Tree traits for cityscapes

Ahead of his address for the annual RHS John MacLeod Lecture in November, **Andrew Hirons**, writing with **Henrik Sjöman**, urges the need to find ways to measure how urban trees might cope with an uncertain future

ANDREW HIRONS

An eclectic mix of plants in Brisbane, Australia. Genetic and taxonomic diversity needs to be high for urban forests to be robust.

TREES ESTABLISHED WITHIN the fabric of our towns and cities enrich the lives of those who encounter them. The evidence for the positive contribution trees make to society is extensive and comes from a diverse range of academic disciplines.

Economists can share examples of how landscapes with mature trees enhance property value, improve the financial performance of commercial districts or reduce the costs associated with stormwater management and energy usage (Mullaney *et al.* 2015). Medical experts testify that trees have important benefits for our health and wellbeing. Indeed, the massive loss of over 100,000,000 ash (*Fraxinus* sp.) trees in North America has been associated with an increase in human mortality due to higher levels of cardiovascular and respiratory disease. Environmental scientists studying urban microclimates advocate trees for their ability to improve thermal comfort through shading, evapotranspirational cooling or the provision of shelter from cold winds (Armson *et al.* 2012). Hydrologists recognize that trees can reduce the intensity of flooding events by intercepting rainfall and enhancing soil infiltration (Berland *et al.* 2017). Ecologists have demonstrated the value of trees in urban landscapes for birds (Le Roux *et al.* 2018) and insects (Somme *et al.* 2016). The multiplicity of benefits that trees bring to society is, therefore, without question: a well-placed, healthy, mature tree may be an asset whose value actually increases over time.

Given the potential magnitude of their value, it is essential that professionals engaged with growing, specifying and establishing trees in our urban landscapes are equipped to make strategic decisions that will enhance the quality and resilience of our urban forests for future generations.

The importance of diversity

There is general agreement that higher species diversity increases the resilience of ecosystems to future biotic and abiotic threats (Hooper *et al.* 2005; Smith *et al.* 2017). In the context of the urban forest, this assumes that the greater the range of species, the more likely it is that the health of fewer trees will be compromised by any single threat. Urban forests, or sectors of the urban forest, become more vulnerable if they are comprised of only a few dominant species as a significant climatic event, pest or pathogen outbreak may make it necessary to remove a high percentage of the trees. For example, by modeling the potential impact of Asian and citrus longhorn beetles (*Anoplophora glabripennis* and *A. chinensis* respectively) to Nordic cities, Sjöman and Ostberg

NEED TO KNOW

The Met Office's UKCP18 project uses cutting-edge climate science to make climate projections to 2100 in the UK and globally. **metoffice.gov.uk/research/collaboration/ukcp**

2008–2017 was around

1°C warmer

than the pre-industrial period (1850–1900), consistent with warming that has been observed at a global scale.

Under a high greenhouse gas emission scenario, the average UK summer rainfall could decrease by

up to 47% by 2070

(2019) showed the introduction of these two pests could lead to the near-total loss of the urban tree population. The analogous species composition between Nordic cities and many UK cities means similar losses would be expected if those pests were to establish in Britain. Additional threats to trees come from climate change. The increased frequency of drought events as well as more intense summer storms are likely to be particularly relevant to the health of trees (Webster *et al.* 2017). Consequently, strategic diversification of the urban tree population is critical for building resilience into the urban forest and associated green infrastructure.

Central to any attempts to diversify the urban forest is the process of species selection. Therefore, it is important to understand how species selection decisions are currently being made as well as develop new approaches to tree selection that will help ensure species resilience to future threats. In a survey of those selecting trees for urban environments, 60% of respondents always or mostly used tree nursery catalogues to make »

An avenue of ash trees on Belvedere Drive in Toledo, Ohio before (2006) and after (2009) the introduction of emerald ash borer (*Agrilus planipennis*). All these ash trees were lost; a scene replicated across temperate North America. The impact of this single pest has been devastating for many communities.

tree species selection decisions. This trend was consistent across all major professional groups: landscape architects, arboricultural consultants and local authority officers. Additionally, 37% of respondents went on to say 'experience' was important to them in their selection decisions.

These results have important implications for species composition within our urban forest. Despite many tree nurseries producing some excellent information, guidance tends to be dominated by the aesthetic features of trees, rather than by characteristics, such as stress tolerance, that are likely to dictate the long-term health of the tree. Furthermore, while experience is clearly a vital attribute for making tree selection decisions, it is necessarily backward-looking. The security of the urban forests of the future require foresight, not hindsight.

Trees have evolved through an iterative process of positive selection: small adaptations that give a competitive advantage persist within a species because it becomes more successful in a particular environment. Therefore, trees have effectively used 'hindsight' over millennia, but they cannot provide foresight. It is the role of those selecting trees to anticipate the conditions that will be faced by trees over their lifetime and choose taxa adapted to those conditions now.

Practical implications

This means that those selecting trees for the planting schemes of today must have an understanding of what the abiotic and biotic environment is likely to be in the future. They must also be equipped with knowledge and tools that synthesize relevant information and make it accessible to a wide audience. This sounds eminently achievable – and it is – but it does require a combination of strategic vision, policy, inter-disciplinary collaboration, science and effective knowledge exchange.

One approach that has the potential to be much

HOW DO PEOPLE CHOOSE TREES?

Results from a survey of those engaged with tree planting in UK green infrastructure responding to a question asking where they currently source guidance on tree selection from (n=223).

	Always	Mostly	Sometimes	Never
Dendrological literature	9%	20%	54%	16%
Online selection tools	3%	17%	58%	22%
Tree nursery catalogues	12%	48%	38%	1%
Recommendations from a tree nursery	4%	18%	67%	10%

more widely adopted is the use of plant traits (characteristics) that provide insight into the life-strategy of the species (or genotype) and its ability to tolerate relevant stresses.

In the urban environment, water deficits caused by a combination of climate, small soil volumes and impermeable surfaces are the main abiotic constraint for trees (Hirons & Thomas 2018). Therefore, a quantitative indication of drought tolerance should always be a fundamental consideration when assessing tree selection for urban environments.

Although strategies to cope with water deficit include avoidance of the stress by rooting into deeper soil-water reserves or restricting water loss from the leaves, strategies that enhance the tolerance of water deficit should be of most interest as they tend to provide the biggest increase in overall performance of trees in water-scarce environments.

Measuring drought tolerance

Traits such as the water potential at leaf turgor loss (Ψ_{P0}) can provide excellent information for those selecting and growing trees as it gives a quantitative measure of drought tolerance (Sjöman *et al*. 2015, 2018).

A more negative Ψ_{P0} allows the leaf to maintain physiological function for longer during the drying cycle (Lenz *et al*. 2006). Species that have a low (more negative) Ψ_{P0} tend to maintain leaf gas exchange, hydraulic conductance and growth at lower soil water potentials (Ψ_{soil}) so are at an advantage in situations where soil water deficits occur during the growth season.

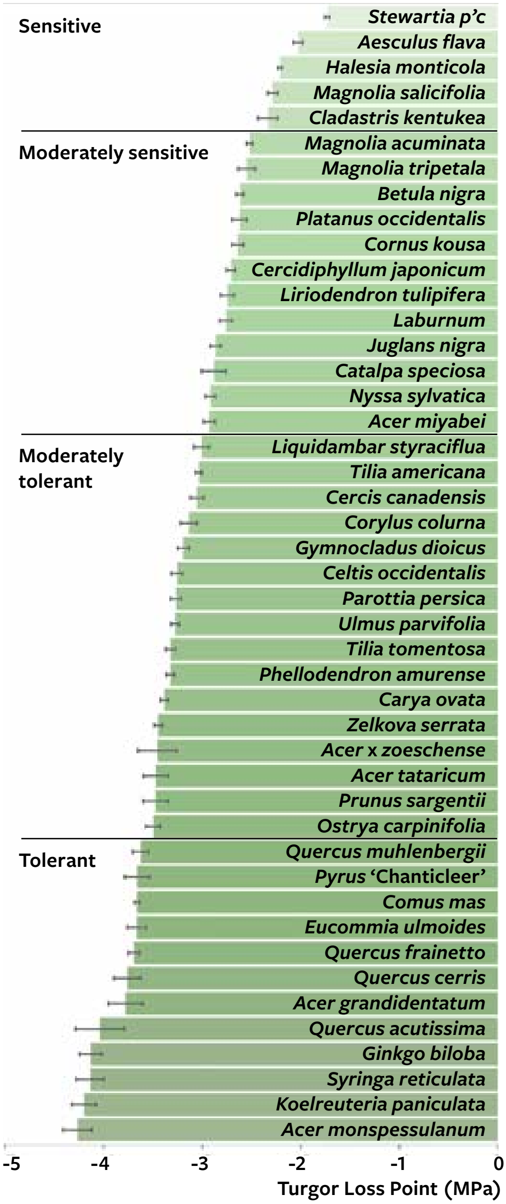
The Ψ_{P0} also provides a surrogate for the Ψ_{soil} below which the plant cannot recover from wilting (Bartlett *et al*. 2012). Therefore, Ψ_{P0} is a trait that provides information about a species' capacity to grow in dry environments and is particularly relevant for paved urban sites.

Another trait that has particular relevance to the ability of trees to survive periods of drought and water deficit is the stem water potential at 50% loss of hydraulic conductivity (Ψ_{P50}) (Choat *et al*. 2012). This quantitative measure estimates the point at which embolism within the xylem (the blocking of the vessel by an air bubble or cavity) reduces its ability to conduct sap by 50%.

Full vulnerability curves (that are used to track the loss of conductivity across a wide range of water potentials) provide even richer and more predictive information with regards to the drought tolerance of a species. »

LEAF TURGOR LOSS

The leaf turgor loss point can be used to rank species' drought tolerance. The most tolerant species have the lowest (most negative) leaf turgor loss point. Here 45 amenity tree species are ranked according to their turgor loss point using data from Sjöman *et al.* (2018).



Depending on the direction of climate change, trees in cities may have to deal with more and longer periods of sustained drought.

Problems in application

In spite of the clear advantages to knowing this type of trait-based information, a number of challenges to their widespread application exist. This level of information is only available for a relatively small number of amenity tree species. Additionally, the collection of this type of information requires specialist knowledge, skills and equipment.

However, a recent project sought to integrate trait-based information into guidance. *Tree Selection for Green Infrastructure: A Guide for Specifiers* (Hirons & Sjöman, 2019 – available for free at www.tdag.org.uk) utilizes traits relating to drought tolerance to justify more readily interpreted qualitative statements. For example, from our own dataset of approximately 200 species, the Ψ_{P0} was used to inform the drought tolerance ranking: generally, species with a Ψ_{P0} of > -2.5 MPa were classed as sensitive; -2.5 to -3 MPa as moderately sensitive; -3 to -3.5 MPa as moderately tolerant and <-3.5 MPa as tolerant. At a more fundamental level, this guidance was designed to provide independent, transparent advice to those wishing to recommend species based on the suitability of the tree to a site, rather than more superficial aesthetic attributes prominently advocated by much of the nursery literature.

Work is ongoing to develop the range of species for which we have trait-based information as well as the range of traits that might yield meaningful information for those tasked with recommending tree species for a changing climate and challenging urban sites. This will continue to involve collaborations between academic institutions, botanical collections and nurseries to carry on the fundamental research as well as organizations such as the Royal Horticultural Society and Trees and Design Action Group to help disseminate information to a wide range of professionals and amateurs engaged with tree planting.

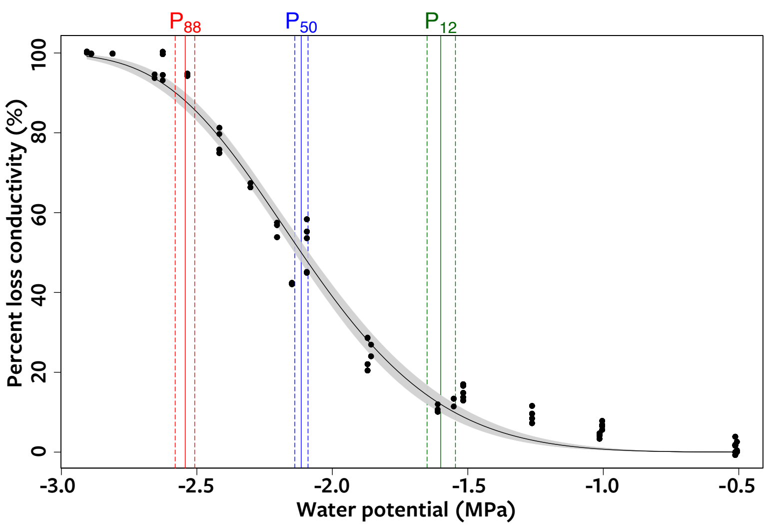
At a time where the role of trees in society is

XYLEM VULNERABILITY

The xylem vulnerability curve for *Cercidiphyllum japonicum*.

The curve estimates the percentage loss of hydraulic conductivity to a declining stem water potential. P_{12} indicates the water potential at 12% loss of hydraulic conductivity (-1.60 MPa); P_{50} indicates the water potential at 50% loss of hydraulic conductivity (-2.11 MPa); P_{88} indicates the water potential at 88% loss of hydraulic conductivity (-2.54 MPa).

P_{50} is a widely used plant trait that allows the comparison of species' vulnerability to drought-induced embolism.



FREE DIGITAL GUIDANCE

Tree Species Selection for Green Infrastructure: A Guide for Specifiers **is freely available digital guidance that incorporates plant traits into the information regarding the stress tolerance of many species. It also includes information on the use-potential of the species, tree size and crown characteristics, environmental tolerance, ornamental qualities, issues to be aware of and notable cultivars.**

being increasingly recognized, it is essential that selection decisions are as robust as they can be and are made with foresight, not hindsight. We must strategically diversify our urban forests with species that have an appropriate degree of stress tolerance for future conditions. We must also strategically diversity to mitigate the threat posed by a variety of pests and pathogens. The future resilience of our urban forests, parks and gardens depends on it. **O**

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JOHN MACLEOD LECTURE 2019

Will take place at 2.30pm on 7 November at Broadway House, London. Attendence is by invite only. Any remaining tickets will be made available to RHS members from October. Members can register their interest in the extra tickets now. For everyone wanting to watch the lecture, a live internet stream will be available.

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