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THE CHALLENGE OF MATURE TREE REPLACEMENT: CONTEMPORARY APPROACHES TO AMENITY TREE REPLACEMENT IN MATURE URBAN LANDSCAPES

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ABSTRACT

The management of amenity tree replacement in mature urban landscapes will influence the character of those landscapes for future generations. The issues associated with tree replacement have been explored through four studies. This paper briefly describes the research and presents some salient findings.

INTRODUCTION

From the earliest villages, through to the development of modern cities, trees have fulfilled both functional and aesthetic roles. The incorporation of trees in streetscapes and the development of public parks can be seen throughout history as being representative of increasing sophistication of city design and open space planning. Trees are currently recognised as providing numerous benefits, including physical (eg. energy conservation), social (eg. psychological well-being) and economic (eg. increased real estate values) benefits (Getz *et al.* 1982; Sommer & Sommer 1989; Dwyer *et al.* 1992; Nowak & Crane 2002). Coincidently there are also costs associated with urban trees, including physical (eg. infrastructure damage), social (eg. allergies) and maintenance costs (Sommer & Sommer 1989; Dwyer *et al.* 1992; Schroeder & Ruffolo 1996). A recent survey of Melbourne councils reported that annual tree maintenance budgets equated to between $11.77 and $33.87 per tree (Beer *et al.* 2001). Amenity trees are a permanent component of the urban environment, and as a resource they must be managed to maintain and increase their benefits to society.

To maintain the benefits that Australians have come to expect of their urban landscapes, a viable and dynamic tree population is required. It is necessary to plant new trees and to replace existing trees when they require removal. The challenge when replacing mature trees is not simply the process of planting a tree when one is removed, but the continual replacement of the entire tree population in a planned and managed fashion. In urban landscapes this is not a natural process, and human intervention is required. The onus is placed on tree managers to create a population of trees with a mix of age classes so that only a small proportion requires replacement at any one time, allowing minimal impact on the landscape and the smallest loss of aesthetics in any particular area at any point in time (Lever 1982; Cobham 1984). Tree managers not only have to decide when to remove and replace a particular tree, but also how this will affect neighbouring trees and the urban forest as a whole. These activities occur over a timeframe that exceeds the human lifespan, and a manager's tenure. The problem of tree replacement is further compounded when replacement specimens are forced to compete with existing vegetation for resources (Workman 1991).

Replacing amenity trees is an issue that will affect the character of urban areas for future generations. Currently there is limited understanding of how tree replacement is performed in tree management organisations, the factors that influence this process and whether there is any consensus across industry. There are few recorded examples of the costs of maintaining mature trees in Australia, and it is not known whether the costs do actually increase as a tree senesces, as is often suggested (Hitchmough 1994). It is also suggested in the literature that young replacement trees can be planted before an original mature trees is removed (Wright 1982). There are few examples of the implementation of such strategies in real situations, and it is not known whether competition from the existing vegetation affects the establishment of younger replacement trees.

Four studies have been conducted to further the understanding of the many facets of tree replacement. These are:

- the Mature Tree Management Study;
- the Mature Tree Costs Analysis;
- the Tree Establishment Experiment; and
- the Root Recolonisation Experiment.

These studies are described briefly.

MATURE TREE MANAGEMENT STUDY

The Mature Tree Management Study is a survey of tree management organisations, aimed at analysing the procedures and practices around the management and replacement of mature trees, and identifying the issues surrounding this process. Further aims were to assess whether current practices are capable of producing a tree population that provides the physical and social benefits of an urban forest and to suggest strategies to improve the tree replacement process. In-depth interviews with tree managers were conducted at eight sites – five public organisations (councils) and three private organisations (large gardens / institutions). The interviews, conducted in February and March 2002, were principally exploratory in that they aimed to collect a range of ideas. The organisations chosen for inclusion in the study were those managing cultural landscapes (opposed to native vegetation types), containing mature tree canopies, and therefore were those that would have faced the removal of senescent trees. For this reason organisations located in the older, inner suburbs of Melbourne were selected.

In each organisation included in the study between one and three managers participated in the interview. Participants were asked about a range of themes, such as: tree removal, tree planting, policies and replacement programs. Matrices were used to compare the range of responses received to each organisation. An example of this can be seen in Table 1 showing the tree planting activities in the different organisations. The matrices enable basic comparisons between the organisations and the identification of a range of ideas and activities. To aid in the interpretation of this information and to provide context for the results, quotes from the participants were also used. In an example related to tree planting, Participant H stated, “we replace the trees in approximately 30 streets annually, and that is where we promote the idea of removing everything in the street.”

Table 1: Tree planting works currently being performed in the 8 organisations.

Response	Organisation							
	I	II	III	IV	V	VI	VII	VIII
New planting & gap filling	✓		✓	✓	✓	✓	✓	✓
One off – remove & replace	✓	✓	✓	✓	✓	✓	✓	✓
Full street replanting	✓		✓	✓		✓	✓	
Staged street replacement	✓			✓				
Community planting			✓			✓		

Some of the major findings to come from this study are presented below.

- In the surveyed organisations, there exist formally structured processes for removing trees. This would include inspections and consideration of a wide range of factors, such as the effect on the immediate environment and notification of relevant stakeholders.
- Trees are no longer removed on a whim or for trivial reasons in the organisations surveyed. This suggests that a high value is placed on trees and is a shift from previous practices, where for example, a tree could be removed, at a residents request, for dropping leaves!
- The planting of trees in these organisations is a planned process, taking into account the many physical site factors and broader planning considerations, and in the public domain, includes consultation with stakeholders.
- Tree removal attracts a lot more attention than planting, with some removal decisions made by panels or senior managers based on the degree of interest or controversy. However with planting, the responsibility for the future of the organisations' tree population often lay with the surveyed participants, suggesting that the senior management is more concerned with short-term issues.
- A range of planting programs exist for renewing the tree population in these organisations. These are designed to have varying results in terms of the loss of aesthetics during the replacement process and uniformity of the renewed landscape. It is also a positive sign for the future that the appearance of the landscape is considered.
- In council-managed landscapes, establishment programs are very important in order for tree planting to succeed. The need for an establishment program in which trees receive a high level of care and maintenance with a realistic irrigation program for a minimum of two years was an opinion strongly expressed by the tree managers in public organisations.

MATURE TREE COSTS ANALYSIS

The Mature Tree Costs Analysis was conceived to aid managers in making decisions on when to remove trees, specifically by addressing replacement models which indicate that as a tree senesces the costs increase and the benefits decrease (Figure 1). As these models are typically hypothetical, it was felt that incorporating actual recorded management and maintenance costs would be useful. To do this, the tree maintenance records and databases of private and public tree management organisations were investigated. However, from the 15 organisations contacted it was found that the recording systems varied in accuracy and complexity and it was very difficult to obtain any consistency. The properties of the databases that restricted their usefulness are listed below.

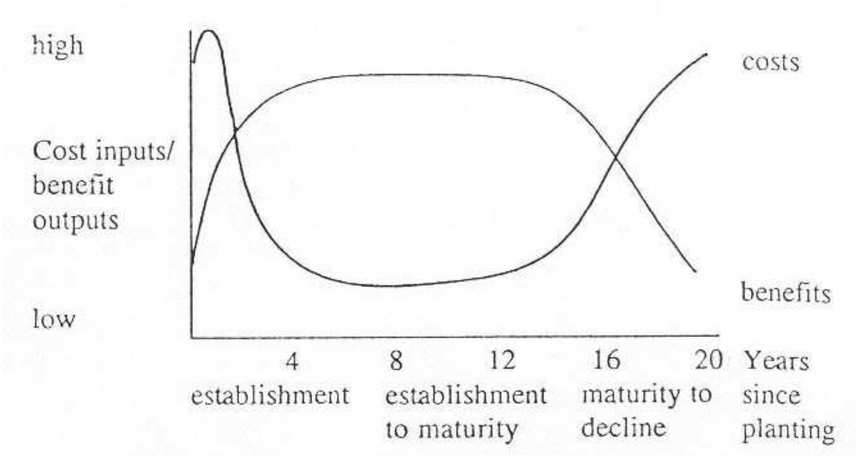

Figure 1: Hypothetical tree replacement model.
Source: Hitchmough (1994).

- The accuracy of information was often a limiting factor, particularly the tree details. For example the genus might be known, but there would be no indication of species, or sometimes neither would be recorded. This inaccuracy was present in both the tree databases and maintenance records.
- There were inaccuracies in the work requests. Identification of work tasks could be by non-arboricultural staff and not be accurate, or different staff might use different categories for the same task. Furthermore, the information entered from a phone request may not reflect the work performed in the field.
- There were very few records demonstrating recurrent works on individual trees, i.e. for a particular tree it was not possible to pull up a maintenance history.
- Often the tree databases were not maintained or current, sometimes representing the tree population as it was five years ago.
- Often there was no link between maintenance activities and the tree databases – with the maintenance databases directed more at recording and tracking requests rather than the work performed on the trees.
- There was often little or no data for trees in parks (particularly of maintenance works), which is possibly indicative of the difference in attention they received compared to trees growing along streets.
- Cyclic maintenance of street trees was generally programmed on a one, two or three year basis. This may not necessarily be recorded in the maintenance database, or the component maintenance tasks (eg. crown lifting) may not be specified, with the record rather reflecting that a program prune was performed.
- Often reactive work requests were the only accessible records.

While the limitations of the databases restricted the original aim of concentrating on individual trees and the senescent phase of their life cycle, some useful tree population trends were however evident in four organisations. The aim of the Mature Tree Costs Analysis then became to identify annual maintenance activities associated with mature trees for various organisations and to provide an indication and comparison of the costs associated with these tasks. In the four organisations providing information, there was one private organisation, one council and two maintenance companies with contracts for councils. For a range of maintenance tasks it was possible to determine the frequency with which they were being performed and an estimation of the costs of each task. An example is shown in Figure 2, where it can be seen that in the four organisations no more than 2% of the tree population is removed each year and often less than 1% is removed. Therefore the tree populations will be replaced within 50 to 100 years, assuming that tree planting is keeping up with removals. A second example of the results (Figure 3) presents an estimation of the cost of various tasks to the different organisations. Two trends standout from these results. Firstly the higher cost of each task to the private organisation compared to the public, and secondly the high cost of labour intensive tasks, such as crown reduction and deadwooding.

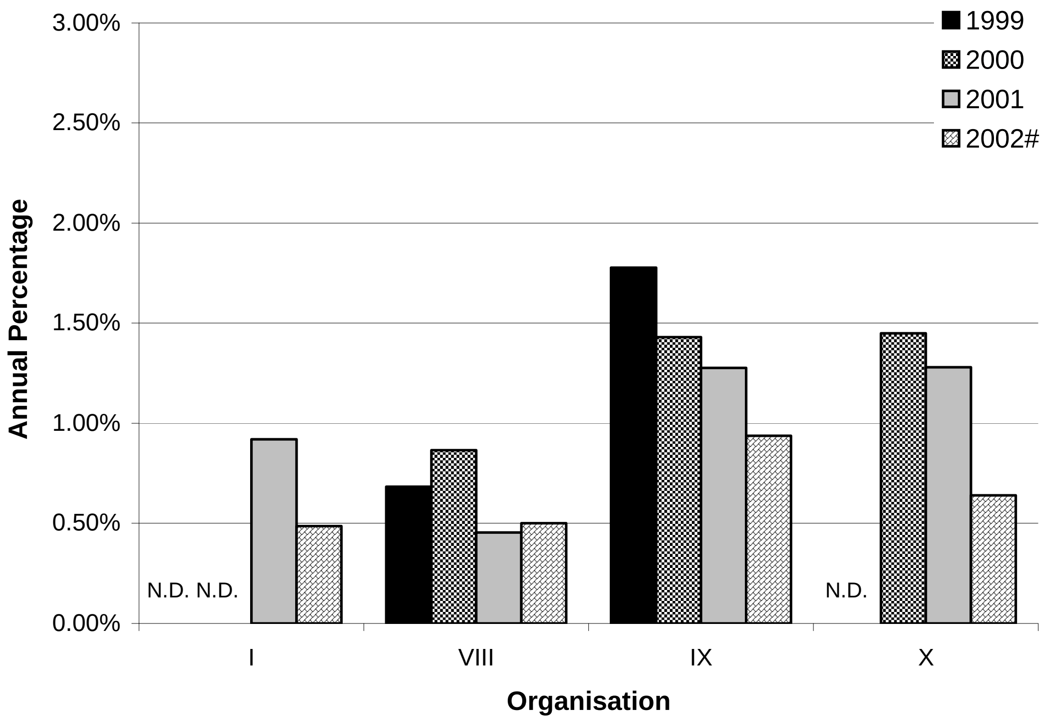

Figure 2: Percentage of trees annually removed in four organisations over four years.
[#] January to early or mid July; N.D. – No Data.
Organisations I, IX and X – councils, Organisation VIII – private

Some findings from this study are shown below.

- Inadequacies exist in current tree management recording systems. Improved record keeping should allow increases in the quality and management of tree assets. A greater understanding of the dynamics of the tree population will enable strategic application of maintenance tasks, control of species diversity and associated costs.
- Current tree removal and replacement levels are inadequate to replace the tree population before individuals could reasonably be expected to senesce, and therefore higher annual replacement frequencies are required.
- The most commonly performed maintenance tasks were tree removal, crown lifting and property clearance.
- The most expensive maintenance tasks tended to be canopy manipulation activities, including crown reduction and deadwooding.
- Due to the cost of planting and establishing trees, increased planting percentages would require appropriate recognition in organisation budgets. It's not simple a matter of

purchasing an extra 100 trees a year but also the funding for their maintenance and establishment.

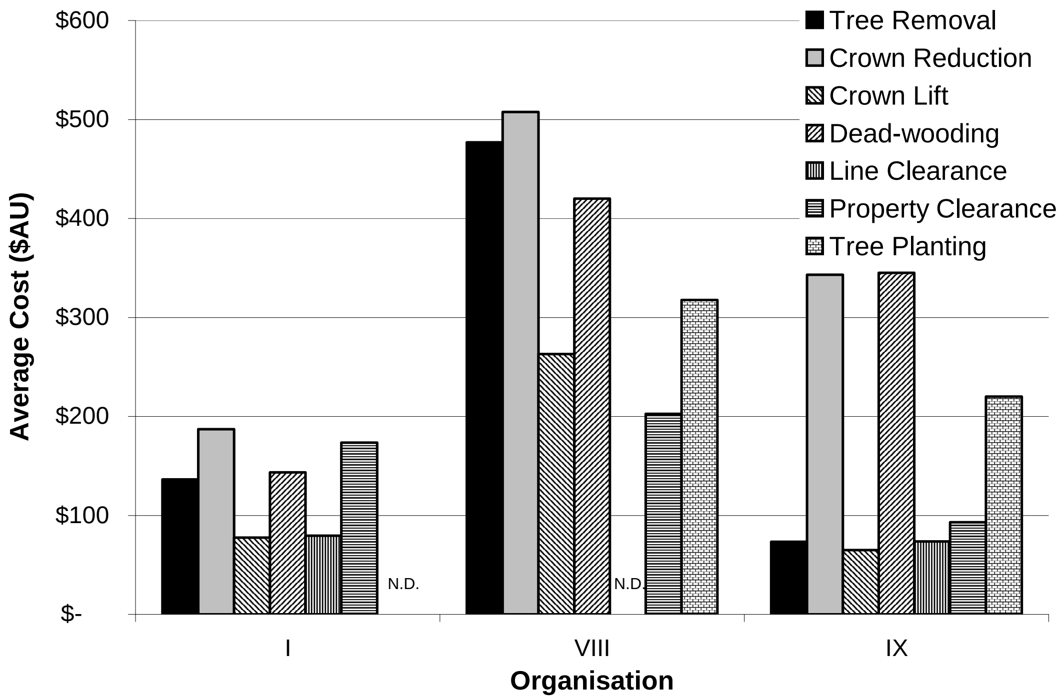

Figure 3: Average cost per application of maintenance tasks for three organisations.
January to early or mid July; N.D. – No Data.
Organisations I and IX – councils, Organisation VIII – private
Values presented are the mean of 2 years (Organisation I), 4 years (Organisation VIII), and 5 years (Organisation IX).

TREE ESTABLISHMENT EXPERIMENT

Several tree replacement strategies exist that involve planting replacement trees near the existing trees prior to their removal (Wright 1982). It is suspected that the close proximity of older trees will result in direct root competition for edaphic resources. Such competition could potentially affect the successful establishment of the young replacement tree. The Tree Establishment Experiment aimed to compare the affect of different planting procedures on the growth and establishment of young trees located near existing vegetation.

For this experiment 18 month old, field grown *Ulmus procera* (Salisb.) trees were planted between an existing row of mature fruiting pear trees. Six different planting treatments were used based on the combination of two planting hole sizes and three root barrier treatments. The small (SPH) and large (LPH) planting holes were 300 mm and 1000 mm in diameter respectively; both were 200 mm deep. Two temporary root barriers were used, the first (PS) consisted of a heavy gauge paper coated with the copper based nursery container treatment – Spin Out™ (7.1% copper hydroxide). The second treatment (RC) was an impermeable commercial root barrier called Rootcontrol®, which was removed after the first season. The third treatment contained no barrier (NB). Many growth and establishment parameters were recorded over two growing seasons.

The pear trees provided minimal root competition. There was some evidence that pear roots had grown under the barriers and into the planting holes. Elm roots grew under the Rootcontrol® barriers and straight through the Paper/SpinOut™ barriers. Figure 4, showing the change in tree height over two seasons, typifies many of the responses where the trees without root barriers had grown significantly more than Rootcontrol® treatment trees. While the mean growth of Paper/SpinOut™ treatment trees was often less than the No Barrier trees, there was often no significant difference between this treatment and the other barrier treatments. The differences between the planting holes sizes were quite profound, with Large Planting Hole trees exhibiting significantly greater growth (Figure 5) and better indicators of establishment than the Small Planting Hole trees. This is consistent with the findings of Struve *et al.* (1989) and supports current recommendations for wide planting holes (Whitcomb 1984; Harris & Bassuk 1993; Moore 1997; Watson 1997).

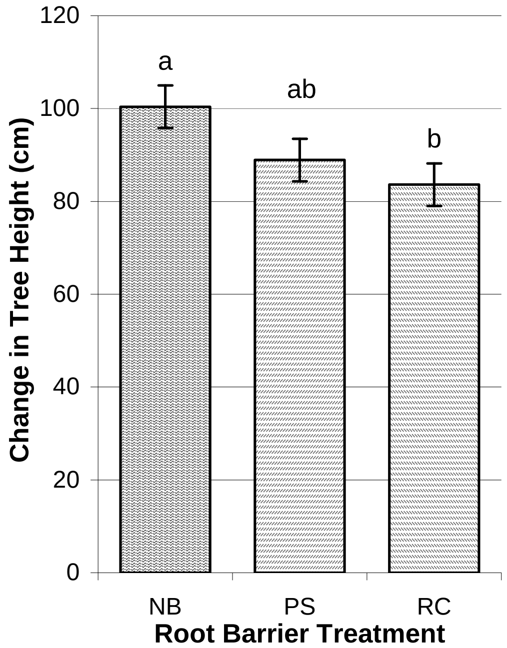

Figure 4: Change in tree height over 2 seasons for root barrier treatments (Means ± one standard error).
NB – No Barrier, PS Paper/Spinout™,
RC – Rootcontrol®
Treatments significantly different at *P*<0.05

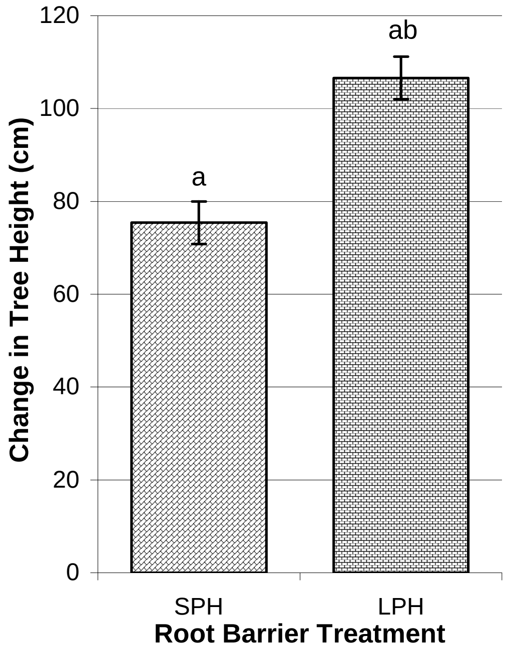

Figure 5: Change in tree height over 2 seasons for hole size treatments (Means ± one standard error).
SPH – Small Plant Hole,
LPH – Large Planting Hole
Treatments significant differently at *P*<0.001

Some conclusions for this experiment are shown below.

- Trees in a planting hole without root barriers grew more after two seasons, had an initial faster growth rate and experienced less stress after planting, than trees grown with root barriers. The recommendation can be drawn from this that in a soil environment with little or no root competition, root barriers are of little or no benefit to tree growth.

- The Paper/Spin Out™ root barrier used in this experiment had little effect on tree growth and provided limited control of root movement in and out of the planting hole. The results do not completely disqualify this treatment for use as a temporary barrier, but suggest that further research is required to find materials that last longer but that are still ultimately biodegradable.

- Trees in large planting holes grew more in two seasons, had a greater growth rate in the first season and had higher indicators of establishment, than trees grown in small planting holes. These results reinforce current recommendations from the literature that the minimum width of planting holes should be at least three times the width of the root ball at planting.
- In order to achieve rapid establishment and better growth when planting trees, large, wide planting holes without root barriers are recommended.
- Severe symptoms of drought stress were witnessed during the exceptionally hot and dry summer of the second season, this suggests that even trees with considerable post-planting growth might not be sufficiently established to avoid such stresses, and therefore in Melbourne the use of supplementary irrigation should be considered in the first and second season after planting.
- The results suggest that inter-planting between trees is possible, but that it can be a highly competitive and difficult environment for trees to establish in. Given the odds against success, it is apparent that more active management and greater resources will be required to establish such trees than required for those in less competitive environments.

ROOT RECOLONISATION EXPERIMENT

This experiment follows on from the Tree Establishment Experiment and addresses tree replacement scenarios and planting near existing vegetation. The aim of the Root Recolonisation Experiment was to assess the extent of planting hole recolonisation by the regeneration of severed existing roots, and how this is affected by the size of the planting hole and the invading species. Holes were dug outside the canopies of mature trees. The soil was sieved to remove all existing roots and then replaced back in the hole. Two treatment holes sizes were used – small (100 mm diameter) and large (300 mm diameter). Four sites were selected with *Ficus macrophylla*, *Cupressus sempervirens*, *Ulmus procera* and a mixed group of four *Eucalyptus* species as the competitive species. Half of the filled holes were re-excavated after three months and the remainder at twelve months.

Roots were found growing in the excavated holes after three months. Similar to Watson (1993), it was also found that roots had regenerated from the root ends severed during digging of the original holes. In both the small and large treatment holes there were more roots present after twelve months than existed previously (Figure 6). A similar result was seen at three of the tree sites, the only exception being the eucalypts, where the root length density after 12 months was less than the existing (Figure 7).

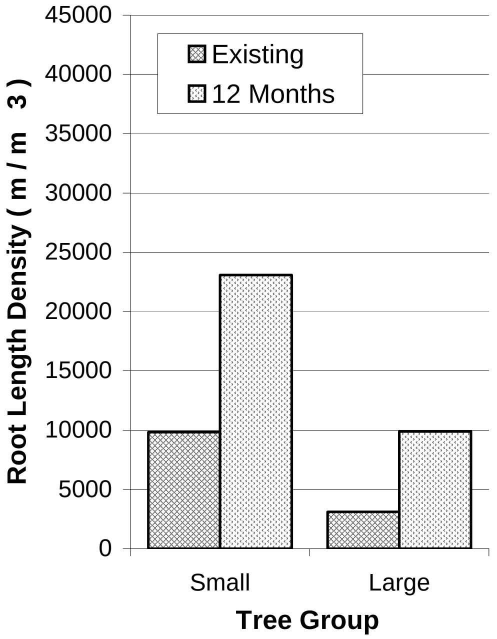

Figure 6: Root length density of existing roots and recolonised roots after 12 months for each hole size treatment.

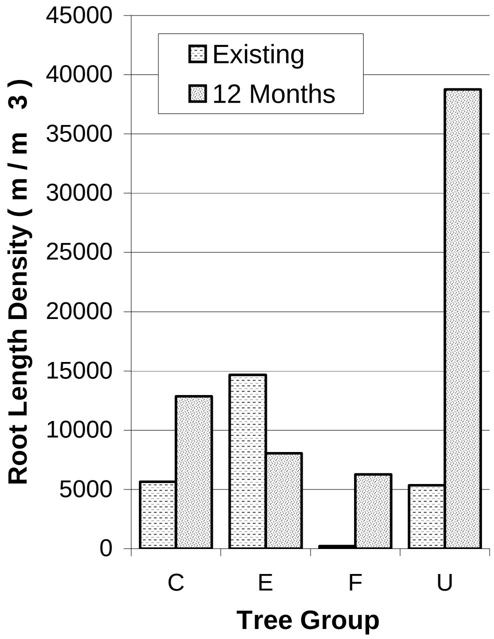

Figure 7: Root length density of existing roots and recolonised roots after 12 months for each tree group treatment.
C – *Cupressus sempervirens*, E – *Eucalyptus* sp.
F – *Ficus macrophylla*, U – *Ulmus procera*

Some conclusions for this experiment are presented below.

- Roots from existing trees were found growing in the 'holes' three and twelve months after the initial excavation. Many of these roots were observed to be regenerating from the severed ends of roots cut while digging the holes.
- The high proportion of fine roots regenerated in 'holes' suggests that this environment would be highly competitive for soil-based resources such as water and nutrients.
- There were significant differences between tree groups in the amount of root recolonisation and the proportion of existing roots regrown, indicating the tendency for tree species to respond differently to root removal. *U. procera* showed the greatest regrowth suggesting that it responded well to root pruning.
- If not by three months, then after twelve months, the density of roots in most 'planting holes' was greater than that previously existing in the area. This indicates that when planting a tree near existing vegetation, it is most likely that within one year root density will exceed that removed when digging the hole, and where possible care should be taken not to sever existing tree roots.
- Furthermore, the quantity of existing roots may not be an accurate indication of the potential for roots to invade a planting hole. Very few *F. macrophylla* roots previously existed in the planting holes, yet a significantly greater proportion invaded the holes than the other tree groups. This suggests that for root recolonisation into the disturbed soil of planting holes to occur, it is merely sufficient for roots to be present in the surrounding area.

SOME FINDINGS ON TREE REPLACEMENT IN MATURE URBAN LANDSCAPES

Drawing on the findings from all four studies, some general conclusions and recommendations can be made on the tree replacement process.

- The processes that exist in tree management organisations for tree removal, planing and planting represent positive advances in the management sophistication required to produce tree populations that will fulfil the requirements and benefits of an urban forest.
- Advanced planning is important to coordinate the timing of replacement activities in relation to the activities on nearby plantings.
- Tree policies that call for a certain number of trees to be planted each year are positive as they instigate the renewal of the landscape.
- Tree establishment programs are important in publicly managed landscapes.
- Flexibility and adaptability are important when approaching tree replacement. Some organisations are using both staged replacements, to maintain the aesthetics in an area while the replacement trees are growing, and full-street replants to create streets with a uniform avenue effect.
- In some cases it may be possible to use different replacement tactics based on the importance of the landscape feature or street.
- While the mentality of maintaining trees until they die or become hazardous is positive in that the desire exists to care for and retain trees in the landscape, it also limits effective long-term management as the ability to remove trees is important for coordinating replacement programs.
- The skill and professionalism of tree managers will have a major impact on the successful planning and management of tree replacement and the future of the treescapes.
- Tree record databases offer the potential for greater strategic planning of tree replacement, however in many organisations the sophistication of systems and minimal updating of records currently limit their use.
- It was possible to establish and obtain adequate growth from trees in an inter-planting replacement situation. However, the success of this method will be dependent on the tree species involved and the local factors in a particular case.
- When planting replacement trees near existing vegetation there will be root invasion of the planting hole, which could be expected to result in a high level of competition between trees for edaphic resources.
- Large planting holes are recommended when planting trees in competitive environments.
- The use of temporary root barriers to restrict the recolonisation of planting holes by surrounding roots requires more research and may only be appropriate in highly competitive sites. The size of the soil volume contained in the root barrier will impact on the growth of the tree.

For much of Melbourne's history, tree replacement has largely been reactive to tree failures. Tree management is now moving to more active processes, with prioritising of removals and deliberate staging of works. The challenge now is to increase the proactive management of tree populations, to allow for the coordinated and continual replacement of trees in our urban landscapes.

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REFERENCES

Beer, R., Frank, S. & Waters, G. 2001, Overview of street tree populations in Melbourne - turn of the 21st century`, Horticultural Project Report, Burnley College, The University of Melbourne, Melbourne, Australia.

Cobham, R. 1984, Blenheim: the art and management of landscape restoration, *Landscape Research*, 9(2), pp.4-14.

Dwyer, J.F., McPherson, E.G., Schroeder, H.W. & Rowntree, R.A. 1992, Assessing the benefits and costs of the urban forest, *Journal of Arboriculture*, 18(5), pp.227-234.

Getz, D., Karow, A. & Kielbaso, J.J. 1982, Inner city preferences for trees and urban forestry programs, *Journal of Arboriculture*, 8(10), pp.258-263.

Harris, J.R. & Bassuk, N.L. 1993, Tree planting fundamentals, *Journal of Arboriculture*, 19(2), pp.64-70.

Hitchmough, J.D. 1994, The management of trees in the urban landscape, in *Urban landscape management*, ed. J.D. Hitchmough, Inkata Press, Sydney, Australia, pp.267-300.

Lever, K. 1982, Cost effective management of amenity trees, in *Cost effective amenity landscape management, Conference Proceedings*, eds. C. Addison & P. Thoday, The Horticultural Education Association, pp.90-93.

Moore, G.M. 1997, Tree biology and successful tree establishment, in *Trees - roots - soils: managing the interaction*, ed. K.D. Smith, The Centre for Urban Horticulture, Burnley College, University of Melbourne, Melbourne, Australia, Melbourne & Sydney, Australia, pp.8-16.

Nowak, D.J. & Crane, D.E. 2002, Carbon storage and sequestration by urban trees in the USA, *Environmental Pollution*, 116(3), pp.381-389.

Schroeder, H.W. & Ruffolo, S.R. 1996, Householder evalulations of street trees in a Chicago suburb, *Journal of Arboriculture*, 22(1), pp.35-43.

Sommer, R. & Sommer, B.A. 1989, The factor structure of street tree attributes, *Journal of Arboriculture*, 15(10), pp.243-246.

Struve, D.K., Sydnor, T.D. & Rideout, R. 1989, Root system configuration affects transplanting of honeylocust and English oak, *Journal of Arboriculture*, 15(6), pp.129-134.

Watson, G. 1993, Root development after transplanting, in *The landscape below ground, Proceedings of an international workshop on tree root development in urban soils*, eds. G.W.

Watson & D. Neely, International Society of Arboriculture, The Morton Arboretum, USA, pp.54-68.

Watson, G.W. 1997, Tree planting from begining to end, in *Trees - roots - soils: managing the interaction*, ed. K.D. Smith, The Centre for Urban Horticulture, Burnley College, University of Melbourne, Melbourne & Sydney, Australia, pp.1-7.

Whitcomb, C.E. 1984, Reducing stress and accelerating growth of landscape plants, *Journal of Arboriculture*, 10(1), pp.5-7.

Workman, J. 1991, Trees in gardens: some notes, *Journal of Garden History*, 11(3).

Wright, T. 1982, *Large gardens and parks: maintenance, management and design*, Granada Publishing Limited, Great Britain.