DEVELOPING AN AUSTRALIAN STREET TREE COST MODEL

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Abstract

The costs of maintaining an urban tree over its lifecycle have been considered in several models. However, are these models typical of larger urban street trees growing under Australian conditions? The costs of maintaining an urban street tree under Australian management regimes, including purchase and planting costs of a common street tree species, herbicide and mulching costs, the cost of irrigation over the first summer after spring planting and of formatively pruning the young tree were calculated based on data obtained from Australian local governments. The models demonstrated that costs associated with a street tree are high in the first 2-3 years of its life but much higher in the final year of life leading to removal. The lifetime costs of maintaining a street tree depending on the management scenario are between $2800 - $5300 and $56 - $106.00 per annum. Doubling the life span of a tree reduces the annual management cost by 30%.

Introduction

The costs of maintaining an urban tree over its lifecycle have been considered in a number of cost models, profiles or curves (Vogt et al. 2015). One often cited in an Australian municipal context is discussed by Hitchmough (1994), who provided a curve described as a typical relationship between the cost and functional and aesthetic benefits of the urban shrub mass (Figure 1). The maintenance cost of a tree is generally considered to be low when compared to other vegetation types (Hitchmough 1994; Vogt et al. 2015). While the curve provided by Hitchmough (1994) is a general model for the urban shrub mass, it is used for urban trees through an extension of the maturity phase to forty or more years. The Vogt et al. (2015) model also reflects higher costs in the establishment and decline phase.

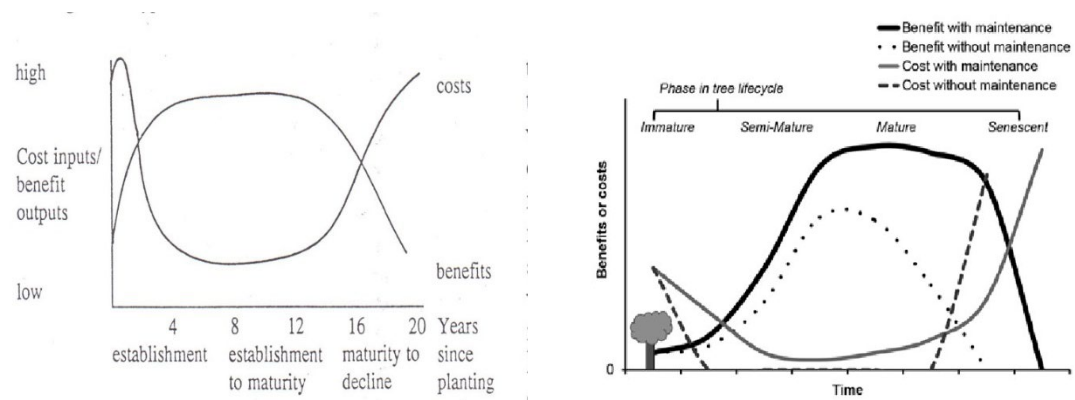

Figure 1. Relationships between maintenance costs and benefits and the life cycle of the urban shrub mass (from Hitchmough 1994, left) and a street tree (from Vogt et.al 2015, right).

The shapes of these curves are important as the impression that they give affects the way people make decisions about and manage trees. For example the curve of Hitchmough (1994) shows a small initial rise then a rapid fall and initial and final costs are similar, while Vogt et al. (2015) shows that initial costs are about 45% of those associated with final tree costs. However, do these curves accurately reflect the lifetime costs of larger, long-lived street tree growing under Australian conditions?

What is included in the costs associated with urban trees varies for different cities, but can include planting, pruning, pest management, irrigation, removal, administration, inspection, infrastructure repairs, litter cleaning and liability claims (Vargas et al. 2007; Fairman and Livesley 2011, Soares et al. 2011; Vogt et al. 2015).

Other costs of risk management, mulching, tree support and protection systems and soil management may not be included in estimates or budgets (Vogt 2015). However, the costs of planting, pruning, irrigation and removal tend to be among the higher costs for most cities (Hauer and Peterson 2016) with pest management and administrative costs being high in some cities and lower in others. The models of Vogt et al. (2015) provided curves with and without maintenance/management costs with a steady increase in costs as the tree senesces.

It is difficult to obtain data on street tree costs from Australian LGAs, because different entities account for and include different items in their costs which contrasts the situation in the USA where the 2014 Urban and Community Forestry Census of Tree Activities provided a revealing, in-depth snapshot of urban tree costs and management (Hauer and Peterson 2016). For LGAs ranging from large inner city to small rural councils, data extracted from their Annual Reports for populations ranging from 12-100 x10^3 trees, revealed that budget allocations per tree *per annum* ranged from $9.20 up to $39.99 with a typical allocation being between $10-12.00 but data were difficult to compare (Table 1). The narrowness of the range is surprising and may reflect that allocations to organisational units managing trees are made on the basis of an amount per tree (ie $10) rather than the actual financial needs for managing urban tree populations.

Table 1. Examples of tree maintenance expenditure on street and public park trees by three representative types of local government agencies (LGAs).

Local Government Agency	Locality	Year	Tree population	Expenditure ($)	Average per tree ($)	Source
State capital city	Inner city	2019	72000	800,000	11.11	Annual report
Major Regional city	Regional town	2015	100,000	1,000,000	10.00	Coroner report 2015
Small country shire	Rural shire	2017-8	12,500	115,000	9.20	Urban Street Trees Asset Management Plan

Many tree cost models recognise that after planting, street trees often receive very little regular maintenance if they are healthy and structurally sound (Hitchmough 1994; Vogt et al. 2015). However, in many parts of Australia, street trees are regularly pruned to maintain utility service clearances. Under the climatic conditions of Australia, utility line clearing may occur as frequently as every 3 years, or as occasionally as 7 years. Clearance pruning cycles are particularly important in parts of the continent where bushfires are a major concern but they are often similar to cycles in other parts of the world that experience a Mediterranean-type climate and to pruning cycles that are implemented for other reasons (Moore 2012; Anonymous 2013).

The life spans of urban trees, particularly street trees, tend to be shorter the closer they grow to the city centre when compared to the same species growing in inner parks and suburbs (Graves 1994; Moll and Urban 1989; Sæbø et al. 2003). While the goal is to have street trees that live for 50 to 100 years to maximise the benefits:cost ratio of the tree, only a small percentage of trees planted in urban and suburban USA each year survive more than 40 years (Moll and Urban 1989; Phillips 1993; Skeira and Moll 1994). While many trees (often 20-40%) die within the first 2-5 years post-planting, others die after about three decades, just when they reach a size that makes them valuable assets (Sampson 1989; Pauleit 2003; Bühler et al. 2007; Hilbert et al. 2019). However, longer lifespans are achievable and in Berlin the average life expectancy for an urban tree is 60 years (Pauleit 2003) and there are many examples of large old street trees in Australian cities that have survived for more than a century

While some mature trees are identified for removal after annual tree inspections followed by full tree risk assessments (Norris and Moore 2020), in many instances, mature, large, long-lived street trees are removed after some major arboricultural event such as storm damage, the failure of a codominant stem or the shedding of a major limb. These latter occurrences warrant a reactive, emergency response while the former may be scheduled as part of routine maintenance depending on the level and immediacy of the assessed risk.

Both involve a significant arboricultural intervention, but routine maintenance is more efficient and cost effective than reactive, emergency and service request responses, with the potential to reduce costs by 50% (Anonymous 2013).

Over the past two decades, there has been considerable research into the economic benefits provided by trees in the urban forest (McPherson 2003; Vargas et al. 2007; Nowak et al 2010; Sander et al. 2010; Soares et al. 2011; Song et al. 2018) and others have used various methods to put a monetary value on urban trees (Neilan 2005; Moore 2006; Price 2007; Helliwell 2008, Sarajevs 2011). Most of these studies do not consider the life time carbon costs associated with the production and planting of street trees or the high carbon footprint of the arboriculture industry (Petrie et al. 2016). The container nursery industry is a net greenhouse gas emitter (Kendall and McPherson, 2012) and it has been estimated that it may take 26-33 years of growth before a nursery produced specimen, such as red maple, *Acer rubrum*, achieves carbon neutrality and that after 60 years of growth, it would only sequester a net 800 kg CO_2e if production, planting, maintenance and removal were considered (Ingram 2012).

This brief paper considers some typical cost cycle scenarios that might be applied to a range of large, long-lived, urban, street trees commonly grown in Australian cities and major regional centres across Australia. The paper uses the real values of costs associated with planting, establishment and maintenance as the tree matures and the costs associated with the removal of the tree for a typical large, long-lived street tree in an Australian city. The data are presented in a form that looks at both annual and accumulated costs over a projected fifty-year life span of an urban tree. The data are then extended over a tree life span of 100 years, which is realistic for some urban street trees growing in Australian cities, to reveal what happens to costs if trees live longer.

METHOD

To compile a basis for calculating the costs of maintaining a typical urban street tree, the purchase and planting costs, the cost of irrigation over the first summer after spring planting and for formatively pruning the young tree were determined for a readily available street tree species planted into a typical urban/suburban street location. The costs were based on a sufficiently large number of plantings to ensure an economy of scale typical of a local municipality street tree planting program.

The cost of a mixed particle sized organic mulch was estimated at $10 per tree. Typically street trees were planted with 1.0m^2 of mulch around the trunk, usually to a depth of 100mm. Herbicide (Roundup - glyphosate 360g/L, Monsanto Australia) was applied at a cost of $10 per tree and formative pruning was undertaken according to the method of Ryder and Moore (2013) at a cost of $5 per tree, which allowed an average of between 2-3 secateurs or pole pruner cuts per tree. The cost of irrigation was calculated to be $10 per tree for a period of 17-18 weeks or $175. Under a typical irrigation regime trees would receive 40 L of water each week in a single application (Leers et al. 2017). Maintenance costs vary enormously but the cost of routine annual maintenance where applicable was estimated at $40 per tree *per annum*.

The cost of major tree surgery for a street tree after storm damage, the failure of a codominant stem or the shedding of a major limb requiring a two-person crew and taking two hours was calculated to be $500. The cost of utility line clearing was estimated at $200 per tree and the pruning cycle of clearing was five years. Finally, once a tree had senesced the cost of removal was determined to be $1600. This paper models the maintenance costs of an urban tree under different scenarios: each scenario based upon the planting of a tree 2-3.0m tall with a projected useful life expectancy of 50 years (Table 2).

S**cenario 1,** the tree is purchased, planted, mulched and irrigated over summer. The tree receives one visit for formative pruning. The total cost of planting the tree was calculated at $400. In its second year, the tree was again mulched, given herbicide treatment to eliminate weed competition and irrigated over its second summer with the cost being $200. In its third year, the tree receives eight weeks of irrigation over summer and a final; herbicide treatment and mulching at a cost of $100. Thereafter the tree receives only routine annual maintenance until, in its 43rd year, the tree has major arboriculture work after an event, such as storm damage, the failure of a codominant stem or the shedding of a major limb at a cost of $500. The tree is removed after 50 years at a cost of $1600.

Scenario 2 is identical to the first scenario, but without the provision for annual maintenance. This scenario would be typical of a majority of large, long-lived street trees growing in suburban Australia. **Scenario 3** is identical to the first scenario, but the tree is subjected to a regular 5-year cycle of maintenance after 15 years which may be for power line or other utility cable clearing. Because of the regular maintenance, there is no need for major arboriculture work (tree surgery) because the tree has been regularly pruned.

Finally, the impact of a longer lifespan where the tree survives for a century is presented using the costs associated with **Scenario 1**.

Table 2. Components of urban tree maintenance costs under three scenarios

Variable	**Cost ($)**	**Scenario 1 Annual maint Arb event 43yr**		**Scenario 2 No maint Arb event 43yr**		**Scenario 3 Pruning 5yr No arb event**	
		Freq	Cost ($)	Freq	Cost ($)	Freq	Cost ($)
Tree	**120**	1	120	1	120	1	120
Planting	**80**	1	80	1	80	1	80
Cost of Mulch	**10**	3	30	3	30	3	30
Formative Pruning	**5**	2	10	2	10	2	10
Herbicide application	**10**	3	30	3	30	3	30
Summer irrigation 1yr	**10**	17.5	175	17.5	175	17.5	175
Summer irrigation 2yr	**10**	17.5	175	17.5	175	17.5	175
Summer irrigation 3yr	**10**	8	80	8	80	8	80
Routine Maintenance	**40**	46	1840			40	1600
Utility pruning	**200**					7	1400
Major Tree Surgery	**500**	1	500	1	500		
Tree removal	**1600**	1	1600	1	1600	1	1600
TOTAL ($)			**4640**		**2800**		**5300**

RESULTS

Scenario 1 When the tree is purchased, planted, mulched, irrigated and formatively pruned over its first two summers, has one major arboricultural intervention and is removed after a 50-year life span the total cost (Figure 2) for maintaining the tree is: Total Lifespan Cost = $400+200+100+(46x40) +500+1600 = $4640.00. Under this scenario the average annual cost is $92.80 per annum.

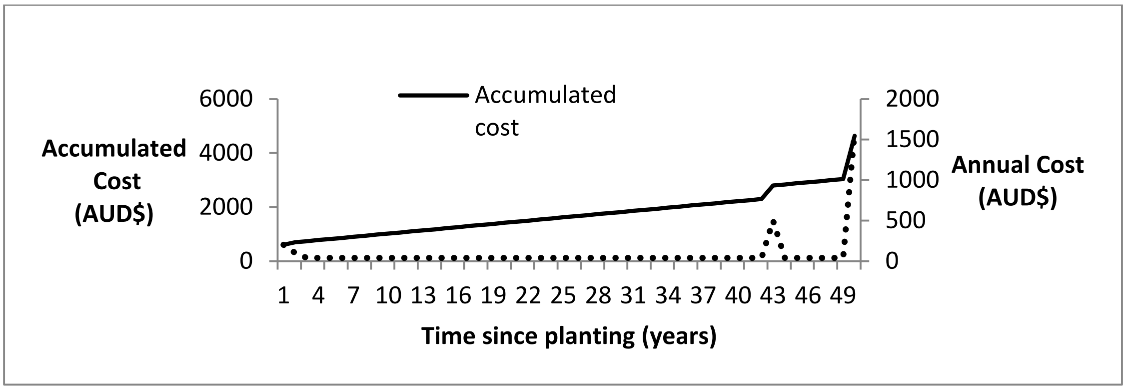

Figure 2. Annual and accumulated cost curves for Scenario 1 (Annual maintenance and a major arboricultural event in the 43rd year).

Scenario 2: With an identical scenario to the first but with no regular maintenance (Figure 3), the total cost for its 50-year life span is: Total Lifespan Cost = $400+200+100+500+1600 = $2800.00. Under this scenario the average annual cost is $56.00 per annum.

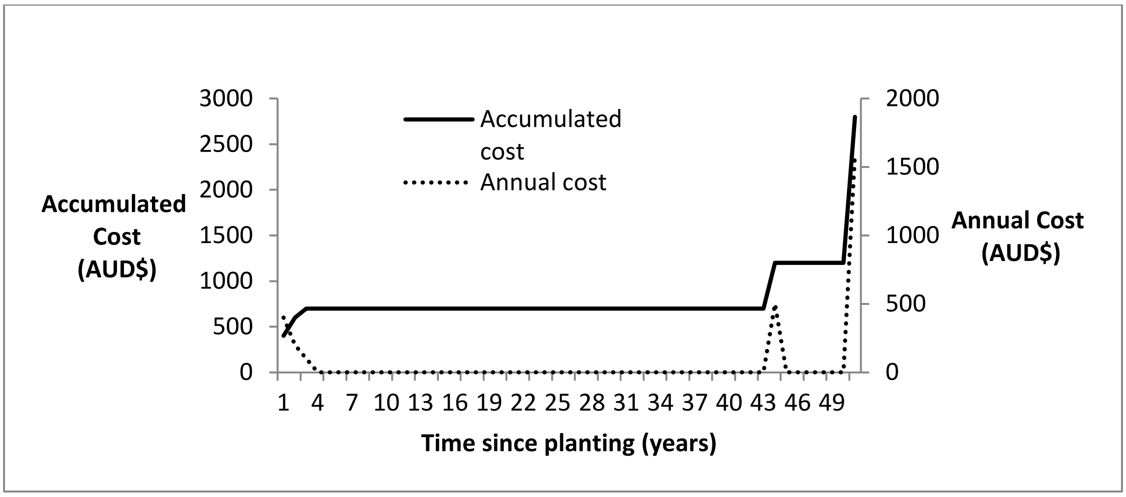

Figure 3. Annual and accumulated cost curves for scenario 2 (No annual maintenance and a major arboricultural event such as storm damage, failure of codominant stem or shedding of a major limb in the 43rd year).

Scenario 3: With an identical scenario to the first but with a regular 5 year cycle of maintenance after 15 years (Figure 4), the total cost for its 50 year life span is: Total Lifespan Cost = $400+200+100+(40x40)+(7x200)+1600 = $5300.00. Under this scenario the average annual cost is $106.00 per annum.

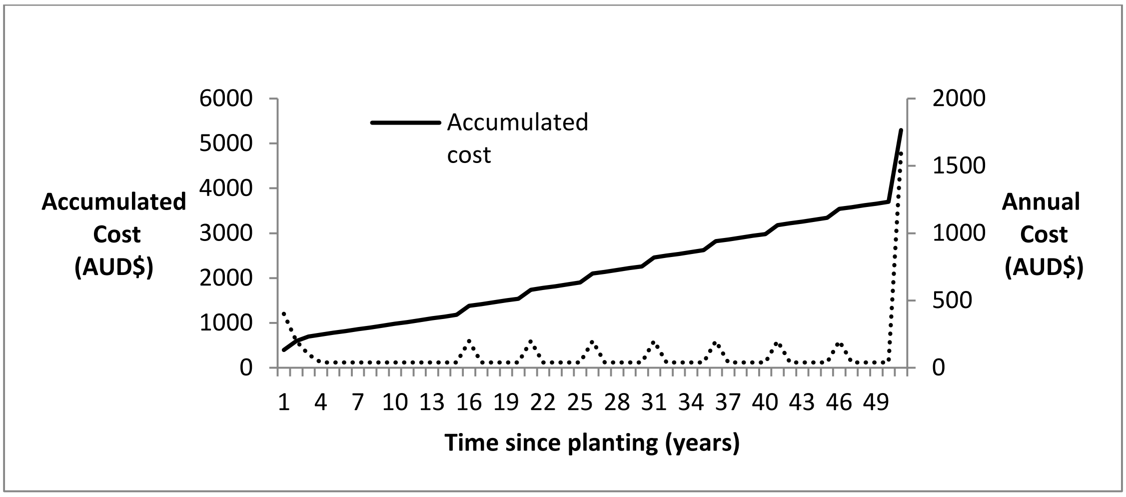

Figure 4. Annual and accumulated cost curves for scenario 3 (After 15 years, pruning every 5 years, but no major arboricultural event).

The results for an extended life span of a century for a tree under the cost structures of scenario 1 show that the total cost will be $6640 (Figure 5). The average annual cost for such a tree would be $66.40 which compares with the figure of $92.80 for a 50-year lifespan. The useful life span of a tree has a large impact on the cost associated with maintaining it, with a doubling of the life span reducing the annual average cost by 28.5%.

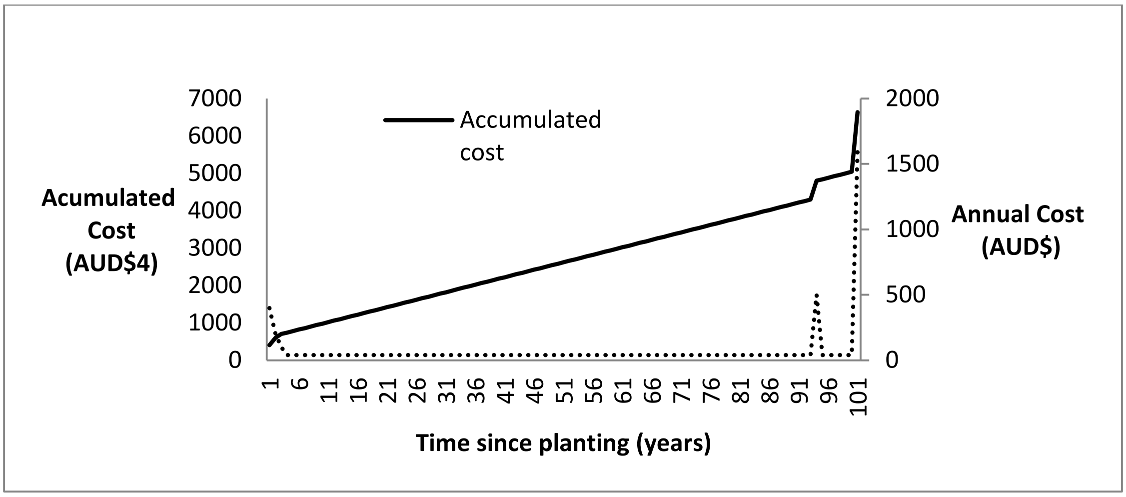

Figure 5. Annual and accumulated cost curves for scenario 1 for an extended life span of a century.

DISCUSSION

The curves demonstrate that costs associated with a typical street tree are highest in the first 2-3 years of its life and in the final year leading to removal, which is consistent with other tree costs models (Hitchmough 1994; Vogt et al. 2015). However, the shape and form of the curves are important as they convey implicit messages and the curves developed for this work differ significantly from other cost models in that the initial costs are much lower than the final costs (Figures 2-5). The costs are highest in the first year and then fall rapidly in the subsequent 2-3 years and then level off depending on the scenario. Other models (Figure 1) show the initial cost at 100% and 45% of the final year cost but the curves presented for these scenarios show that initial costs are only 25% of the costs of the final year. Costs fall rapidly after planting before rising more rapidly in the final year than other models predict. In the intervening period of 46 years for most of the scenarios proposed, the cost of maintaining the tree is very low. During this period, the costs associated with street trees are much lower and for much longer periods of time than other models demonstrate, which emphasizes just how low maintenance costs for an average street tree can be during this maturation and growth phase.

Looking at the accumulated cost curves, if the total costs of planting and maintaining a typical street tree are averaged over a fifty-year life span, the cost ranges from $92.80 to $124.40 per annum. Longer life spans have a significant effect on reducing the costs associated with urban street trees. A doubling of the lifespan of a tree under scenario 1 reduces annual coast by 28.5% and if there is no annual maintenance as in scenario 2, the costs are halved from $56.00 to $28.00 per annum, which highlights the economic value of maximizing the potential life spans of street trees.

If there is no annual routine maintenance, periodic utility line clearing and the tree does not shed any major limbs, annual costs may be very low for many decades and the only significant costs will be those associated with the final removal of the tree. Under the scenarios presented for street trees growing in Australia, the cost of final removal will be more-or less fixed as the removal of a single large street tree can be expensive. If a whole row or group of trees were removed at the same time, there will be economies of scale and the removal cost per tree could be significantly lowered. Planned routine maintenance is more efficient and cost effective, potentially reducing costs by as much as 50% by leveraging economies of scale from block pruning instead of emergency and service request responses (Anonymous 2013). There is an advantage in following planned tree replacement programs and letting removal contracts that attract such a discount.

The analyses of the curves indicate that the simplest ways of reducing the annual costs associated with a street tree are to eliminate regular high cost actions such as utility line clearing, eliminating the need for major arboricultural interventions and extending the tree's useful life. One way of eliminating the high cost of utility line clearing would be to underground services.

These services are very costly to retrofit, but one way of off-setting the expense could be by demonstrating the savings made in street tree maintenance, especially if useful life expectancy was extended due to reduced interference with the canopy (Andrews at al. 2010).

The retention of sequestered carbon in the street tree canopy with the elimination of line clearing and the increased environmental services such as shade, flood water mitigation and cooling would be added economic benefits (Moore 2009; 2016).

Eliminating the cost of the major arboricultural intervention, valued in these scenarios at $500, through preventative action such as formative pruning, which has been included in the costs of street tree establishment, could also significantly reduce costs. Formative pruning of young, and structural pruning of older street trees, not only reduce the likelihood of faults developing in the canopies but are economically efficient arboricultural practices (Ryder and Moore 2013). This would also reduce the risks of unplanned major arboricultural interventions requiring a reactive response which can be very expensive if work is done outside regular business hours or in high road traffic situations. Such an approach would also reduce the high carbon footprint currently associated with arboricultural intervention (Ingram 2012; Petrie et al. 2016).

Extending the useful life expectancies of urban street trees reduces their costs substantially for every decade of extra useful life. Ensuring that planted trees establish and survive the first 2-5 years post-planting would be a good start, as would avoiding the loss of trees that occurs at about three decades (Sampson 1989; Pauleit 2003; Bühler et al. 2007) so that more street trees survive beyond 40 years of age (Moll and Urban 1989; Phillips 1993). In a survey of over 300 mature urban southern conifers most of which were over 100 years old, Andrews et al (2010) concluded that freedom from urban development interfering with their roots systems and canopies was the most important factor contributing to their longevity and generally good health and vigour.

The costs presented under these different scenarios can be contrasted with the recent per annum benefit value calculations as part of a street tree benefit:cost analysis. In an Australian context, ecosystem service benefits of between $89 and $163.00 per annum were calculated using i-Tree (Fairman and Livesley 2011). While the total economic benefit (such as aesthetic, and real estate value) provided by a typical Adelaide street tree were estimated to be $424 per annum (Brindal and Stringer 2009). The cost scenarios provided in this paper allow more accurate benefit:cost ratios to be determined and the example of an Adelaide street tree would provide a benefit: cost ratio of between 3.4 and 4.6:1 for annual economic benefits versus total annual tree costs for the scenarios modelled. Urban street trees represent very good economic value to society and every effort must be made to maintain urban tree cover and prolong street tree longevity.

ACKNOWLEDGEMENTS

I am grateful to my colleague Dr Peter May for his helpful and insightful comments and suggestions on an early draft of the paper. Dr E Moore, linguist, is thanked for her helpful comments on the manuscript.

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