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TREENET

PROCEEDINGS OF THE

3RD NATIONAL
STREET TREE SYMPOSIUM

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Phil has worked as tree manager in local government positions for more than twenty years in Hobart and Sydney. He has taught full time in NSW TAFE arboriculture courses and still teaches part-time. He operated a private tree management consultancy in Sydney for four years but returned to local government two years ago in order to change the prevailing discriminatory attitudes and reactive approach in municipal tree management. As City Arborist for the City of Newcastle, has set a goal of informing community leaders, council management and Councillors, of the full range of benefits that a well planned, adequately resourced and systematically managed urban forest can provide.

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Lyndal has guided the management of Brisbane's street and park trees for Brisbane City Council for the last 12 years, and describes her current role as maintaining, protecting and enhancing the amenity values of Brisbane's urban forest. Lyndal has an Honours degree in Botany from James Cook University in North Queensland and joined BCC after seven years with the Queensland Forestry Department and one year with the City of Perth.

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Judy has been teaching the practical and theoretical aspects of soils and arboriculture at Ryde TAFE for many years. She occasionally consults on tree-related matters to councils and government organisations. It has become very obvious to her that many tree problems are below ground so a good working knowledge of soils is indispensable to the arborist.

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Michael has qualified as an architect and landscape architect and has recently obtained a master's degree in Landscape Architecture with the subject "Asset and risk management of mature trees", with special reference to how local government manages its trees. Michael been designing with trees since 1960 and assessing trees, in local (UK) and state government (here and WA) since 1968. In terms of trees and urban design, Michael worked for two councils and was resident landscape architect consulting to the city of Islamabad, the then new capital of Pakistan.

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Jim Hay is Senior Arborist, City of West Torrens. Since joining West Torrens in 1992 Jim has been involved in all aspects of arboriculture. While committed full time to arboriculture service delivery his involvement has extended to the review and upgrading of work processes, staff training, species trials, equipment evaluation and purchasing. Future goals include the continued improvement of urban tree conditions and increasing community recognition and appreciation of the benefits they provide and those who provide them.

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Greg Moore has been Principal and Head of Burnley College since 1988. Apart from a general interest in horticultural plant science and ecology, Greg has a specific interest in all aspects of arboriculture. He has written one book, contributed to another and has had over 50 research papers and articles relating to tree biology and management published.

THE VALUE OF TREES – THE BIG PICTURE

Philip Hewett - City Arborist , Newcastle City

INTRODUCTION

Eleven years ago, Canberra hosted the Royal Australian Institute of Parks and Recreation's first national tree seminar titled, Trees: Management Issues for Urban Australia (RAIPR 1991). I distilled these three key points for my tree care students at the time:

1. The value of urban amenity trees is seriously underestimated
2. As strategic national assets, urban amenity trees require the same level of management as other national assets
3. Education is the only long term tool in rescuing urban amenity from population decline

Now as I sit down eleven years later and reflect on our progress, I see that the true value of urban trees is still seriously underestimated. It is apparent that most of our urban street tree populations are still managed as unrelated individuals. I see that we still feel comfortable counting numbers of trees planted whilst we continue to ignore the vast number of planted trees left unmanaged for life, and our education programs have yet to make any significant in-roads to arresting urban tree population decline.

I also recorded these three proposals from the Canberra seminar:

1. That 'crisis' tree management is inappropriate because it does not address tree decline, loss of tree values, increased costs and liability, and the confrontational nature of reactive tree work
2. That our old prescriptive recipes for tree care must be wholly replaced by the new science based tree biology and by contemporary management philosophy
3. That risk management cannot be discounted, as the public authority duty of care is expanding

I will discuss these points to put the current circumstances into perspective.

Crisis management

We are still 'putting out fires' in dealing with urban tree issues - and there really is little choice but to work inefficiently because we have no legislative and resource framework to enable us to properly plan for and manage whole urban tree populations. I anticipate the reactive response will remain our *modus operandi* until we develop a broader, more rational and strategic approach to urban trees under the guidance of urban ecosystem management systems.

City, suburban and rural communities across Australia are facing the synchronous decline of large numbers of trees planted at the turn of the century and after the Great Wars. Most of these historic and venerable trees are large and so they are likely to present significant health and safety issues.

At the same time, communities are facing the premature decline of many of the popular native *Eucalyptus*, *Casuarina* and *Melaleuca* trees planted en-masse in the early 1970's. These trees are in decline either from the stressful nature of urban environs - eg toxic run-off, polluted air, loss of roots and growing space, and past bad care practices - or they are removed because we did not anticipate their eventual size and vigour. Australia's seemingly insatiable appetite for unhindered motor vehicle access is also a primary source of urban trees

stress including the loss of adequate growing space. It is also important to acknowledge that most of the 1970's native planting's were selected from wild sources rather than from stock bred for urban tolerance. This TREENET conference will develop this important theme further.

Knowing exactly when a given tree is about to collapse, fracture or die, is one of the most difficult tree management decisions for any urban community. Tree failure simply cannot be accurately predicted, but of course trees cannot be just left to die or collapse where they stand. For obvious legal, health and safety reasons most urban trees are, or will be manually felled long before they collapse or die. This poses some very interesting challenges for Councils, authorities and whole communities – for example, how would you convince a community that a great and statuesque avenue, planted in memory of fallen soldiers has to be removed when it still looks green and healthy. How should we respond when our cultural trees must go - can we agree on the point at which we should intervene. We need to consider this matter with care and compassion, whilst still acting responsibly.

There are encouraging developments in some larger management authorities, for example, the ACT government commissioned the development of a data system to manage about 500,000 trees in Canberra. A second project developed a precinct-scale tree management system to manage about 7,000 trees on a 150 ha campus in Canberra city (Bracks 1999).

Both of the Canberra management systems were developed by trained foresters. It is interesting to note that foresters have not been involved in urban tree management planning in NSW where amenity horticulture and arboriculture have tended to be at the centre of urban tree management. However, a review of urban forestry sites on the internet shows the significant input of forest science to strategic urban forestry planning in the USA.

I believe that with the right blend of forest science and modern arboriculture, with support from urban and social planning, landscape architecture and civil design, we could establish urban forestry and urban ecosystem management systems that will address many of the current tree related problems that beset us.

Outdated practices

The old 19th century prescriptive recipes such as wound painting and tree topping have been largely replaced in our major urban centres by modern arboriculture, but old practices continue to impress many tree workers and their clients outside our capital city areas. The teachings of modern arboriculture and the efforts of the city based tree maintenance sector should be credited for their success in eliminating tree topping from acceptable general practice. However, we cannot relax since there are still many authorities and communities who want tree topping to remain as the preferred solution to many tree problems. It seems to me that few public authorities are yet willing to adopt a contemporary management approach for their urban tree populations.

Risk management

I expect the current public liability insurance crisis in Australia will sooner or later motivate us to seek new ways to accommodate and care for urban trees. If we do not quickly find appropriate solutions to address the increasing demands for tree risk elimination coming from the utilities, insurers, lawyers and risk managers - to remove so-called 'costly' trees, then we must expect to continue to breathe toxic air, travel in streets cluttered by timber poles and dense aerial cable networks, and walk our children to school on shade-less footpaths where the tallest greenery is in the form of large shrubs.

If such conditions prevail we should also expect the urge to escape our urban surrounds as often and for as long as possible to continue to frustrate us all. It would be better of course, if we could live satisfying lives in sustainable, healthy and attractive urban communities in the first place. We do have choices.

URBANISATION

Australians are said to be amongst the worlds most urbanised cultures, with more than eighty percent of the population living in towns or cities (Solness 1999), and more than two-thirds of the population of Europe now live in urban areas. Despite our national denial, we are indeed urban beings, and in some ways I feel our rather bucolic national self-image may be part of the reason we are reluctant to look more critically at the health and status of our urban ecosystems.

Urbanisation leads to rapid transformation of soil and vegetation such as bushland, woodland, forests, and agricultural land, and it introduces significant amounts of heat absorbing and radiating materials, impervious ground surfaces, and it carries high levels of polluted run-off to receiving waters. Transport, communications, water and energy infrastructure, and buildings rapidly become the dominant urban form. Most of us have seen bushland cleared very short time, then transformed a couple of months later into perhaps a supermarket complex with hectares of shade-less roof area, heat absorbing car parks and roads. Tokenistic tree planting usually completes the 'development' – at least until the retailers need to expand their shops and parking areas again, and then again!

The on-going process of urbanisation should have motivated our community leaders and policy makers to plan, develop and maintain truly sustainable communities by addressing the problems of air, noise and water pollution, waste management, energy consumption, in synergy and not in isolation as at present. Community leaders are unable to lead in this critical area because we lack the legislative framework and the primary data on which to base policy planning and future action.

Urbanisation is much more than just a process of environmental transformation – it effects people at a psychological level as well. For example we know that people deprived of green space and trees in their daily lives tend to act in destructive and often violent ways, and we know that the recovery of hospital patients is influenced by the presence or absence of trees (Prow 1999)

I have been asked on occasions to address senior high school students on the planning and political issues leading to clearing and development of bushland surrounding their school campus.

On every occasion, the students felt that whilst they understood the social need for development, they could not understand the obvious destructive impacts but felt powerless to effect the outcomes. I am convinced that as a society we can and must do better.

Tree Preservation regulations

Most communities in urban parts of NSW have adopted a tree management model based almost solely on the regulatory power of a Tree Preservation Order (TPO). As a principal mechanism for tree management, regulation has proven wholly inadequate mainly because it addresses trees in isolation, and does not consider the collective ie an 'urban forest' and therefore does not account for cumulative impacts.

A TPO really functions most effectively as one tool in a planned and systematic urban forestry program. It is therefore essential that we seek new, more inclusive ways of addressing the impacts of urbanisation and urban ecosystem management. In my view the way forward is through adoption of an urban forestry planning framework.

AN OVERVIEW OF URBAN FORESTRY

Urban Forestry in the USA

Urban forestry is particularly well developed in the United States where strong Governmental support is a feature of its development.

The US Federal Government introduced the *Urban Forestry Act* in 1971 followed in 1978 by *The Cooperative Forestry Assistance Act* authorising the financial and technical assistance of state foresters under administration of the USDA Forest Service.

The *Urban and Community Forestry Act* was introduced in 1989, and the *1990 Farm Bill* called for the establishment of a National Urban and Community Forestry Advisory Council (NUFAC) One of NUFAC's assigned tasks was to develop a national urban and community forestry action plan. (NUFAC 2002)

Intensive community participation is a key characteristic of successful urban forestry programs in the USA.

Urban forestry in the European Union

The European Union recognises urban forestry as a separate scientific, multi disciplinary domain. In 1997 the European Community approved COST Action E12 involving 21 countries by June 2000. COST is a loose acronym for *European Co-operation in the field of Scientific and Technical Research*. The intent of COST E12 is to coordinate urban forestry research, avoid duplication and improve efficiency (Gerhold 2002)

The objectives of E12 program are to:

- improve the knowledge base and understanding of urban trees and woodlands;
- promote better planning, design, establishment and management of urban trees and woodland;
- establish urban trees and woodland as a recognised scientific domain in Europe;
- place urban trees and woodland on the European and national political agendas.

Each country involved produced a *State of the Art* report on the extent of their urban forestry research. The reports were combined into a single publication by the European Union (Forrest 1999)

The importance of E12's focus, according to Simson (2001) is in its linking of science, policy and practice in urban forestry, but the links were often not strong. Good examples of successful inter-disciplinary work can be found however in Denmark, Sweden, the Netherlands and the United Kingdom, but they were not considered to represent the norm.

Urban forestry in Australia

Urban planners and designers in Australia seem largely unaware of or choose to ignore arboricultural best practice, and managers have limited appreciation of urban design theory, and both pay insufficient attention to the socio-economic benefits of community and urban forestry.

As might be expected, the concept of urban forestry is poorly developed in Australia. (Fakes 2002) This concurs with my observations over two decades of municipal tree management.

However, many Australian tree managers are now developing understanding of the ecological, social and environmental values of the 'collective' of urban trees – or urban forest as it is commonly called. The lack of a clear conceptual, legislative and planning framework in which to articulate collective tree values severely hinders national and local progress.

All Australian communities, from rural villages to the largest cities are presently labouring under an unprecedented expansion in public liability responsibilities effecting almost every aspect of public administration. Urban street trees are very much caught in this situation, and in my recent experience I believe street trees are amongst the most seriously threatened because of the plethora of infrastructure and management jurisdictions in our streets.
If we do not respond immediately and in concert to this situation, then there is every possibility we will not be permitted to plant anything taller than shrubs in our streets in the very near future. (Anon 2002)

THE CHICAGO STUDY – A MODEL TO CONSIDER

I will now give a broad overview of the direction we might take in order to create urban areas truly supportive of people and trees, and I will conclude with an overview of my attempts to introduce urban forestry thinking to the City of Newcastle, NSW.

I am grateful to Dr Jane Tarran, of the Department of Environmental Sciences at the University of Technology, Sydney, for providing me with a copy of the Chicago Urban Forest Climate Project (CUFCP) - an immense, unique three year study quantifying the effects of urban vegetation on the local environment and to help city planning and management organisations increase the net environmental benefits derived from Chicago's urban forest. (McPherson et al 1994)

The CUFCP evaluated the role of trees and other vegetation in the Chicago regional urban forest ecosystem. Analysis of the ecosystem provided an effective approach to planning and controlling the distribution of benefits and costs associated with ecological effects. Importantly, the study found that the flow of energy, water, carbon, and pollutants through the urban ecosystem can be changed by changing the amount and spatial distribution of trees. This is a very important point to consider.

The findings of a benefit-cost analysis of estimated net present value for proposed tree plantings revealed that despite the expense of planting and caring for trees in Chicago, with time the benefits that healthy trees produce can exceed their costs. (McPherson et al 1994) This is a very important finding when we consider that many Australian authorities are questioning the economic wisdom of retaining urban trees in streets at all!

For example in 1991 the Chicago urban forest removed an estimated 15 tonnes of carbon monoxide, 84 tonnes of sulfur dioxide, 89 tonnes of nitrogen dioxide, 191 tonnes of ozone, and 212 tonnes of particulate matter. In addition, in terms of reducing atmospheric CO_2 trees in urban areas offer the double benefit of direct carbon storage and the avoidance of CO_2 production through energy conservation from properly located trees. (McPherson et al 1994) The CUFCP is too detailed to expand further in this paper but the few findings I have given reveal the enormous unrealised potential of urban trees to achieving sustainable Australian communities.

I believe the full Chicago urban forest climate report should be studied by all local government councillors and community leaders.

THE NEWCASTLE EXPERIENCE

Risk drives the process

Newcastle City Council committed to the Statewide Mutual's *Best Practice* risk management regime in 2000 to address burgeoning public liability claims for slips, trips and falls on member Council's footpaths. The insurer was concerned that member Councils lacked a systematic, integrated approach to managing public trees and infrastructure maintenance.

The insurer developed a series of *Best Practice* management guidelines including one for tree root management, to be used by member Councils under the Statewide insurance members scheme. The approach was essentially a 'carrot and stick' model since member Councils that fail to adopt the model are warned they may loose their liability protection for existing trees and for new planting. This inducement, coupled with loss of the historical local authority liability protection under misfeasance rules, left Councils extremely exposed and especially nervous about their trees.

The *Best Practice - Trees and Tree Roots* manual was supported by Council but got very little support from the arboriculture profession generally because it promoted a biased and negative view of urban trees, it contained incorrect technical information, and it would have eliminated a large number of street trees. The process introduced draconian guidelines for new tree selections by drawing 'damage circles' around utility services and structures that made it almost impossible to plant on or near a public footpath or other structure without risk of losing liability protection altogether. (Anon 1999)

As a result I proposed a total review of the *Best Practice* trees and tree roots manual to remove the bias, correct technical errors and provide a more reasonable approach to managing and selecting trees. My review in conjunction with Judy Fakes of NSW Tafe Commission, was completed in July 2002 and is under consideration by StateWide Mutual.

I believe the rationale behind the Statewide Insurance *Best Practice* approach is sound – it promotes a systematic, planned and integrated approach to trees and public risk management. Member Councils must develop an inventory on the condition of all public trees along with records of public requests and all tree maintenance work undertaken. Tree requests and necessary work are to be scheduled according to risk profiles and an inspection cycle has to be set. A similar inventory and management program has already been developed for Council footpaths and the tree data will form another layer on a multi layered graphical based information system.

The strategic value of the *Best Practice* approach was realised on completion of the tree resource inventory. We now know we have 54,000 street trees and we are now analysing the data to develop species and risk profiles. It has become clear that the full environmental and social values of appropriate urban trees planted at the right densities, can only be addressed when the full extent of existing resource is known.

The *Best Practice* approach highlighted the inadequacies of our traditional crisis response to trees in Newcastle. The electricity distributors, whose mostly uninsulated cables are carried on timber poles on most Newcastle streets, also operate under a strict liability regime leading to tree trimming far in excess of that tolerated in the past. The electricity distributor further seeking to reduce future street tree planting to shrubs that do not require any trimming whatsoever under their cables. (EnergyAustralia 2002) It is apparent that the Newcastle community is not sufficiently informed on the values of urban trees to counter the energy distributors negative policy toward its street trees.

This was a critical time to introduce urban forestry concepts to senior management and elected Councillors. I began promoting urban forestry as an economical and effective means to address the social and environmental consequences of intense urbanisation such as powerlines and communications cable proliferation.

I held a series of briefings for Councillors presenting graphic PowerPoint images from the American Forests and USDA internet sites combined with images of Newcastle streets to give the ideas local application. My aim was to translate tree values for decision makers who needed to feel confident they understood the issues before they could consider and make critical decisions – in my view this is all about developing attitudes in decision makers rather than telling them what to do.

I adopted the anthropocentric view of 'trees at work' operating without respite in our streets, coupled with images of veteran trees in Newcastle streets and Parks, focussed my messages. Discussion about skin cancer and the need for shade over footpaths and in coastal parks and car parks was supported by images of barren areas of bitumen and unshaded picnic areas. I downloaded images from the American Forests websites and other links to graphically illustrate the role of urban trees in stormwater capture, and I quantified dollar savings from urban forestry programs that used the Urban Ecosystem Analysis (UEA) software developed by American Forests. Individual Councillors spoke to me after the briefings expressing their interest in further developing opportunities for urban forestry planning at Newcastle. A Greens Councillor immediately took the process further, gaining the General Managers support for me to assist him develop a policy motion on urban forestry to be put to the NSW Local Government Association at its 2002 conference at Broken Hill. I now that sense change is close at hand.

Urban Ecosystem Analysis

The voluntary American Forests organisation pioneered the development of urban ecosystem analysis (UEA) designing computer software to calculate in dollar terms the contribution of trees to carbon sequestration, stormwater control, ultra violet radiation control, heat energy reduction and absorption of suspended particulate matter. UEA software was trailed 'off the shelf' by Brisbane City Council in 1999 but with limited success as the program uses US soil, plant and climate data requiring extensive conversion for application in Australia. (pers com Lindal Plant, 2000)

There is scope to research UEA further and this challenge has been taken up by the NSW Local Government Association in partnership with Newcastle City.

Street tree survey

The Newcastle street tree survey took two staff 18 months to complete, recording the health and condition of 54,000 street trees. Data was collected using a pen computer from a motor vehicle. Park trees are yet to recorded. The street tree database has been used to profile potentially high risk trees and a policy is being developed to address tree management needs.

I should add that the separate but sudden failure of seven prominent large trees in the past two years at Newcastle has focussed Council attention on urban tree issues. My fear now is that short term cost savings from wholesale removal and non-replacement of street trees may prove more attractive than strategic expenditure for long term urban sustainability.

It remains to be seen if the urban forest 'genie' can be kept out of the bottle and in front of the right people in order to bring about the necessary change in attitudes.

CONCLUSIONS

I opened this address lamenting the slow pace of change in our approach to urban trees. I highlighted the problems of inappropriate tree management models, outdated tree care practices, and the public liability insurance situation.

I gave an overview of urban forestry in the USA and Europe and noted its poor development in Australia. I outlined the Chicago urban ecosystem research project to illustrate a direction I believe we need consider, and I cautioned on the risk of delaying action especially in the current liability environment as it effects our street and park trees.

I gave support to the StateWide Mutual's *Best Practice* tree management approach and gave insights into how I am attempting to convince community leaders and Council management of the benefits of further researching and supporting urban forestry principles.

I congratulate the University of Adelaide for presenting this timely symposium on street trees and ask you to reflect on the presentations within the 'big picture' framework of urban and community forestry If this happens, there is every chance we will be inspired by our progress in ten years time.

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THE TREENET WEB APPLICATION

Sean Donaghy - TREENET

The web application will be central to the TREENET project, and will allow us to take the next the step toward realising the primary aim of the organisation – to improve the urban forest through information sharing and research.

When we started work on the system, we decided quite early on that it would serve two main purposes:

(a) It would provide a system to allow different stakeholders in street trees to share information and experience
(b) Provide a system to collate different types of trial site data from different organisations

Whilst providing this functionality, however, it was imperative that we maintain the design principles of

(a) **Cross-organisational standards**, that all organisations could easily adopt
(b) **Flexibility**: so that we could accommodate different organisations with different time/resource constraints
(c) **Ease of use**

To do this, we decided to adopt some widely used technologies; namely *Microsoft's Active Server Pages, Visual Basic, Microsoft Access databases, Javascript* and *HTML*. Standards used across much of the Internet and supported by most relatively recent browsers such as *Internet Explorer 4* and *Netscape 4*.

Users would simply access the TREENET system via the TREENET web site.

The system has been written to be easily expanded and maintained as we adopt new technology and improve the system to accommodate users' needs.

The Problems

The problems that we encountered trying to collate data and information from so many different organisations and from so many different parts of Australia (and, indeed, the world) could be summarised as follows:

(a) Maintaining maximum flexibility whilst minimising complexity for the end-user

(b) Catering for different organisations and individuals with (i) different areas of expertise and (ii) different time/resource constraints

(c) Allowing organisations and individuals to co-operate to collect and contribute data

(d) Building in the flexibility to accommodate user suggestions and easily integrate related organisations' data and technology

(e) Designing the system so it can grow to accommodate new ideas utilising technologies such as ASP.NET, C# or Java – if future developments necessitate it.

(f) Bringing different types of information together - raw trial data, anecdotal evidence, articles, papers and user feedback so that it can be accessed as a whole.

The Solutions

(a),(b) Customisation: allowing users to collect as much data as they want, by organising TREENET data into optional modules. Users can then select the data they are interested in.

(c) Users can also ask for help collecting or creating data, the system will link people who need help to those willing to provide it based on geographical criterion.

(d), (e) The modular nature of the approach allows new elements to be accommodated as new modules.

(f) All data can be related together using keywords/semantic analysis engine. Searches can reveal information from all sorts of modules - messages, anecdotal evidence, trial data, etc, this bringing together customised sets of data that can be stored as part of the user's preferences.

For those who do not have access to the Internet, we will be providing the functionality to summarise a great deal of the data and make it available in publications and regular newsletters made available by traditional post as well as email.

The web application will streamline administration so that we can reduced administrative overheads to a minimum.

The Future

The next year will be a period of testing, consolidation and improvement. Early adopters of the TREENET model will have the opportunity to markedly influence the development of the system. We would really appreciate your feedback, and will attempt to improve the system to meet your needs.

QUALITY TREES = QUALITY STREETSCAPES

James Will - Burnley College, The University of Melbourne

I contend that the success of a tree in the landscape is determined by four factors:

1. selecting a tree that will match the edaphic, climatic and site (height, width) restrictions,
2. selecting the tree that has the quality to grow into the tree you need,
3. carefully maintaining the tree during its period of establishment, and
4. providing appropriate maintenance through the tree's life.

If a good design can be part of this equation as well, then the resulting streetscape will be fantastic, but an excellent design without the appropriate horticultural and maintenance considerations is bound to fail. Trees have an æsthetic function in the landscape, but this function cannot be fulfilled unless the tree is growing well in its site.

The factors which make up an appropriate quality tree are discussed below. These factors should be considered by any purchaser of trees for urban use. Purchasing the correct quality of tree will ensure that a successful outcome can be achieved. The methods identified for achieving these quality outcomes may seem prescriptive, and many managers can recall high quality streetscapes where these methods have not been followed; but the techniques for growing appropriate quality trees listed below give the purchaser surety of that quality.

Cost at purchase is a significant factor for many streetscape managers. I contend that a $20-40 premium at purchase for the best quality tree will result in many $100s saved over the life of that tree. Implementing the techniques for growing appropriate quality trees in the nursery will cost the grower more than if not introduced, but this extra nursery cost will save the streetscape manager money later on.

Quality techniques in the nursery are a component of a total quality management system for the streetscape. If streetscape managers choose trees of this correct quality, the client requirements in the streetscape can be more readily achieved.

The quality of the tree's genes

With introduced tree selections, tree buyers frequently can purchase a tree based on its cultivar name, expecting that all the trees of a certain cultivar will be asexually propagated from a single parental source plant. Also, there is a widespread perception that exotic trees are always what the label says they are.

I have experienced many problems associated with tree naming. My colleague Jill Kellow and I investigated *Pyrus ussuriensis* a few years ago, and discovered that all the trees (save 1 here in Adelaide at Mt Lofty) labelled *P. ussuriensis* were in fact a selection of *Pyrus calleryana*. This mis-naming led to many streetscapes full of poor-growing, short-lived pears (Kellow & Will, 1995). I am equally convinced that through some mix-up, many of the *P. calleryana* 'Bradford' are in fact the cultivar 'Red Spire' (and *vice versa*). In Melbourne, arborists have made much money from the mis-named *Alnus jorullensis*, which is actually the much-larger-growing *A. acuminata* ssp. *glabrata*.

There are a number of seed raised cultivars grown in the streetscape, including the so-called "digitate" Plane Trees. Trees sold as *P. orientalis* 'Digitata' come from a number of sources, and the buyer has to go beyond a simple cultivar name in understanding the growth form of

the trees purchased. Some growers are offering the Hillier's selection of *P. orientalis* 'Digitata', as well as the closely-allied 'October Glory' selection of *P. orientalis* insularis-type (*see* Spencer, 1997, for a discussion of these Plane selections).

With Australian trees, things become muddier still. Many of the best-known Australian trees grow over wide ecological/geographic ranges, and seedlings from one ecological zone may not be appropriate for another ecological area, even though the species itself is endemic to that area. Selecting seedlings from the same geographic area or from a similar ecological zone will probably give better streetscape results.

Many eucalypts are promiscuous breeders, and will freely interbreed with related species when they are in close proximity. As seed propagation is necessary, seed collected from these cross-breeding trees will not yield offspring similar to the parent selected. For this reason, seed collected from genetically-appropriate seed orchards or from known, isolated wild stands is essential.

Propagation practice

Techniques for growing high quality trees begin at the propagation phase. Most nursery growers will identify that poor quality tubestock, transplants or seedlings will inevitably lead to poor quality finished trees. The best technique for managing poor quality transplants is to throw them away before you waste money trying to improve them.

I believe that the best deciduous trees are produced by budding known and compatible scion varieties onto known rootstock selections. This production practice gives the opportunity for the grower to get a straight trunk without excessive staking, and will also give repeatable outcomes when the same scion:rootstock combinations are used. Budding also gives the possibility for specialised rootstocks to be used, but this refinement will only occur when tree buyers are sophisticated enough to insist on them.

It is more difficult to implement high quality production with seedling propagation. Many trees propagated by seed have seedling growth patterns that make transplantation difficult until the seedling is approximately 400mm tall, and the seedling rootball is appropriately developed. This requirement for later transplanting goes against traditional nursery practice, where seedlings are pricked-out of a community seedling tray and transplanted into a tube. Research has shown that pricking out of eucalypt and acacia seedlings will often lead to "j" rooting of the seedling, as the pricking-out process invariably leads to root malformation when the seedling is "tucked into" its new growing media (May, 2002). To overcome this potential root deformation, seed should be direct-sown in individual tubes that are large enough to support the growth of the tree until it is ready for transplantation. Further, if multiple seedlings germinate in each tube, the excess seedlings should be cut off rather than pulled out, to minimise root disturbance of the remaining seedling.

Transplanting seedlings too early may result in root distortion, but equally, transplanting pot-bound seedlings may also lead to a tree with serious root deformity. The grower must design a growing system, whereby he/she can get appropriately sized seedlings that have a large and vigorous root systems without any distortion or malformation.

Tree buyers should be aware of the propagation system that a grower has used, as the propagation phase will directly affect the quality of the finished tree.

Growing systems: root structure

There are three growing systems typically used for growing trees: bare-root, balled-in-burlap (b&b) and container-grown. Each growing system has its advantages.

Bare-root trees are grown in-ground, root-pruned, and lifted when dormant. Buyers will find bundles of 5 or 10 trees, possibly heeled-in or refrigerated until sale. These trees have these advantages:

- you are not paying for soil or growing medium, either its value or the cost to transport it to site, and
- you can examine the tree roots to see if appropriate for the size of the above-ground portion of the tree.

Bare-root production has the following limitations:

- harvest time and planting season are restricted to just a few months in winter, as the tree must be fully dormant before lifting,
- the root systems on these trees are fragile and must be kept hydrated to avoid tree death,
- care must be taken during transport to avoid root damage,
- establishment irrigation must be very carefully timed as there is little lee-way for error (trees can die very quickly if not watered exactly when needed), and
- only some taxa of deciduous trees will respond well to bare-root transplantation into the streetscape.

Balled-in-burlap production (from now on, b&b) is a production system where trees are grown in-ground, root-pruned to achieve a fibrous and compact root ball, and then harvested when dormant with a surrounding soil ball. This soil ball is covered in hessian (= American "burlap") and shipped. This production system has these advantages:

- many taxa respond well to this transplantation technique,
- trees, once harvested, can be held for a few days-to-weeks before planting, and
- this technique is easily adapted for any size tree.

B&b growing systems have these limitations:

- root-pruning, through undercutting, is essential for the development of a compact root ball, and this is rarely carried out as often as necessary in Australia,
- the harvest period is restricted to several months in winter,
- the cost of purchasing and transporting soil can be extremely high,
- the root balls are fragile, and care must be taken during transport, and
- the buyer cannot examine the root ball to check for root distortion before purchase.

Container growing is most commonly used in Australia because:

- most taxa respond well to container growing,
- there is a 12 month harvest/sales/potential planting season per year,
- containers are easily shipped with minimal damage to the root balls,
- growing media can be readily formulated for best tree growth, and
- buyers can examine root systems at purchase.

There have been many reports of problems with root deformation associated with root spiralling and root distortion in container growing systems. Gilman (1997) and May (2002) thoroughly discuss these issues, and give prescient recommendations. I am unsure whether

there is a single system that will eliminate all root distortion, but in reading the literature and observing tree root systems, I believe that these are the most important factors for “root conscious” production:

- There needs to be adequate root mass to support the shoot mass; in other words, the container has to be large enough to support the growth of the tree growing in it. I recommend:
    - 15-20 litre root volume for a 1.5 to 2.0m tree
    - 40-50 litre root volume for a 2.1-3.0m tree
    - 75-100 litre root volume for 3.1-4.0m tree.
- That some form of root control system be used, whether copper based paint or air pruning. Ridges in the straight-sided plastic containers are not enough on their own to control root growth with trees. An advanced “root conscious” growing system will use both ridges or other physical control as well as air or chemical root pruning.
- The profile of the container needs to be broad and shallow rather than tall and deep to ensure oxygenation both in the nursery and in the streetscape as the majority of tree roots are found in the upper 200mm of container-grown trees.

Canopy and trunk development

Again, see Gilman (1997) for an excellent discussion of all factors associated with tree canopies and trunk formation for non-Australian taxa.

Eucalypts are notoriously difficult to grow straight and strong-trunked. I believe that staking eucalypts for some time in their growth is essential in gaining an acceptably-straight trunk, but I also am convinced that these stakes need to be removed as soon as the trunk is straight. This stake removal (when associated with appropriate canopy pruning) will give a straight-trunked tree with adequate trunk taper and strength. As a general rule, I believe that stakes should be removed after active tree growth has slowed for the year, as the hardening-off phase of the tree’s growth will also give greater trunk taper if there is no stake. Also, I believe that most trees should be unstaked for a minimum of six weeks before delivery, to assure trunk strength and that the tree can stand up without any staking in the streetscape.

Canopy pruning is also difficult with many Australian taxa, especially when planted as trees <2.0m tall. With many of these trees, the canopies that are planted will not be the canopies that remain in the streetscape. Also, as these trees are seedling-produced, they frequently will show the juvenile growth form of that tree (especially true in eucalypts and *Angophora*), and will be atypical of the adult tree. There are a few guidelines that are important with selecting canopies on seedling-grown Australian trees:

- there must be no co-dominant leaders (bifurcations),
- canopies should be light enough to be supported by the trunk without staking,
- the canopy should be radial, and not arising from a single place (whorl) on the trunk,
- there should be no obvious crossing or deformed branches, and
- there should be adequate foliage on the canopy to allow for ample photosynthesis and quick growth in establishment.

In discussing the canopy and trunk development of many Australian and other evergreen trees, I have mentioned the necessity for a “hardening off” phase in production. In this phase, the tree stops active extension growth, tissues lignify, leaves fully cuticularise and the trees accumulate sugars (and sugars are converted to starches). I believe that trees are best transplanted after hardening off, as they withstand movement into the harsher streetscape

from the nursery with less wilting. Unfortunately, growers cannot time when they want to harden plants off, as temperature is frequently the major factor contributing to extension growth. I recommend that streetscape managers fit their planting times to suit the growth state of the plant, rather than trying to keep trees alive if not hardened off properly.

Pests and diseases

Plants of a reasonable quality for the streetscape will show vigorous and healthy growth. There should be no signs of leaf discolouration, leaf necrosis or trunk cankers. It is unlikely that trees grown in containers will show signs of the root-rot disease, *Phytophthora cinnamomi*, as the pinebark-based soil media used in container growing are suppressive of this disease. The only way that these growing media can support root-rot fungi is after a significant period of waterlogging. Buyers should note if there are areas of the nursery where trees are standing in water. If tree buyers notice containers standing in water, they should avoid buying any tree from that nursery. (Brereton, IN Will, 1999)

Weeds are the major pest problem with quality tree production. When buyers visit nurseries, they should immediately notice the weed loads found throughout the nursery. I can honestly say that weed-free nurseries rarely produce poor quality trees; conversely, it is rare to find good quality stock coming from a weedy nursery. Many nursery weeds, including Willow Herb (*Epilobium* sp.) and Flick Weed (*Cardamine hirsuta*) must be controlled throughout the tree's growth, as hand removal before sale will not remove the problem. Seeds of these nursery weeds will germinate, and take necessary water from the tree during establishment.

Some insect and mite pests must be avoided, but minor infestations of Lerp Psyllids (*Cardiaspina* sp.) on eucalypts and Eriophyd/Erinose Mites on other Australian trees are acceptable. These endemic pests will somewhat disfigure the tree's foliage, but have little overall effect. Infestations usually occur when growing a large number of the same tree taxa close together, and will not re-infect new growth in the streetscapes.

Summary & recommendations

I recommend that streetscape managers or tree buyers consider the following checklist when purchasing trees:

- is the tree the cultivar/variety/seed source that you want, and are the trees true-to-type?
- has the selection been propagated in the optimal manner and without root distortion?
- is the growing system appropriate for the time of planting and establishment maintenance?
    - if bare-root or b&b, have the trees been root-pruned appropriately and is the root system adequately large?
    - if b&b or container-grown, is the root profile appropriate or too deep?
    - if b&b or container-grown, is the soil mass appropriate for the root and shoot mass?
    - if container grown, have the containers been selected to reduce root deformities?
- is the canopy appropriate for the size of tree and does it have a well-formed structure?
- does the trunk show an appropriate taper from 100mm above ground to 1400mm?
- is the tree free of disease, weeds and excessive pest damage?

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PYRUS IN THE WAITE ARBORETUM

David E. Symon - State Herbarium of South Australia

The genus *Pyrus* stretches from north Africa through southern Eurasia to Japan. It does not extend to the Scandinavian or Siberian levels nor to India and S. E. Asia. This suggests it likes some cold in its life. Virtually all species are small or large deciduous trees with a few nearly evergreen in the Mediterranean. An important fact for both horticulture and taxonomy is that they are largely self sterile and need outcrossing.

I know of no comprehensive revision of the genus. Although standard taxonomy is, in these days of molecular biology, considered 'old hat', 'not quite with it' or 'boring' it provides the words we use to name things and without that we do not know what we are talking about.

There are regional accounts of *Pyrus* from the Flora Europaea, Russian Flora, Turkish Flora, Iranian Flora to Chinese and Japanese Floras. These include a great many overlapping names. There is also a problem: the individual flowers of *Pyrus* species are not very distinctive but the fruits are helpful and getting flowering and fruiting specimens from the same tree is much rarer than you might expect. As the genus is outcrossing it is highly heterozygous and provides a huge array of variants – useful for horticultural selection but a nightmare for taxonomy.

A good effort at the whole genus was one by Challice and Westwood in 1973. Challice was at Long Ashton Research Station, University of Bristol, U.K. and Westwood at the Department of Horticulture, Oregon State University, U.S.A.

Both had access to large living collections. They started with a working set of 22 species broken down to five mainly geographical groups . Five Asian pea pears – all small fruited e.g. *calleryana*; five Asian medium or large fruited e.g. *pyrifolia*; and six West Asian species – a more varied lot, rarely edible but include *salicifolia*, *amygdaliformis*, *syriaca*; three North African species *gharbiana*, *mamorensis*; and three European species e.g. *communis* and *nivalis*.

May I remind you that *pyrifolia* (Nashi) and *communis* common pear both have long histories of domestication – verging on 3,000 years with an infinite number of cultivars, back crosses and feral forms.

The basic chromosome number is 17 and apart from a few oddities in cultivation no wild pears are polyploids.

Pyrus and *Malus* are closely related, though hybrids are difficult. Pears usually have a short central stalk to the flower cluster (i.e. a short raceme) while apples are more closely an umbel (i.e. no short stalk). Pears usually have stone-cells (grit cells) in the fruit that are absent from apples.

Challice and Westwood applied both chemical and morphological analysis to 244 living specimens thought to cover the range of species. Computer programmes were used (early by current standards). Even so, five species were dropped because of 'missing values' (*gharbiana*, *mamorensis*, *regelii*, *syriaca*, *glabra*). Leaf phenols and 10 flavone glycosides were used with morphological characters, a total of 51.

The results were as follows:

1) A group of European and West Asian species *communis*, *salicifolia*, *elaeagrifolia*, *amygdaliformis*, *nivalis*
2) A group of large fruited Asian: *pashia*, *pyriformis*, *hondoensis* , *ussuriensis*, Kansu pear

3) Asian pea pears: *calleryana*, *koehnei*, *dimorphophylla* and *fauriei*
4) A connecting group of *longipes*, *betulifolia*, *cordata*.

The Africans missed out.

Now all this more or less supports the grouping they started with, but alas, it was not followed by a taxonomic account.

Where do all the other names fit in? They gave no key to the species they did separate. So a disappointing conclusion to a promising start, and great problems of taxonomy remain. Where do *kawakamii*, *phaeocarpa*, , *tadshikistanica* and numerous other Asian names fit in? Are they 'good species'? I can only commend to you G. Krussmann 'Manual of Cultivated Broad-leaved Trees and Shrubs' Vol III, 1986, Batsford, London.

The Waite collection

The Waite collection started with a single *calleryana* which grew and flowered well, and as Adelaide is short of good spring flowering deciduous trees it was decided to explore the genus further. It was as simple as that. We got bud wood from several research stations and botanic gardens – put onto *calleryana* stocks.

About this time 'Bradford' pear was becoming popular in the U. S. A., but that was not the initiative for our collection – it was rather the idea of applying the homoclime concept and getting southern European material. Then came seed from Greece and Crete with *amygdaliformis* and *pyraster*, the latter either a precursor to the cultivated *communis* or feral forms of it. A row of *calleryana* seedlings was planted in Claremont Avenue, adjacent to the Waite Institute. I have said they are heterozygous and this row demonstrates that. Our excellent early 'Claremont' came from there, as did 'Bryan's Late' so far not developed. A further round of seedlings would undoubtedly extend the range further.

The *amygdaliformis* range from deciduous to semi-evergreen. They flower densely and regularly, fruits have not been a problem, although some like other pears are a bit malodorous; *pyraster* grows and flowers well but produces lots of fruits.

Then came a couple of African species from Westwood, then our first 'Bradford', then seedlings from Iran and later Turkey – at least three or four species amongst those but not yet identified, and lastly the generous gift of some of the American cultivars from Fleming's Nurseries and Lawrys Nursery.

Now two sad stories.

I began to make crosses between some the early flowering species. Seedlings raised and planted out in the two rows in the orchard area (on the side of the new Wine Laboratory). These were about 1 –2 m apart and grown to see what range we got. Well, an early flowering cross between *P. calleryana* and *P. amygdaliformis* showed promise – others were just coming in to flower when instruction came to remove the row as building was going to start. Trees went and only P. 'Prescott' was salvaged. Time and effort lost. About 40 seedlings started and a few marked 'good' in the old record sheets.

When Jennifer came we thought a proper orchard trial of promising trees desirable so a randomised replicated plot of three or four cultivars was set out. They had just started to flower when the University began charging for every square metre of space used. This was going to run into hundreds if not thousand of dollars per year, so that effort had to be scrapped.

Flowering records have been kept on our collection. Weekly recordings during the flowering and if I say it myself, a remarkable record. Some trees have over 100 notes over many years.

What can we offer you after these years? Firstly a reminder that these results are under Urrbrae rainfall which is at the lower end of *Pyrus* distribution. There is no doubt that there is a future for pears as decorative trees in higher rainfall, in colder areas. I can't answer for tropical areas but I expect some search in Asia would be profitable.

The northern Asian species are struggling here - *bretschneideri, boissierana, pyrifolia* - unfortunate as some have large attractive flowers. The last is now an established orchard tree.

P. calleryana 'Lynington' is now on the go. Doing well, flowering freely, some seasonal colour.

P. calleryana 'Claremont' is the earliest flowering of that species, good and regular in the Arboretum and should be made available.

P. 'Prescott', the hybrid, another very early flowering cultivar, has been a bit uneven at the Waite. Slow in the Arboretum, but better in the Urrbrae House Sensory Garden. Those at Mt Lofty Botanic Garden have done much better and have really showy early flowers.

P. amydaliformis has done well. Deciduous or evergreen range of flowing times, somewhat dense tree, heavy flowering but a bit malodorous. [We have more specimens from Turkey, but they have not yet flowered.]

P. pyraster has done well (wild type pear). It grows and flowers well but has heavy crop of useless fruits.

It is too early to assess the American cultivars though it is intriguing that our 'Bradford' now columnar trees to 4 m high have scarcely produced a flower. Do they need chilling?

Our own selection of an erect form from plants at North Adelaide flowers well and colours well and certainly looks interesting.

I think it is a collection we can be proud of and will have more to offer.

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Postscript:
39 specimens of *Pyrus* 'Lynington' in bags will be available for sale at the symposium. These were budded from the trees in the rose garden of Urrbrae House by Freshford Nursery, grown on by Lawrys Nursery and donated. All proceeds will go to support TREENET.

CONSTRUCTING ROOT SPACE FOR TREES IN AUSTRALIAN CITIES

Lyndal Plant - Brisbane City Council, Brisbane

Abstract: Over the last 6 years Brisbane's central business district has grown significantly greener and more pedestrian friendly, using a combination of "tree trench" technology and footpath widening. Millions of spectators at the Olympic Games in Sydney in 2000, walked along boulevards lined with fig trees and jacarandas growing in tree trenches covered with porous paving. Incorporating tree trenches beneath pavements in both site upgrades and new projects, is an exciting and cost effective approach to greening urban centres.

INTRODUCTION

Those parts of our towns and cities covered with impervious pavements like car parks, footpaths, and malls, are usually the most "tree hungry" sites. Trees in paved areas provide relief from the surrounding built forms, and they shade, cool and beautify these locations. Yet paved sites present unique challenges to planting and growing new trees, as well as preserving existing trees. The typical street tree planting space, which is inhospitably sandwiched in a narrow strip between the road and footpath, places severe limitations upon healthy tree growth and development. Impervious pavements exacerbate the already disturbed, deoxygenated and contaminated soil conditions by requiring surface compaction of these small spaces (Craul, 1985). Without providing adequate space, of suitable quality, for tree root growth, new trees can not grow to their full potential, and therefore are more likely to cause damage to surrounding pavements, require more maintenance, deliver less benefits and die earlier.

Recent research in the United States has developed a stone-soil media ("structural soil") for tree planting sites where the stone matrix bears the load of compaction required for paving while the spaces between the stones provide an uncompacted voids for soil media and root growth (Grabosky & Bassuk, 1995,1996). When added to excavated spaces under pavements, "structural soils" provide "tree trenches" where roots have access to a much greater volume of suitable growing space than conventional planting holes. "Amsterdam tree soil" (Couenberg, 1994) is another type of gap-graded matrix which has been used to enhance tree performance in Europe for 30 years.

This paper describes the application of "structural soil" technology and other "tree trench" designs in Australian cities.

GREENING CITY CENTRES

Since Grabosky & Bassuk's publication, several city centre projects in Brisbane, Sydney, Melbourne, and Hobart have incorporated "tree trenches" into major streetscape improvement projects where large growing tree species were an important part of the desired outcomes.

In 1995 Brisbane City Council initiated a City Signature Program which reclaimed 2 lanes of roadside carparking along 6 blocks of a central city street and converted that space into a pedestrian friendly tree lined boulevard. A key justification to look beyond conventional tree planting holes in the pavement was introduced early in the design phase when concept plans began to show an avenue of large upright trees humanising the scale of the surrounding high

rise buildings, shading wide pavement areas and framing a view from the heart of the city through to the City Botanic Gardens (Figure 1). Two important pieces of information were introduced to the design team. Firstly, to grow a 10m tall, 6m wide dense canopied tree to meet the design intent would require at least 8.3 cubic metres of soil volume for root growth which needed to be rewet to 20% water holding capacity every 4 days and have no less than 20% air-filled porosity (Lindsey & Bassuk, 1991). Secondly, core samples along the proposed tree line revealed that the site soil consisted of a 200-300mm layer of fill, overlaying a plastic alluvial clay with high moisture content. It was obvious that existing site conditions were not going to support the desired species within a standard 1.5 cubic metre planting hole. The decision to install tree trenches was also helped by the need to excavate to relocate existing underground services along the new road edge. Additional excavation for the tree trench, therefore, did not add significantly to the construction costs. It must be emphasised that assessments of existing soil conditions and estimates of soil quantities and qualities required to support desired tree growth are vital to designing spaces for large growing trees.

Structural soil tree trenches in the first two City Signature projects in Brisbane used 200mm bluestone as the structural component and a composite loam soil media as the backfill for the voids between the bluestone. These large stone mixes have also been used in Brisbane's Roma St Parklands project and Grey St Boulevard.

The structural soil trench incorporated into the tree lined entrance to Stadium Australia at the Sydney Olympic site used a smaller stone/gravel (45mm), and premixed the gravel with a filler soil of high cation exchange capacity (Leake, 2001 pers com). Care was taken to add only enough filler soil that would occupy 50% of the gravel voids. This premixed structural soil is now available as part of the product range of Benedict Soil and Gravel Pty Ltd in Sydney. This mix has also been used in city centre projects in Sydney, including some trials on improving root zones of existing street trees.

A third Brisbane city centre project used a different style of tree trench – a reinforced slab suspended between the back of the new kerb and the old footpath pavement. The slab supported the new footpath pavement and provided a tree trench which was completely filled with growing media (Figure 2). Capped access points midway between each tree site were provided to allow watering and fertilising. The void between the slab and the soil surface allowed aeration between each grated tree site. This suspended slab technique makes even more space available for root growth than structural soils, where the stone matrix occupies up to 60% of the tree trench volumes.

Although each of these projects are relatively young, early tree performance has been significantly better than street tree counterparts planted in small holes, and there have been no signs of pavement upheaval or subsidence.

MODIFYING BACKFILL IN SERVICE TRENCH EXCAVATIONS

Structural soil technology has also been used to provide better conditions for root growth within the backfill of a large service trench. A new 1.75m diameter water pipe had to be constructed close to a row of significant fig trees using open excavation style. A layer in the existing soil profile was found to support root growth, and it was therefore decided to replace that layer in the backfill soil using structural soil like a filling in a sandwich of fine gravel supporting the pipe and the new road surface. A premix of recycled concrete (80-100mm diameter) and clay/loam was used in at this site. Although it is always better to avoid root damage in the first place, providing suitable conditions for root regeneration is an important tool in preserving significant trees in urban landscapes.

SHADE TREE PLANTING IN CAR PARKS

Trees in car parks are given little opportunity to perform when planted in compacted subgrade and confined in small spaces surrounded by kerbing. Those trees which do better have usually escaped the kerbed space and have roots upheaving the surrounding pavement. Structural soils are being trialed as an alternative for half of the tree plantings in an 80 space car park to allow space for root growth under the pavement. This is a joint project between Brisbane City Council and a private construction company. Construction modifications were simple and included a slightly deeper excavation, drainage installation at that depth, and additional capped vertical pipes to allow watering at the edges of the tree trench. Although the results of these modifications can not be evaluated until at least another 3-4 growing seasons, there is a strong case for wider use of the technique in car park construction.

COST EFFECTIVENESS OF TREE TRENCHES

On a per tree basis, tree trench installation is much more costly than conventional street tree planting in a paved footpath. However, when costs of poor tree performance, higher maintenance of both tree and pavement, tree replacement and loss of amenity values are considered, there is little doubt that tree trench installations provide a cost effective alternative. Such installations are often a very small part of overall costs for large scale construction projects. In locations like car parks, where only slight changes are made to the existing construction processes, installations of alternative, tree root friendly pavement subgrades adds little cost.

OPPORTUNITES FOR IMPROVEMENT OF TREE TRENCHES

Each new project in Australian cities has offered the opportunity to improve tree trench techniques, often because each site has its own unique constraints. Experiences so far have highlighted the need to further investigate the quality and quantity of filler soils. Managing the ongoing moisture, aeration and nutritional requirements of these man-made root zone spaces is also a challenge.

CONCLUSION

There is no doubt that the use of tree trench technology in high profile projects, especially the Sydney Olympic site, has increased interest in and application of such techniques in Australia. This has helped to further improve techniques, encourage discussion between arborists, engineers, soil scientists, landscape architects and project managers, and broaden the application beyond high budget projects. The use of structural soil as an alternative to conventional road base materials in car parks is one of the most exciting low cost applications of this technique.

However, tree trench techniques is but one of many tools to help achieve a better balance between infrastructure and tree cover in highly urbanised environments. It is a man-made root zone that has limitations. Options such as choosing species to match site conditions, or small scale site changes such as drainage installation, or site-soil chemistry adjustment should always be considered before more complex modifications such as underground tree trenches and extensive pavement coverings.

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GET DOWN AND GET DIRTY!
A PRACTICAL APPROACH TO ASSESSING SOILS

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Introduction.

Many tree planting and establishment problems are the result of an inadequate assessment of the characteristics of the medium into which trees are planted. The following presentation outlines a very simple approach to assessing soils in the field. Field results and observations may suggest that further investigations should be carried out. These may require a specialist soil scientist or soil-testing laboratory. The paper also includes a simple guide to collecting soils for sampling.

Step 1: Dig a hole.

Use an auger, post-hole digger or shovel to dig a hole to a depth of at least 600mm. If you use a soil auger, empty the auger onto a strip of plastic and record the depth of each "dig" on the plastic as you go. (NB. If you are using a tractor-mounted/ power auger make sure that you know where the underground services are located!!) You should note the depth at which obvious changes occur; eg. changes in compaction, layers of stones, a change in colour. You may also discover that the soil has been disturbed.

Step 2: Look at the colour of the excavated/ exposed soil profile.

Colour is a useful indicator of possible drainage problems. Moving from the surface to the lower levels look for the following colours: black/ dark brown surface layers may indicate the presence of organic matter; pale surface layers may indicate soil leached of nutrients; red indicates oxidised or "rusty" iron which usually indicates that the soil is well-drained and aerated; orange indicates that the soil is less well-drained; yellow indicates poor drainage and aeration; mottled red/orange/yellow/grey indicates a fluctuating water table and therefore poor drainage in wet times; grey indicates that the soil is likely to be waterlogged most of the time.

Inadequate depth of drained soil is a major limiting factor to plant growth. A drained depth of 400 mm is considered to be adequate for good tree growth. If this is not the case, consider tree species tolerant of poor drainage, avoid trees altogether or install sub-soil drainage.

Step 3: Smell the soil.

A good 'earthy' smell indicates that the soil is adequately aerated. A sour 'sewer' smell suggests that the soil is less well aerated and oxygen is limited. A rotten egg gas smell indicates serious problems with drainage, anoxia and possible toxicities.

A common cause of "smelly" soils is the presence of organic matter below the top 100-200 mm of soil. Aerobic organisms use soil oxygen to consume organic matter. As the oxygen level drops these organisms may be replaced by anaerobic bacteria. These organisms produce intermediate products which are not available to plants and which may be toxic to roots. In extreme conditions, the 'land-fill' gas, methane may be produced.

Remember that in natural soil profiles, undecomposed organic matter (o.m) is on the surface and that decomposing organic matter is within the top 100-200 mm of the soil. There is virtually no organic matter in subsoils.

Step 4: Determine the texture of the soil.

A Field Texture Assessment (FTA) is a simple method of determining the texture class of a soil. Texture is defined as the relative proportions of sand, silt and clay in a soil. The proportions of these particles influences fundamental soil properties such as water-holding capacity, drainage, aeration, susceptibility to compaction or ease of leaching. Soils dominated by sand tend to be well aerated and drained but retain less water and nutrients than soils with more clay in them.

A FTA involves taking a handful of soil, removing any rocks/lumps of o.m. over 2 mm in size, gradually adding water until it forms a moist ball or bolus. The bolus is worked and then extruded between thumb and forefinger to give a 'ribbon' of a certain length. Other characteristics such as grittiness, silkiness and plasticity are noted. Grittiness indicates sand, plasticity indicates clay and silkiness indicates silt. Greasiness may indicate organic matter. The longer the length of the ribbon, the greater the amount of clay in the soil. Texture should be assessed down the profile.

Natural soil profiles have a particle size distribution from the top to the bottom that goes from coarse to finer. A finer layer over a coarse layer may lead to drainage problems through the creation of a 'perched' water table. A dramatic change from a coarse layer to a much finer layer may lead to drainage problems from a 'rising' water table. An impeded layer may also limit the potential for root growth.

Step 5: Assess the structure of the soil.

Many generalizations are made about clay soils in particular. To many people a clay soil is a "bad" soil. However, some of the most productive soils in the country are clays. The range of properties in clays from poorly drained, hard-setting and crusty to very free draining depends on their structure. Soil structure is defined as the arrangement of the solids and the pore spaces. The terms pedality or aggregation are used to describe structure.

To determine soil structure, pick up a handful of soil and gently try to break it apart. Observe the degree of pedality, the ease with which it broke apart and the size of the peds (if any).

Soils dominated by sand are unlikely to form peds, ie. the sand grains don't stick together and the particles act as individuals. These soils are referred to as apedal. This means that they are likely to have a low water-holding capacity but are usually well-drained and resist compaction.

Medium to fine-textured soils (loams to clay) have enough clay in them to form peds or aggregates. An aggregated structure where the peds look and stay like cake crumbs is a great arrangement for roots. The large gaps or macropores between the peds facilitate drainage, aeration and root penetration and the tiny pores or micropores within the ped act as water reservoirs. The size of peds influences the balance between air and water in the soil. Where a clay soil looks like one large solid lump it may have a 'massive' apedal structure. This is unsatisfactory for plant growth.

There are a number of common causes of the decline of soil structure and the creation of massive soils. These include compaction, over-cultivation and structural instability.

Compaction: Compaction results from compression and shearing forces applied to soils by any kind of traffic – foot or vehicle. The effects are worse in moist conditions. The result is the reduction in size of pore spaces with negative effects on water infiltration, gaseous exchange and root penetration.

A very simple way of assessing if there is a compaction problem is to try to push a large screwdriver into the soil. Whilst this is technically more an assessment of soil strength it can be very useful guide to surface and sub-surface compaction. A surface covering of grass on a nature strip or a recent building site may overly a highly compacted mix of subsoils and construction waste. Previous agricultural land may have 'plough pans' at depth. Note that a dry soil will be 'harder' than a moist or wet soil.

Soil stability: One of the most common generalisations that people make about clay soils is that they all need gypsum to break them up. This is not true and may lead to other problems. Some aggregated soils can be cultivated to a good crumbly tilth. However, when the soil is wet by rain or irrigation the structure may collapse and a surface crust develops. This indicates that the soil has an unstable structure and will be prone to erosion. Unstable soils also provide challenging conditions for root growth.

To test for the cause of the instability problem, carry out this simple test. Take a lump of dry soil and carefully place it in a glass of distilled or rain water. It may also be very useful to see how your soil behaves in tap or irrigation water. Leave the soil undisturbed. Look at the soil after 2 and 24 hours. If the ped remains intact, the soil is said to be stable. If the ped has collapsed but the water is clear, the soil has slaked. If the soil has slaked and the water is cloudy or 'milky', the soil is dispersive or sodic.

A slaking soil is the result of physical instability and can be improved by incorporating composted organic matter into the top 100 mm or so and or protected by placing a 75 mm layer or organic mulch on the surface.

A sodic soil contains too much sodium on the clay particles. These need to be displaced. The safest material to use is natural gypsum or calcium sulphate. The calcium ions displace the sodium ions from the clay particles and lead to 'flocculation' or aggregation of the soil. Gypsum will not alter the pH.

The simple test outlined above is a modified version of the Emerson Aggregate Stability Test. To take the test a little further, work a moist ped into a little ball, place it in water and observe as before. The working of the soil may reveal some dispersion and thus some response to gypsum. This is important if the soil is likely to be cultivated.

If a soil is likely to be excavated, for example if a battered bank was to be developed, the subsoil should also be assessed for stability.

Step 6: Test the pH.

pH is a measure of the acidity or alkalinity of a soil and of the potential availability of essential plant nutrients. It is not the be-all and end-all of tests, just another piece of the jigsaw.

A simple colorimetric test kit such as that developed by the CSIRO is adequate for most landscape applications. Do not waste your money on pH/ moisture probes.

A pH range of 5.0 to 7.5 is reasonable for most nutrients and most plants. However, some plants are adapted to grow beyond these levels. pH is a useful tool for plant selection, as a guide to possible remediation and diagnosis of problems. If the pH is extreme, you may need specialist help – see Step 8.

Step 7: Repeat the process elsewhere on the site.

Soils can be spatially quite variable, particularly on disturbed sites so it may be sensible to dig a few holes.

Step 8: If you suspect nutrient disorders or salinity, collect samples for testing.

If you see salt crusting on the surface, the edges of leaves turning brown or consistent discolouration of foliage, there may be a chemical problem. Most chemical testing requires a specialised soil-testing laboratory and the input of a soil scientist.

Before collecting samples for testing, find a laboratory and ask them a few questions; for example: Will the results be interpreted? What will be tested for? How much will it cost? How long will it take? How much soil is required? How should it be prepared and delivered?

A range of chemical properties may be determined including pH in water and in calcium chloride, exchangeable cations, cation exchange capacity, % organic matter, amount of particular nutrients, electrical conductivity and so on. Make sure that you get the results interpreted in plain English otherwise you will end up with a page of numbers.

If an area is to be managed as a unit, for example a median strip or grassed area in a park, then you need to collect a number of samples to make a composite sample for testing. Depending on the area, you may collect 15 or 20 sub-samples. To do this, remove the surface vegetation or mulch and take a sample from about 100 mm below the surface. Put this into a clean bucket or plastic bag. Put all sub-samples into the same bag/ bucket. Once collected, tip the composite sample onto a clean sheet of plastic, mix it up and divide the sample until you have the amount required for testing. Put this into a clean plastic bag. Make sure that you label the bag!

Do not mix topsoil and subsoil (unless it is already mixed). If the subsoil is to be exposed, this should also be sampled and tested. Before using underground water for irrigation it should be tested for its salinity, pH and sodium content.

Conclusion.

Having a look at what lies below the surface can be a very useful investment of time and resources. It may save considerable lost time and wasted resources if trees are planted into an environment in which they are unlikely to survive. It is critical that the physical properties of the soil are determined and modified if necessary in order to provide a suitable balance between air and water for roots and desirable soil organisms. In some areas the chemical characteristics of the soil will provide challenges to be overcome by careful plant selection or possible remediation.

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SOIL PROFILE DATA COLLECTION SHEET.

Described by: …… Date: …….
Location: …….
Site Description:

Geology: **Aspect:** **Slope:**
Vegetation:
Site and or soil disturbance factors:

SOIL PROFILE

Sketch – show layers/	Depth (mm)	Texture	Structure	Colour	pH	Stability	Compaction	Other

REDUCING TREE HAZARDS IN URBAN HORTICULTURE

Phil Kenyon - Melbourne University Burnley College

"A stitch in time saves nine"
"Prune and shape early saves dollars and deaths later."

"Life Time" v "Tree Time"

The average Australian lives for about eighty years.

As a species we are conceited, we live on earth, believing we will be here forever, and that we are the most important event the world has witnessed. Most of us will be lucky if we have the honour of planting a tree and watching it grow through the various stages from a seedling, to a young tree to semi-mature to a mature fine specimen, admired by all, providing shade shelter and habitat.

Hang on! DO we see it Mature?

Will we be here long enough to see it mature? If it is an *Acacia confusa* maybe! But the average life of many tree species is one hundred years, two hundred is not uncommon, and in some cases many more years. As humans we want things to happen quickly. If a branch is to be removed, out comes the chainsaw, off goes the branch. If the tree 'decides' that a branch is no longer paying it's rent, the process of branch death and eventual expulsion may, and usually does, takes years.

We need to contemplate and further study trees, forests and the natural order of the forest environment. Time, and the concept of time is another important consideration with regard to trees. Trees are, in general, when compared to man, very long-lived. In many situations, tree failures develop slowly. A Red Gum may take twenty years to shed a branch; the changes can be very subtle. Twenty years in the life of a four hundred year old tree, is not a very long period.

We need to think in terms of **"Tree Time" not "Human Time"**

As arborists it is possible to locate faults and to predict tree failure, what is particularly difficult to predict is: 'When will the failure occur?'

If we are accurate to within a ten year period in predicting tree failure then in terms of tree time, that is pretty good.

Hazard abatement programs are usually based on inspections of mature and semi-mature trees. "Large, old trees are more likely to fail than are smaller or younger trees of the same species." [Harris, Clark, Matheny 1999]

Because of a poor understanding of the requirements for trees to have a well formed root system, a large percentage of the trees planted during the 1970's, have deformed root systems (Moore, 1987) (May, 1990).

Programs of reducing or preventing hazards by looking at 'whole tree management systems' may be much more cost effective long term, than hazard assessment and abatement of mature and senescent trees.

Such programs need to consider nursery systems, site planning, site preparation, planting techniques, through to pruning and shaping young and semi-mature trees. Poor nursery practices and resultant root deformities such as J roots, and root girdling have been shown to

be the reason for many tree failures. Sometimes these root deformed trees fail within a five to ten year period, but other root deformed trees may not fail for twenty plus years. Root deformed trees are often stressed trees and are more susceptible to insect and pathogen attack. Many of the trees planted over the last thirty years have been planted with poorly developed root systems. These trees are a costly burden to maintain as they develop. Often to actually beat the vandals, the mowers, the engineers, the road construction workers, and the environment, parks departments struggle for years to maintain and grow root deformed trees. Unfortunately so much time effort and expense is wasted, as many of these root-deformed trees are unstable in the ground. Many of these trees are time bombs. It may be that an extremely wet winter, or severe windstorm, or an uncommon wind direction, either singly or in combination are the factors that contribute to the eventual failure. Trees with good anchorage and sound root systems are less likely to fail in these conditions.

Whole tree failures have the mass and potential force to cause far greater damage than branch failure. During hazard assessment greater care and more in-depth assessments need to be made of tree stability. There are very few references to techniques or methods to determine tree stability. 'The Burnley Test' for trees up to approximately 150mm is to rock the trunk at breast height and examine the root zone for root crown movement. The canopy of a tree has adapted to move and sway in the wind, tree trunks bend and flex, but how much should root crowns and systems move in the ground? Most landscape trees should firm up and be stable within five to six years after planting. After this time the trees should feel stable and not exhibit 'excessive' root crown movement. (What is excessive? At this stage it is difficult to define.) Further research is needed to investigate root crown movement and what is excessive!

For trees over 150 mm at breast height it may be necessary to establish a line into the crown to test for stability of the root crown. The line may be used to gently set up a sway or rocking motion in time with the natural frequency of sway motion of the tree. Whilst this is occurring the root crown may be examined for excessive movement. This test must be used carefully if there is real concern that the tree may not be stable in the ground. On two occasions trees have actually failed and commenced to fall over when subjected to this test by the author.

When Testing Trees over 150mm trunk Calliper at Breast Height

> Care should be taken not to pull the tree over during testing!
> Beware of dead wood and hanging branches in then crown.
> Watch the root crown at ground level for movement.
> Watch for ground heave. Cracks in the soil opening and closing.

Another method is to use an air knife to remove some soil from the root crown and visually inspect the root crown for decay or deformities such as root girdling.

The latest method is to attach a load cell and an inclinometer to the tree and actually pull the tree with a winch. The winch is anchored and the tree is pulled from approximately 6 m up the trunk. The tree is pulled in four directions, an equal amount of force is exerted each time the tree is pulled and the movement of the tree in the ground is measured using the inclinometer. Ken James (Burnley College) is currently working on this system to further refine it .The advantage of this method is that some actual numbers are given to indicate the strength of the trees stability by comparing pulls on each of the four compass points. In two recent tests visual assessment suggested that each tree was moving excessively in the ground, but when the load cell and inclinometer test was undertaken the arborists present were confident that the tree stability was not an immediate problem.

Whole nursery systems need to be reviewed to reduce the incidence of root deformed trees. Specifications for the supply of trees should demand and ensure that only trees with quality root systems will be accepted.

Tree planting site preparation and planting pit design are also responsible for many tree failures. Inadequate, effective anchor root zones, waterlogged planting pits, incorrectly shaped planting holes are all factors which have contributed to many tree failures. Many tree species have evolved in a forest situation where the root systems are inter-woven and interdependent. Each tree provides wind buffering and increased stability to it's neighbour. Trees share mycorrhiza and much of the soil flora and fauna. There is a lot of interaction between trees. We have taken these trees out of the forest and asked them to grow in a stressful, often solitary environment. To reduce hazardous failures we need to ensure that each municipal tree is propagated, grown and established to " Best practice" utilising all the technological advances of the year 2002.

Old, and stressed trees, are more likely to have potential for failure. Because of the number of root deformed trees planted, there is the potential for an epidemic of tree failure. Australia, along with the rest of the world, is becoming increasingly litigious. As managers of this tree resource, it is our responsibility to manage our resources to minimise the hazards associated with trees.

"A tree is hazardous if it has both a structural defect that predisposes it to failure, and a target that would be struck if it were to fail" (Smiley and Fraedrich). The target can be any object of value, whether this be fixed, such as a house or mobile, such as people, animals and vehicles. The situation is a little more complex than this. There are obviously levels of tree failure or hazards, and there are levels of target value and exposure. All trees have the potential to be hazardous, and it could be argued that as a tree ages, it inevitably would become hazardous. A four hundred year old *Eucalyptus camaldulensis*, a species that is an acknowledged large limb shedder, growing in the middle of a paddock at Epping, Victoria would normally pose little threat to man or his assets, the risk of an accident is very remote. If the paddock is stocked with a large number of stud cattle, then the possibility of loss is increased. Stock will often seek shade and shelter in both hot weather and stormy weather. If a house was constructed under the canopy of this tree, then it is really only a matter of time before major damage may result from branch failure.

Hazard assessment is a very difficult area for any tree manager to quantify. There are many variables, and many areas that need to be considered. The following is a list of possible considerations:

Potential for tree failure.
Presence of a target.
Target value.
Target risk time.
Potential of tree to cause damage.
Tree value.

If each of these factors could be rated, it may be possible to develop a formula to assist in decision making when faced with difficult decisions

The potential for a tree to actually fail can be extremely difficult to predict. In order to determine the potential for tree failure, the arboriculturalist needs to have an intimate knowledge of tree physiology, tree structure, tree disorders or stress factors, how certain species respond to stress, characteristics of particular species as forest trees, and as isolated urban trees. This knowledge, combined with information on many other factors including;

history of the site, normal weather patterns, drought, rainfall, wind, incidence of severe storms, soil type, how the soil reacts when saturated, how the soil reacts when it dries out, are among some of the factors that an arboriculturalist would consider. A qualified arboriculturalist, with years of experience in a particular area, working with a limited number of species, cannot be expected to predict all potential failures. Only qualified and experienced arboriculturalists should assess trees for potential failure. A systematic approach to the inspection of trees for hazard potential should reduce the risk of overlooking possible failures. The following lists may be useful guides in assessing trees for potential failure.

A SYSTEMATIC APPROACH TO HAZARD TREE INSPECTION

- Tree Stability (root system)
- Trunk Failure, Trunk Integrity
- Major Scaffold Limb Failure
- Branch Failure
- Fruit Fall (Small number of species)

Visual Tree Assessment Hazard Indicators

TREE STABILITY	TRUNK INTEGRITY	BRANCH INTEGRITY
Buttressing absent	Co-dominant stems	History of branch shedding
Existence and location of major roots	Cracks, vertical, horizontal.	Unusual, excessive Branch Collar formation
Trunk lean	Discoloured or dead sections of bark.	Dead wood
Excessive growth on one side	Fungal fruiting bodies	Defoliation
Trunk movement at ground level (Test)	Trunk deformities	Ant nests
Fine cracks in soil	Hollows, cavities	Burls, deformities
Root tension, opposite side to lean.	Flush cuts on trunk	Epicormic shoots
Ground heave	Exudates	Cracks
Fungal fruiting bodies	Decay	Delamination
Level changes	Wire, foreign objects	Included bark
Severed roots	Sound the tree?	Branches bending down
Root plate hollow	Drill	Very long branches
Major change (trenching, clearing)	Resistograph/ PIRM/ SM 80	Lack of branch taper
Dead or deformed trunk sections at ground level	Acoustic devices (Tomograph)	Signs of branch stress
Dead tree	X-ray	Dead areas or sections of branch or bark

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RISK MANAGEMENT OF URBAN STREET TREES

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1. INTRODUCTION

We live in times of rising expectations. What was a luxury yesterday is taken for granted today; and tomorrow is expected to be better than today. Therefore, in terms of risk, what we could get away with yesterday, we can't get away with now. Tomorrow's failure to manage risk will have greater consequences than today's failure to manage it.

When managing risks, five questions arise;

1 what is risk management?
2 where does risk management fit into an organisation?
3 why is risk management important?
4 what are the risks with street trees?
5 how can those risks be managed?

2. WHAT IS RISK MANAGEMENT?

AS/NZS 4360:1995 defines risk management in 1.2 as

> A logical and systematic method of identifying, analysing, assessing, monitoring and communicating risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise opportunities.

Risk is defined as

> "The chance of something happening that will have an impact on objectives. It is measured in terms of consequences and likelihood".

The objectives for street trees are to:

- Perform their intended function;
- Remain safe at all times.

In terms of consequences and likelihood, table 1 provides a qualitative risk analysis matrix, taken from Table D3 in AS/NZS 4360:1995, noting how risks can be categorised.

Table 1 Risk assessment matrix to determine a risk event level

LIKELIHOOD	CONSEQUENCE				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
A (almost certain)	S	S	H	H	H
B (likely)	M	S	S	H	H
C (moderate)	L	M	S	H	H
D (unlikely)	L	L	M	S	H
E (rare)	L	L	M	S	S

H = High risk; S = Significant risk; M = Moderate risk; L = Low risk

According to the Standard, the main elements of risk management are to:

- ESTABLISH CRITERIA against which risk will be assessed;
- IDENTIFY what, why, and how risks can arise for further analysis;
- ANALYSE risks in terms of controls, likelihood, and consequences;
- ASSESS and PRIORITISE risks, compare the level of risk against the risk criteria;
- TREAT RISKS, accept low risk, develop and implement plans for others;
- MONITOR and REVIEW the system, making necessary changes;
- remember the process is ITERATIVE and requires records to be kept.

Conclusion One: If councils are not conducting any of these tasks, or only some of them, can they claim to be managing risk?

According to Helliwell (1990), the combined effect of condition and location determine likely risk from a tree and he cautions assessors

> "not to be unduly swayed by pressure to retain them against his or her better judgement".

In terms of risk likelihood, Helliwell (1990) provided for the British insurance industry a suggestion that a 150-year-old tree has a 1:10 risk of limb loss in one year. He (Helliwell, 1990, pp. 159-161). proposed a risk frequency for falling branches causing serious injury or death as follows:

- **very high risk**, e.g. overhanging a busy road 1:2
- **high risk**, e.g. overhanging a well-used park 1:10
- **moderate risk**, e.g. overhanging a minor road 1:100
- **low risk**, e.g. in a large private garden 1:1 000
- **very low risk**, e.g. in remote woodland 1:10 000.

Conclusion Two: If councils are not setting risk management standards and guidelines, and *publicising* them, can they claim to be managing risk?

3. WHERE DOES RISK MANAGEMENT FIT IN AN ORGANISATION?

Nowadays government agencies and all major organisations are required to manage their assets. For example, an asset may be

- buildings
- roads
- parks or reserves
- adventure play areas
- street trees

In South Australia, Division 4. Management Plans; Section 196 (3) of the Local Government Act 1999, councils are required to

> "prepare and adopt a management plan or plans for its community land that must:
>
> (a) identify the land;
> (b) state the purpose for which council holds the land;
> (c) state the council's objectives;
> (d) state performance targets and how the council proposes to measure its performance against its objectives and performance targets".

Council's may need to state the purpose and objectives for holding its trees; say what performance it expects from them; and measure how they perform against targets set for them. Thus there are risks of non-compliance with this legislation, in not having statements that define the purpose and performance of street trees.

The South Australian Government has also adopted Australian Accounting Standards 27, requiring councils to record, map and value all their Assets. As a consequence, trees need to be treated as assets; be recorded; and be valued and managed.

Conclusion Three: If councils are not complying with the Local Government Act or Australian Accounting Standards 27, where trees are concerned, they have not understood street tree management, nor the concept of tree risk management.

4. WHY IS RISK MANAGEMENT IMPORTANT?

One reason for managing trees and the risks associated with them is to comply with the above requirements. Another is for further legal reasons, for instance the Occupational Health, Safety and Welfare Act (South Australia), 1986, provides for owners, occupiers and designers to ensure that appropriate steps are taken to identify all *reasonably foreseeable* hazards that may affect persons at the workplace. General provisions allow a person to move conveniently and safely about, and to have reasonable access to any workplace or workplace amenity. This legislation covers members of the public against risks to health or safety.

Conclusion Four: If councils are not aware of legislation relating to trees, especially street trees, they are probably not complying with it, and may be at risk.

5. WHAT ARE THE RISKS WITH STREET TREES?

There are many risks or potential risks associated with street trees. In organisational terms, risks may be:

- procedural
- legal
- operational
- situational

Procedural risks include not having a Tree Management Plan, which has:

- policies, strategies and criteria
- definitions
- a database, backed by up-to-date reporting
- a process for review

Without this, a Council may be exposed to a failure to discover how many trees need to be managed, a failure to discover how many Significant trees need to be protected, and a failure to discover how many hazardous trees need to be treated

When a sample of Australian councils were asked if they had a Tree Management Policy, 57% of the 28 responding councils did; 39% (11 councils) did not, and one council did not reply. Of those without a tree policy, only one had no plans to draw one up.

Conclusion Five: Councils without a Tree Management Plan, have no process by which all trees, the good, the average and the bad, can be managed? If they have no database that can highlight matters of risk, the hypothesis is that they cannot manage an unknown quantity.

Legal risks may include consequences of:

- physical damage
- personal injury
- nuisance
- encroachment
- non-compliance with regulations under several acts

Council may be exposed to these risks by a failure to act prudently or exercise a proper duty of care, a failure to keep adequate records, and a failure to deal with risk once pointed out, causing costly litigation.

As an example of tree-related risk, table 3 shows a limited survey of seven countries:

Table 3

COUNTRY	MAIN CAUSE OF PERSONAL INJURY	MAIN CAUSE OF PROPERTY DAMAGE
Australia	Disrupted paving	Storm damage
New Zealand	Storm damage	Limb fall
United States	Disrupted paving	Limb fall
United Kingdom	Limb fall	Disrupted paving
Germany	Disrupted paving	Storm damage
South Africa	Storm damage	Storm damage
France	Disrupted paving	Storm damage

To overcome the risk potentials above, Australia needs to manage disrupted paving and storm damage better.

Operational risks may include:

- failure to conduct tree regular audits
- failure to deal with audit findings
- inappropriate tree management techniques
- failure to respond to ratepayer notification
- failure to make-good physical damage from trees
- inappropriate planting conditions
- inappropriate or inadequate establishment techniques
- inadequate summer irrigation
- failure to appreciate risk
- failure to identify hazardous trees
- failure to remove hazardous trees or tree parts soon enough

In terms of hazardous trees, table 4 asked what councils' percentage of hazardous trees were, in a limited survey of seven countries:

Table 4

Country	Percentage hazardous trees
Australia	Range between 0.1%, 20%, 50% to 75%
New Zealand	**Range between 0.3 % to 10 % but mainly under 1%**
United States	Range between 10% to 90%, with an average around 12%
United Kingdom	Range between 1 and 3%
Germany	Range between 0.4 to 1%
South Africa	Sole figure of 5%
France	Sole figure of 20%

Three observations occur; firstly the range is far too big for risk control; secondly, 20% and 50% returns are extremely and unacceptably high; thirdly, there is probably no definition of the term "hazard" in the policy document. Note that a council with 20 000 trees with 10% of them at risk, has 2 000 dangerous trees. What is a responsible safety goal? Is it 1% (200 trees), is it 0.1% (20 trees) or 0.01% (2 trees)?

Conclusion Six: If councils do not have a policy document defining matters such a "hazardous trees or hazardous conditions" how can they claim to be managing risk, when it has not been identified?

A second risk management query asked for the most favoured pruning technique.
Table 5 shows their replies.

Table 5

MOST FAVOURED TECHNIQUE/COUNTRY	AUS	NZ	USA	UK	GER	SA	FRA
Remove 1 co-dominant stem		**1**					**1**
Cabling and bracing		**2**	**1**				
Crown lifting	**2**		**2**		**2**	**2**	
Whole limb removal	**1**					**1**	**2**
Included bark removal				**2**			
Dead-wooding					**1**		

It is worth asking how far crown-lifting and whole limb removal deal with the highest risks expressed in Australia, namely disrupted paving and storm damage? Do the treatments match the complaints?

Situational risks may include:

- tree canopy amongst power lines (very high risk)
- tree canopy overhanging roads (very high risk)
- trees causing property damage (very high risk)
- trees encroaching someone else's land (high risk)
- fast-growing trees (high risk)
- brittle-limbed trees (high risk)
- trees obscuring sight-lines (high risk)
- trees about to do any of the above (high – moderate)
- trees causing a nuisance (high – moderate)
- trees with nuisance properties or characteristics (moderate risk)

- short-lived trees (moderate risk)
- trees obscuring traffic signs (moderate risk)
- trees obscuring a right of way (moderate risk)

A 1991 survey of 20 United States cities found that the average life of a downtown tree is a mere 13 years (Skiera & Moll, 1992). The survey points to an urban setting that provides more stress factors for trees to cope with than a rural one. Sample findings from the Skiera & Moll survey were:

- increased urban tree mortality;
- average street tree lives for 13 years;
- half of the tree spaces were empty;
- 45% of cities had no maintenance program;
- public concern for trees is at an all-time high;
- people see trees as an indicator of community quality;
- ALL surveyed cities had tree damages claims pending.

However (Bassuk, 1999), claims that, in the United States, urban trees surrounded by pavement live on average for only 7 years. Bassuk found that the same species growing in verges have an average life of 32 years, while the same species growing "in a more hospitable setting" have a *safe useful life expectancy* of 60-200 years.

City trees have a considerable asset value, yet it appears that they are not well managed. British researchers examined tree performances from 11 cities in the north of England in 1983 (Gilbertson & Bradshaw, 1985). Their results found that:

- inner city trees were limited to a few species (lacking species diversity);
- all showed poor growth (having a poor appearance);
- there was a vast range in performance (inconsistent results);
- 10% of all trees were dead (10% of costs wasted);
- tree guards, so often used for protection, caused 12% of tree deaths;
- compaction by machine and bitumen or concrete surfaces impede infiltration and reduce soil moisture and aeration and are prime causes of tree death (Gilbertson & Bradshaw, 1985:pp.132-141). Bracketed comments belong to the study.

These, and other reasons, enabled Gilbertson & Bradshaw to conclude that death rates for urban trees were unacceptably high; and that growth rates were too low. This feedback suggests that managers should upgrade field practices and increase the establishment of healthy trees in order to reduce the likelihood of failures later on.

Condition audits are needed to manage risk in living things and to monitor their progress and decline. This process must be iterative, say 1-5-yearly, so that changes can be recorded and compared with an extending level of risk. Both present and future condition lead to a risk analysis for the tree and for its effect on its surroundings.

Tree performance records provide a good basis for future species selection, because analysis can discriminate between better and poorer performers. Poor performers need not be replanted, while good performers are sought after and may be candidates for genetic improvement.

Conclusion Seven: A wide range of evidence now covers risks to street trees throughout their lifetime. Councils owning street trees with "very high" to "moderate" risks, cannot claim to be managing risk.

6. HOW CAN RISKS BE MANAGED?

Risk is managed by a process that first advises managers to establish the risks to or from a tree, by setting out the criteria against which risk will be assessed.

The next step is to identify what, why, and how risks can arise. A tree owner is expected to foresee likely risks and to forestall them by strategies or actions. Once risks have been identified, they need to be analysed in terms of controls, likelihood and consequences. Likely risk events seem should be assessed and prioritised, then compared, to rate their level of risk against the risk criteria. From this level of risk management preparation, the manager should develop and implement plans for the major and moderate risks, eliminate or reduce their severity, accepting low-level risks, until they become a first priority.

The University of Ulster collected the following data from UK Councils:

No accurate tree records	54%
All trees	4%
Street trees	49%
Park trees	15%
Open space trees	10%
Public housing trees	12%
School trees	4%
Cemetery trees	7%
Council with a computerised tree inventory	50%
Council without a computerised tree inventory	50%
Increased mortality of newly planted trees	24%
Decreased mortality of newly planted trees	27%
About the same	49%

To avoid risk, there are two aspects of trees that need to be managed,

1. their performance
2. their safety

Table 7 shows some risks from trees:

Table 7 State Emergency Service Storm damage data 1995-99

RISK EVENT/YEAR	95/96	96/97	97/98	98/99 APR	TOTAL
Tree down on driveway	23	8	55	19	105
Tree down	63	41	216	57	377
Tree down on road	82	57	223	110	472
Tree down on house	50	10	152	38	250
Tree down on cars	11	6	21	13	51
Tree down on fence	23	7	65	24	119
Tree down on power lines	8	12	110	22	152
Tree down on carport	9	5	42	17	73
Tree down on footpath	3	5	17	15	40
Total	**272**	**151**	**901**	**315**	**1639**

Risk is best avoided by establishing a risk management system containing

- a list of risk sources TO trees
- a list of risk sources FROM trees

Conclusion Eight: If councils do not have a Tree Management Plan, involving record keeping, how will risks be identified, analysed, prioritised and treated? If councils are not doing these things, can they claim to be managing risk?

Summary

There is sufficient evidence from researchers and court proceedings to show that risk management should be taken seriously and be a standard process in corporate affairs.

EUCALYPTS WITH POTENTIAL FOR STREETS

Dean Nicolle - Flinders University

The eucalypts (genera *Eucalyptus*, *Corymbia* and *Angophora*) are a group of trees, mallees and shrubs distributed almost exclusively in Australia, but with a few species extending to New Guinea and a few other island to the north of the continent. The eucalypts dominate many Australian landscapes and are present in almost all landforms throughout Australia, being absent only from tropical rainforest and some extremely arid environments in central Australia. The eucalypts vary in form from almost prostrate shrubby groundcovers such as *Eucalyptus vernicosa* to the largest flowering plants in the world in *E. regnans*, which can grow to over 100 metres tall. Approximately 1000 taxa (species and subspecies) are known, with new species still being recognised. The majority of these species are poorly known or unknown in cultivation and their potential for a myriad of uses is unknown. Some appear to have potential in suburbia for uses such as street trees and garden and park plantings because of their unique combinations of ornamental appeal and suitability for a range of specific sites.

THE ROLE OF CURRENCY CREEK ARBORETUM IN ASSESSING THE POTENTIAL OF EUCALYPTS FOR STREET TREES

Currency Creek Arboretum (CCA) is a specialist eucalypt arboretum located approximately 80 km south of Adelaide in South Australia. As of January 2002, CCA had approximately 6000 plants from 1800 accessions of 850 eucalypts species and subspecies growing. CCA is helping to assess eucalypt species for street tree potential in the following manner:

- Basic knowledge on each species characteristics. The flower colour of *E. histophylla* was unknown and assumed to be white (based on related species) until the species was grown to maturity at CCA and flower colour was seen to be consistently yellow. Tree and mallee forms of *E. conglobata* was shown to be caused by site conditions alone as both developed into small bushy trees at CCA.

- Basic knowledge on each species site suitability. Growth rates, survival rates, and health indices are recorded for all plantings at one-year intervals. Time to first bud initiation and first flowering are recorded.

- Assessment of ornamental qualities including form, bark, foliage, flowers and fruits.

Examples:

Angophora euryphylla (form and bark)
Corymbia ficfolia (form and flowers)
E. apodophylla (bark and foliage)
E. macrocarpa subsp. *elachantha* (foliage and flowers)
E. synandra (foliage and flowers)
E. wyolensis (foliage)
E. youngiana (flowers and fruit)

THE RECOGNITION OF REGENERATIVE STRATEGIES IN THE SELECTION OF POTENTIALLY USEFUL STREET EUCALYPTS

Through research at CCA and much field work, it has become apparent that there are distinctive regenerative strategies amongst the eucalypts that will have an impact of the selection of species for street trees. Two main groups can be identified, obligate seeders and resprouters. Obligate seeders will regenerate only by seed and are killed by terminal crown destruction. Resprouters will regenerate vegetatively via epicormic shoots as well as regenerate by seed.

Obligate seeders

General characteristics:

- Very quick growing.
- Tend to be short lived (10-20 yrs), at least in natural conditions, death usually resultant from wildfire.
- Killed by terminal crown destruction caused in the wild by fire or in cultivation by severe pruning of accidental damage.
- Can be prone to wind damage

Common examples of obligate seeders used as street trees, with varying effectiveness include *E. spathulata, E. sargentii, E. platypus, E. torquata, E. steedmanii* and *E. woodwardii.*

Resprouters

General characteristics:

- Are not generally as quick growing as obligate seeders.
- Are usually very long lived (2000 yrs + have been reported.)
- Will resprout following terminal crown destruction (fire, pruning, other damage)

The resprouters can then be classified into three groups amongst the eucalypts, depending on where the species will resprout following terminal crown destruction.

Lignotuber sprouters (mallees) resprout from a lignotuber at ground level only and stem coppice is absent. Common examples used as street trees, with varying effectiveness include *E. caesia, E. formanii, E. viridis, E. diversifolia, E. erythronema* and *E. macrocarpa*.

Stem sprouters resprout from the stems and branches only as a lignotuber is absent in such species. Common examples used as street trees, with varying effectiveness include *E. cladocalyx, E. gomphocephala* and *E. punctata*.

Combinations sprouters resprout from stems and branches and also from the lignotuber if the damage is severe. Common examples used as street trees, with varying effectiveness include *Angophora costata, C. maculata, C. ficifolia, C. ptychocarpa, E. sideroxylon, E. leucoxylon, E erythrocorys, E. mannifera* and *E. miniata*.

THE DISCOVERY AND RECOGNITION OF NEW EUCALYPTS WITH POTENTIAL IN SUBURBIA

The discovery of new eucalypt species has declined gradually over the last few decades, as most areas in Australia are now relatively accessible due to improved transport and technology. Most new discoveries are made in remote areas, such as the deserts and northern Australia, or in relatively small inaccessible areas such as on mountain peaks.

A far greater number of eucalypt species have been discovered for some time, but due to various factors, remain untrained in cultivation and as such are poorly known in terms of their potential.

Examples of recently discovered eucalypts with potential as street trees include:

(Southern regions)

- The purple-crowned silver mallet (*Eucalyptus purpurata m.s.*). A soon to be named small tree from powdery white loam in southern W.A. with reddish-purple new growth.
- *E. mimica,* a recently named small erect tree with fine, dark green foliage from saline flats in southern W.A.
- Pink flowering variant of *E. cosmophylla* known from Fleurieu Peninsula in S.A.
- *E. mcquoidii*, a recently named small bushy tree from coastal southern W.A. with fine foliage and large, elegant buds and greenish yellow flowers.
- *E. x stoaptera*, a recently discovered natural hybrid between *E. stoatei* and *E. tetraptera* from southern W.A., having the small tree form of the former and large colourful buds and flowers intermediate between the two species.
- *E. urna*, a common but recently named medium tree from limestony soils in southern W.A. with good form and very shiny green leaves.
- *E. victoriana*, a small stringybark from the Grampians (Vic.) with good form and deep green foliage.

(Tropical regions)

- *Corymbia aspera*, a small ghost gum (powdery white bark) from very rocky sites in semi-arid northern Australia.
- *C. flavescens*, a small ghost gum with undulate, shiny green leaves from the Pilbara (W.A.) to Mt Isa (Qld.) regions of northern Australia.
- *E. brachyandra,* a small tree with light green rounded leaves (like a poplar) from cliff faces or otherwise very harsh sites in far northern W.A. and N.T.
- *E. ceracea,* a recent discovery from the northern Kimberley (W.A.), a small tree with silver leaves and large clusters of orange flowers.
- *E. aff. melanophloia,* a mallee ironbark from the Mt Isa (Qld.) area with silver foliage.

As well as these taxa which are untrialed in cultivation, some newly recognised or newly trialed species are known to be superior to related well known species used in suburbia in terms of greater ornamental appeal and/or superior site tolerances.

Examples of poorly known eucalypts which may be superior to their more well-known counterparts as street trees include:

- *Angophora leiocarpa* which is superior to the popular *A. costata* (the former has finer, graceful leaves and smaller capsules; originates from lower rainfall areas).
- *Eucalyptus petiolaris* which is commonly planted and superior to the easily confused *E. leucoxylon* (the former has a more graceful crown, more varied flower colours, the flower colour breeds true; tolerates saline soils).
- *E. preissiana* subsp. *lobata* which is superior to subsp. *preissiana* (the former has a lower habit, larger leaves, buds and fruits; grows on coastal limestone bluffs).
- *E. astringens* subsp. *redacta* which is superior to subsp. *astringens* (the former is a smaller tree, smoother bark, smaller capsules).
- *E. kingsmillii* subsp. *alatissima* which is superior to subsp. *kingsmillii* (the former has red flowers (rather than pale yellow), winged buds and fruits and pruinose branchlets).

No doubt further eucalypts will be continue to be discovered, recognised, trialed and selected for that will be superior to the species we know today and be suitable for increasingly difficult sites.

EARLY OBSERVATIONS IN THE IMPROVED SELECTION AND PROPAGATION OF *EUCALYPTUS LEUCOXYLON* FOR URBAN USE

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INTRODUCTION

In the past, the improved selection of Australian native trees by means of vegetative propagation has been limited to high value forestry trees, with little of this knowledge applied to important amenity trees. One tree worthy of such an approach is *Eucalyptus leucoxylon* (Yellow Gum, South Australian Blue Gum), which has been planted extensively throughout metropolitan Victoria and South-Australia. The use of *Eucalyptus leucoxylon* within urban areas has for the most part been of the variety 'Rosea'. Despite this, the natural origins of this cultivar are unknown. Consequently, as progeny have been derived from a tree in cultivation there is the distinct possibility there has been a loss of vigour due to inbreeding. This paper reports preliminary work which should lead to the identification of natural populations of *Eucalyptus leucoxylon* with qualities to equal those of 'Rosea'. The subsequent development of vegetative propagation methods will ensure that regardless of the extent of use, desirable characteristics will be retained with no loss of vigour.

PROVENANCE TRIAL

The variation within *Eucalyptus leucoxylon* is significant, with seven subspecies (Boland, 1979; Rule, 1989 -1992; Rule, 1998) described. One of these has been regarded as different enough to be elevated to species status, *Eucalyptus petiolaris* (Rule, 1989 - 1992). To understand the growth, development and variability within *Eucalyptus leucoxylon*, several of these subspecies were monitored for a period of nine months from germination.

Materials

Seed of *Eucalyptus leucoxylon* was sourced from eight locations (selected purely on the commercial availability of the seed) representing four subspecies (Boland, 1979), *Eucalyptus leucoxylon* ssp. *leucoxylon*, ssp. *megalocarpa*, ssp. *pruinosa* and ssp *petiolaris* (still used in this trial despite its current species status). For ease of labelling and identification, each population has been designated by a code letter, A-H (see Table 1). There is uncertainty as to the origins of the West Bendigo seed (D and E), but for the purposes of this paper they will be referred to as the West Bendigo provenance or population.

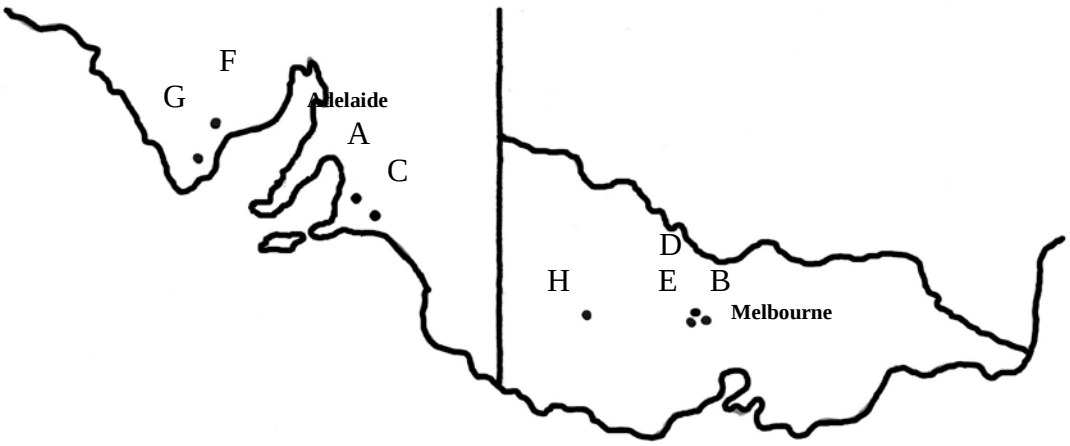
Table 1 Eight collection sites of *Eucalyptus leucoxylon* seed, including subspecies and identification code.

Species	Subspecies	Code	Location	State
Eucalyptus leucoxylon	*leucoxylon*	A	Adelaide Hills	South Australia
		B	Bendigo	Vctoria
	megalocarpa	C	Monarto	South Australia
		D	West Bendigo (Red Flowered)	Victoria
		E	West Bendigo (Yellow flowered)	Victoria
	petiolaris	F	Ungarra-Cockaleechie*	South Australia
		G	Warunda-Koppio*	South Australia
	pruinosa	H	Horsham area	Victoria

* Eyre Peninsula

The distribution of the selected populations of *Eucalyptus leucoxylon* is shown in Figure 1.

Figure 1 *Eucalyptus leucoxylon* populations used in the trial from South-eastern Australia.



***Eucalyptus leucoxylon* ssp. *leucoxylon*, A; Adelaide Hills, B; Bendigo. *Eucalyptus leucoxylon* ssp. *megalocarpa*, C; Monarto, D&E; West Bendigo *Eucalyptus leucoxylon* ssp. *petiolaris*, F; Ungarra-Cockaleechie, G; Warunda-Koppio. *Eucalyptus leucoxylon* ssp. *pruinosa*, H; Horsham area.**

Experimental Design and Measurements

Seed Characteristics

All seed was separated from the chaff, to ensure there was no bias towards size. 30 replicates of 30 seeds were selected and weighed for each seed lot. From these weights the number of seeds per gram was derived (Figure 2).

Germination, Growth and Development

A glasshouse germination trial was established at Burnley College, in September 2001. Seedling trays were set up in a randomised block design with 12 blocks, each representing the eight populations. To satisfy the light requirement for germination (Turnbull & Doran, 1987), the seed was sown on top of Burnley seedling raising mix, and sprinkled with vermiculite. Initially there were three seeds per cell for a total of 720 seeds per provenance, however after recording daily germinants for six weeks these were randomly culled to only one plant per cell (240 per provenance). At four months of age these were transplanted to 14cm olive pots, and placed outside under 50% shade. Regular measurements were taken to assess the form and variability between and within all provenances (Table 2).

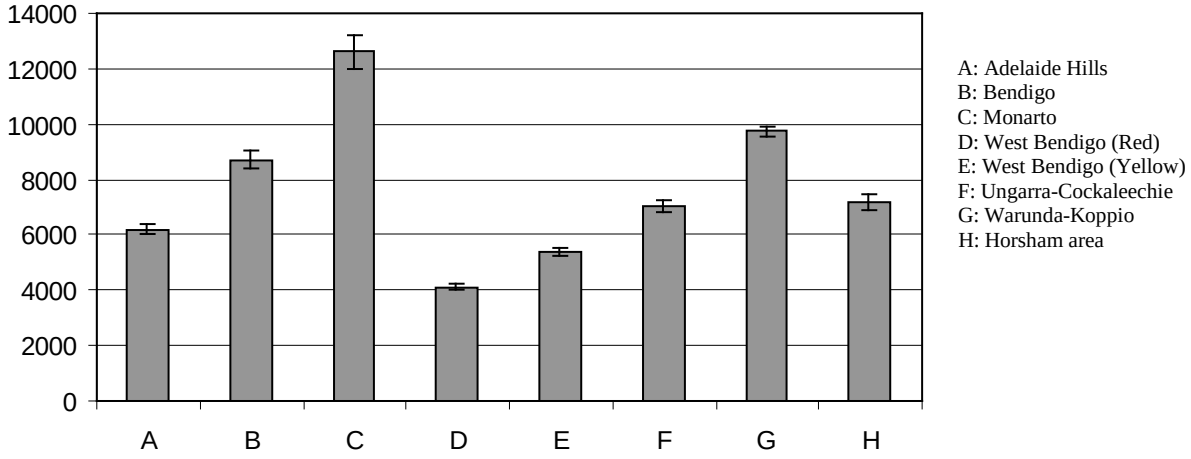
Table 2 Summary of the attributes recorded for *Eucalyptus leucoxylon* and the regularity of measurements taken.

ATTRIBUTE	TIME FRAME	DETAILS
Seed Weight	Initially	30 groups of 30 seed
Number of seeds with embryos	Initially	For each provenance, 100 seeds were checked for embryos (129 for *Eucalyptus leucoxylon* ssp. *leucoxylon* from Adelaide Hills)
Number of days to first germination		Emergence of radicle
Number of days to final germination		Last germinant from each population
Final Germination Percent	Day 42	(no germinates the preceding week)
Height	Weekly	Week 1 - 12
Height	Fortnightly	Week 16 -52
Leaf Size	6 Weekly	Largest Length Breadth Length from base to widest section. 6th leaf pair Length Width Length from base to widest section
Leaf Petioles	Fortnightly	Present / Absent Length Transition from sessile to petiolate
Leaf Arrangement	Fortnightly	Opposite / Alternate
Number of Leaf Pairs	Fortnightly	number
Leaves	Fortnightly	number
Lignotuber	Fortnightly	Present / Absent Number of nodes involved
Root Weight	6 Weekly	Fresh and Dry
Leaf Weight	6 Weekly	Fresh and Dry
Stem Weight	6 weekly	Fresh and Dry

Results

All of the seed groups had significantly different ($p<0.05$) weights, except for sample F (*E. leucoxylon* ssp. *petiolaris*) and H (ssp. *pruinosa*). In general (Figure 2) the seed of *Eucalyptus leucoxylon* ssp. *megalocarpa* was heavier than for the other subspecies, with the exception of the population from Monarto (C), which had the lightest seed, however the proportion of those with no embryo may have contributed to this result (Table 3).

Figure 2 **Number of seeds per gram for eight provenances. *Eucalyptus leucoxylon* ssp. *leucoxylon* (A & B), ssp. *megalocarpa* (C & D & E), ssp. *petiolaris*, (F & G), and ssp. *pruinosa* (H).**



The modified final germination percentage (Table 3) reflects the number that actually germinated as a percent of those that would be expected to be viable given that they have an embryo (although it is acknowledged that the presence of an embryo is not necessarily an accurate indication of viability). For all provenances, this is greater than 80%. The two provenances of *Eucalyptus leucoxylon* ssp. *leucoxylon* from the Adelaide Hills and Bendigo, and *E. leucoxylon* ssp *petiolaris* from Ungarra-Cockaleechie both had final germination percents, which were higher than those that were expected to be viable.

Table 3 **The percentage of seeds germinated, and the modified final germination percent, given the number of seeds without an embryo.**

Seed Source	Final (%)	N	Embryo (%) Present	Absent	N	Modified Final %
Eucalyptus leucoxylon ssp. *leucoxylon*						
Adelaide Hills	51.67	720	47.30	52.70	129	100.00
Bendigo	92.64	720	92.00	8.00	100	100.00
Eucalyptus leucoxylon ssp. *megalocarpa*						
Monarto	36.25	720	44.00	56.00	100	82.39
West Bendigo (Red)	85.83	720	88.00	12.00	100	97.53
West Bendigo (Yellow)	85.97	720	90.00	10.00	100	95.52
Eucalyptus leucoxylon ssp. *petiolaris*						
Ungarra-Cockaleechie	89.44	720	89.00	11.00	100	100.00
Warunda-Koppio	74.17	720	91.00	9.00	100	81.51
Eucalyptus leucoxylon ssp. *pruinosa*						
Horsham area	95.56	720	97.00	3.00	100	98.52

Table 4 outlines some of the characteristics that vary between the provenances. Many differences are evident, however the most prominent is probably the petiolate leaves in the two populations of ssp. *petiolaris* (*Eucalyptus petiolaris*) from the Eyre Peninsula. Generally these petioles are between 3 - 12mm in length, compared to the other subspecies which rarely

reach 5mm. This and the early development of alternate leaves - as early as the fifth leaf pair in this provenance - are among the main criteria for its elevation to species status (Rule, 1989-1992). For most of the other subspecies, alternating leaves occur rarely (although most plants still have less than 20 leaf pairs), and if so, it is generally not until at least the 11th leaf pair.

The shape (as described by Brooker & Kleinig (1999)) and size of the leaves vary considerably with most displaying ovate leaves for the first seven or eight leaf pairs. The Eyre Peninsula provenances have elliptic leaves, and the leaves from both populations of *E. leucoxylon* ssp. *megalocarpa* from West Bendigo are considerably larger (see Table 4) and generally cordate and amplexicaul. Also worth noting is the tendency to develop lateral stems. The Victorian *megalocarpa* subspecies very rarely did, however it is strongly pronounced in ssp. *megalocarpa* from Monarto, and *E. leucoxylon* ssp. *leucoxylon* from the Adelaide Hills. The leaves in these latter subspecies are becoming distinctly lanceolate.

The glaucous covering that is unique to *Eucalyptus leucoxylon* ssp. *pruinosa* (Boland, 1979) within this group is evident in only half of those from the Horsham area, and even these only have a very fine waxy covering, with usually only two or three leaf pairs affected.

Discussion

The differences evident within the selected subspecies of *Eucalyptus leucoxylon* have so far been limited to the juvenile characteristics. Differences have been observed in the growth rate, leaf size, shape, and arrangement; the presence or absence of petioles and lignotubers; seed weights, and the rates of germination. The effect that these differences will have on future growth and vigour is yet to be determined, however the close monitoring of these trees for a further 18 months should facilitate a greater understanding of how these traits relate to the development of mature trees.

Table 4 Growth characteristics of selected attributes in eight provenances of *Eucalyptus leucoxylon*.

Eucalyptus leucoxylon	**ssp. *leucoxylon***		**ssp. *megalocarpa***			**ssp. *petiolaris***		**ssp. *pruinosa***
	Adelaide Hills	**Bendigo**	**Monarto**	**West Bendigo (Red)**	**West Bendigo (Yellow)**	**Ungarra-Cockaleechie**	**Warunda-Koppio**	**Horsham**
Days to first germination	4	4	4	4	4	4	4	3
Days to 50% germination	10.92 ± 0.43	5.71 ± 0.11	6.75 ± 0.43	5.5 ± 0.15	6.17 ± 0.27	6.67 ± 0.14	9.33 ± 0.28	5.42 ± 0.46
Days to final germination	35	32	25	32	35	30	32	28
Lignotuber present	78.79% (n=33)	97.22% (n=36)	48.28% (n=29)	93.94% (n=33)	100.00% (n=34)	91.67% (n=36)	94.44% (n=36)	96.88% (n=32)
Leaf size (mm) – 6 months old (n = 36) 6th leaf pair								
Length	47.53±2.08	53.75±8.21	40.73±1.91	59.89±3.20	59.44±2.60	44.28±1.90	44.67±2.02	42.78±1.83
Breadth	18.67±0.95	24.19±1.17	17.91±0.97	27.53 ±1.69	35.17±2.02	28.83±1.37	25.56±1.11	25.69±1.27
Percent with petiolate leaves	80.55%	22.22%	88.25% (n=34)	61.76% (n=34)	16.67%	100.00%	100.00%	2.77%
Mean petiole length (mm)	1.55±0.21	1.88±0.64	2.73±0.30	1.33±0.20	1.17±0.17	5.75±0.46	4.00±0.29	1.67±0.67
Mean height increase per week (mm)								
Week 0 – 12	2.34	3.69	2.12	3.85	2.68	2.11	2.35	3.42
Week 12 – 24	26.31	22.84	16.96	24.35	22.05	19.33	23.05	20.65
Week 24 – 36	35.95	53.40	26.88	44.67	42.48	31.51	33.89	40.92
Current Height (44 weeks) (mm)	504.30± 84.64	610.20± 43.28	443.67± 110.33	662.22± 56.61	639.92± 32.14	600.87± 58.67	374.75 ±24.05	694.28 ± 41.78
Current number of leaf pairs (44 weeks)	16.20±1.17	16.60± 1.09	15.50± 2.18	16.67± 1.01	18.69± 0.86	18.50± 1.74	14.00 ± 1.08	17.42± 1.06

VEGETATIVE PROPAGATION

The inability to predict the final height and habit of *Eucalyptus* when growing in streetscapes is often the result of raising plants from seed. There is a need for the development of propagation systems to ensure offspring can be produced with desirable qualities, and a predictable mature height and form.

Budding and grafting of plants onto suitable rootstocks will ensure that subsequent scion growth will be representative of the material from which the plant was sourced. The success of this approach in *Eucalyptus leucoxylon* has not been well documented, so this preliminary trial was done to determine whether it is possible to graft six month old *Eucalyptus leucoxylon* ssp. *megalocarpa* plants onto other ssp. *megalocarpa* plants, of the same age and from the same seed source. It was also set up to determine whether a successful union could take place if a plant is grafted back to itself. Part of this trial will include the prevention of the cut surface from drying out, by keeping all surfaces wet during the grafting procedure.

Experimental Design

Eucalyptus leucoxylon ssp. *megalocarpa* plants were purchased from Mildura Native Nursery in October 2001. These were grown on until January 2002, 6 months of age. A total of 144 plants were used.

The plants were randomly allocated to groups and treatments, to ensure there was no bias as the budding and grafting techniques improved. Plants within the group were chip budded and grafted using the splice (whip) and whip and tongue graft (Hartmann *et al*, 2002).

To prevent the cut surface from drying out, half of the plants were fully submerged and the whole process was carried out under water, including the tying. For others, the time that the cut surfaces were exposed to air was kept to an absolute minimum, however in some cases this may have exceeded ten seconds. The four treatments for each graft type were as follows:

1.	The scion taken from a plant and grafted back to itself	EXPOSED
2.	Plants are paired and the scions swapped between them	EXPOSED
3.	The scion taken from a plant and grafted back to itself	SUBMERGED
4.	Plants are paired and the scions swapped between them	SUBMERGED

This trial was undertaken in January 2002 at Burnley College Nursery. It was carried out undercover, however it was still subjected to air drafts and temperature changes. Air temperature for this trial was between 16^{o}C and 22^{o}C (Bureau of Meteorology). Water temperature was between 20^{o}C and 22^{o}C, and the relative humidity was quite high (Bureau of Meteorology).

Grafted plants were placed in a fog house maintaining 90% humidity for two weeks. Following this they were placed in a misting house for a further three weeks until the tape was removed, and then taken outside.

Results

Overall results for this experiment were disappointing, with around a 10% success rate. This further fell to 4.17% in the following weeks, as the successful chip budded plants failed a week or so after tape removal.

Mortality rate was quite high with rootstock death occurring in 12 of 144 (8.33%) of the plants.

There was some sprouting of the scion buds on those plants that were whip and tongue, or splice grafted within the first week following the graft procedure. Some of these continued to develop; however in many trees the scion, and consequently the buds, died after a few days.

To date, the only successful grafts have been the whip and tongue, and the splice graft. These are still alive after seven months with even growth and a strong union.

Even though the numbers remaining are too small to get a clear indication as to the effect of submerging the cut surfaces, it can be seen that the plants are able to be grafted onto themselves, or others from the same seed stock, in either wet or dry conditions.

Discussion

Although not actually measured, it appeared that the successful grafts were generally on plants that had slightly thicker stems. Most of the failed grafts showed early necrosis beginning at the tip of the scion. The young age of these plants combined with the inexperience of the grafter may explain this low success rate. Further trials are planned for the future.

CONCLUSION

The preliminary results obtained, have emphasised the considerable variation that is present within *Eucalyptus leucoxylon*. The appearance and habit of the juvenile plants sourced from eight different sites throughout Victoria and South Australia have shown differences in both the pattern of development, and juvenile features. Whether these differences will be evident or significant in the mature plant, remains to be determined.

Despite the low success rate, the ability to vegetatively propagate *Eucalyptus leucoxylon* ssp. *megalocarpa* appears to be promising. The rate of failure could be attributed to the young age of the plants, and the small surface area over which the union was to occur. Further work has been planned which will involve the use of older plant material, with the effect of stock pre-treatment and season also investigated.

At the conclusion of this project - June 2004, it should be possible to recommend provenances of *Eucalyptus leucoxylon* that are suitable for planting in urban areas. A method of vegetative propagation, which will ensure that a sustainable number of plants can be produced, reliably exhibiting the various features the provenance was selected for, should also have been determined.

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IMPROVEMENT OF ORNAMENTAL EUCALYPTS (Abstract)

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Many species from the genus *Eucalyptus* have economic potential for the ornamental horticulture industry, including *E. erythronema, E. stricklandii* and *E.* 'Urrbrae Gem'. To bring these plants into cultivation propagation techniques must be developed other than the more conventional seed methods. Vegetative propagation involves the multiplication of an individual plant into a series of plants, genetically identical with the parent and each other. The advantage of vegetative propagation is that desirable features can be maintained and reproduced. Seed generated plants are variable as a result of natural outcrossing mechanisms. In addition, plants that are vegetatively propagated generally flower much younger, which is especially important for commercial sales. Successful vegetative propagation of adult trees will enable the clonal reproduction of plants that have shown outstanding ornamental characteristics.

The selection of certain individuals that can be successfully vegetatively propagated is crucial to reduce the lengthy selection processes normally associated with trees. Molecular genetic maps provide large amounts of information that can be used to identify traits of interest. Mapping strategies for quantitative trait loci (QTLs) involve the construction of genetic linkage maps of molecular markers and the identification of QTLs for individual genotypes. Detection of traits relating to vegetative propagation in ornamental eucalypts will provide valuable ways of identifying plants that can be successfully propagated.

Tremendous scope exists for the development of eucalypts through the creation of hybrids and the selection of particular cultivars using vegetative propagation techniques. Development of these techniques will greatly increase the range of plants available for the horticulture and floriculture industries. However, unless efficient vegetative propagation techniques are developed, these plants have no commercial future.

The aim is to develop successful vegetative propagation techniques for ornamental eucalypts. A variety of propagation techniques are being used, including cuttings, grafting, budding and aerial layering. In addition, the detection of genes associated with vegetative propagation will provide a way of identifying plants that can be readily propagated.

DIEBACK IN CLARET ASH

Samantha Titheradge - School of Forestry, Australian National University

Claret Ash, *Fraxinus oxycarpa* Raywood is a popular ornamental tree widely planted in Canberra for its exquisite red autumn foliage. Many trees are today exhibiting crown dieback which takes several seasons to become apparent and eventually ends in tree death. The cause(s) of this dieback are unknown. They could be caused by an unknown pathogen or be related to site conditions.

This study aims to provide data on the speed with which the dieback advances through tree crowns, and to identify any links between the dieback and other environmental factors such as tree age, the level of tree maintenance, inherent site parameters, and site disturbance.

The project focuses on dieback in Claret Ash street trees in four suburbs, Ainslie (established in 1944), Narrabundah (est. in 1947), Weetangera (est. 1970) and Gowrie (est.1981).

DISMUT (decision information system for the management of urban trees), 1997-2000 showed dieback in these suburbs varied from 5% and 11%. The present survey in 2002 showed 29% and 54% respectively indicating that dieback in these suburbs is rapidly increasing and is therefore a major problem in Canberra's urban forest.

The average diameter at breast height of trees varies across the four suburbs. When looking at the effect of dbh on dieback it was found that in the 0-5cm dbh class, healthy trees exceed trees with dieback. For those trees in the 6-14cm dbh class, trees with dieback are generally equal or exceed healthy trees.

A statistical analysis of the data collected from the survey suggests that large diameter trees are more likely to suffer from dieback than small diameter trees. Trees are also more likely to suffer from dieback if their roots are not exposed. Another interesting result was that trees growing on slopes are more likely to suffer from dieback than those trees growing on level ground.

As the second part of this project, the duration and severity of dieback on tree growth will be examined by studying the annual growth rings.

STREET TREE SPECIES TRIALS IN BRISBANE

Lyndal Plant &Maureen See - Environment and Parks Branch, Brisbane City Council

Introduction:

Trials of the first five of eleven indigenous tree species with potential for street tree use began in Brisbane last year. The aim of these trials is to expand the current recommended street tree species for Brisbane to especially showcase the natural biodiversity of this area. Increasing the use of indigenous tree species along Brisbane footpaths will not only encourage more use of such species in private landscaping but allow more appropriate species choices for new residential developments in environmentally sensitive areas.

Council's policy position at present is to choose new or replacement street tree species from a list of 25 tried and proven natives and non-invasive exotics. With a current street tree population of around 360,000 and plantings continuing at the rate of around 10,000 per year, a broader list of suitable species choices can help control the maintenance demands of this growing population, and improve the habitat value of Brisbane's streetscapes.

Healthy, attractive shade trees along streets continue to improve property values and support the outdoor lifestyle in Brisbane.

The trial species:

The eleven species chosen for trial were shortlisted from more than 50 species suggestions made by a local community group, The Brisbane Rainforest Action and Information Network (BRAIN) who have been revegetating creeks and rainforest remnant areas in Brisbane for many years. Their first hand experience provided informed suggestions which were screened down to the eleven species based on potential to perform in footpath conditions, ease of propagation, and lack of undesirable features such as prickly foliage, which cannot be tolerated in public spaces. Other reasons for excluding species were root issues, suckering, fleshy fruits, excessively slow growth, and poor shade provision.

BRAIN volunteers also provided fresh local seed for propagation of species that were not commercially available.

Preference was also given to small to medium shade tree species, which are in highest demand for renewal projects in existing suburbs with overhead powerlines, and some species which had shown good potential in smaller trials installed 12 years ago. Final tree heights and canopy dimensions were estimated for cultivated specimens, not those from native stands which are generally much taller with narrower canopies. Not all species chosen are native of wet rainforest environments, others are native of hardy dry South East Queensland rainforest scrubs. Although hardiness was considered, some rainforest species which prefer better sites, but have outstanding features, have been included in the trial. An overview of the Stage 1 trial species is provided in Table 1.

Methodology of the trial:

The field trials consist of planting up to 100 specimens of each species in at least four different districts of the city on a variety of footpath sites, using a minimum of 10 specimens in any one trial street site. Stock size is usually around 1 m tall within a 250mm diameter container. Stock quality is a critical element and has been consistently good to date, meeting Council's Street Tree Stock Standard. Planting takes place within either the "spring planting window" (Sept-Nov) or the "autumn planting window" (March-May). Residents living adjacent to the new plantings are informed, as per standard street tree plantings, of the species planted and some tree care tips. Regular watering, fertilising, weeding and mulch maintenance is provided at the same frequency as other standard street tree early care practices (weekly for first month and then monthly for next 11 months)

Planting site details and plant dimensions are recorded at planting and performance is monitored twice per year.

So far, 96 Tulip Satinwoods (*Rhodosphaera rhodanthema*) have been installed on 10 sites. 87 Yellow Woods (*Flindersia xanthoxylla*) have been installed on 8 sites. 137 Whalebone Trees (*Streblus brunonianus*) have been installed on 5 sites, 18 Golden Ash (*Hodgkinsonia ovatiflora*) have been installed at one site and 20 Hard Quandong (*Eleaocarpus obovatus*) have been installed at one site.

Results so far:

Of the five species installed up to 15 months ago, all are performing satisfactorily so far through an exceptionally dry past 12 months in South East Queensland.

More specifically:

- Tulip Satinwoods have performed the best with an average of 450cm height increase (34%) and glossy healthy foliage
- Tulip Satinwoods on more fertile, moist soils appear to be performing better than those on poorer, drier sites
- Yellow Woods appear uniformly healthy but exhibited an average growth increase of only 10cm (.07%)
- There was variable performance evident between individual Whalebone Tree specimens with some showing dense, healthy growth compared to others showing yellowing of leaves and leaf drop in dry conditions. However, for all the latter specimens, healthy new buds are evident. There is negligible height increase in this species to date, with most biomass increase reflected in lateral growth.
- Whilst only 8 specimens of Golden Ash have been assessed to date, all specimens appear healthy and vigorous but with a negligible increase in height.
- No evidence of pests and diseases and 100% survival rates to date.
- Application of the liquid organic fertiliser during watering visits has contributed to shoot extension, even in winter. This is consistent with other street tree species performance since a change from inorganic to organic fertiliser.

The balance of the first five species stock, together with up to four of the remaining six species is scheduled for planting this spring. The Stage 2 trial species include:-

- *Dissilaria baloghioides* (Lancewood)
- *Alectryon tomentosus* (Hairy Bird's Eye)
- *Rapanea variabilis* (Muttonwood)
- *Aphananthe philipinensis* (Native Elm)
- *Atalaya salicifolia* (Scrub White Wood)
- *Brachychiton discolor* (Lacebark Tree)

It is anticipated that useful data on some of the faster growing species such as *Flindersia* and *Rhodosphaera* will be available by early 2004. Slower growing species such as the Whalebone Tree may take up to 4 or five years to reveal more about their potential as street trees in Brisbane.

Species which prove successful in these Brisbane trials could be expected to perform comparably from north coast New South Wales through to the Sunshine Coast.

This trial work is planned to continue and there are still many more potential street tree species to be found amongst the diverse rainforest flora of South East Queensland.

Table 1

Stage 1 Trial Species List and features

Streblus brunonianus Whalebone Tree (Moraceae)			
General Description (ht, spread, foliage, flowers)	Tolerances/ Resistance	Lifespan	Other comments
• Small to medium size tree of dry rainforest • grows to approx 4 –6 metres in cultivation. • upright columnar to rounded dense canopy with thin,dark-green serrated lanceolate to ovate foliage -lightly sandpaperish to touch (3 - 8cm long x 3cm wide). • Flowers insignificant • fruit a small yellowish 5mm berry • closely related to Sandpaper Fig and Rough-leaved Elm	Known to look good even after being neglected	Unknown but not shortlived	Trees may be seen in the wild at Rafting Ground Reserve Propagation from cuttings Useful shade tree Extremely tough and flexible timber. Called Whalebone Tree because stiff tough timber used to make women's corsets
Elaeocarpus obovatus Hard Quandong (Elaeocarpaceae)			
• Bushy tree to > 10m tall in the wild (likely to be up to 6-8m in cultivation) • elliptical leaves 10cm x 3.5 cm. • occurs naturally along Brisbane creeklines, • Becomes covered in sprays of tiny white bell flowers in spring - highly scented • attractive round blue berries. • reasonably fast growth rates in cultivation. Like moisture. Slight buttressing at base in older specimens.	Adaptable to wide range of situations and soil types. Tolerant of wet soils and shade	Longlived. Remnant specimen in Rotary Park, cnr Graham Rd & Gympie Rd, Carseldine 10m high	Birds are attracted to fruit Cultivated specimen at entrance to Downfall Creek Bushland Centre, McDowall Propagation by cuttings mainly as seed difficult to propagate. Not commonly available White, hard & tough wood. Used in making oars and furniture

Rhodosphaera rhodanthema Tulip Satinash (Anacardiaceae)			
General Description (ht, spread, foliage, flowers)	Tolerances/ Resistance	Lifespan	Other comments
• Medium sized fast growing tree to 20m in wild (possibly 8-10m in cultivation) • pinnate lanceolate leaflets to 7cm long. • bears sprays of red small flowers in spring • glossy brown dry berries 1.2cm in diameter that tend to remain on the tree. • separate male and female trees.	BRAIN members sugest insect attack may be problem in young specimens occasionally but doesn't affect tree	Longlived	Beautiful foliage plant Highly ornamental species Semi–mature specimens at Kevin Daley's Nursery, Belmont
Flindersia xanthoxylla Yellow Wood or Long Jack (Rutaceae)			
• Large straight tree up to 15m high in cultivation (>20m in the wild) • spreading canopy. • deep green thin leaves; pinnate 75cm long with 4 – 11cm lanceolate leaflets each to 10cm long. • bears small yellow flowers in terminal clusters • oblong woody brown 7-10cm pods covered with small prickles	Tolerates heavy shade	Long lived	Attractive foliage and useful shade tree. Propagate from fresh seed. Easy to grow. Strong durable timber
Hodgkinsonia ovatiflora Golden Ash (Rubiaceae)			
• Small to medium sized tree to 6m • rounded canopy . • flowers insignificant followed by masses of black berries 0.5 cm wide.	Quite tough but probably prefer better sites	Long lived	Birds just love fruits. Berries on ground not a problem underfoot –not mushy.

(NB: The maximum heights shown in the table below for some of the species may be considerably lower than those quoted in reference texts. This is because the latter are usually referring to specimens in closed forest conditions where strong light competition exists with surrounding trees. The heights quoted below however are recorded from open grown specimens in cultivation).

STREET TREE TRIALS IN THE CITY OF WEST TORRENS

Jim Hay, Tim Johnson & Lisa Kirwan - City of West Torrens, SA

The City of West Torrens has been associated with and supported TREENET since 1997. Association with TREENET provides a range of benefits. Through its focus on information sharing and partnerships TREENET has helped Council to improve planning and engineering for street trees, tree selection, planting and maintenance practices, staff development and training and the education of the wider West Torrens community.

Raising the Profile of Street Tree Issues

West Torrens' street tree trials have featured nationally in magazines, on television and in press articles. Increased exposure has highlighted the complexity of urban tree issues and helped street tree planting to be seen more clearly as a specialist area in its own right. Association with TREENET has helped to improve the way other professions and the general community view our greening work.

It is now accepted within Council that past standards and procedures are no longer applicable. Procedures and standards are being improved to allow the practical application of increasing corporate knowledge and understanding of street tree issues.

Planning and Engineering for Street Trees

Neither the need to adequately plan and engineer for trees or the conflicts over space in urban design are new. What is new is the pressure for a sustainable resolution of these conflicts. Limiting the space available to street trees may make short-term financial gains, but these are too often outweighed by ongoing maintenance costs and reduced benefits.

One example of a near perfect marriage between trees and infrastructure is evident in Northcote Street, Torrensville. Trees that are close to celebrating their 80th birthdays have co-existed with bitumen and concrete without damage and subsequent associated costs of repair. The only damage that was inflicted was to the trees themselves when the obligatory lopping took place (when it was considered an acceptable arboricultural practice). The verge width is a substantial 4 meters from footpath to kerb, providing a favorable environment for a healthy root system to develop. The narrow road width acts as a self-regulating traffic device, eliminating the need for expensive and inconvenient (to residents and services) protuberances and humps. The result being a beautiful tree lined street that is quiet, inexpensive to maintain and appreciated by those that live there.

Recent years have seen increased consideration of tree related issues during planning and development processes but with increasing land value and decreasing block sizes, a reduction in available tree space can result. Development of the former Apollo Stadium site at Richmond is testament to improved planning processes that provide greater functionality and amenity while reducing infrastructure construction and maintenance costs. On the Apollo Stadium site:

- Paved footpaths are to be located only on the south or east sides of the streets, leaving maximum verge space for trees to shade streets from the north or west.

- Locating larger trees *(Celtis occidentalis)* on the north side of the streets will reduce shading issues on neighbouring properties but provide for shade in the street where needed. Smaller species (*Pyrus* and L*agerstroemia* cultivars) will be planted in the narrower nature strips provided on the east and south sides of streets.
- The extensive mix of underground services, including large capacity storm-water pipes which perform a temporary detention function, are located beneath pavements on the south or east sides of the streets.

During recent road reconstruction projects the scale of existing and required infrastructure was reviewed. Arboriculture staff were consulted in the planning stages of kerb and water table reconstruction works near mature Golden rain trees *(Koelreuteria paniculata)* in Park Street at Glandore. Reducing the road width and increasing the area of nature strip improved the intended engineering outcome. This minor adjustment to plans allowed many additional benefits to be achieved:

- By placing the new kerb 500mm further from the trees than the previous one significant injury to the tree roots was avoided.
- By completing the works in winter the resultant impacts on tree health were minimised.
- The increased size of the nature strip provides improved conditions for the trees.
- The larger nature strip and narrower road improves street amenity
- The larger nature strip reduces stormwater run-off and increases water availability to the trees.
- The narrower road provides a cost-effective traffic calming effect.
- On-going road and tree maintenance costs will be significantly reduced.

Similar benefits are being realised in Arnold Street at Underdale and in Ashley Street at Torrensville through Council's current Capital Works Program. The works in Ashley Street have also provided an opportunity to reconsider the wisdom of planting Plane trees *(Platanus x acerifolia)* beneath high voltage powerlines.

Increasing Staff Knowledge & Experience

West Torrens has added numerous varieties of trees to its urban forest over the past decade. This has required that tree maintenance staff increase both knowledge and experience to ensure their appropriate care.

Through external and in-house training, including theory and practical work, skills and knowledge have developed to the point where arboriculture staff are equipped to work with the new varieties. The tree trial program provides personal benefits to many staff, the increasing diversity of trees encouraging personal interest and contributing to increased job satisfaction.

Points To Consider When Planning a Street Tree Trial:

1. Trials should utilize a small number of trees so that if issues or problems arise they will remain manageable. An ideal trial size is 5 to 10 trees.
2. Trials should be located such that if issues or problems arise they have little impact on neighbouring properties. Reserve frontages make good trial sites for larger species. Avoid high profile sites.

3. Species should not be excluded from trial due to the possibility of problems arising (see 1 & 2 above) as expected outcomes may not eventuate under your local conditions. For example, Queensland box *(Lophostemon confertus)* litter causes much concern in Adelaide but they do not fruit to the same extent in Sydney (Fakes, J. 2001 pers. com.) or in areas of the U.S.A. (Gilman, E. (1997) p.558)
4. Knowledge of species gained through experience with seedling varieties or one selected form cannot be applied to other forms. Selected forms are selected for their differences! Consider these differences as different horticultural or amenity products. Different products require different materials and processes in their production, so one selection may thrive where other selections have failed. Ideally all selections should be tested.
5. Trees are typically selected to suit a given location. This is not possible in tree trials as there is inadequate local knowledge of tree growth habits and characteristics. The probability of success can be increased by reversing the process: select an unfamiliar tree, learn everything possible about it, then locate a planting site where the limited knowledge available about the tree suggests it is most likely to grow (but remember 1 & 2 above).
6. Learn from all available sources. Talk to colleagues, use the Internet, check the TREENET web site and talk to nursery personnel (at the very least they'll be able to advise regarding feeding, watering, pests, disease & climate issues etc.)
7. Some species and/or varieties may take a few years to produce to required specification so plan to order them early.
8. Plant something you're unfamiliar with & unsure of.

Street Tree Trials: Summary of Progress

The following notes summarize the City of West Torrens' recent experience with a range of tree species. Local experience with many of the varieties listed here is limited to immature trees over a short period, so comment relates to progress and development during initial establishment only. As tree development is dependent on nursery stock quality, planting and maintenance practices as well as site conditions it is impossible to make any judgment of species suitability for street planting at this stage.

This summary is compiled with the aim of promoting the ongoing and widespread trial of alternative tree species for street use. Street tree trials are essential to provide the mature specimens necessary to determine species costs and benefits. Only an assessment of mature trees living in street situations will provide insight into their suitability to environmental conditions and any issues that surround them.

The summary below provides observations of 68 varieties. The summary should be read in conjunction with the notes that follow. The symbols used in the summary table are straightforward:

✔	=	positive and/or acceptable
✖	=	negative and/or unacceptable
?	=	uncertain or under consideration
±	=	variable and/or uncertain

Defining what is acceptable or unacceptable depends on a range of factors, in the summary the terms are more qualitative than quantitative. Acceptable survival rates indicate that few trees required replacement in years one and two (except for reason of vandalism, accident etc.).

Growth rates are typically slow for young street trees in West Torrens. The frequency and quantity of water supplied most often limit growth. Standard maintenance procedures provide the following water volumes each week on average over the first three years:

1st year:	45-50 liters per week
2nd year:	30 liters per week
3rd year:	20 liters per week

The decreasing volume of water supplied each year results from the breakdown of the dish prepared at planting. Watering does not normally continue into year 4.

For most street trees, a growth rate of 25mm to 100mm in the first year is common and acceptable. In the notes "slow growth" refers to this range. With normal maintenance most Pyrus achieve this rate of growth in their first year with increases in subsequent years. A growth rate averaging less than 25mm in the first year is described as "unacceptable" in the notes.

The summary lists some varieties that have shown acceptable survival and growth rates yet they are on longer being considered for future plantings in West Torrens. The accompanying notes may explain this apparent discrepancy. The explanation in most cases being that the number of trees planted to date is considered adequate to enable mature characteristics under local conditions to be determined in the future and that further planting is being postponed until that time.

References:

Gilman, Edward (1997) *Trees for Urban and Suburban Landscapes*, Delmar Publishers.
Fakes, J (2001) Senior Lecturer: Arboriculture, North Ryde College of T.A.F.E.

		Survival rate	Growth rate	Further Further planting / trials
Acacia melanoxylon	*Blackwood*			
Acer buergerianum	*Trident maple*	±	±	
Acer campestre "Evelyn"	*Queen Elizabeth hedge maple*			
Acer monspessulanum	*Montpellier maple*	*?*	*?*	
Acer pseudoplatanus	*Sycamore*		±	✗
Acer x freemanii "Jeffersred"	*Autumn Blaze hybrid maple*		±	
Acer x freemanii "Scarsen"	*Scarlet Sentinel hybrid maple*		✗	
Angophora costata "Little Gumball"	*Little Gumball apple myrtle*	✗	✗	✗
Backhousia citriodora	*Lemon-scented myrtle*	*?*	✗	
Banksia integrifolia	*Coast banksia*	*?*	*?*	
Banksia grandis	*Bull banksia*	?	?	*?*
Banksia serrata	*Saw banksia*	✗	*?*	*?*
Brachychiton acerifolius	*Illawarra flame tree*			?
Brachychiton populneum	*Kurrajong*			?
Brachychiton rupestris	*Queensland bottle tree*			?
Buckinghamia celsissima	*Ivory curl tree*	±	±	*?*
Caesalpinia ferrea	*Leopard tree*	✔	*?*	*?*
Castanospermum australe	*Black bean*	±	±	
Cercis canadensis	*Redbud*	✔	✔	
Cercis canadensis "Forest Pansy"	*Forest Pansy*	?	?	*?*
Corymbia eximia		✔	✔	
Corymbia ptychocarpa x ficifolia "Summer Red"	*"Summer Red")*	✔	✔	*?*
Cupaniopsis anacardioides	*Tuckeroo*	✔	±	*?*
Dais cotonifolia			*?*	*?*
Elaeocarpus reticulatus	*Blueberry ash*	✔	±	*?*
Eucalyptus dielsii	*Diel's mallee*	✔	✔	
Eucalyptus leucoxylon "Austraflora Euky Dwarf"	*"Euky Dwarf")*			✗
Flindersia australis	*Crow's ash*	±	±	*?*
Flindersia xanthoxyla	*Yellow wood*	✗	✗	✗
Fraxinus americana "Autumn Applause"	*Autumn Applause American ash*	*?*	*?*	*?*
Fraxinus ornus	*Manna ash*			*?*
Fraxinus ornus "Arie Peters"	*"Arie Peter's" Manna ash*	✔	✔	*?*
Fraxinus Raywood grafted to F. ornus rootstock	*Claret ash*	✔	✔	*?*

Fraxinus pennsylvanica "Urbanite"	*"Urbanite" green ash*			
Fraxinus velutina	*Velvet ash*			
Geijera parviflora	*Wilga*	✔	✔	
Ginkgo biloba	*Maidenhair tree*		✔	✔
Gleditsia tricanthos "Elegantissima"	*"Elegantissima" Honey locust*	*?*	*?*	
Harpullia hillii				
Harpullia pendula	*Tulipwood*		✘	*?*
Lagerstroemia indica x fauriei				
Biloxi	*"Biloxi" crepe myrtle*	✔	✔	✔
Natchez	*"Natchez crepe myrtle*	✔	✔	✔
Sioux	*"Sioux" crepe myrtle*	✔	✔	✔
Tuscarora	*"Tuscarora" crepe myrtle*	✔	✔	✔
Michelia doltsopa	*Wong lan*	✘	✘	✘
Pistachia chinensis	*Chinese pistachio*			
Pyrus calleryana				
"Bradford"	*Bradford callery pear*	✔	✔	✔
"Capital"	Capital callery pear	✔	✔	✔
"Chanticleer"	Chanticleer callery pear	✔	✔	✔
"Lynington"		✔	✔	✔
"Winterglow"	Winterglow callery pear	✔	✔	*?*
Pyrus ussuriensis	*Manchurian pear*	✔	✔	
Quercus canariensis	*Algerian oak*	✔	✔	?
Quercus cerris	*Turkey oak*	✔	✔	?
Quercus coccinia	*Scarlet oak*	?	?	?
Quercus ilex	*Holly oak*	✔	✔	✔
Quercus palustris	*Pin oak*	✔	✕	?
Quercus robur	*English oak*	✔	✔	✔
Quercus robur "Fastigiata"	*Fastigiate English oak*	✔	✔	
Quercus suber	*Cork oak*	✔	✔	
Robinia x decaisneana	*Pink wisteria tree*	✔	✔	✕
Sapium sebiferum	*Chinese tallowwood*	✔	±	✔
Sequoiadendron giganteum	*Big tree*	*?*	✕	✕
Sophora japonica	*Japanese pagoda tree*	*?*	*?*	
Sophora japonica "Princeton Upright"	*"Princeton Upright" pagoda tree*	*?*	*?*	
Stenocarpus sinuatus	*Firewheel tree*		*?*	
Taxodium distichum	*Swamp cypress*			*?*
Tilia americana "Bailyard" Frontyard		?	?	?
Tilia cordata 'Chancole' Chancellor		?	?	?
Toona ciliata	*Australian red cedar*	✔	✔	✔
Zelkova serrata	*Japanese zelkova*	✔	✔	✔
Zelkova serrata "Green Vase"	*"Green Vase" Japanese zelkova*	?	?	*?*

Acacia melanoxylon (Blackwood)

Sites: Azalea Drive Lockleys, planted 2001
Shannon Avenue Glenelg North, planted 2000
Stock type: 300mm spring ring

Comments:

- Shannon Avenue planting in 2000 showed surprisingly good survival and growth rates, similar rates since achieved in Azalea Drive.
- Mature characteristics under street conditions are as yet unknown.
- Suitable for additional small street plantings on a trial basis or for wider use on reserves etc.

Acer buergerianum (Trident maple)

Sites: Berrima Street Glenelg North, planted 1998, sand, pH 7.5
Byron Avenue Netley, planted 1998, Sand, pH 7.5
Garfield Avenue Kurralta Park, planted 1998, clay, pH 5.5 - 7
Goldfinch Avenue Cowandilla, planted 1998, clay, pH 7.5
North Parade Torrensville, planted 1998, clay, pH 6.5 - 7
Woodhead St. West Beach (removed winter 2000) sand, pH 6 – 6.5
Stock type: bare-root trees approx 1.5 to 1.8m tall

Comments:

- The trees in alkaline loams and clays have performed well with good survival & growth rates, slower growth rates neutral soils.
- Trees in the acidic sandy site (Woodhead Street) all performed poorly & were replaced in year 2.
- Several trees were destroyed at various sites (vandalism), other trees died as a result of gas leakage at the Goldfinch Avenue site.
- Experience with small bare-root stock (1m to 1.4m tall with 8 -–10mm caliper) in both street and nursery suggests it is likely to fail (most examples did not survive through their first spring) while larger bare-root stock (~ 1.5 – 1.8m tall) had good survival and growth rates.

Acer campestre “Evelyn” (Queen Elizabeth hedge maple)

Sites: Brook Street Plympton, planted 2000,
Halifax Street Hilton, planted 2000
Henry Street Plympton, planted 2000, clay, pH 7 – 7.5
Raffles Crescent Plympton, planted 2000, clay, pH 7.5
Cawthorne Street Thebarton, median, planted 2000,
Stock type: bare-root trees approx 1.5 to 1.8m tall

Comments:

- Good survival and growth rates at all sites.
- Apparently hardy & worth considering for street planting.
- Viable winged seed may become an issue.

Acer monspessulanum (Montpellier maple)

Site: Liley Street Hilton, planted 2000, clay
check mature examples at the Waite Arboretum.

Stock type: 10 liter polythene bag, approx 1.2m tall

Comments:

- Results inconsistent, only 10 trees planted of average quality stock, growth slow.
- More trial planting needed.
- Difficult to obtain good stock.

Acer pseudoplatanus (Sycamore)

Sites: Berrima Street Glenelg North, planted 1998, sand, pH 7.5
Castlebar Road Lockleys, planted 1998, loam & clay, pH 6 – 6.5
Daringa Street Mile End, planted 1998, clay, pH 6 – 6.5
Garfield Avenue Kurralta Park, planted 1998, clay, pH 6.5 - 7
Pine Avenue Novar Gardens, planted 1998, sand, pH 7
Woodhead St. West Beach, planted 1998, sandy loam, pH 6 – 7.5
Stock type: Bare-root trees approx 1.8-2 meters tall x 20mm caliper

Comments:

- Apparently hardy.
- Very slow growth rate, particularly in lighter soils.
- Mature examples located since trial planting confirm mature height of approx 5 metres.
- Extensive & unsightly leaf burn in summer.
- No further trial plantings planned, established sites considered adequate.

Acer x freemanii "Jeffersred" (Autumn Blaze hybrid maple)

Sites: Marion Road Plympton, planted 1999, sandy loam, pH 8.5 - 9
Autumn Avenue Lockleys, planted 1999, clay, pH 7
Falcon Avenue Mile End, Neighbourhood House front garden
Kimber Terrace Kurralta Park, planted 2001
Langdon Street Brooklyn Park, planted 2002
Stock type: advanced bare-root stock, approx 3m tall with 30mm caliper

Comments:

- 100% survival rate and variable but good growth rates at all sites.
- no leaf burn evident.

Acer x freemanii "Scarsen" (Scarlet Sentinel hybrid maple)

Site: Mortimer Street Kurralta Park, planted 2001,
Stock type: bare-root stock

Comments:

- Good survival rate but slow growth rate in first year.
- Requires further local trials.

Angophora costata "Little Gumball" (Little gumball apple myrtle)

Site: Shannon Avenue Glenelg North, planted 1999
Stock type: 300mm spring ring

Comments:

- No trees surviving past year 2.
- No further trials planned.

Backhousia citriodora (Lemon-scented myrtle)

Sites: Craig St. Richmond, planted 2000, sandy loam, pH 7.5,
Carlisle St. Camden Pk, planted 2000, sandy loam, pH 8.5,
Stock type: 330mm spring ring, approx 1.3m tall with 20mm caliper

Comments:

- Inconclusive, small number of trees planted for individual residents (trees not watered by Council but by residents).
- Survival whilst not maintained by Council suggests the species warrants further planting on trial basis.
- Growth rate slow (expect more satisfactory with regular maintenance)
- Future small scale trials needed.

Banksia grandis

Sites: Norman Street Underdale, planted in traffic calming devices at intersections with Fernleigh and Pearse Streets, planted 2001.
Dew Street Mile End, in road closures.
Stock type: 330mm spring ring

Comments:

- Good survival rates, growth rates slow but acceptable.
- Road closure locations etc. selected to minimize "care" by local residents.

Banksia integrifolia (Coast banksia)

Sites: Shannon Avenue Glenelg North, site excavated to construct Sturt River levees prior to lining with concrete, texture & pH vary greatly.
Wilkes Street West Beach, planted 1999.
Stock type: 200mm pot

Comments:

- Variable, significant losses.
- Those surviving have slow growth rate, some chlorosis.
- Mature examples can be seen in Raymond Avenue Netley and Sandilands Street Lockleys.
- Worth considering for planting as individual specimens in reserves, limited street application.

Banksia serrata (Saw banksia)

Few examples planted on Shannon Avenue verge in 1999, significant losses, similar results to B. integrifolia. Surviving plants deteriorating.

Brachychiton acerifolius (Illawarra flame tree)

Sites: Diosma Crescent Lockleys, planted alternately with *Jacaranda mimosifolia* for contrasting flower colour in spring/summer, planted 2000.
Douglas Street Lockleys, planted 2000.
Stock type: Advanced balled & burlapped.

Comments:

- All trees surviving.
- Slow growth rate.
- Limited street application due to mature size and space requirements.

Brachychiton populneum

Sites: Airport Road Brooklyn Park, planted on median in 2001.
Stock type: 400mm rocket pot.

Comments:

- 3 months since planting, all growing vigorously.
- Limited street application due to mature size and space requirements.

Brachychiton rupestris (Queensland bottle tree)

Sites: Airport Road median Brooklyn Park, 11 trees planted 2002.
Westside Bikeway Reserve, cnr. Birkalla Terrace and Stonehouse Avenue Camden Park, 3 trees planted 2002
Stock type: 400mm rocket pot.

Comments:

- 3 months since planting, all growing vigorously.
- Limited street application due to mature size and space requirements.

Buckinghamia celsissima (Ivory curl tree)

Sites: Concord Street Netley, planted 1998, sand, pH 7.5 - 8
Allchurch Avenue Plympton, planted 1998, clay, pH 6 - 7
Wyatt Street Plympton, planted 1998, clay, pH 6.5 - 7
Stock type: 200mm pot and 500mm spring ring

Comments:

- Larger stock showed good survival and growth rates.
- Survival and growth rates of small stock lower than larger stock.
- Large stock flowered well in first year, smaller stock first flowered in year 3.
- Survival and growth rates at the sandy (Concord Street) site were unsatisfactory.
- Worthy of further planting on trial basis but not in light soils.

Caesalpinia ferrea (Leopard tree)

Sites: David Court Lockleys, planted 2000, sandy loam, pH 6 - 7
Muirfield Street Novar Gardens, planted 2000, sand, pH 7
Edward Davies Street North Plympton, planted 2000, clay, pH 8
Stock type: 300mm spring ring

Comments:

- Survival rate good but growth rate slow
- Worthy of consideration for further trials of limited numbers
- Further trials may include increased feeding to determine impact on growth rates

Castanospermum australe (Black bean, Morton Bay chestnut)

Site: Talbot Street Plympton, planted 1998, clay, pH 6.5 – 7.
Stock type: 200mm pot

Comments:

- Growth and survival rates good in bare earth and dolomite but poor in turf.
- Trees in turf improved markedly following heavy application of organic fertiliser.
- Worthy of further trial to determine suitability to alternative conditions.

Cercis canadensis (Redbud)

Site: Dudley Avenue North Plympton, planted 1999, sandy loam, pH 8
Stock type: 25 litre bag

Comments:

- Good survival and growth rate
- Worth considering further trial planting

Cercis canadensis "Forest Pansy"

Site: Harris Street Netley, planted 2002
Stock type: 33cm pot

Comments: no information available.

Corymbia eximia (Yellow bloodwood)

Sites: Raymond Avenue North Plympton, planted 1999, sand.
Reserve cnr. McArthur Avenue & Long Street Plympton, planted 1999.
Frank Norton Reserve, Rankine Road Torrensville, planted 1999.
Stock type: 25 litre bag

Comments:

- Good survival & growth rates.
- Stock at planting showed weak/poor root development, would not have passed the "Burnley Test."

Corymbia ptychocarpa x ficifolia "Summer Red." ("Summer Red")

Sites: Lorraine Avenue Lockleys, planted 1999.
Sir Donald Bradman Drive Brooklyn Pk, planted 1999, clay, pH 8.
Hoylake Street Novar Gardens, planted 2000.
Freda Street Netley, planted 2000.
Stock type: 200mm pot

Comments:

- Survival rates generally good but growth rates slow to average
- Basal suckering from rootstock (*E. tessellaris*) is of concern, occasional suckers on heavy soils but very few in sandy areas, suckers rapidly outgrow the grafted hybrid
- Future planting will be limited until mature characteristics can be determined

Cupaniopsis anacardioides (Tuckeroo)

Sites: planted as a replacement for Queensland box *(Lophostemon confertus)* in many locations throughout West Torrens since 1998 including:
Rawlings Avenue Torrensville, planted 1998, clay, pH 6.
Baroda Avenue Netley, planted 2000, sand.
Hayward Avenue Torrensville, planted 1998.
Lorraine Avenue Lockleys, planted 1999.
Stock type: 300mm spring ring

Comments:

- Survival and growth rates good in most situations.
- Early indications suggest a hardy species suited to local conditions.
- Vandalism has been an ongoing problem in some locations.
- Future planting will be limited until mature characteristics can be determined.

Dais cotonifolia (Pompom tree)

Site: reserve on cnr. Henley Beach Road and Ayton Avenue at Fulham.
Stock type: bare-root specimens removed from private garden, height 1.1–1.3m.

Comments:

- Surviving in a relatively harsh & exposed site with little attention.
- Slow growth rate.
- Further trials to be considered in future.

Elaeocarpus reticulatus (Blueberry ash)

Site: Selby Street Kurralta Park, planted 1998, clay, pH 8.5 – 9
Stock type: 330mm spring ring.

Comments:

- Survival rate acceptable but growth rate slow.
- Fruit (similar in size & appearance to that of *Ligustrum lucidum*) may be of concern.
- No further trials planned.

Eucalyptus dielsii (Diel's mallee)

Sites: Shannon Avenue Glenelg North, planted 2001.
Dew Street Mile End (road closure) planted 2001.
Stock type: 330mm spring ring.

Comments:

- Good survival and growth rates at all sites.
- Planted on road closures for screening (bushy growth habit while young).
- Further trials required.

Eucalyptus leucoxylon "Austraflora Euky Dwarf" ("Euky Dwarf")

Sites: Myzantha Street Lockleys, planted 1998, sandy loam, pH 8
Carlisle Street Camden Park, planted 1998, sandy loam, pH 7.5
Stock type: 200mm spring ring.

Comments:

- Rapid growth rates but poor survival rates due to high incidence of vandalism (eucalypts unpopular with many residents).
- Variable growth habit, frequently multi-stemmed.
- At this stage similar in appearance & growth characteristics to *E. leucoxylon ssp. megalocarpa.*
- No further trials anticipated.

Flindersia australis (Crow's ash)

Sites: Tennyson Street Kurralta Park, planted 1998, clay, pH 7 – 7.5
Allchurch Avenue North Plympton, planted 1998, clay, pH 7 – 7.5
Howden Road Fulham, planted winter 1998, clay, pH 6 – 6.5
Planted: winter 1998
Stock type: 330mm & 500mm spring ring

Comments:

- Variable & inconclusive, good survival & growth rates in Tennyson Street and Allchurch Avenue but poor in Howden Road, apparently preferring slightly alkaline soil to slightly acid
- Best growth & vigor in bare earth and dolomite verges, worst in turf
- Trials have been restricted to large sites, future use will be limited until mature characteristics in street situations can be determined.
- Mature example in street situation can bee seen in Plympton Primary School grounds cnr. Long & Owen Streets Plympton.

Flindersia xanthoxyla (Yellow wood)

Site: Airport Road Brooklyn Park (median) planted 1998, 31 trees.
Stock type: 200mm spring ring

Comments:

- variable & inconclusive
- trees in more sheltered areas had higher survival and growth rates but growth still slow.
- Many trees replaced in winter 2002 with *Brachychiton populneum*
- No further trials planned.

Fraxinus americana 'Appldell' Autumn Applause

Sites: Good Street Reserve Fulham, planted 2001
Kesmond Reserve, Everard Avenue Keswick, planted 2001
Stock type: 40cm rocket pot

Comments:

- Only 2 trees planted as a preliminary trial
- Both trees survived a dry summer with minimal care
- Ongoing monitoring over coming years will determine suitability for additional trials

Fraxinus ornus (Manna ash)

Sites: Allen Avenue Brooklyn Park, planted 1998.
Marshall Terrace Brooklyn Park, planted 1997.
Hunter Street Fulham, planted 1997.
Stock type: Bare-root stock, 1.2 – 1.5 m tall

Comments:

- Good survival and growth rates**.**
- Ash white fly infestations seasonal, can be severe.

Fraxinus ornus "Arie Peters" ("Arie Peter's" Manna ash)

Sites: James Street Brooklyn Park, planted 2000, clay, pH 8.5 – 9.
Watson Avenue Netley, planted 2000, clay.
Stock type: bare-root stock

Comments:

- good survival rate but growth slowed by heavy infestations of ash white fly
- Flowers more abundant than for seedling F. ornus.

Fraxinus Raywood grafted to F. ornus rootstock (Claret ash)

Sites: Lewis Street Brooklyn Park, planted 1998, clay, pH 5.5 – 7.
North Parade Torrensville, planted 1998, clay, pH 6.5 – 7.
Examples in Waite Arboretum on alternative rootstock.
Stock type: bare-root stock.

Comments:

- Good survival and growth rates.
- Further trials required

Fraxinus pennsylvanica “Urbanite” (“Urbanite” green ash)

Sites: Hounslow Avenue Cowandilla, planted 2001.
48-50 Capper Street Camden Park, planted 2001.
Stock type: 200mm pot.

Comments:

- Stock delivered midday during 40° C January heatwave, wilted & shed most leaves, vigorous new leaf growth within fortnight.
- Survival rate good, growth rate slow.
- Further trials required.

Fraxinus velutina (Velvet ash)

Sites: Allen Avenue Brooklyn Park, planted 1998, clay, pH 6 - 7
Talbot Street North Plympton, planted 1998, clay, pH 6 – 8
Chatswood Grove Underdale, planted 1998, clay, pH 6 – 6.5
Lewis Street Brooklyn Park, planted 1998, clay, sandy loam, pH 6
Stock type: Advanced bare-root stock

Comments:

- Proving reliable in dolomite & lawn verges
- Good survival & growth rates

Geijera parviflora (Wilga, Australian willow)

Sites: Carlisle Street Camden Park, planted 1998, sandy loam, pH 7.5
Owen Street Plympton, planted July 2001
Grove Avenue Marleston, planted 2002
Lasscock Avenue Lockleys, planted 1998, clay, pH 6.5 - 7
Argyle Avenue Marleston, planted 1998, clay, pH 7
Garfield Avenue Kurralta Park, planted 1998,
Stock type: 200mm spring ring (Owen & Grove: 300mm spring ring)

Comments:

- Good survival rates in bare earth and dolomite.
- Competition with Kikuyu turf significantly reduces success, slowing growth rate & increasing losses.
- One example not watered for 6 weeks over summer shed all leaves but regenerated well soon after regular watering began again.
- Limited stock availability due to 3 year production time to 330mm spring ring size requires stock ordering up to 3 years in advance.
- Now planted in annual greening projects.
- Experience in the United States suggests life expectancy as street specimens of 25 to 50 years (McPherson et. al (1999) p. 52)

Ginkgo biloba (Maidenhair tree)

Sites: Boston Avenue Lockleys, planted 1997.
Brooklyn Avenue Brooklyn Park, planted 1998.
Samuel Street Fulham, planted 1999.
Sycamore Avenue Novar Gardens, planted 1998
Stock type: 200mm pot & 25 litre bag.

Comments:

- Observation of a single example planted by a resident in an exposed dolomite verge first suggested suitability for street use.
- Survival rates generally good, growth rates slow.
- Some trees lost due to ring-barking by brush cutter.

Gleditsia tricanthos "Elegantissima"

Sites: 18 Packard Street North Plympton, planted 2002.
Lyons Street Brooklyn Park, cnr Clivan Street, planted 2002
Keswick Road Ashford, planted 2002
Stock type: 25 litre bag.

Comments:

- No information available.

Harpullia hillii

Site: Basnett Street Kurralta Park, planted 1998, sandy loam, pH 8
Stock type: 200mm pot & 330mm spring ring.

Comments:

- Larger stock has good survival rate and fast growth rates following year 2, initial growth slow.
- Larger stock flowered in year 4.
- Marked difference between larger & smaller stock, small stock has reduced growth rates, has not yet flowered and was subject to vandalism.
- Requires further trials.

Harpullia pendula (Tulipwood)

Site: Wyatt Street Plympton, planted 1998, clay, pH 6.5
Stock type: 25 litre bag.

Comments:

- Acceptable survival rate but slow growth rate
- Greatest growth occurred within a few weeks following summer rainfall
- Reports indicate reasonable performance in trials in City of Marion
- Further trials required

Lagerstroemia indica x fauriei "Indian Summer" crepe myrtles. *"Tuscarora," "Biloxi," "Sioux" & "Natchez" varieties.*

Sites:
"Tuscarora" Cygnet Street Novar Gardens, planted 2001
Kimber Terrace, planted 2001
Samuel Street Fulham, planted 1999
"Biloxi" Elm Street Mile End, planted 2001
"Sioux" Chambers Avenue Richmond, planted 2001
"Natchez" Prettyjohn Court Underdale, planted 1999

Stock type: 25 litre bag, bare-root (Samuel Street)

Comments:

- Good survival rates & acceptable growth rates.
- Moisture appears to be the major limiting factor initially.
- May bloom in first summer given adequate watering, making them a favourite with many residents.

Michaelia doltsopa (Wong lan)

Sites: Cummins Reserve, Saratoga Drive Novar Gardens, planted 2000
Wilson Street Cowandilla, planted 2000, removed 2001
Stock type: 200mm pot

Comments:

- 10 trees planted, most died within six months
- Single surviving tree in sheltered location with root competition from surrounding reserve trees, has not grown since planting.
- No further trials planned.

Pistachia chinensis (Chinese pistachio)

Sites: Bignell Street Richmond, planted 2000
Glenburnie Terrace Plympton, planted 2000
Neston Avenue Plympton, planted 2000
Talbot Street Hilton, planted 2000

Stock type: 300mm and 200mm pot.

Comments:

- Good survival and growth rates, significantly better for larger stock.
- Difficult to source stock of 2m height with a single straight leader of sufficient strength to be free standing at planting.
- Recommend personal selection of stock.

Pyrus calleryana (Callery pear)

P. calleryana "**Bradford**" Pistolier Street Plympton, planted 1994
Weetunga Street Fulham, planted 1999/2002
P. calleryana "**Capital**" John Street Marleston, planted 1999
Albert Street Richmond, planted 2001 & 2002
P. calleryana "**Chanticleer"** Roeburn Street Lockleys, planted 1999
Durant Street Plympton, planted 2000
Marion Road North Plympton, planted 2000
P. calleryana "Lynington" Noble Avenue Lockleys, planted 2002
P. calleryana "**Winterglow** " Bonython Avenue Novar Gardens, planted 1997
Stock type: most stock bare-rooted, few 25 litre poly bag.

Comments:

- all varieties appear hardy & suitable to most local conditions
- high survival rates, though losses common in summer 2000/01 when weekly watering was restricted to approximately 15 litres by dish size (normal weekly watering 1st year is 45 – 50 litres)
- widely planted in annual greening programs
- bare-root stock passes "Burnley Test" after 6 months

Pyrus ussuriensis (Manchurian pear)

Sites: White Avenue Lockleys

Results similar to P. calleryana varieties, widely used in greening programs.

Quercus

Quercus canariensis (Algerian oak)
Arden Avenue Lockleys (median), planted 2000

Quercus cerris (Turkey oak)
Errington Street Reserve Plympton, planted 1999
Cummins Reserve, Sheoak Avenue Novar Gardens, planted 1999
McArthur Avenue North Plympton, planted 2000
Brecon Court Lockleys, planted 2000
1999: 500mm spring ring, 2000: adv balled & burlapped

Quercus coccinia (Scarlet oak)
Cummins Reserve, Sheoak Avenue Novar Gardens, planted 2001

Quercus ilex (Holly oak)
Northern Avenue West Beach, planted 2001
Siesta Avenue Reserve West Beach, planted 2001
Kevin Avenue Reserve West Beach, planted 2001
All of the above: 330mm spring ring.
Mature examples: Victoria Street Henley Beach

Quercus robur (English oak)
Tyson Street Ashford, planted 1995, 25 litre poly bag
Birdwood Court North Plympton, planted 1999, 25 litre poly bag

Quercus robur "Fastigiata" (Fastigiate English oak)
Hoylake Street Reserve Novar Gardens, planted 1997
Wells Reserve, Errington Street Plympton, planted 1997
10 litre poly bag.

Quercus suber (Cork oak)
Layton Street Fulham, planted 2001
Stuckey Avenue Underdale, planted 2001
Lindfield Avenue Reserve Novar Gardens, planted 2002
College Grove Reserve, Lipsett Terrace Brooklyn Park, 2002

Stock type: 2001: 330 spring ring, 2002: 400mm rocket pot.

Comments:

- All species show good survival rates
- growth rate reasonable for Q. cerris, other species slow, Q. palustris extremely slow

Robinia x decaisneana (Pink wisteria tree)

Sites: Cranbrook Avenue Underdale, planted 1994, removed 2001
Birkalla Terrace Plympton, planted 1995
Harvey Street Marleston, planted 1995
Frasten Street Torrensville, planted 1995, removed 2002

Stock type: bare-root stock.

Comments:

- Good survival and growth rates at all sites.
- Root suckering problems identified early at many sites.
- Problems with thorns, particularly if basal suckers not maintained.
- Most trees removed within 5 years due to problems.

Sapium sebiferum (Chinese tallowwood)

Site: Dudley Avenue Plympton, planted 1999, clay.
Stock type: 25 litre poly bag

Comments:

- Variable, some trees died during first year or so, some with slow growth rates.
- Good survival and growth rates in sites where additional water provided by residents.
- Feeling in first 2 years was that the species did not warrant further consideration, but after 3 years some trees began to show promise.
- Further trials needed provided quality stock are available.

Sequoiadendron giganteum (Big tree)

Planted for curiosity value in 1999.
Sites: Eltham, Orwin and Sherwin Courts Fulham (1 tree in each median)
Lockleys Oval, Moresby Street frontage, Lockleys
Kesmond Reserve, Everard Avenue Keswick
Stock type: 24" plastic tub.

Comments:

- Seven trees planted in total, one tree died and one damaged through vandalism, one tree was overlooked by relief water truck operator for four weeks during summer 1999/2000 and did not recover.
- The four trees remaining have slow growth rates, approximately 150mm apical growth in 3 years.

Sophora japonica (Japanese pagoda tree)

Sites: Lew Street Netley, planted 2000, loam
Ruthven Avenue Glandore, planted 2000, compacted heavy clay
Stock type: 25 litre bag

Comments:

- Planted in difficult sites, some losses

Sophora japonica "Princeton Upright" ("Princeton Upright" pagoda tree)

Sites: Cranbrook Avenue Underdale, planted 2001, loam
Gunnawarra Avenue Camden Park, planted 2001, clay
Lea Street North Plympton, planted 2000, sand

Stock type: advanced bare-root

Comments:

- Some losses, growth slow.

Stenocarpus sinuatus (Firewheel tree)

Sites: Lorraine Avenue Lockleys, planted 1999
East Parkway, planted 2001 / 2002
Stock type: 25 litre bag

Comments:

- Good survival rates but growth slow.
- Trees suffer during winter, minor frost damage.

Taxodium distichum (Swamp cypress)

Site: Mile End Common, Bagshaw Way Mile End, planted 2000
Stock type: Advanced balled & burlapped.

Comments:

- 2 trees only planted in a poorly drained site.
- Both trees surviving, growth slow

Tilia americana "Bailyard" Frontyard

Sites: Good Street Reserve Fulham, planted 2001
Kesmond Reserve, Everard Avenue Keswick, planted 2001
Stock type: 40cm rocket pot

Comments:

- Only 2 trees planted as a preliminary trial
- Both trees survived a dry summer with minimal care
- Ongoing monitoring over coming years will determine suitability for additional trials

Tilia cordata "Chancole" Chancellor

- Details as for Tilia americana

Toona ciliata (Australian red cedar)

Site: Airport Road Brooklyn Park (median), planted 2000
Stock type: 25 litre poly bag

Comments:

- Drip irrigated, 100% survival rate.
- Growth rapid & rate increased further following mulching to 3.5m diameter.

Zelkova serrata (Japanese zelkova)

Sites: Sarah Street Marleston, planted 1998, clay, pH 8.5-9
Washington Street Hilton, planted 1998, clay, pH 8
Wakefield Street Brooklyn Park, planted 1998
Stock type: Bare-root

Comments:

- Good survival & growth rates.

Zelkova serrata "Green Vase" ("Green Vase" Japanese zelkova)

Site: Henley Beach Road Torrensville, planted 1999
Stock type: Bare-root

Comments:

- Contaminated site, trees were replacements for failed *Platanus.*
- Many losses, though some trees survived where *Platanus* did not.
- Further trials required.

THE ECONOMIC VALUE OF TREES IN URBAN AREAS: ESTIMATING THE BENEFITS OF ADELAIDE'S STREET TREES

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Introduction and Overview

As populations become increasingly urbanised, national governments to local councils are recognising that the trees that line our streets, fill our parks and shade our houses make up an urban forest. Urban forests provide multiple benefits that go far beyond adding an aesthetic beauty to our neighbourhoods**.** Trees in parts, streets and yards, conserve energy, reduce carbon dioxide in the atmosphere, improve air quality, reduce storm runoff, enhance the beauty of our communities by adding colour, texture, and form to our landscapes.

In addition, no matter where trees are located, they represent an interdependent part of complex ecosystems capable of providing a wide range of economic, social and environmental benefits. All these benefits should be considered when attempting to measure the economic, social and environmental benefits of our street trees. These benefits and services, however, are valued differently by different people and different groups in society. Local, regional, national and international interests in our urban trees and the resources they provide also differ greatly and tend to shift over time.

As interests shift and expectations conflict, difficult policy and management challenges are created, requiring innovative national, regional and local strategies that better integrate urban trees into community development efforts and balance economic, social and environmental needs among local, national, and even international interests. The emerging views of what urban trees are and what they contribute requires local governments to search for pragmatic management strategies that deal coherently with both the contributions of trees to urban development and to search for organisational structures to make better use of these contributions.

The roles of urban forestry in general, and street trees in particular (ie., the knowledge, concepts, institutions and practices through which multiple and competing demands for trees are managed), are changing as well. The changes are emerging as awareness grows of how local communities control and depend on trees and urban forests, prompting efforts to strengthen local stakes in urban forestry and street tree management, programs and activities.

Developing effective forestry strategies and policies involves an array of difficult choices. Some choices result in inefficient resource use because many essential benefits and services of street trees, such as aesthetic values, watershed protection, conservation, biological diversity and climate regulation are not priced. Markets with corresponding prices just do not exist for many important street tree services and benefits. The result is that street tree decisions are often biased because information is lacking.

An important message of this paper is that it is very difficult to address the total economic, social and environmental benefits of street trees because of the multiple roles and the competing interests. To some, street trees represent a nuisance, dropping their fruit, branches, and leaves, raising side walks or shading their 'heritage' roses. To others, street trees are a noise barrier and an air filter, adding value to their neighbourhood and their properties.

Urban forests as part of the development process

In general, Australia's forests need to be better recognised as an integral part of national and urban economies. Trees and forests contribute to urban development in many ways, including as natural capital, as production inputs and as environmental goods. Several factors help explain how urban trees contribute to Adelaide's development strategies.

First, urban trees are undergoing 'urbanization'. Urban trees are increasingly managed for their range of resource flows, their ability to support urban welfare, and their capacity to promote growth opportunities. Urban trees provide large albeit different ranges of goods and services for virtually all patterns of urban settlement and livelihood.

Second, urban development strategies are beginning to include the capital values of forests in policies and programs that modify tree stocks, qualities and distributions. Urban trees are more widely acknowledged as both *productive capital stocks* and as components of *public infrastructural systems.* As ecological analogs of industrial capacity and physical infrastructure, urban trees are entering the central equations of urban growth, often with new definitions of what trees are and do.

Advances in accounting practices make it possible to explicitly incorporate the capital value of trees as *productive stocks*, and to assess the effects of changes in them on productive capacity. Conventional accounting systems overstate national income in two ways. First, the accounts disregard depreciation of tree capital. Second, the costs of mitigating or offsetting the side effects of resource depletion (eg. electric power reducing contributions of urban trees) are not subtracted from national income. This sends the wrong message about the full contributions that urban tress make.

As *infrastructure*, street trees provide services that otherwise would require capital expenditures or reductions in human wellbeing. Urban trees cool cities, conserve energy, reduce runoff, and absorb pollutants, substituting for more conventional infrastructure that otherwise would be needed. Strategically placed trees can reduce home air conditioning needs by providing shade on buildings, houses and street pavements and side walks. Although the concept of urban forests as infrastructure is not yet widely held, the absence of trees clearly requires constructed infrastructure at a cost to other potential uses of scarce capital.

Third, urban trees represent productive assets that can be used as a means for attaining urban development objectives, including attracting new investment and growth. Community tree programs also encourage civic participation. For all of these reasons, urban forest politics and policies need to evolve out of a narrow sectoral prerogative to enter broader mainstream political interests involving highly diverse groups. The emergence of organisations like TREENET demonstrate how urban forests are gradually becoming topics of discussion among articulate groups of tree specialists, city dwellers, scientists and educators.

Estimating the benefits and costs of street trees in Adelaide

Estimating the financial, economic, social and environmental benefits and costs of Adelaide's street trees requires a detailed study well beyond the scope of this report. Nevertheless, inferences from other studies on the value of trees provide useful insights into the costs individuals, communities and taxpayers nation wide would be facing.

For example, the benefits trees provide for climate modification and energy conservation is crucial for South Australia residential and commercial offices. Some 95 percent of South Australia's population lives in urban forests and a major part of the state's electricity consumption is due to heating and cooling. The following examples from a range reports illustrate the economic value of these benefits to other communities[1].

Air temperature: reductions from 1 to 8 ºC can be expected due to the presence of tree cover. For instance, temperatures in a Davis, California neighbourhood were as much as 7 ºC cooler than recorded at the same time in a nearby unirrigated field[2].

Wind speed: reductions in wind speed of up to 10 percent can be obtained by providing tree canopy. This may cause small increases in cooling load in some cases, somewhat larger reductions in heating load more than offset the increased cooling load.[3]

Building energy use for heating and cooling: Trees reduce building energy use by lowering temperatures and shading buildings during the summer, and blocking winds in winter Trees also increase energy use by shading buildings in winter, and may increase or decrease energy use by blocking summer breezes. Thus, proper tree placement near buildings is critical to achieve maximum building energy conservation benefits.

When building energy use is lowered, power plants pollutant emissions are lowered. Lower pollutant emissions generally improve air quality and lower nitrogen oxide emissions, particularly ground-level emissions, may lead to a local increase in ozone concentrations under certain conditions due to nitrogen oxide scavenging of ozone. The cumulative and interactive effects of trees on meteorology, pollution removal, and VOC and power plant emissions determine the overall impact of trees on air pollution.[4]

Shade: Trees shading building surfaces reduce a major source of heat gain and hence air conditioning cooling load. Reduced solar heat gain in winter leads to small increases in heating load. Annual air conditioning savings from 3 trees, each 25-ft tall around a typical California residence, ranged from $23 in San Diego California to $83 in El Centro California[5].

A number of studies document the effects of urban trees on energy use and air quality[6]:

a)Direct shade from proposed planting of 11 million trees in the Los Angeles basin are predicted to result in $50 million reduction in annual air conditioning bills;

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[1] This material is from Simpson, J.R. and E.G. McPherson. 1999. *Energy and air quality improvements through urban tree planting*. In: Proceedings of the Ninth National Urban Forest Conference, Sept. 3-11, Seattle, Washington, American Forests, In Press.

[2] Myrup, L.O., McGinn, C.E. and Flocchini, R.G., 1993: *An Analysis of Microclimatic Variation in a Suburban Environment*. Atmospheric Environment. 27B, 129-156.

[3] Heisler, G.M. 1990. Mean wind speed below building height in residential neighborhoods with different tree densities. ASHRAE Transactions. 95(Part 1):1389-1396. and Heisler, G.M. 1990. Mean wind speed below building height in residential neighborhoods with different tree densities. ASHRAE Transactions. 95(Part 1):1389-1396.

[4] David J. Nowak 1999, *The Effects Of Urban Trees On Air Quality* USDA Forest Service, Syracuse, NY.

[5] Simpson, J.R.; McPherson, E.G. 1996. *Estimating urban forest impacts on climate-mediated residential energy use.* In: Preprints of 12th Conference on Biometeorology and Aerobiology. Boston. American Meteorological Society. pp. 462-465.

[6] Ibid

b)Cooling of air by these trees will save an additional $35 million annually;.

c)Cooler air temperatures reduce smog concentrations by 6%, resulting in an estimated savings of $180 million annually, assuming an offset commodity market existed for ozone;.

d)The total present value of these benefits for a single tree is $211 assuming a 20 year service life and 3% real discount rate;.

e)The cost of a tree planting program is estimated to be $35 per tree, resulting in a benefit-cost ratio of 6.0

Sacramento Shade [7]

a)From 1990 to 1996, over 200,000 trees were planted through Sacramento Shade, a partnership between the Sacramento Municipal Utility District (SMUD) and the Sacramento Tree Foundation.

b)Sacramento Shade has a benefit-cost ratio (BCR) of 1.1. This BCR includes benefits from direct shading only. If air temperature cooling effects are considered the BCR doubles to about 2.2.

Sacramento County[8]:

a)Each year about 1,300 GWh (1GWh = 1,000,000 kWh) of electrical energy is used for air conditioning in Sacramento County, at a retail cost of about $105 million.

b)The 6 million trees that comprise Sacramento's existing urban forest are responsible for annual savings of approximately 157 GWh of air conditioning electricity due to shading and cooling effects.[9]

c)Energy conservation stemming from trees saves Sacramento residents approximately $19.8 million each year.

d)The 6 million trees in Sacramento County absorb 1,457 m tons of air pollutants annually (ozone, nitrogen dioxide, particulate matter) with an implied value of $28.7 million.

e)Through energy conservation these trees reduce emissions of carbon dioxide from power plants, as well as directly remove atmospheric carbon dioxide during their growth process and store it as woody biomass. Approximately 238,000 m tons of CO2 are removed by the region's urban forest each year, with an estimated value of $3.3 million.[10]

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[7] Simpson, J.R. and E.G. McPherson. 1998. Simulation of tree shade impacts on residential energy use for space conditioning in Sacramento. Atmospheric Environment: Urban Atmospheres, 32:69-74.

[8] McPherson, E.G. 1996. Urban forest landscapes, how greenery saves greenbacks. Wagner, C., ed. 1996 Annual Meeting Proceedings, American Society of Landscape Architects. Washington, DC. ASLA. pp. 27-29.

[9] Simpson, J.R.; McPherson, E.G. 1995. Impact Evaluation of the Sacramento Municipal Utility District's Shade Tree Program. Davis, CA. USDA Forest Service, Western Center for Urban Forest Research. 35p.

[10] McPherson, E.G. 1998. *Atmospheric carbon dioxide reduction by Sacramento's urban forest*. Journal of Arboriculture. 24(4): 215-223.

f)These environmental benefits total approximately $8 per tree per year, and increase to about $90 once benefits such as increased property values, scenic beauty, wildlife habitat, community bonding, and recreation are added. Sacramento residents are estimated to spend about $5 to 10 per tree each year for watering, pruning, pest/disease control, and removal of dead trees. The Sacramento City Tree Services Division spends about $20 per tree to manage 150,000 street and park trees. Hence, initial research indicates that benefits are several times greater than costs. [11]

Removal of Air Pollutants:

Trees remove gaseous air pollution and some airborne particles. Some particles can be absorbed into the tree and others returned to the atmosphere (by rain back to the ground with leaf and twig fall). New York City trees removed an estimated 1,821 metric tons of air pollution at an estimated value to society of $9.5 million in 1994. The value in other U.S. cities included Atlanta (1,196 t; $6.5 million) and Baltimore (499 t; $2.7 million).

Large healthy trees greater than 77 cm in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than 8 cm in diameter (0.02 kg/yr).[12] In urban areas with contiguous forest stands tree cover, short-term improvements in air quality (one hour) from pollution removal by trees were as high as 15% for ozone, 14% for sulfur dioxide, 13% for particulate matter, 8% for nitrogen dioxide, and 0.05% for carbon monoxide[13]

Trees serve multiple functions function as "nature's air conditioners" by cooling urban heat islands and shading buildings. As long as trees are growing, their rate of uptake of CO2 through photosynthesis is greater than their release of CO2 through respiration. Trees around buildings can reduce demand for heating and air conditioning, thereby reducing emissions associated with electric power production. Annual CO2 reductions achieved through shade tree programs could offset about .2 to 2% of annual emissions. Not only that, but tree planting and stewardship programs can provide many social, environmental, political and public benefits to utilities as well.

A study on Tree Guidelines for San Joaquin Valley Communities quantified benefits and costs of "green infrastructure" to increase awareness and investment in urban and community forests. The study found that average annual net benefits from large trees such as a London plane can be as much as 6 times greater than from small trees like crape myrtle (the most frequently planted street tree in California). Average annual net benefits (benefits -costs) for a small, medium, and large street tree were $1, $26, and $48, respectively. The Guidelines also describe optimal

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[11] McPherson, E.G.; Simpson, J.R.; Scott, K.I. In Press. *Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models*. Atmospheric Environment:Urban Atmospheres. McPherson, E.G. 1998. *The Sacramento Urban Forest Ecosystem Study: Urban Greenery Saving Greenbacks*. In: Kollin, C. ed. Cities by Nature's Design: Proceedings of the 8th National Urban Forest Conference. Washington, DC: American Forests: 170-173.

[12] Nowak, D.J. 1994d. Air pollution removal by Chicago's urban forest. In: McPherson, E.G, D.J. Nowak and R.A. Rowntree. Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. USDA Forest Service General Technical Report NE-186. pp. 63-81.

[13] Nowak, D.J. and Crane, D.E. In press. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In: Hansen, M. (Ed.) Second International Symposium: Integrated Tools for Natural Resources Inventories in the 21 st Century. USDA Forest Service General Technical Report.

configurations of trees, recommend tree species for different situations, and identify sources of funding and technical assistance. In June we co-hosted with LGC a one-day workshop on "Strategies for Supporting and Funding the Urban Forest" to follow-up on interest generated by the Guidelines. We regard this publication-workshop format as a model to replicate in other regions as funding becomes available. What is the potential increase in tree plantings in Australia as a result of a carbon credit trading scheme?

The potential value of carbon credits

Uncertainty about the rules for international trading of carbon credits and the emission allowances, sequestration and the related uncertainties associated with forecasting the future to make the prediction of probable permit prices a difficult task. Some emission permit price predictions have arisen from studies that employ various mathematical models. The studies may tend to overstate the potential permit prices suggesting a range of permit price predictions, from $10/tonne to $50/tonne. Carbon credits would have to be below the permit price for them to be an attractive alternative strategy.

Cost-benefit study of Modesto California's urban tree management

A benefit-cost analysis of Modesto California municipal urban forest revealed that for every $1 spent on the 92,000 city-owned trees, residents received nearly $2 in benefits.[14] On average the city spends $29 per tree on management with residents receiving an estimated $55 a year in benefit: a net annual benefit of $26 per tree. The largest benefits are from air pollutant uptake, air conditioning energy savings, and aesthetics. The majority of the city's expenses (74 percent) are for mature tree care. The study concludes that without continued program funding to maintain the health of these trees, the benefits they produce will be lost prematurely. Some 14 per cent of the current tree management budget is spent on sidewalk repair, current studies examining strategies for reducing sidewalk damage have potential to save residents a substantial amount. These strategies include: 1) directing tree roots away from paving such as propagating trees with vertical rooting patterns, 2) engineering designs that are less costly to repair, and 3) providing more space for tree roots through design and planning.

[14] E. Gregory McPherson , *California Trees: Exploring Issues in Urban Forestry* 10(3): 5,9. 1999.

Table 1 summarises many tree benefits, including various estimates of the values associated with those benefits.[15]

Table 1 An overview of tree benefits: selected studies

Temperature and Energy Use a)Community heat islands (3o to 10oF warmer than surrounding countryside) exist because of decreased wind, increased high density surfaces, and heat generated from human associated activities, all of which requires addition energy expenditures to off-set. Trees can be successfully used to mitigate heat islands. b)Trees reduce temperatures by shading surfaces, dissipating heat through evaporation, and controlling air movement responsible for advected heat.
Shade a)20oF lower temperature on a site from trees. b) 35oF lower hard surface temperature under tree shade than in full summer sun. c)27% decrease in summer cooling costs with trees. d)75% cooling savings under deciduous trees. e)50% cooling energy savings with trees. (1980) 20oF lower room temperatures in uninsulated house during summer from tree shade. f)$242 savings per home per year in cooling costs with trees. g)West wall shading is the best cooling cost savings component. h)South side shade trees saved $38 per home per year. i)10% energy savings when cooling equipment shaded (no air flow reduction). j)12% increase in heating costs under evergreen canopy k)15% heating energy savings with trees. (1980) l)5% higher winter energy use under tree shade m)$122 increase in annual heating costs with south and east wall shading off-set by $155 annual savings in cooling costs. n)Crown form and amount of light passing through a tree can be adjusted by crown reduction and thinning. o)Shade areas generated by trees are equivalent to $2.75 per square foot of value (1975 dollars).
Wind Control a)50% wind speed reduction by shade trees yielded 7% reduction in heating energy in winter. b)8% reduction in heating energy in home from deciduous trees although solar gain was reduced. c)$50 per year decrease in heating costs from tree control of wind. d)Trees block winter winds and reduces "chill factor." e)Trees can reduce cold air infiltration and exchange in a house by maintaining a reduced wind or still area. f)Trees can be planted to funnel or baffle wind away from areas -- both vertical and horizontal concentrations of foliage can modify air movement patterns. g)Blockage of cooling breezes by trees increased by $75 per year cooling energy use.

[15] Kim D. Coder *Identified Benefits of Community Trees and Forests*, The University Of Georgia Cooperative Extension Service Forest Resources Unit Publication, For96-39,University of Georgia, 1996.

Active Evaporation

a)65% of heat generated in full sunlight on a tree is dissipated by active evaporation from leaf surfaces.
b)17% reduction in building cooling by active evaporation by trees.
c)One acre of vegetation transpires as much as 1600 gallons of water on sunny summer days.
d)30% vegetation coverage will provide 66% as much cooling to a site as full vegetation coverage.
e)A one-fifth acre house lot with 30% vegetation cover dissipates as much heat as running two central air conditioners.

Pollution Reduction

a)Community forests cleanse the air by intercepting and slowing particulate materials causing them to fall out, and by absorbing pollutant gases on surfaces and through uptake onto inner leaf surfaces.
b)Pollutants partially controlled by trees include nitrogen oxides, sulfur dioxides, carbon monoxide, carbon dioxide (required for normal tree function), ozone, and small particulates less than 10 microns in size.
c)Removal of particulates amounts to 9% across deciduous trees and 13% across evergreen trees.
d)Pollen and mold spore, are part of a living system and produced in tree areas, but trees also sweep out of the air large amounts of these particulates.
e)In one urban park (212 ha), tree cover was found to remove daily 48 lbs particulates, 9 lbs nitrogen dioxide, 6 lbs sulfur dioxide, and ½ lbs carbon monoxide. ($136 per day value based upon pollution control technology).
f)60% reduction in street level particulates with trees.
g)One sugar maple (one foot in diameter) along a roadway removes in one growing season 60 mg cadmium, 140 mg chromium, 820 mg nickel and 5200mg lead from the environment.
h)Interior scape trees can remove organic pollutants from indoor air.

Carbon Dioxide Reduction

a)Approximately 800 million tons of carbon are currently stored in US community forests with 6.5 million tons per year increase in storage ($22 billion equivalent in control costs).
b)A single tree stores on average 13 pounds of carbon annually.
c)A community forest can store 2.6 tons of carbon per acre per year.

Hydrology

a)Development increases hard, non-evaporative surfaces and decreases soil infiltration -- increases water volume, velocity and pollution load of run-off -- increases water quality losses, erosion, and flooding.
b)Community tree and forest cover intercepts, slows, evaporates, and stores water through normal tree functions, soil surface protection, and soil area of biologically active surfaces.

Water Run-Off

a)7% of winter precipitation intercepted and evaporated by deciduous trees.
b)22% of winter precipitation intercepted and evaporated by evergreen trees.
c)18% of growing season precipitation intercepted and evaporated by all trees.
d)For every 5% of tree cover area added to a community, run-off is reduced by approximately 2%
e)7% volume reduction in six-hour storm flow by community tree canopies.
f)17% (11.3 million gallons) run-off reduction from a twelve-hour storm with tree canopies

in a medium-sized city ($226,000 avoided run-off water control costs).

Water Quality / Erosion

a)Community trees and forests act as filters removing nutrients and sediments while increasing ground water recharge.
b)37,500 tons of sediment per square mile per year comes off of developing and developed landscapes -- trees could reduce this value by 95% ($336,000 annual control cost savings with trees).
c)47% of surface pollutants are removed in first 15 minutes of storm -- this includes pesticides, fertilizers, and biologically derived materials and litter.
d)10,886 tons of soil saved annually with tree cover in a medium-sized city.

Glare Reduction

a)Trees help control light scattering, light intensity, and modifies predominant wavelengths on a site.
b)Trees block and reflect sunlight and artificial lights to minimize eye strain and frame lighted areas where needed for architectural emphasis, safety, and visibility.

Property Values -- Real Estate Comparisons

a)Community trees and forests provide a business generating, and a positive real estate transaction appearance and atmosphere.
b)Increased property values, increased tax revenues, increased income levels, faster real estate sales turn-over rates, shorter unoccupied periods, increased recruitment of buyers, increased jobs, increased worker productivity, and increased number of customers have all been linked to tree and landscape presence.
c)Tree amenity values are a part of real estate prices.
d)Clearing unimproved lots is costlier than properly preserving trees.
e)6% ($2,686) total property value in tree cover.
f)$9,500 higher sale values due to tree cover.
g)4% higher sale value with five trees in the front yard -- $257 per pine, $333 per hardwood, $336 per large tree, and $0 per small tree.
h)$2,675 increase in sale price when adjacent to tree green space as compared to similar houses 200 feet away from green space.
i)$4.20 decrease in residential sales price for every foot away from green space.
j)27% increase in development land values with trees present.
k)19% increase in property values with trees. (1971 & 1983)
l)27% increase in appraised land values with trees. (1973)
m)9% increase in property value for a single tree. (1981)
n)Values of single trees in perfect conditions and locations in the Southeast range up to $100,000.
o)$100 million is the value of community trees and forests in Savannah, GA.
p)$386 million is the value of community trees and forests in Oakland, CA (59% of this value is in residential trees).

Animal Habitats

a)Wildlife values are derived from aesthetic, recreation, and educational uses.
b)Lowest bird diversity is in areas of mowed lawn -- highest in area of large trees, greatest tree diversity, and brushy areas.
c)Highest native bird populations in areas of highest native plant populations.

d)Highly variable species attributes and needs must be identified to clearly determine tree and community tree and forest influences.
e)Trees are living systems that interact with other living things in sharing and recycling resources -- as such, trees are living centers where living thing congregate and are concentrated.
f)The annual ecological contribution of an average community tree is estimated at $270.

Aesthetic Preferences

a)Conifers, large trees, low tree densities, closed tree canopies, distant views, and native species all had positive values in scenic quality.
b)Large old street trees were found to be the most important indicator of attractiveness in a community.
c)Increasing tree density (optimal 53 trees per acre) and decreasing understory density are associated with positive perceptions.
d)Increasing levels of tree density can initiate feelings of fear and endangerment -- an optimum number of trees allows for visual distances and openness while blocking or screening developed areas.
e)Species diversity as a distinct quantity was not important to scenic quality.

Visual Screening

a)The most common use of trees for utilitarian purposes is screening undesirable and disturbing sight lines.
b)Tree crown management and tree species selection can help completely or partially block vision lines that show human density problems, development activities, or commercial / residential interfaces.

Health

a)Stressed individuals looking at slides of nature had reduced negative emotions and greater positive feelings than when looking at urban scenes without trees and other plants.
b)Stressed individuals recuperate faster when viewing tree filled images.
c)Hospital patients with natural views from their rooms had significantly shorter stays, less pain medicine required, and fewer post-operative complications.
d)Psychiatric patients are more sociable and less stressed when green things are visible and immediately present.

Human Social Interactions

a)People feel more comfortable and at ease when in shaded, open areas of trees as compared to areas of hardscapes and non-living things.
b)People's preferences for locating areas of social interactions in calming, beautiful, and nature-dominated areas revolve around the presence of community trees and forests.
c)Trees and people are psychologically linked by culture, socialization, and coadaptive history.

Recreation

a)Contact with nature in many communities may be limited to local trees and green areas (for noticing natural cycles, seasons, sounds, animals, plants, etc.) Trees are critical in this

context. b) $1.60 is the willing additional payment per visit for use of a tree covered park compared with a maintained lawn area.
Noise Abatement a)7db noise reduction per 100 feet of forest due to trees by reflecting and absorbing sound energy (solid walls decrease sound by 15 db) b)Trees provide "white noise," the noise of the leaves and branches in the wind and associated natural sounds, that masks other man-caused sounds.

Source: Kim D. Coder *Identified Benefits of Community Trees and Forests*, The University Of Georgia Cooperative Extension Service, Forest Resources Unit Publication, For96-39,University of Georgia, 1996.

Calculating the gross benefits of Adelaide's street trees

Quantifying the exact net value of Adelaide's street trees is beyond the scope of this paper. Instead the aim here to provide an overview of the kinds of benefits and costs that should be considered and estimates, especially for some of the benefits. The costs of street tree management will vary by council, so the responsible officials are best placed to quantify the costs per tree.

The core benefits street trees provide can be captured as follows:

B = E+A+C+H+P+F

Where

B = street tree annual benefits
E = annual price of energy savings (cooling and heating);
Q = annual price of air quality improvement(pollutant uptake and avoided power plant emissions);
C = annual price of carbon dioxide reductions;
H = annual price of stormwater runoff reductions;
P = annual price of property value and related benefits;
F = annual savings for reductions in repaving streets.

A suggested formula for estimating annual costs is:

C = M+T+R+D+I+S+L+A

Where

C = annual costs of street trees;
M = annual price of tree planting;
T = annual price for pruning;
R = annual price of tree removal;
D = annual price for pest and disease control;
I = annual price for repairing tree-damaged infrastructure;
S= annual price of litter and storm clean up;
L = annual insurance costs for street tree liability;
A = annual price for program administration.

Our assumptions include the following:

- The estimated number of street trees in Adelaide is 128,000 (based on 1927km of roadsides;
- If all Adelaide's street trees were removed summer temperatures would be from .5^{o}C to 2^{o}C warmer due to the heat island impact--lack of evapotranspiration and, most importantly, shade on paved streets and side walks;
- The average Adelaide household spends $193 on air conditioning due to heat (more than $80 million per year);
- Spending on air conditioning energy consumption would increase by $20 per household per year if street trees were removed or an increase in 57 million kWh power consumption;
- Difference in street tree growth rates, size, leaf area, and canopy are ignored and a typical medium sized tree is used for a typical tree;
- Street tree CO_2 sequestration is offset by CO_2 released but CO_2 is reduced due to reduced power consumption;
- Air Pollution (Ozone, NO_2, SO_2,PM_{10},VOCs, and BVOCs) are based on California data (city of Buena Vista);
- Power supply in Adelaide is 50 -50 gas and petroleum with .2299 grams carbon per kWh for petroleum and .1562 grams carbon per kWh for gas;
- Street trees contribute 1 percent to average house values (studies suggest 1 to 3 percent) and the average house is $145,000;
- Air quality price is based on average market value of pollution reduction credits in Southern California, USA;
- Our estimated residential energy use for summer cooling is given in the table below; we ignore commercial and industrial savings, but suggest additional savings of around 40 percent of total residential or $3.3 million or $25.6 per street tree;

	Average Input wattage (kW/h)	Mean Estimate Summer Use (Hours)	Total kWh	Price per kWh ($)	Air Cooling expenditure per household per year	Number of Households (1996)	Total power use (Mw)h
Ducted Refrigerative: reverse cycle	5	700	2800	0.1466	$410	83600	234080
Refrigerative: split system wall/window	2.1	700	1323	0.1466	$194	175560	232266
Ducted Evaporative	1.2	700	840	0.1466	$123	83600	70224
Ceiling Fans/Other	0.3	700	210	0.1466	$31	75240	15800

Sources: Paul Spicer: AGL; ABS Census 1996.

Gross annual Benefits from a typical Adelaide Street Trees

BENEFIT CATEGORY	Value
Energy Savings	$64.00
Air Quality	
CO_2 (reduced power output)	$1.00
Air Pollution	$34.50
Storm Water	$6.50
Aesthetics/others	$65.00
Repaving Savings	?
Estimated Gross Benefits	$171.00

Our estimate of gross benefits of a typical Adelaide street tree is $172. As the assumptions above suggest, other than energy savings these numbers are based on extrapolations from other studies in cities with similar climates to Adelaide. These estimates represent only a rough idea of the average annual benefit of a typical street tree in Adelaide. Without, adequate data on prices, tree numbers, and proper computer simulations the numbers only represent an initial 'guestimate'. Moreover, data is needed on how benefits (and costs) differ between tree varieties and tree sizes. However, the authors are confident that the gross benefits would actually be significantly higher if a proper study could be undertaken. The aim here is to provide this initial study to encourage others to confirm or contradict our findings.

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