Thesauruses, not encyclopaedias

HARRY WATKINS[1] (St Andrews Botanic Garden) and HENRIK SJÖMAN (Gothenburg Botanic Garden) describe some of the difficulties in ensuring that the specified plants are used in new townscapes and suggest some practical steps for improving tree selection in urban forestry.

It's hard not to feel that the forester's mantra of the 'right tree for the right place' is something of a unicorn for those working in urban environments. How often do we see new developments with houses laid out along streets lined with cherry trees and birches, when we know that the shallow-rooted cherries will soon be lifting paving slabs and the pioneer birches don't stand a chance of reaching maturity in the faces of the stresses these streets create? The tragedy is that in spite of the unprecedented appreciation for urban nature and the ever-growing range of guidance and regulation, we continue to see the wrong tree in the wrong place. This tragedy is an open secret in our industry but whilst the existential threats posed by biosecurity and climate change grab the headlines, there are more prosaic reasons why the quality of urban tree planting in the UK is slow to adapt. In this article, we will explore blindspots in UK policy development and practice, and suggest pragmatic ways of resolving these so that we can then address the existential threats more effectively.

We know that provenance is key not only in terms of the production of plants but also in terms of the adaptive processes that give each tree its unique combination of qualities but do we know where our trees marked for urban plantings actually come from? In a recent research exercise (Sjöman & Watkins, 2020), we found that we know very little: we approached 24 of the biggest tree nurseries in northern Europe and focusing on five widely available species, asked questions such as 'Do you know where your material for these species was propagated,' 'Do you know what country the parent material originated from,' and 'What sort of habitat did the parent material came from?'. Perhaps the largely negative answers to these questions should not be surprising but they illustrate a serious challenge for biosecurity and make it impossible to handle complex biological considerations such as intraspecific variation, let alone select the right tree for a given place in a sensitive or detailed manner.

A complementary study is being carried out by St Andrews Botanic Garden and Forest Research (the research arm of the UK Forestry Commission), asking developers simple questions about urban forestry in new projects, such as 'Which taxa are most frequently specified?' and 'Which taxa are the most frequently planted?' (these are rarely the same thing), and to what extent the specifications respond meaningfully to location, habitat or land use. The answers, sadly, paint a worrying picture: in spite of (or perhaps because of) the recent efforts to improve the planning process which oversees large scale developments, we are finding that across England and Scotland only 25 to 40% of new developments actually deliver the approved plans that were submitted by developers. Bear in mind that these are plans that are designed by the developers themselves and once approved, are legally binding! We found that as suspected, inappropriate maintenance during the first year of establishment plays an important role in this failure but very often the tree-lined avenues or shrub beds in the plans are not even planted in the first place.

This research provides data on a situation that many in the industry know at some level but are reluctant to admit. Until we have data, changing policy and practice will remain difficult. Moreover, these research exercises are purely observational and to get to the bottom of why this situation arises, we produced a report for Defra in 2020 that explored how landscape architects, contractors and nurseries collaborate to select trees and plant them in urban and peri-urban areas. Encouragingly, we found that governmental policy on biosecurity and climate change is increasingly well-understood by each sector but that two core problems prevent policies from being implemented: a lack of the right data to enable urban foresters to make informed decisions, and a lack of integration between the format in which information is produced and the systems that professionals use to carry out their work. The encouragement we take from this is that these two issues are more easily resolvable than biosecurity risks or climate change, and if resolved will be transformational to our ability to address these global challenges.

When it comes to tree selection, the urban forester has a wide range of resources to draw upon. Our research for Defra found that of these resources, landscape architects in the UK draw most upon nursery catalogues, followed by industry guidance and horticultural encyclopaedias. Frustratingly for those working in both academia and practice, we found that original academic research was barely considered, and that the data provided in industry-specific software such as AutoCAD, Vectorworks or Revit was used least of all. Whilst this is no doubt encouraging for nurseries, it points to a fundamental issue that we reported in a study of *Magnolia* literature (Watkins *et al*., 2020), which found that this 'heuristic' literature is the least accurate or robust when it comes to describing what conditions a tree will tolerate. The tension here is that the horticultural literature focuses on describing ideal growing conditions based on personal experience, rather than the stresses a tree is capable of handling before it slows growth or enters terminal decline, and the challenge that confronts an urban forester is rarely one of how to create ideal growing conditions: we need to know how far we can push a taxon out of its comfort zone so that we can make an informed decision about whether a tree is likely to be able to withstand future conditions.

This same research found that the most useful work for these purposes is being carried out by ecologists working at the intersection of biogeography and

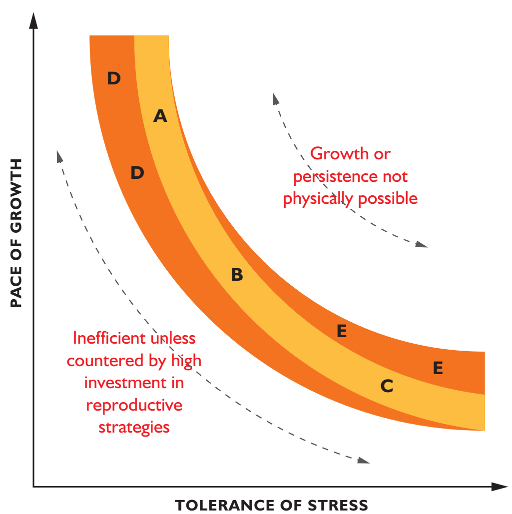
[1] The IDS awarded a grant to Harry Watkins in 2018 to travel to Japan to study *Magnolia* species in the wild and assess their potential for urban sites as part of his PhD.

plant traits. The challenge here is that these are research fields that the urban forestry industry is barely engaged with at the moment, and that overcoming the task of translating the work in these fields into formats that can be used by urban foresters will require substantial effort in terms of collecting the right data and changing the way that urban foresters access that information.

Some might quite reasonably say that trait data are noisy, the dynamics between traits are hard to elucidate or that the methods to capture them are often coarse, and that every decision is site-specific but the response to the question of what the right tree for the right place is cannot be 'it depends'. The lessons of chaos theory have reinforced the mythos that everything is connected but one of the lessons of plant trait research is that not everything is connected equally. Complex multidimensional stress environments like paved streets are capable of surprising us, especially under climate change, but nonetheless, system responses tend to be driven by a small subset of interactions. If we want to progress beyond heuristics and old favourites, we need a framework for embracing probability. The principle of making testable predictions and confronting them with data is at the heart of the scientific method, and urban foresters need to become more comfortable with literature that embraces this process, rather than reaching for the familiar manuals or catalogues: we need thesauruses, not encyclopaedias which give us strict definitions.

Trait-based ecology allows us to quantitatively describe specific charac-

Figure 1a.



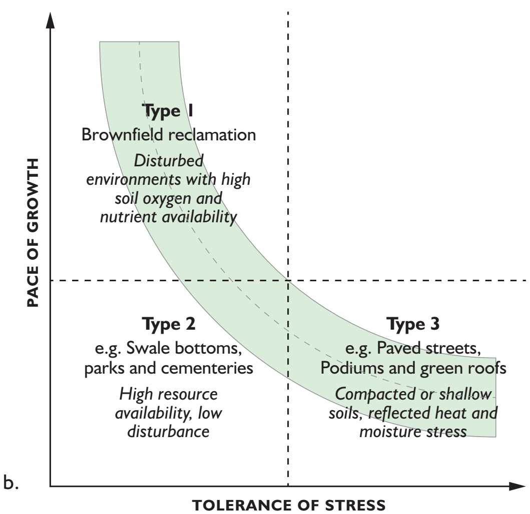
A rubric for matching trees to urban sites, showing the variety of viable plant strategies in a trade-off between fast growth and high tolerance of stress. In Fig 1a, positions A and C equate to different extremes of the trade-offs between competitive-stress tolerant strategies, with position B representing a generalist strategy. A greater investment in reproduction and faster growth is required in disturbed environments, resulting in more ruderal strategies (D), whilst in more

teristics. For example, a study of the genus *Acer* (Sjöman, Hirons and Bassuk, 2015) showed how a dimension of variation can describe important traits such as drought tolerance. The next challenge is to understand how this can be understood in the context of alternative evolutionary strategies (such as drought avoidance) or other axes of variation, such as reproductive ability or vigour. The seminal work by Sandra Diaz (Díaz *et al.*, 2016) goes a stage further, showing how these traits are traded off against each other in predictable but endlessly variable ways resulting in the spectrum of plant form and function that fascinates dendrologists. This exciting research begs the question, how can we harness these insights to better match a particular tree to a specific site?

In a recent work (Watkins *et al.*, 2021), we proposed a way that urban foresters could do just that. By testing which traits are most effective at describing the pace at which plants grow and the extent to which they are able to tolerate stresses, we developed a rubric that would allow us to visually understand how species might differ and in turn, what sort of applications they might be suited to (Figures 1a and 1b). Excitingly, this method appears to be both sensitive enough to identify fine scale variation within a species but also robust enough to distinguish differences at the level of genus or species too (Figure 2, overleaf).

It is essential that these steps are used to generate hypotheses that are tested in practice, and it will be interesting to see how far we need to tune our

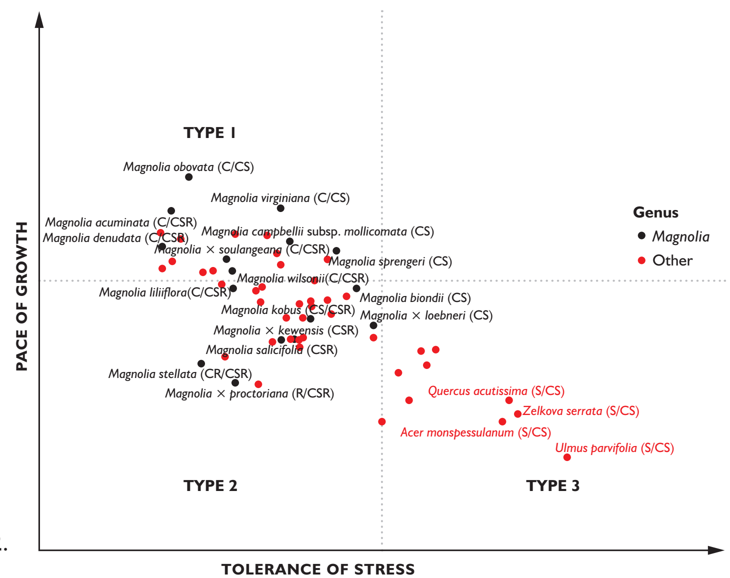
Figure 1b.



stressful situations, delayed sexual maturity allows for greater investment in dense structural and photosynthetic tissues (E). Note that unlike other similar graphs, the trait trade-off is fitted by a quadratic rather than linear line of best fit. Figure 1b overlays environments found in urban forests upon this model, resulting in a method for best fitting tree species to urban forestry sites. From (Watkins *et al.*, 2021).

understanding of these traits in order to select species with confidence. The IDS has generously supported some of this research and one of the key findings from our investigations into the variation of magnolias across Japan and the Kurile Islands was that whilst these methods are sensitive enough to identify intraspecific variation, some species vary more than others in response to climate and competition than others. *Magnolia obovata* (opposite), for example, is typically a competitive and fast-growing tree regardless of whether it is in northern Kyushu or southern Kunashir, whilst *Magnolia salicifolia* varies greatly between stress tolerant and pioneer strategies in response to factors such as annual rainfall. Given that the range of these species overlap so much, unpicking why and how this is the case will need to be investigated. Nevertheless, with progress being made on these methods, it will be possible to harness the big data sets that are collated globally by ecologists (Maitner *et al.*, 2018; Kattge *et al.*, 2020) coexistence, biogeography, evolution, and many other fundamental biological processes. Understanding these processes is critical for predicting and handling human-biodiversity interactions and global change dynamics such as food and energy security, ecosystem services, climate change, and species invasions. The Botanical Information and Ecology Network (BIEN) and meteorologists (Fick and Hijmans, 2017) and rapidly scale up species selection guidance for towns and cities around the world.

Figure 2.



Finding the most appropriate places for *Magnolia* species in urban environments, from (Watkins *et al.*, 2021). The letters in brackets after the species name refer to the species ordination with CSR space (Grime and Pierce, 2012).

photograph © Harry Watkins

Magnolia obovata, largely indifferent to its climate in Kaisho Forest, near Seto.

In an ideal world, an urban forester would be able to use these methods to give a nursery a list of desired taxa alongside a shortlist of acceptable alternatives, and the non-plant specialist project client would thereby have a transparent way of knowing whether what has been delivered to site is in line with the original objectives of the designer. In a number of sites that we studied across England and Scotland, we found that substitutions were regularly made by a contractor or nursery not knowing the original intentions of the project: in some cases this was as simple as substituting *Davidia involucrata* for *Pyrus calleryana* 'Chanticleer', but in its worst cases we saw an avenue of oak trees being substituted for rows of *Phormium tenax*. In this case, the client didn't know that what had been delivered was a long way removed from what they had ordered, and didn't have the means to know that they had been duped.

This process of data-driven tree selection will be transformational for the effective delivery of ecosystem services, allowing taxa to be compared on equal and transparent criteria. One of the outcomes will be that species or genotype recommendations can be made based on weightings (e.g. compacted soils or high reflectance of heat) that are judged by an urban forester, and crucially, this process allows us to judge what acceptable alternatives might be if a desired taxon is not available from a nursery. The mantra of 'the right tree for the right place' implies that there is only one right tree but if we can think in terms of spectrums of possibility rather than a rigid specification from a landscape

Harry Watkins with James Hitchmough and Henrik Sjöman, his PhD supervisors, in Hokkaido.

architect, it is possible to revisit the way that specification takes place in the urban forestry industry. In the face of existential threats to our urban forests it's too easy to feel overwhelmed but there are many dimensions to the challenges we face that can be addressed by taking practical steps. Practical does not mean simple, of course, but they are within our grasp and the international dimension of the IDS membership provides encouragement that there are global networks of committed dendrologists who want to see trees thrive in our towns and cities.

References

Díaz, S. *et al.* (2016). 'The global spectrum of plant form and function', *Nature*. Nature Publishing Group, 529(7585), pp. 167–171. doi: 10.1038/nature16489.

Fick, S. E. and Hijmans, R. J. (2017). 'WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas', *International Journal of Climatology*, 37(12), pp. 4302–4315. doi: 10.1002/joc.5086.

Grime, J. P. and Pierce, S. (2012). *The Evolutionary Strategies that Shape Ecosystems*, *The Evolutionary Strategies that Shape Ecosystems*. doi: 10.1002/9781118223246.

Kattge, J. *et al.* (2020). 'TRY plant trait database—enhanced coverage and open access', *Global Change Biology*, 26(1), pp. 119–188. doi: 10.1111/gcb.14904.

Maitner, B. S. *et al.* (2018). 'The bien r package: A tool to access the Botanical Information and Ecology Network (BIEN) database', *Methods in Ecology and Evolution*, 9(2), pp. 373–379. doi: 10.1111/2041-210X.12861.

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*. Elsevier GmbH., 14(4), pp. 858–865. doi: 10.1016/j.ufug.2015.08.004.

Sjöman, H. and Watkins, J. H. R. (2020). 'What do we know about the origin of our urban trees?—A north European perspective', *Urban Forestry and Urban Greening*, 56(May). doi: 10.1016/j.ufug.2020.126879.

Watkins, H. *et al.* (2021). 'Can trait-based schemes be used to select species in urban forestry?', *In prep.*, pp. 1–37.

Watkins, J. H. R. *et al.* (2020). 'Using big data to improve ecotype matching for Magnolias in urban forestry', *Urban Forestry & Urban Greening*. Elsevier, 48(January). doi: 10.1016/j.ufug.2019.126580.