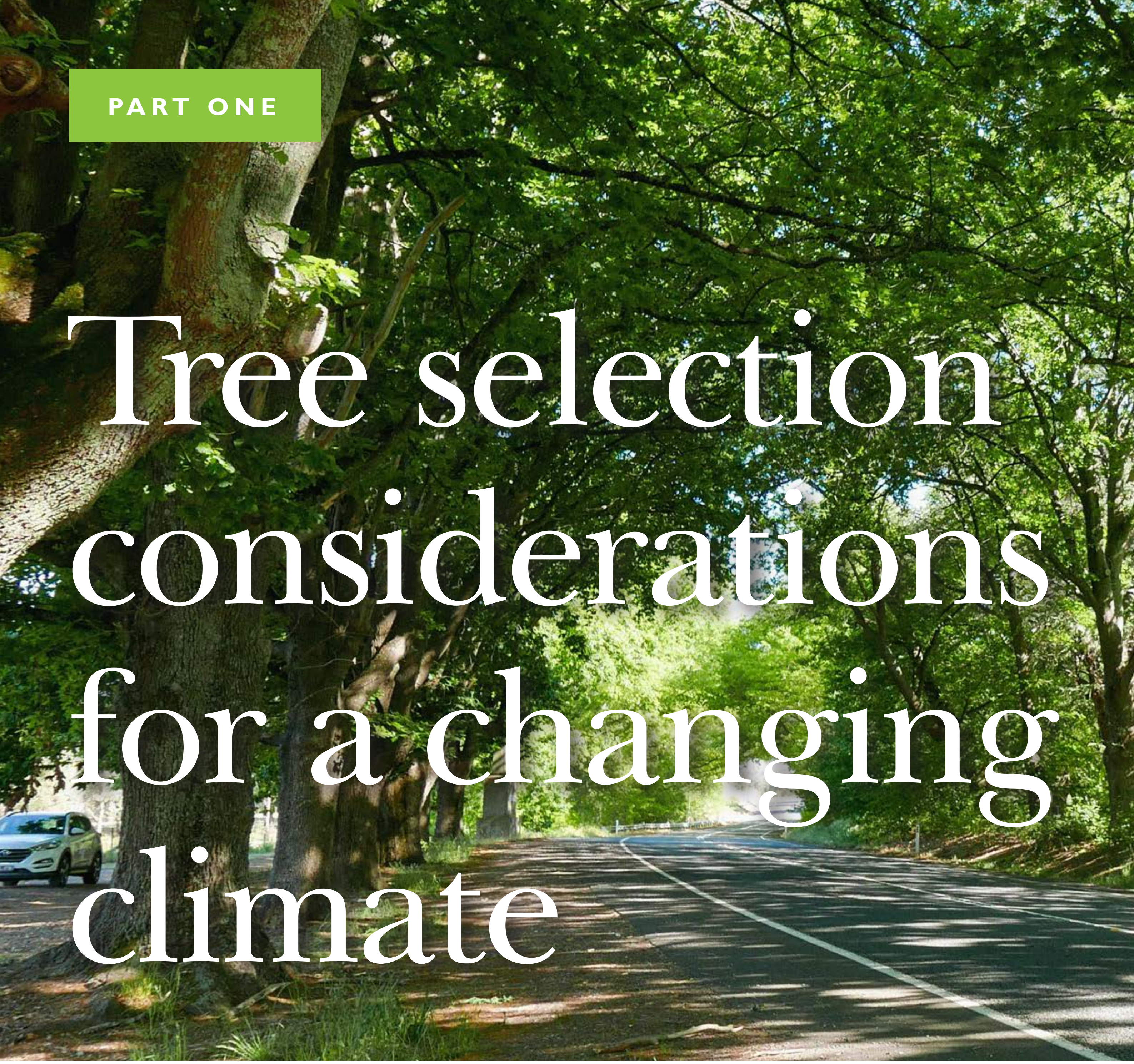
PART ONE

Tree selection considerations for a changing climate



By Stephen Frank
and Kirsten Raynor

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.

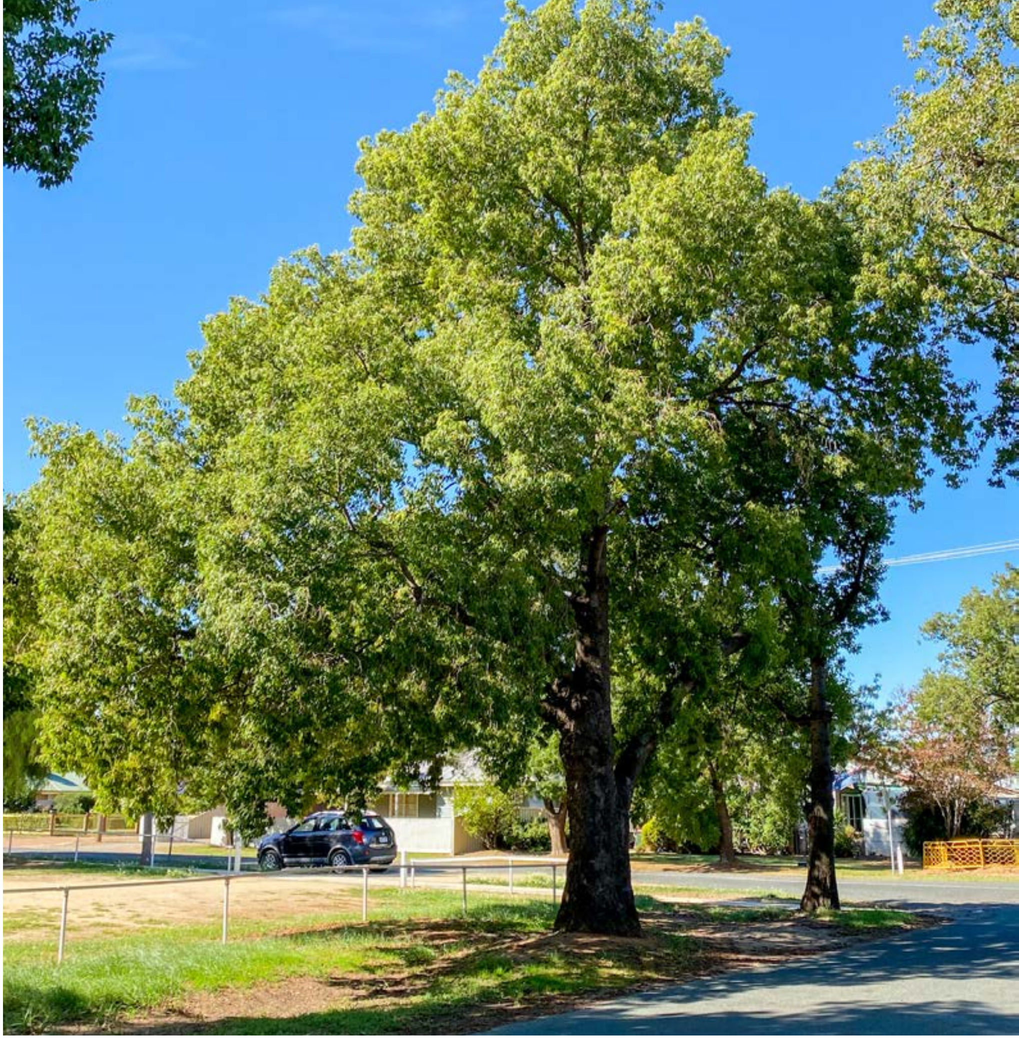
Above: English Oaks (*Quercus robur*). Yakandandah-Wodonga Road, Staghorn Flat. Photo: Stephen Frank

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. Unlike trees in the peri-urban and rural landscape, urban trees are subject to high levels of physical change in their environment, as well as the effects of climate change. 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).

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.

The primary objective in selecting trees for urban landscapes is to maximise the beneficial services they provide. The ongoing delivery of these services can only be provided by maintaining a healthy, resilient, and safe tree population that can be sustained through climate change impacts. It is imperative that



we understand fully the conditions and stresses that these trees must tolerate. As well as benefits, managers need to consider future maintenance costs. We should not lose focus on the fact that trees are living assets and require our constant and undivided attention in order to maintain them in a safe and aesthetically pleasing manner.

Predicted broad changes to the 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
- 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.

These predictions are dependent on the level of emissions. Higher ongoing emissions of greenhouse gases will lead to greater warming and associated impacts. Reduced emissions will lead to less warming and fewer associated impacts.

Effects on plant growth

It is expected that reduced rainfall, increased temperatures and more extreme heat days (intensifying 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 would potentially lead to widespread decline in tree growth and an increase in tree mortality.

The effect of warmer summers overall would be:

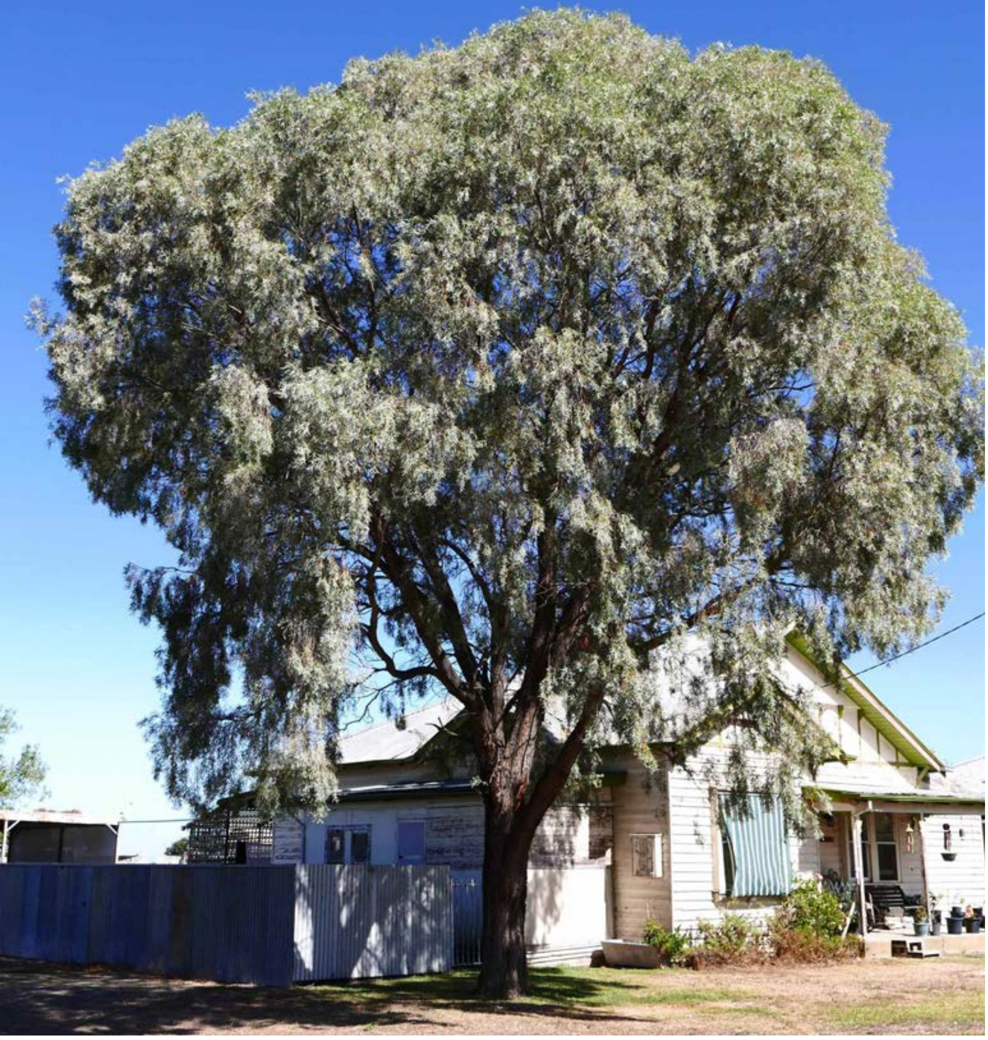
- More days exceeding 30°C
- More daily temperatures exceeding species-specific growth optimums
- Increase in the experience of heat stress (exacerbated by reduced access to water during these events)

Water, temperature 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 for 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 can be expensive and difficult to organise.

Also, as water loss in trees is primarily a physical process controlled by temperature, heat loading on trees must be understood and appreciated. Trees, hot temperatures, and water deficits are intimately bound together in a stress

Above, left: Kurrajong (*Brachychiton populneus*). Bromley St. Nathalia. Photo: Stephen Frank



syndrome. Any discussion of water in trees must deal with site heat loads to fully understand tree water stress and provide adequate water resources to alleviate such stress (Coder, 2012).

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. 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).

Tree selection in relation to climate change

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) (Burley, et. al., 2019). These models assume that climate, particularly precipitation, broadly drives native tree species distribution and, in combination with edaphic factors, determines which introduced tree species can successfully grow in an area.

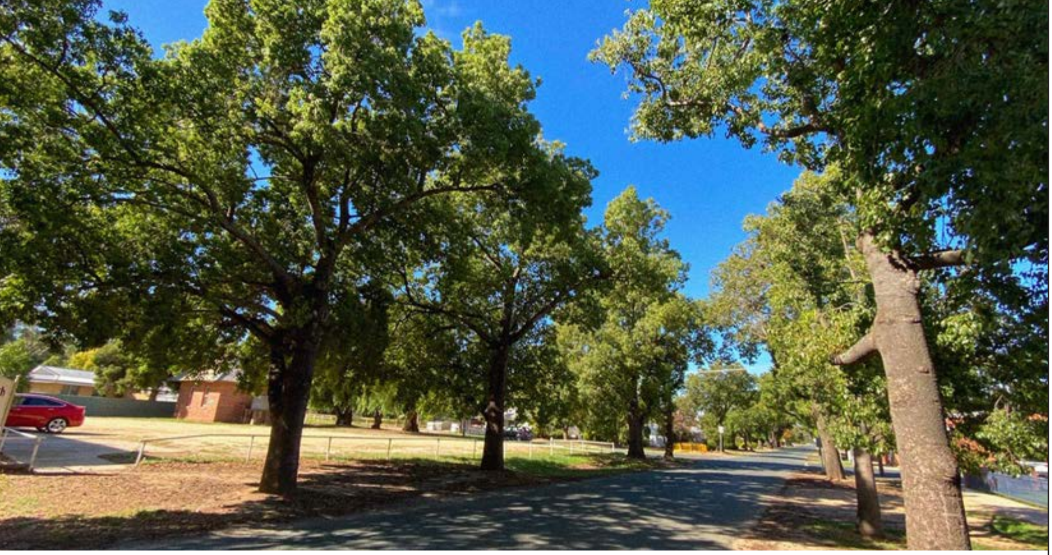
CSMs are widely used tools for forecasting climate impacts on species' suitability for an area. These models assess the relationship between the location of individuals of the species and the environmental characteristics of those locations, assuming that the species' environmental tolerances are described by the location of previously recorded individuals (Franklin and Miller, 2010). 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). CSM's provide a predictive framework to identify species less likely to survive under future climate within a region (Burley et. al. 2019). However, the general 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 of the taxa, will also influence the suitability of species for particular urban areas (Burley et. al. 2019).

Predictions of an area having negligible suitability for a species does not preclude that taxa from being grown there, however it does indicate that a higher input of resources may be required to sustain it. For instance, lethal temperature thresholds of species may be increased under supplemental irrigation or provision of shade (Burley et al, 2019). Specific planting or microclimatic contexts may also permit some plants to survive in areas that are broadly climatically unsuitable (such as within areas less affected by urban heat, reducing transpiration losses). Monitoring of tree health after extreme events would also help tree managers to identify individuals or taxa experiencing or tolerating stress.

Species selection can also be complicated by the genetic plasticity of trees, also known as phenotypic variability, under different site conditions. This is where

Above, right: Weeping Myall (*Acacia pendula*). Rockley St., Nhill. Photo: Stephen Frank



Left: Kurrajong (*Brachychiton populneus*). Avenue of Honour, Bromley St. Nathalia. Photo: Stephen Frank

individuals of the same species can express different characteristics or traits within different environments.

There is also the consideration that many species that are likely to be adaptable to climate change may be impractical for urban plantings, due to horticultural, functional or logistical considerations, such as propagation and growth rate to market, profitability, aesthetics, litter drop, aggressive roots or risks such as limb drop. Therefore, to comprehensively assess the suitability of new tree species, it will be necessary to undertake assessment of not only climate suitability, but also of species' traits such as physiology, phenology, and morphology (Burley et al, 2019).

Burley, et al., (2019) promote an approach that combines multiple lines of evidence to assess plant responses to climatic factors, including transient extreme events. They suggest using measurements from plant trait and physiological experiments (if available) to ascertain viable tree selections for the long-term.

Analysing a combination of information sources promotes a more holistic understanding of the suitability of taxa within a climate change scenario.

For tree selection purposes, species-level data should be 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). This information should be used in conjunction with the personal experience and knowledge of the horticultural/arboricultural team driving the tree selection process (Burley et. al. 2019).

Care must be taken to avoid the low road, identified by Brune (2016), of tree selection criteria reinforcing existing tree species due to dominant landscape character (for better or worse), being based on limited research provided from literature or growers, or being subjective in nature.

In short, it is difficult to predict the effect of climate change on vegetation, but it is highly probable that the availability of soil moisture will be the greatest threat to trees in the future. Tree selection criteria need to include consideration of multiple aspects, including tree physiology, horticultural realities and climate suitability models.

Part 2 (next issue) of this discussion will explore the specific constraints on plant performance caused by the urban environment and their ramifications on tree selection. It will also discuss the need to implement adaptive management and research to enable sustainable urban tree selections.

References

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

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.

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

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

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

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

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.

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.

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.

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