STREET TREE PLANTING: SOME RECIPES FOR SUCCESS AND PRESCRIPTIONS FOR FIRST AID

G M Moore

School of Ecosystem and Forest Sciences, University of Melbourne, Burnley College, University of Melbourne, 500 Yarra Boulevard, RICHMOND, AUSTRALIA 3121

Abstract

After 20 years of TREENET symposia, there is a much better understanding of what makes a street tree planting successful. Proper tree selection and using the highest quality stock are a great start, but problems with planting technique are still too common. Trees are planted too deep or shallow and the process of planting can contribute to site compaction. Even the mulch and paving materials surrounding street trees can affect their success.

Street trees can benefit enormously from cost-effective formative pruning. However, this simple and efficient technique is still practised rarely in municipal horticulture. Even simple maintenance such as deadwooding canopies is often forgotten. Many street trees suffer damage and wounds from neglect or the human activity that takes place around them. Appropriate action such as bark grafting and the use of epicormic and lignotuberous shoots can quickly restore the amenity of a tree.

In an era when the use of drones and ground penetrating radar allows better inspection of tree canopies and root systems, it is disappointing that street tree plantings often fail through ignorance and the failure to apply basic arboricultural principles. This paper is a timely reminder of what can be done to make street trees great again.

Introduction

In Australia, a forest is defined by a tree canopy cover equal to or greater than 30%; less than this is woodland. So if the term urban forest is to be widely used then should canopy cover also be equal to or greater than 30% or if not, is it really an urban woodland? As we know, language and words matter as they connote concepts and meaning. When the term urban forest is used does it connote a canopy cover that is greater, and often far greater, than the reality of woody cover in Australian cities?

In general, to maximise the benefits that canopy can provide in terms of environmental services requires a canopy cover of about 30%. Once the figure exceeds 30%, the law of diminishing returns takes effect and there is relatively little extra benefit for the increased cover. In work on the effect of trees on Brisbane house sale prices, Plant (2017) found that while street trees nearby added up to a 3.7% premium on median house price, positive effects of trees growing on the property were capped at a threshold of no more than 20% tree cover, after which greater cover led to a decrease in value. The recurrence of a canopy cover figure around or approaching 30% prompts the rhetorical and tongue-in-cheek question, “Is 30% an arboricultural magic number?” It also prompts a conclusion that the target tree canopy cover for cities in Australia, under current climate change scenarios, should not be less than 30%.

The task of achieving acceptable levels of tree cover in Australia’s cities and suburbs is daunting. Reporting the work of Jacobs et al (2014) at TREENET in 2017, it was noted that over half the local government agencies in greater Sydney, Melbourne, Adelaide and Perth had less than 20% canopy cover, and that in Melbourne canopy cover was being lost at a rate of 1-1.5% per annum (Moore 2017). In its recent *Living Melbourne: Our Metropolitan Urban Forest* report, The Nature Conservancy (2019) reported the current tree canopy cover and the targets of cover proposed for different regions of Melbourne by 2050 (Table 1). It is pleasing to see that in some regions of Melbourne (Eastern, Inner South East and Southern) a 30% goal for canopy cover by 2050 has been set and that for two other regions and for Melbourne as a whole a target of over 27% has been listed. But for the west it remains at less than 20%, which raises the questions, “Why 27% in places and not 30%?”, “If the target is so close to 30%, why not aim just a little higher?” and “Why is the target for the west so different from the other regions and so low?” The canopy cover can be seen as an indirect index of sustainability, quality of life, human health and well-being and socio economic status, none of which are to be taken lightly as they directly affect peoples’ lives. Indeed they can be matters of life and death and certainly impact on peoples’ longevity.

Table 1 .Current and Targeted canopy cover for Metropolitan Melbourne by 2050 (The Nature Conservancy 2019).

Region	Current canopy cover (%)	Target canopy cover – 2050 (%)	Target Canopy increase (%)
Eastern	25.2	30.0	4.8
Inner	12.5	27.5	15
Inner South East	21.7	30.0	8.3
Northern	12.1	27.1	15
Southern	16.4	30.0	13.6
Western	4.2	19.2	15
Metro Melbourne	15.4		

Given the arboricultural magic number of 30%, it seems logical to suggest that all the regions have the same target of 30%. It may be argued that some regions with historically fewer trees should have lower targets. However, suburbs are suburbs regardless of their vegetation history and the issues being faced under climate change relate to urban development. It seems reasonable that given the regions are essentially similar suburban parts of Melbourne, the 19.2% target for the western region should be questioned. Such a low target would seem destined to entrench the lower socio-economic status of this part of the city rather than aiming for 30% which would play a part in redressing some of the imbalance. There is also concern that by not aspiring to a higher target, the opportunity for achieving a high cover will be lost permanently as planning and development will be so intense that there will be no space provided for tree planting. It might be argued that having lofty targets, where half of the regions would have to double their current canopy cover, is unrealistic, even daunting – why set a target that cannot be achieved! However, by having lower targets the desired cover of 30% and the multiple benefits that it confers on a region will never be achieved.

While it is commendable that there is an aspiration to achieve an increase in canopy cover by 2050, the truth is that in most regions, and despite the best efforts of local governments and programs like 20/20/20 Vision, canopy cover is declining at a rate of 1-1.5% per annum largely due to tree losses from private open space (front and back yards) (Moore 2017). At the 2019 Arboriculture Australia conference, McManus (2019) presented a fine case study on canopy cover in the suburb of North Sydney. With a traditionally high suburban canopy cover, it seemed that their goal of 30% canopy cover would be achieved relatively easily, especially when they had moved from 19% in 1997 to 33.9 % in 2008 (Table 2). However, by 2014 a decline in cover was becoming evident and by 2017 the cover had fallen to 28%.

Table 2 .Targeted canopy cover and changes in canopy cover in different parts of North Sydney from 1997 to 2017 (McManus 2019).

Description of land type	% of LGA	Canopy target	1997 %	2001 %	2008 %	2014 %	2017 %	Decline since 2008
Overall canopy cover	100	34.4%	19	24	33.9	30.7	28.2	5.7
CBD	10	15%			16.5	13.5	14.2	2.3
Urban	48.3	25%			32.4	28.8	26.9	5.6
Suburban	41.7	50%			39.8	37	33.0	6.8
Public Land	25.7				50.5	52.8	50.0	0.5
Private Land	58				31.6	26.4	24.0	7.5
Roads	16.3	30%			28.1	26.1	23.4	4.7

There is a recurring pattern in this declining canopy cover across Australia. Cover on public land is relatively stable and local governments have policies seeking to increase the tree canopy cover of their region, but despite this, overall canopy cover is falling. In some instances virtually every available space in public open space for tree planting is occupied but due to tree losses in urban and suburban private open space due to in-fill development, along roads and in heavily urbanised districts, the number of trees and their canopy cover declines (Table 2). Overall canopy decline in North Sydney has been 5.7% with the greatest contributors to loss being from suburban and private land. The imperative of retaining current tree cover and expanding it has never been greater. It is essential that when we plant street trees not only are we successful, but that the trees we plant need to persist and reach the full potential of their life spans.

After 20 years of TREENET symposia, there is a much better understanding of what makes a street tree planting successful. However, whole tree planting schemes still fail and multiple tree failures in an otherwise successful planting are common. Lack of success may be due to failure in the planning, implementation or management phase of a street tree planting project. These failures are costly to the authorities responsible for them and to society as a whole, but there are opportunity costs and the loss of environmental and ecological services associated with such failures. Amenity is diminished, time and resources are wasted and a future generation is deprived of an asset.

The long-term success of street tree planting relies upon early tree establishment and long-term performance, which are different aspects of street tree growth. Tree establishment relates to the extension of the recently planted root system into the backfill soil which increases the available resources to and stabilizes the tree. It also relates to adequate canopy health, structure and growth which allow successful street tree performance in the long term. Tree performance is assessed by how the tree grows within the landscape over time and is often characterised by measures such as growth rate, height increment, canopy spread and density and measurements of girth increase (Leers et al 2017). The term tree establishment is commonly used by urban tree managers but rarely defined. In this paper, establishment of street tree stock is defined as the tree being of an acceptable height for its species and age, having a good canopy spread and density and being stable in the ground two growing seasons after planting (Leers et al 2018).

In an era when ground penetrating radar and the use of drones allow better inspection of tree canopies and root systems, it is disappointing that street tree plantings often fail through ignorance and the failure to apply basic arboricultural principles. In any endeavour management can only be as good as the quality of the information that informs it. Urban street tree management requires accurate measurement and quality data that can inform the decisions made. This paper is a reminder of some of the things that can be done to make street trees great again.

Some Recipes for Success

Purpose, design and species selection

Before any tree is planted in a street, there should be a clear design intent that specifies what the planting is expected to achieve. While species' genetics and aesthetics may be components of the design intent and brief, other factors such as the provision of shade, water management, carbon fixation, and other environmental and ecological services have their place (Table 3). It is re-assuring that the list of benefits provided by trees has expanded significantly over the past couple of decades as multi-disciplinary research into urban trees has developed and increased the understanding of the benefits that trees provide, and the list continues to expand. Tree planting in public open space has always been multi-functional and many factors must be considered in the design and subsequent species selection. Proper tree selection and using the highest quality stock are a great start. The use of AS 2023: 2015 Tree Stock for Landscape Use has an important role to play but must be specified in tender documents and purchase contracts to be effective.

Table 3. Some of an expanding list of benefits provided to society by urban trees.

Biodiversity	Shade/thermal comfort	Human health - mental
Aesthetics	Human health - physical	Increase biodiversity
Air quality/pollution reduction	Increased employment	Flood mitigation
Air quality/humidification	Stormwater management	Food production
Moderation of wind	Recreation – active/passive	Tourism
Noise abatement	Increase property value	Increase biodiversity
Water quality management	Provide habitat	Noise abatement
Carbon sequestration	Reduced vandalism/graffiti	Reduction in sun glare
Soil Management	Reduced crime/violence	Human well-being
Urban heat island management	Pollination	Heritage conservation
Altered effective precipitation	Better education outcomes	Dust control

Tree establishment

Successful street trees require effective and efficient tree establishment which can be assessed using the criteria recommended by Leers et al (2018) such as, appropriate planting depth, whether trees exhibited trunk movement at or below the soil surface, damage to the trunk, whether there were co-dominant stems, and presence of epicormic shoots on the trunk/branches (Table 4). The Burnley test (Figure 1) proved a simple, effective and reliable indicator of tree stability and a test of root system establishment. Criteria such as these require measurement and management of the data acquired, but they effectively replace the subjective assessment of street tree establishment and performance that has so often been the hallmark of horticultural management with objective assessment and quantitative data.

Table 4. Practical criteria for assessing street tree establishment (Modified from Leers et al 2018).

CRITERIA	Implications for tree establishment
Whether trees had been planted too deeply or too shallow	Poor root system development
Trunk movement at or below the soil surface	Burnley test indicates root system development which can adversely affect establishment
Damage to the trunk	Reduced canopy growth and poor tree establishment
Trunk sunscald injury	Reduced canopy growth and poor tree establishment
Epicormic shoots on trunk/branches	Indicator of general tree stress
Co-dominant stems.	Poor form requiring structural pruning
Canopy dieback	Indicator of general tree stress and poor establishment
Shoot tip extension	Allows a quantitative measure of canopy growth

Reliable, accurate, objective and practical indicators of whether street trees have successfully established can inform decisions about irrigation, formative pruning, removal of supporting stakes and ties, the monetary value of an individual street tree, pest and disease management and whether poor performing trees should be removed and replaced. In some jurisdictions there are legal or regulatory implications that arise once a tree is established. AS 4970 - 2009 Protection of Trees on Development Sites, for example, stipulates that the standard only applies to established trees. In other situations, site plan agreements or requirements may stipulate that trees will be inspected to determine if they have successfully established, whether trees will be then accepted or removed and when, or if, final payments to contractors will be approved.

Figure 1. The Burnley test for investigating street tree stability and root development

Soils, compaction and tree selection

In a study of street trees growing in the Western region of Melbourne, it was shown that there were considerable differences in compaction and penetrative resistance on different sides of the same street tree (Fitzgerald 2012). This suggested that the insertion and levering of the mechanical spade used in creating the planting pits compacted the soil on one side. Specifying that the sides of the planting holes need to be decompacted after planting, or perhaps more proactively and simply, that the soil surrounding the planting hole must not be compacted in the process of planting should be written into street tree planting contracts. The use of good mulch, discussed later in this paper, is also an important part of successful tree planting.

In the same study, it was suggested that street trees growing in this soil type (basaltic clay) could be placed into three categories based on their growth in compacted and uncompacted urban soils (Fitzgerald 2012).

Category 1: trees increased growth in compacted soil, were more tolerant of soil compaction than other species and may not require soil amelioration prior to planting.

Category 2: tree growth was unaffected by compacted soil. Trees were tolerant of soil compaction, but may benefit from site amelioration to alleviate compaction for optimum growth. They will grow adequately if the soil remains compacted.

Category 3: trees had reduced growth in compacted soil. Trees did not tolerate soil compaction and site amelioration would be necessary for growth. These species may be unsuitable for compacted soils.

Categorising tree species in this way for other soil types and climates could be useful to urban tree managers in informing their approach to and procedures for street tree selection and planting.

Correct planting

Problems with planting technique are still common. Planting advanced stock too deeply (or more rarely too shallow) is still a regular occurrence, which can affect street tree establishment and performance. This has been a matter of concern for over forty years and something this simple should no longer be a problem. However, several recent studies have confirmed that up to 25% of some street tree plantings have-not been planted at the correct depth (Leers et al 2018). Planting depth specifications are usually quite clear, but too often they are not enforced.

Formative pruning

In their research on formative pruning, Ryder and Moore (2012) reported that only 22% of the young, newly-planted street trees surveyed were without structural defects and that species such as *Pyrus calleryana* were prone to such high rates of defects that their selection for street tree planting could be questioned. Structural defects were clearly defined (Table 5) in a way that would enable their identification and rectification to be part of routine street tree management. The defects can be counted and assessed giving quantitative data for use in future decision making. About a third of the trees surveyed had codominant stems with included bark which represented a significant risk of future failure. The results highlighted the issues of sound street tree selection and the importance of good quality planting stock.

Table 5. Definition of structural defects in street trees (Modified from Ryder and Moore 2012)

Fault	**Description**
Codominant stems	Stems equal in size and relative importance, usually associated with either the trunks or stems or scaffold limbs.
Included bark	Bark is turned inwards at branch junctions instead of being pushed out, which may result in the branch or stem being weakly attached and prone to fracturing
Low Branching	Branches low on the stem of a tree that has established or branches encroaching on the road or pathway that require a canopy lift. Removal of low branches earlier rather than later reduces the wound on the trunk.
Epicormic Shoots	Shoots which may not be well attached to the trunk or stem and can present a hazard when they get larger.
Suckers	Shoots arising from roots at or below the soil surface which are often from grafted rootstock. Suckers can be vigorous but may not be the desired cultivar
Broken Branches	Branch may not completely break off and continue to grow with a weak point becoming a danger.
Broken Stems	Main stem broken.
Deadwood	Dead wood in the canopy requiring removal. Often coincides with poor health.
Rubbing or Crossing Branches	Branches rubbing against each other wound, which may weaken the branch and provide an open wound for entry of pathogens.

The economic value of formative pruning is sound. The average cost of formatively pruning different species of trees that were in the range of 4-6.0m tall was estimated at $2.80 per tree (Ryder and Moore 2012). If the tree was not formatively pruned, then ten years later the cost of remedial structural pruning can be estimated at about $200.00 and at twenty years the costs will be $500-1000 per tree, and could be more depending on its position and accessibility. The economic benefits of formative pruning are clear, and if such work is undertaken, funds can be freed up in tight arboricultural budgets for more proactive work. However, formative pruning is still the exception rather than the rule for many large scale street tree planting projects around Australia.

Some First Aid Prescriptions

Mulching

In work on the effects of compaction on root growth and tree establishment, Fitzgerald (2012) showed that over a 20 month period, the bulk density of an uncompacted control soil remained constant while that of the compacted soil reduced. It is possible that root penetration may have reduced compaction, but it is well known that mulch is a cost-effective remedy to soil compaction over the medium to long term. While other studies have reported that it often takes several to many years before the mulch is effective in reducing compaction depending on soil type (Scharenbroch et al. 2005; Urban 2008), this research supported the view that mulch can significantly reduce soil compaction but over the shorter period of 20 months.

For years, a mixed-particle size organic mulch, 75-100mm deep has been recommended for placement around newly-planted street trees and in garden beds containing trees. Some of the many benefits of doing so include, better water infiltration, reduced evaporation of water from the soil, elimination of competition from other plants such as turf or weed species, easier weed control and better soil organic matter content and structure. To this list can be added the results of research showing that addition of biochar to soils was no better than mulch, and that there was no synergy between biochar and mulch, in improving growth in *Corymbia maculata* and *Eucalyptus torquata* (Somerville et al 2019). Ambient temperatures around street trees can also be impacted by mulch which is cooler than other surface materials that are often placed around trees (Leers et al. 2017). Good mulch sensibly applied really is marvellous!

Bark grafting

It is inevitable that from time to time, some established trees will suffer significant wounds to the trunk or major branches where the bark is dislodged or the tree ringbarked. Bark grafting may provide an effective first aid for some of this damage. In 1991, a bark patch was attached to an *Ulmus procera* growing at Burnley after the removal of a large branch (Figure 2) and remained intact and healthy until the removal of the tree in 2014. The wound had successfully grown over ("healed") very quickly (<2years) compared to an unpatched wound of such a size and had successfully compartmentalised.

Figure 2. A successful bark patch graft on an elm at Burnley Gardens

This successful bark patch graft precipitated experiments which investigated whether bark patches could be removed and then successfully replaced on the same tree, whether there were differences between tree species in their responses and whether the season when the damage and patch grafting was done had any effect of successful bark re-attachment (Moore and McGarry 2017). The experiments showed that the right orientation of bark tissue enhanced the potential of successful re-attachment in all seasons and that the greatest success was achieved when tissues were re-attached at their original orientation in spring. The work showed that grafts larger than 100mm in diameter may need to be secured in position and proposed a set of steps for successful bark re-attachment first aid (Table 6).

Table 6. Recommendation for bark replacement or bark grafting of wounded street trees (Moore and McGarry 2017)

Recommendation	Rationale
Bark patch grafts should be applied to a trunk wound, or branch stub, as soon as possible after wounding or pruning.	Prevents drying of tissues and further damage to cambial
The wound must be kept clean and moist while preparing the patch graft. The material for the patch may come from damaged bark, or fresh bark taken from a limb removed from the tree.	Basic plant hygiene to reduce the risks of infection. Moisture keeps cells and tissues from desiccating
The edges of the wound and the bark patch graft must be clean and neat to ensure good cambial contact and to minimize the risk of disease.	Basic plant hygiene to reduce the risks of infection and maximise cambial contact
The bark patch grafts should be placed in cambial contact that ensures the maximum amount of cambial alignment.	Maximise cambial contact between patch and cambium of tree
The orientation of the tissue should be as close as possible to the original	Retain tissue orientation and minimise stress
The bark patch should be well-covered with budding tape (or similar) for at least 2 and up to 4 weeks.	Secures patch, retains moisture and reduces the risk of pest attack
If the bark graft patch is not attached when the wound area is uncovered, remove the patch and allow natural callus growth to enclose the wound	Removes dead tissue that might harbour insect of fungal pests
Bark patch grafts are most successful in spring, so try to perform elective bark patch grafts during this season.	You may not have a choice of seasons, but sometimes you might

The use of bark patch grafts may mean that the removal of a tree limb could be less of an eyesore. Covering the wound with a bark patch graft conceals the fact that a limb has been removed and hides obvious scarring, while at the same time the risk of disease and stress to the tree may be reduced by closing the wound more quickly than would normally occur due to natural callusing. The use of bark patch grafts provides arborists with a method of dealing with tree trunk wounds caused by vandalism and accidents, and would be particularly useful if a tree was of special, historic, or environmental significance to the landscape.

Tree inspections and deadwooding

Tree risk inspections are a routine part of most local government tree management programs. While there is neither time nor space to discuss this aspect of urban tree management in detail, it is worth being aware or the Victorian coroner's recommendations in relation to tree risk inspections after a tree related fatality (Moore 2016). The eight recommendations (Table 7) are a strong incentive for undertaking inspections professionally using qualified arborists on a regular basis.

As part of a regular tree inspection and assessment program, there are good reasons - aesthetic, biological, economic or safety - for the deadwooding of tree canopies, but some are more compelling than others. The advantages of deadwooding as part of formative pruning for young and developing trees are manifold especially for reducing the incidence of and costs associated with the later management of trees with poor canopy structure. However, deadwooding is more commonplace in the management of mature and over-mature trees than young specimens.

The aesthetic argument for deadwooding urban forest trees is quite strong, especially for many eucalypts that produce copious amounts of relatively small deadwood as a consequence of the dynamic nature of their crowns (Moore 2018). The deadwood can look unsightly, is nearly always present, but is rarely large enough to be hazardous. This dynamic crown is quite different from the crowns of many exotic trees such as oaks or elms which tend to slowly expand once the tree is mature. The biological advantages of deadwooding not only relate to the development of a sound canopy, but also to compartmentalisation, wound closure and the minimisation of pest and disease attack. Wound closure can be obstructed and delayed by the presence of dead branches and stubs.

Table 7. Coroner's recommendation in relation to Tree risk Inspections (Abridged from Moore 2016)

Number	Recommendation
1	All local government agencies (LGAs) should have a computer-based inventory of all trees for which they are responsible, which identifies the species of the tree and its location.
2	All LGAs should have a computer maintenance program linked to the inventory which provides dates and details (what was done and why) of all maintenance and inspection operations undertaken on the trees.
3	All LGAs should have a computer-based risk assessment system that is applied to all trees within the tree inventory. Such a system may incorporate widely available systems such as QTRA or TRAQ, or other systems which embody the principles of risk assessment specified in the relevant Australian Standard.
4	All LGAs should have a formalized tree inspection protocol, which specifies the purpose of the inspection and what form the inspection takes (walk-by Visual Tree inspection, use of technological aids) and whether the inspection is ground-based, or from above. The inspection record should also indicate what arboricultural works, if any, are recommended for the tree and why these works are recommended.
5	All inspections must be undertaken by a qualified (Level 4 or above) arborist. A level 5 qualification or above is preferred, but may not be applicable to all council--based situations at present.
6	All inspection and assessment protocols should be dated and indicate a time line for the next inspection /assessment. The inspection/ assessment record should also indicate what further arboricultural works, if any, are recommended for the tree and by what date in the future these should be undertaken.
7	In any tree inspection or risk assessment, it should be noted that the anatomy of branches and epicormic shoots are different. The term "branch" should only be applied to structures that have branch anatomy and epicormic shoots should be clearly identified as such in assessment or inspection procedures.
8	All inspection protocols should assess trunk and canopy components (above-ground) and root system (below-ground) using criteria that allow assessment against these criteria at the time of inspection.

The most compelling reasons for deadwooding mature trees relate to safety. Leaves and higher order branches act as mass dampers when they were alive and they continued to do so for some time after they die (James 2003). Mass damping is part of the tree's responses to strong winds (Moore 2014), but on a windy day, small dead branches (less than 75mm in diameter) without leaves or lower order branches can begin to vibrate quite rapidly. Over time as tissues dry, weaken and decay, it becomes likely that on windy days these movements may lead the smaller dead branches to fail. This is one of the reasons why dead branches will often fail during windy weather. Any rapid vibration in a living branch is not usual and may be indicative of poor branch development, a lack of taper, internal structural problems or that the branch is in decline.

Arborists are told never to attach their ropes to a dead branch or to loop ropes around the main axis of a tree above a dead branch. These dead branches can be set vibrating simply by moving a rope which may be enough to cause them to fail, but if a climber's weight is added to the dead branches then significant vibration of the dead limb is unavoidable and the risk of failure is increased. As an arborist, if you feel vibrations or jerkiness when you are within, or attached to, a tree or branch, exercise greater caution. If there is no wind then the tree should be still. In a wind, the tree or branch may gently sway with the breeze, but if there is any jerkiness in the action, it can be a sign that the branch or whole tree is structurally compromised. In common high-risk situations that can exist with street trees, trees in public parks and trees growing near schools or public buildings, inspection and deadwooding of trees on a regular (annual) basis should be recommended.

Value of root and dormant bud systems

Over the past twenty years, a lot has been written to reinforce the recognition of the value of root systems, epicormic buds and lignotuberous shoots. Because they are essentially out of sight, their values as assets are often unrecognised. Too often stump grinders are used routinely, without thinking of the potential use of these assets that may allow the re-establishment of a badly damaged tree at a fraction of the cost and time that it takes to remove a damaged tree and re-establish it. A tree can be removed without the recognition of the value of its root system and lignotuber or a tree is removed because of canopy damage without consideration of reconfiguring a sound canopy from epicormic or lignotuberous shoots.

Adaptive management

Adaptive management (AM) strategies can be both effective and resource efficient in dealing with pest and diseases. The AM framework provides a context for practicing arborists to address the uncertainty in pest and disease management of urban forests during climate change (Moore 2018). The AM model consists of a loop that involves: knowledge of past infestation and management practices - monitoring the current pest or disease outbreak - learning from data collected in the field- evaluation of consequences - deciding on action - implementing action – monitoring consequences of action - learning from data collected - evaluation of consequences - deciding on action - implementing action and so the loop continues (Figure 3).

There is a strategic opportunity for urban tree managers to integrate AM control of mistletoe, elm leaf beetle, fig psyllid and other infestations of urban trees with climatic events (Moore 2018). Such an approach relies on monitoring of pest numbers to collect data on the level of infestation. The surveys provide hard data that trigger control programs when pest levels are above a certain point, but which also allow the suspension of control programs possibly for several years if numbers are low. This contrasts situations where routine control or spraying programs are undertaken regardless of pest numbers. It means that in situations where urban forest budgets are tight, funds can be freed up for other proactive arboricultural activities.

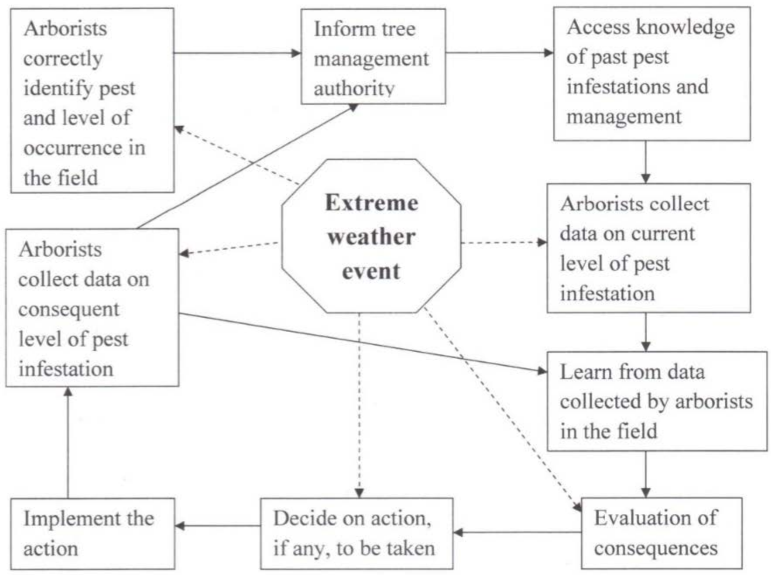

Figure 3. The role of arborists in the adaptive management of urban tree pest species showing the possible impact of extreme weather events on pest numbers and the consequences for tree management (from Moore 2018).

Conclusion

Trees are an essential part of urban infrastructure and are crucial to the liveability and economic and environmental sustainability of cities. In marking the twentieth TREENET Symposium, it is gratifying to see the progress that has been made in urban tree management and to see that so many, but by no means all local governments have street tree policies, urban canopy targets and significant tree protections. However, despite the support for and positive rhetoric surrounding trees in cities, the number of trees and the canopy cover they provide is continuing to decline in many cities and local government areas. As climate changes, it raises the questions as to what sort of urban environmental legacy will be left for future generations of Australians.

Urban trees are societal assets and every effort has to be made to ensure that street tree plantings are both efficient and effective. Once planted it is in society's general interest that the trees survive, thrive and reach their full potential life spans. Anything that TREENET and other relevant groups can do to facilitate such an outcome in the coming decades will prove to be worthwhile in cementing a better urban forest legacy for the future.

References

Fitzgerald. A. 2012. The root system and canopy relationships in urban trees: Doctoral Thesis, School of Land and Environment, University of Melbourne.

Jacobs, B., Mikhailovich, N. and Moy, C. 2014. Benchmarking Australia's urban tree canopy: an i-Tree assessment, prepared for Horticulture Australia Limited by the Institute for Sustainable Futures, University of Technology Sydney.

James, K. 2003. Dynamic loading of trees. Journal of Arboriculture, 29:163-171.

Leers, M., Moore, G. M. and May P.B. 2017. The effects of paving surfaces and planting orientation on street tree growth and trunk injury. Arboricultural Journal 39, (1), 24-38.

Leers, M., Moore, G.M. and P.B. May. 2018. Assessment of six indicators of street tree establishment in Melbourne, Australia. Journal of Arboriculture and Urban Forestry: 44**:**12-22.

McManus, M. 2019. The North Sydney Council Experience - Tracking canopy change over 20 years, the ups, the downs and taking a new approach. Conference Proceedings, 2019. Arboriculture Australia.

Moore, G.M. 2014. Windthrown Tree: Storms or Management? Journal of Arboriculture and Urban Forestry, 40: 53- 69.

Moore G.M. (2016) Drones will be Arboricultural Busy Bees. Arborist News 25 (1): 30-

Moore, G.M. and McGarry P.J. 2017 Investigation of the Potential for Bark Patch Grafting to Facilitate Tree Wound Closure in Arboricultural Management Practice, Journal of Arboriculture and Urban Forestry **43** 186-198**.**

Moore, G.M. 2017. "Taking it to the Streets" - Celebrating a Twenty Year History of TREENET - responding to the urban forest challenge. Williams G. Editor, Proceedings of the Eighteenth National Street Tree Symposium, 23-33, University of Adelaide/Waite Arboretum, Adelaide, ISBN 978-0-9942149-3-5.

Moore, G.M. 2018. Do Heat waves give us a glimpse of the future under climate change? Arborist News 27 (6), 24-28.

Moore, G.M. 2018. Deadwooding Tree canopies: Cosmetic or Safety Surgery? Arborist News 27 (1), 30-33.

Plant. L, Rambaldi A, and Sipe N. 2017. Evaluating Revealed Preferences for Street Tree Cover Targets: A Business Case for Collaborative Investment in Leafier Streetscapes in Brisbane, Australia. Ecological Economics 134: 238-249.

Ryder, C. and Moore G.M. 2013. The Arboricultural and Economic benefits of Formative Pruning Street Trees, Journal of Arboriculture and Urban Forestry **39** (1), 17- 23.

Scharenbroch, B.C, Lloyd J.E. and Johnson-Maynard J.L. 2005. Distinguishing urban soils with physical, chemical, and biological properties. Pedobiologia 49(4):283-296.

Somerville. P.D, Farrell C, May P.B. and Livesley S.J. 2019. Tree water use strategies and soil type determine growth responses to biochar and compost organic amendments. Soil and Tillage Research. 192: 12-21.

The Nature Conservancy. 2019. Living Melbourne:our metropolitan urban forest, The Nature Conservancy.

Urban, J. 2008. Up By Roots. Illinois: International Society of Arboriculture.