roots, root pruning may help distribute regenerated roots through the backfill instead of the concentrating them at the base of the planting pit. Shaving the outer surface of the root ball also results in more normal, radiating root growth from the trunk.

Figure 4. Example of shaving root ball to remove circling roots (Watson & Himelick, 2013)

Setting of trees

Base of planting hole

- The hole should be thoroughly tamped and watered prior to the setting of trees so as to prevent settlement following planting. Plants should be placed at such a level so that the top of the root ball is level with existing grade on well drained sites. On poorly drained sites, the root ball should be set proud (approximately1/3 the depth of the root ball) to prevent plants from suffocating in saturated soils.

Root ball condition

- If roots are not visible growing from the trunk at the soil line within the root ball, remove all soil media and root material from the top of the root ball so that uppermost root emanating from the trunk is just below the finished soil grade. Failing to do this will have the same consequences as planting too deep.

Tree orientation

- Where possible, the tree should be orientated in the hole so that the crown receives maximum amount of sunlight. The portion of the crown facing the maximum amount of sunlight within the planting location should be the same as the portion facing the light in the nursery. This is to prevent sunscald of the trunk that may develop due to lack of exposure.

Backfilling

Soil tilth

- Spoil from sandy regions is generally loose enough that will not require additional working. In heavier soils, clods will need to be broken up before backfilling so as not to create air pockets that could reduce root growth during establishment.

Backfilling

- The planting hole should be filled to 75 percent of the total planting depth by working in with a spade the original soil from the planting hole, lightly tamped and watered. The remaining 25 percent of the planting hole should then be filled in with the original soil, watered and settled so that the final planting level is as stated earlier.

Ameliorants

- Watering in of tree stock should be the only ameliorant used at the time of planting. The use of fertiliser, polymers, organic matter, mycorrhizae, etc provide little or no benefit in the establishment process unless the site soil is incapable of supporting plant life and then soil replacement is generally the preferred strategy.

Staking

- Staking has two functions; one is to support the trunk of the tree and the other is to anchor the root ball against unnecessary and damaging movement within the planting pit. Quality tree stock that is properly planted does not generally require staking.
- Support staking is required to hold a weak trunk straight, in an upright position. The development of supportive trunk tissue is inhibited on staked trees. Trunks that are subject to natural wind movement develop better taper and subsequently improved trunk strength. Trees that are not self-supporting should not be selected for use in the landscape. If support staking is required, the trunk should be secured at the lowest point that will hold the tree erect.

Mulch

- Mulch will be maintained to a depth of between 75 to 100 millimetres and extending from the edge of the root ball to the edge of the planting pit. A thin layer of mulch not exceeding 20 mm in depth may be spread over the root ball to maintain an aesthetic continuity. Never pile mulches up over the root ball or around the trunk (mulch volcanoes) as they can reduce the efficacy of irrigation and cause collar rots. Mulch ring size should extend out as far as is practicable based on-site constraints.

After-care maintenance

The efforts and expense committed to site preparation, species selection, high quality stock and planting procedures can all be wasted without proper after-care maintenance.

Transplant survival is influenced by a range of factors. The principal elements essential for successful tree establishment have been identified as tree ecophysiology (the trees response to the growing environment); rooting environment; plant quality, planting technique and post-planting maintenance (Hirons and Percival, 2011).

In particular, utilising high plant quality, best planting and post-planting practices are fundamental to urban tree establishment success.

Tree establishment describes the period directly after transplanting of a tree, during which the tree adjusts to the new site and its growing conditions. This will include a modification of the root systems so that a functional root:shoot balance can be restored. The establishment phase is often described as a period of reduced tree vitality and growth, in which the tree also has a reduced capacity to resist various types of stress. Reducing this stress and securing the establishment of a tree is of high importance for long-term survival and future thriving. Therefore, it is recognized that during the establishment phase extra management is needed, predominately supplemental irrigation, as the root systems have not yet adapted to the hydraulic cycle of the site (Levinsson, 2018).

Drought induced water deficits are regarded as one of the major causes of failure of newly planted trees (Watson and Himelick, 2013; Pallardy, 2008).

Irrigation frequency can have a significant impact on the performance of newly planted trees. The ideal is to maintain a moist root ball and backfill and to avoid saturation during the establishment of new trees. Nursery grown trees are generally watered daily and containerised root balls can dry within several hours following watering. Trees planted in warm dry conditions from containers or recently dug field stocks that have not been hardened off are usually not watered frequently enough to ensure optimum growth and subsequently either fail or establish much more slowly. Research indicates that trees receiving frequent irrigation establish their roots in the landscape soil much quicker and become tolerant to drought much sooner than those receiving only periodic watering of once a week (Gilman 1997).

Tree performance post-planting suggests that the first few months after planting are critically important in tree success. Many planting failures are due to problems with water supply (too much or not enough). The bigger the tree at transplant and the drier the weather at time of planting, the more difficult the project will be to manage from a water point of view (May 2004).

A new planting can be described as established once it no longer requires supplemental irrigation to maintain an appearance and growth consistent with species expectation. Dependent on pervading climate, soils, species, size of stock and planting site, this will generally occur within 24-months following planting. This period becomes extended on larger calliper trees or on sites where poor natural rain percolation occurs such as cut-out plantings in hard surfaces or where the species selected are not well adapted to dry climates.

Application of Water

Water must be applied directly to the root ball in the months following planting as this is where the majority of the roots are located. The irrigation of surrounding soils where new roots are forming may only become necessary when the area around the tree becomes dry. This can be easily tested by forcing a steel probe into the adjacent soil profile to determine the level of moisture.

Moisture will not flow from wet surrounding soils back into the root ball. So, watering must concentrate on wetting the root ball itself. As well as creating berms at the time of planting, there are products available that can help direct irrigation into the root ball and surrounding root zone. Water wells around the tree allow a greater volume of water to be pumped within a short time and retained in the well close to the tree to slowly soak into the soil.

Do not use strong jets from hoses and pumps such as those used on water trucks. Using high pressure water application actually delivers less useable water and can wash away the berms and mulch.

Do not stop watering in the event of rain. It might wet the ground but, unless heavy and/or prolonged, rain normally will not deliver adequate moisture to the root ball.

Water loss can be reduced, and soil conditions improved by adding a 75-100 mm layer of approved organic mulch to the area on top of and adjacent to the root ball. But make sure that this mulch is not heaped up against the stem of the tree (like a mulch volcano).

Frequency

The frequency and amount of irrigation supplied to newly planted trees will determine the success of the landscape planting. However, frequency and amounts of irrigation will be dependent on available resources combined with the levels of desired landscape performance.

There are many guides and formulas (Gilman, 1997, Handreck and Black, 1984, Harris, Clark and Matheny, 1999.) used to determine how much water a tree needs after planting, but these are a guide only and no two sites are the same.

Planting sites must be evaluated to understand the conditions you are working in and consider the weather conditions because these factors will determine how often to irrigate and how much.

Considerations to determine watering amount for your street tree plantings.

- Time of year
- Temperature
- Rainfall
- Wind
- Humidity
- Aspect (amount of direct sun hours)
- Cloud cover
- Drainage
- Compaction
- Soil texture of root ball
- Size of tree being planted
- Plant production method
- Timing of planting
- Transpiration rate
- Evaporation rate

Make any physical changes to the planting site before planting to provide the best environment possible for the successful establishment of the newly planted tree.

Appropriate and regular irrigation will result in faster establishing trees that will become tolerant of drought sooner.

Monitoring soil moisture levels in the root ball and surrounding soils would assist in determining water frequency. In summer the root ball can become very dry in two or three days while the surrounding soil remains moist. The use of low-cost electronic soil moisture meters may be accurate enough to indicate when the root ball should be watered. TDR meters can also be used. Time domain reflectometry, or TDR, uses an electromagnetic frequency to measure how much water is present in the soil.

Sampling can also be done with a soil profile tube which can remove a small core which can be examined to determine moisture content (feel via ribbon test). Determining soil resistance by probing the root ball and the backfill with a pointed metal rod can also be used to estimate soil moisture. Very dry soil will resist penetration of the rod and indicate the need for watering. If suction develops when removing the rod and the rod is muddy when removed, then the soil is too wet.

Newly planted trees or shrubs require more frequent watering than established trees and shrubs. They should be watered at planting time and at these intervals:

- 1-2 weeks after planting, water daily.
- 3-12 weeks after planting, water every 2 to 3 days.
- After 12 weeks, water weekly until roots are established.

These recommendations assume the trees are planted correctly into sites with good drainage.

The objective of any irrigation program should be to maintain the root ball and surrounding soil moist but not waterlogged. Over watering is the major reason for trees dying; under watering will not necessarily kill the tree but retard critical root development outside the root ball, essential for successful establishment.

Amount

Guidelines for amounts and frequency can only be generalised and are highly dependent on prevailing weather, site soil conditions, timing of planting and type and size of tree stock. Water frequency and amount will also change over the seasons (or even during a season dependent on rainfall events).

The development of the landscape coefficient methodology of estimating plant water use (Costello and Jones 2000 Connellan and Symes 2006) seems better suited to diverse urban landscapes, and this system is the basis for irrigation scheduling training currently endorsed by Irrigation Australia, a national body representing the irrigation industry. The landscape coefficient methodology (Costello and Jones 2000) incorporates reference evapotranspiration (ETo), a landscape coefficient (KL), plant species factor (ks), microclimate factor (kmc), and vegetation density factor (kd) to estimate Landscape Evapotranspiration (ETL) and is summarized as follows:

$ET_L = K_L (ks \times kmc \times kd) \times ET_0$

This methodology is also incorporated into the American National Standard Industry ANSI/ASABE S623 Standard, *Determining Landscape Plant Water Demands*.

Also see Estimating Tree Water Requirements at https://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Estimating_Water_Requirements_of_Landscape_Trees/ for further information and access to calculators (in imperial measurements.)

General Approaches

Moisture needs to be always available in the soil for the tree as transpiration is taking place, not just when you decide to water. The irrigation needs to be matched to the weather conditions and the stage of growth.

Trunk Diameter	Watering Requirements	Approx. Irrigation Volume
50mm	Daily for 2-4 weeks; every other day for 2 months; weekly until established.	11-23 litres
100mm+	Daily for 2 months; every other day for 5 months; weekly until established.	45 litres

(Adapted from Gilman 1997)

The above chart is based on weather conditions not dissimilar to South-eastern Australia but does not consider weather conditions, time of year and drainage rates from soil. The assumption here is that trees are planted into well drained sites. Remember that minimum irrigation to keep trees alive eliminates daily irrigation and could be extended to once a week.

References

Australian National Botanic Gardens Library (2009) *Fires, gardens and fire retardant plants - a bibliography* (Updated 13th January 2006). Available at http://www.anbg.gov.au/bibliography/fire-plants.html [Accessed 9 March 2009].

Australian Plant Study Group (1990). 'Fire-retarders' in *Grow what where: over 2,750 Australian native plants for every situation, special use and problem area*. Viking O'Neil, South Yarra, Vic., pp. 42-43.

Baumgartner, J.B., Esperón-Rodríguez, M., Beaumont, L.J., (2018). Identifying in situ climate refugia for plant species. *Ecography* 41, 1850–1863.

Behrens F. M.-L. (2011) *Selecting public street and park trees for urban environments: the role of ecological and biogeographical criteria*. A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy. Lincoln University.

Brune, M. (2016). *Urban trees under climate change. Potential impacts of dry spells and heat waves in three German regions in the 2050s. Report 24*. Climate Service Center Germany, Hamburg.

Burley, H., Beaumont, L. J., Ossola, A, Baumgartner, J. B., Gallagher, R., Laffan, S., Esperon-Rodriguez, M., Manea, A., Leishman, M. R. (2019). Substantial declines in urban tree habitat predicted under climate change. *Science of the Total Environment* 685 (2019) 451–462.

Clark, J. R., Matheny, N. P., Cross, G., and Wake, V. (1997). A model of urban forest sustainability. *Journal of Arboriculture* 23(1) January 1997.

Coder, K. D. (2012). Heat Stress & Trees. Trees & Water Series WSFNR12-17. Warnell School of Forestry & Natural Resources, University of Georgia.

Connellan, G., and Symes, P. (2006). The development and evaluation of landscape coefficients to determine plant water requirements in the urban environment. In: Proceedings of Irrigation Association of Australia Conference, May 2006, Sydney, Australia.

Costello, L.R., and Jones, K.S. (2000). A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California. Sacramento, University of California Cooperative Extension, California Department of Water Resources.

Cooperative Research Centre for Water Sensitive Cities (2020). Designing for a cool city–Guidelines for passively irrigated landscapes. Melbourne, Victoria: Cooperative Research Centre for Water Sensitive Cities.

CSIRO and Bureau of Meteorology, Climate Change in Australia website (http://www.climatechangeinaustralia.gov.au/), cited [Accessed *19 May 2020*]

Diamond Head Consulting Ltd. (2017) Urban Forest Climate Adaptation Framework for Metro Vancouver. Tree Species Selection, Planting and Management. Metro Vancouver.

Dirr, M. A. & Warren, K. S. (2019). *The tree book. Superior selections for landscapes, streetscapes, and gardens*. Timber Press.

Franklin, J., & Miller, J.A., (2010). *Mapping Species Distributions: Spatial Inference and Prediction*. Cambridge University Press.

Gerhold, H. D., & Porter, W. (2007). Selecting trees for community landscapes. In J. E. Kuser (Ed.), *Urban and Community Forestry in the Northeast (2nd ed.)*. Springer.

Gilman, E. F. (1997) *Trees for urban and suburban landscapes.* Delmar

Gratani, L. (2014) Plant Phenotypic Plasticity in Response to Environmental Factors. *Advances in Botany*. Volume 2014, Article ID 208747.

Hirons, A. D. and Sjöman, H. (2018) *Tree Species Selection for Green Infrastructure: A Guide for Specifiers*. Trees & Design Action Group.

Hirons, A. D., Sjöman, H. & Bassuk, N. L. (2018). Improving confidence in tree species selection for challenging urban sites: a role for leaf turgor loss. *Urban Ecosystems* (2018) 21:1171–1188

Jenerette, G.D., Clarke, L.W., Avolio, M.L., Pataki, D.E., Gillespie, T.W., Pincetl, S., Nowak, D.J., Hutyra, L.R., McHale, M., McFadden, J.P., Alonzo, M., (2016). Climate tolerances and trait choices shape continental patterns of urban tree biodiversity. *Global Ecology and Biogeography* Volume 25, Issue 11.

Johnson, D., Moore, G., Tausz, M., Nicolas, M. (2013). The measurement of plant vitality in landscape trees. *Arboricultural Journal: The international journal of urban forestry* 35:1, 18-27.

Kendal, D., Dobbs, C., Gallagher, R.V., Beaumont, L.J., Baumann, J., Williams, N.S.G., Livesley, S.J., (2018). A global comparison of the climatic niches of urban and native tree populations. *Global Ecology and Biogeography* Volume 27.

Kendal, D., Baumann, J. (2016). *The City of Melbourne's Future Urban Forest. Identifying vulnerability to future temperatures*. The University of Melbourne, Burnley Campus, School of Ecosystem and Forest Sciences.

Kuhns M. (1999). Are small trees always appropriate as street trees? Brochure, Utah State University forestry extension, Utah.

Landscape Plants. Urban/suburban design to support trees [Seen at: https://hort.ifas.ufl.edu/woody/urban-design.shtml. Accessed: 6/1/2021]. University of Florida.

Leake, S. & Haege, E., (2014). *Soils for landscape development: Selection, specification and validation*. CSIRO

Miller, R. W., Hauer, R. J., Werner, L. P. (2015). *Urban forestry. Planning and managing urban greenspaces. Third edition*. Waveland Press. Inc.

Miller, R.H. and Miller, R.W. (1991). Planting survival of selected street tree taxa. *Journal of Arboriculture* 17:185-191.

NRCS Soil Quality Institute. 2000. Urban Soil Compaction. United States Department of Agriculture Natural Resources Conservation Service Soil Quality – Urban Technical Note No. 2.

Percival, G.C. (2004). Evaluation of physiological tests as predictors of young tree establishment and growth. *Journal of Arboriculture* 30:2, 80-91.

Peterson, A. T. (2011). Ecological niche conservatism: a time-structured review of evidence. *Journal of Biogeography,* 38: 817–827.

Richards, N.A., (1983). Diversity and stability in a street tree population. *Urban Ecology* 7:159-171.

Richards, N.A., (1993). Reasonable guidelines for street tree diversity. *Journal of Arboriculture* 19(6), 344-350.

Roloff, A., Korn, S., & Gillner, S. (2009) The Climate-Species-Matrix to select tree species for urban habitats considering climate change. *Urban Forestry & Urban Greening* 8: 295–308

Royal Botanic Gardens Victoria. (2016). Landscape Succession Strategy – Melbourne Gardens 2016-2036. Royal Botanic Gardens Board Victoria.

Santamour, Frank S. Jr. (1990) *Trees for urban planting: Diversity uniformity, and common sense*. U.S. National Arboretum Agricultural Research Service U.S. Department of Agriculture. Proceedings from Metria 7.

Schneemann, B., Brack, C., Brookhouse, M., Kanowski, P. (2019). *Urban Forest Tree Species Research for the ACT*. The Australian National University. College of Science /Fenner School of Environment and Society.

Sjöman, H., Gunnarsson, A., Pauleit, S., and Bothmer, R. (2012). Selection Approach of Urban Trees for Inner-city Environments. *Arboriculture & Urban Forestry* 2012. 38(5): 194–204.

Sjöman, H., Hirons, A. D. and Bassuk, N. L. (2015) Urban forest resilience through tree selection: Variation in drought tolerance in Acer. *Urban Forestry and Urban Greening*, 14: 858-865.

Stewart, V.I., and J. Scullion. 1989. Principles of managing man- made soils. *Soil Use and Management* 5:109–116.

Symes, P., and Connellan, G. (2013) Water Management Strategies for Urban Trees in Dry Environments: Lessons for the Future. *Arboriculture & Urban Forestry* 2013. 39(3)

Urban, J. (2008). *Up by roots. Healthy soils and trees in the built environment*. International Society of Arboriculture.

Wahid, A., Gelani, S., Ashraf, M., Foolad, M. R. (2007). Heat tolerance in plants: An overview. *Environmental and Experimental Botany* 61 (2007) 199–223

Watson, G. (2018) Are there practical limits to urban tree species diversity? *Arborist News*, 27:4, International Society of Arboriculture.

Watson, G. W. and Himelick, E. B. (2013). *The practical science of planting trees.* International Society of Arboriculture.

Watson, G. W, Hewitt, A. M., Custic, M., Lo, M. (2014). The management of tree root systems in urban and suburban settings: A review of strategies to mitigate human impacts. *Arboriculture & Urban Forestry* 2014. 40(4), 193-217.

Watson, G. W, Hewitt, A. M., Custic, M., Lo, M. (2014). The management of tree root systems in urban and suburban settings II: A review of strategies to mitigate human impacts. *Arboriculture & Urban Forestry* 2014. 40(5), 249-271.

Webster, J. K. (2000). *The complete bushfire safety book, 3 rd rev. edn*., Random House, Milsons Point, NSW.

Williams, N. G. S., Hunter Block, A., Livesley, S. J (2012). *Responding to the Urban Heat Island: A Review of the Potential of Green Infrastructure*. Victorian Centre for Climate Change Adaptation.

Xu, Z., Zhou, G. and Shimizu, H. (2010). Plant responses to drought and rewatering. *Plant Signal Behaviour*. 5(6): 649–654.