THE VALUE OF URBAN TREES: ENVIRONMENTAL FACTORS and ECONOMIC EFFICIENCY

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It can be argued that trees occupy the same zone in the emotional intelligence of our species as do Pandas: there are many species of animals which are far more threatened than the Panda but there is something about its size, general appearance and the way in which it lives its life that strikes such particular resonance with humanity as to make it a suitable symbol of all endangered species. In the Kingdom of flora, trees occupy that same niche[8].This view has, and is likely to continue to be re-enforced by the Kyoto Protocol and its successors.

For a decade, the National Street Tree Symposium has played an important role in the education and development of the Australian community. Any cursory glance at the quality of its presenters and the range of their papers leaves no doubt as to the efficacy and significance of these proceedings.

Though 'time and tide wait for no man'[9], symposium papers have kept pace with the ebb and flow of ideas, prejudice and public policy. However, as Shakespeare said:

> 'There is a tide in the affairs of men,
> Which, taken at the flood, leads on to fortune'[10]

In their contributions to this forum, Dr G M Moore (Moore 2006)[11], Hon Dr Bob Such MP (Such 2007)[12], though balanced by the observations of Jeff Angel (Angel 2007) provide pointers to new possibilities. This paper argues for the exploitation of those opportunities.

The 2002 presentation 'The Economic Value of Trees in Urban Areas: Estimating the Benefits of Adelaide's Street Trees' (Killicoat, Puzio et al. 2002) (revisited by Stringer in 2007 (Stringer 2007)), develops an argument which goes beyond environment for the environment's sake and triple bottom line accounting. The authors reason that urban trees have a quantifiable economic value[13]. Extensive studies both before (Simpson and McPherson 1996; McPherson 1998; Simpson and McPherson 1998; McPherson, Simpson et al. 1999) and since (Geof Donovan 2008); (Connellan 2005); (Lohr, Pearson - Mims et al. 2004) have put this hypothesis beyond dispute.

It is equally beyond dispute that the world in which we live has been indelibly marked, during the past 500 years, by the inexorable development of the market economy. Trying to understand its forces led to the evolution of the study of economics and, in turn, to the domination of the thinking of Neo classical Economists.

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[8] Kim D Coder *Identified Benefits of Community Trees and Forests*, The University of Georgia Cooperative Extension Service forest Resources Unit Publication, For 96-39, University of Georgia, 1996
Robertson, M. and R. Walford (2000). "Views and Visions of Land Use in the United Kingdom." The Geographical Journal **166**(3): 239-254.

[9] The origin is uncertain, although it's clear that the phrase is ancient and that it predates modern English. The earliest known record is from *St. Marher*, 1225:"And te tide and te time þat tu iboren were, schal beon iblescet."

[10] Brutus in **William Shakespeare's** Julius Caesar Act 4, Scene 3,218-224

[11] "Such opportunities come but rarely and they must be seized upon if public open space and urban trees are to be professionally managed; Moore, G. M. (2006). Urban Trees and the Global Greenhouse. 7th National Street Tree Conference, Treenet Inc**:** 6. ,p5

[12] This is the age of the managed tree and the managed urban forest, based on science and on accumulated experience and skills; Such, B. (2007). Setting a New policy Agenda for the Urban Forest. 8th National Street Tree Symposium**:** 6. ,p5

[13] A conservative estimate of $171AUD (in 2002 dollars);Killicoat, P., E. Puzio, et al. (2002). The Economic Value of Trees in Urban Areas: Estimating the Benefits of Adelaide's Street trees. 3rd National Street Tree Symposium**:** 12.

To the chagrin of environmentalists and others seeking alternate paradigms, their theories[14] have become so pervasive as to colour opinion, shape policy and influence legislation. Killicoat, Puzio and Stringer (Killicoat, Puzio et al. 2002) highlight a future in which environmentalists are no longer relegated to the contemporary equivalence of Old Testament prophets but have an indisputable seat at the table of mainstream economic thought.

Urban green space should no longer be considered and managed as a liability or 'cost centre'. It is an 'asset', whose value increases with time and whose beneficial outputs should be accounted. Fixing an accurate value is one of the challenges we face.

Accountants like nothing better than a neat ledger. They claim that economic efficiency is enhanced when 'cost centres' can be clearly defined. Such unbundling, however, may be to the detriment of efficient resource management. Those concerned with street trees or urban green spaces should not fall into the same trap.

While street trees are an important component of the urban landscape, many contemporary thinkers conceive the totality of urban green spaces as constituting the urban ecological system (Miller and Hobbs 2002; Roetman and Daniels 2008). Whether a tree is planted in the street, in a park, car park or backyard, or simply some neglected remnant of the indigenous vegetation, its contribution to the environment is related to species, health, age and its relationship to understory plantings (if any), rather than where or why it was planted.

Apart from their intrinsic worth, street trees have an almost unique capacity to provide those linkages without which the urban landscape might fragment into isolated green islands set in a sea of concrete, steel and bitumen. By broadening its vision to include the cities' flora (no matter where it is situated), we not only educate and champion eco-friendly cities, we elevate street trees to an unassailable position within that construct. The components are already understood. The challenge is to synthesise them into an integrated whole.

Efficiency

Efficiency is the linchpin of economic profitability. If urban green space can be conceived and safeguarded because of its economic profitability, then those responsible for its planning and management should be mindful of increasing that profitability through efficiency.

For trees, and especially for urban street trees, efficiency gains can be made through increasing their longevity, reducing maintenance costs and reducing damage to infrastructure.

Matching species to location is of prime importance. While the debate will continue on the relative merits of indigenous, native and exotic species, it is the suitability of species to modified locations (likely to become more hostile with global warming) which should form the paramount concern of urban planners.

Increasing Genetic Efficiency

An argument can be mounted that we should draw on the expertise of arborists, botanists and geneticists in institutions such as the CSRIO and the Waite to develop new varieties and even new species which, while serving existing ecosystem needs, are capable of providing additional environmental services [15]in the urban setting[16].

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[14] Some of which, it can be argued, are tragically flawed and may well be responsible for creating many of our problems (eg (a) the notion that for every depletable resource, a substitute will arise and (b) the notion that the economy is infinitely expandable)

[15] Least-Cost Input Mixtures of Water and Nitrogen for Photosynthesis Author(s): Ian J. Wright, Peter B. Reich, Mark Westoby

[1616] Ms Helen Leicht, working with a grower, trialled a range of power line friendly street trees. This culminated in the release of a new tree (Noel Surprise) in January 2006; hleicht@bigpond.net.au Leadbeater, S. (2006). A Community in Conflict- Discussion Paper. 7th National Street Tree Symposium: 9.

Research has shown, for instance, that the tree roots of certain species are capable of assimilating toxic pollutants from the urban environment: organic compounds are often broken down by the tree. In the case of inorganic pollutants, such as heavy metals, evidence suggests that these are accumulated and stored benignly in the tree's root structures and not transmitted to the trunk, branches or leaves (Seuntjens, Nowack et al. 2005). This capacity creates the potential for urban street trees to play an even greater role in bio-remediation than was previously conceived.

Some, remembering the paper 'A Community in Conflict - Discussion Paper' (Leadbeater 2006) which was presented at the 2006 symposium, might consider that this implies the development of cultivars whose trunk reaches 2.5m above the ground before its lowest branch is extended and whose maximum canopy height is less than 4.5m. Such trees would obviate the need for the pruning and maintenance. Indeed, there may be some locations in which such trees would offer the most efficient solution. However, given that many studies suggest that the economic benefit of trees increases directly with their longevity and size, the most economically efficient solution may well lie in alternate strategies for service provision[17].

Matching the most suitable species to its ideal location enhances the likelihood of producing the most economically efficient tree.

Environmental Efficiency

Like all species, the genetic potential of street trees is limited by their environment.

Soil

A suitable and adequate milieu for root development is essential so that the tree might reach its full potential. It also promotes greater efficiency by lessening the maintenance required because of root damage to road surfaces and pavements (Leadbeater 2006). While the efficacy of 'structural soil' has been well tested (Grabosky et al. & Couenberg from (Plant 2002)) and its success when used in trenching documented (Plant 2002)[18], the technique has been limited to green-field sites or to sites requiring major remedial works. To date, because of cost and potential root disturbance, trenching has not been considered a viable means of environmental improvement for existing urban street trees. Notwithstanding this, the technique is now so extensively accepted that a range of premixed structural soils are among the products available from at least one Australian firm[19]. Providing a suitable environment for root growth promotes longevity and increases the economic efficiency of trees.

Sharing Water Efficiently

The most important factor in tree development and longevity is water. While provision may be made for trees to access adequate water supplies through trenching or the provision of an adequate permeable zone beneath their canopy, water supply is generally determined by weather patterns.
Street trees, in particular, are forced to extract water from soil which has a continuous and impermeable barrier on both sides beneath the tree's canopy. A permeable zone may either not exist[20] or be as narrow as 40cm. Yet this zone is expected to supply the water needs of mature trees growing 6 apart, with transverse intercepts (driveways) every 8 metres. Such trees survive because their root systems manage to access neighbouring gardens, or sources of supply including underground streams and leakage from both the potable water supply and sewerage systems.

The Costs of Efficiency Gains in the Water Delivery System

In South Australia that regime is changing. Water scarcity is increasing its resource value. However, the debate about what constitutes 'best practise' in water resource management 'continues to be hampered by a sort of water blindness favouring a basically technical conceptualisation of water. In line with such a view, water resources management is taken as various ways of controlling and governing direct water use and related waste flows, not as managing water's various functions in the landscape' (Falkenmark 2003, p237).

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[17] The undergrounding of power cables being the most obvious example

[18] " 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 outcome"(Plant 2002)

[19] Benedict Soil and Gravel Pty Ltd. (Sydney) www.**benedict**.com.au *The products are marketed as Benedict Smartmix2 & 3*

[20] As in many urban car parks

SA Water estimate system losses at about 10%. Water use in Adelaide is approximately 300,000ML pa. This equates to the system providing 30,000MLs of water to the urban environment through leakage (South Australia 2004, p11). The sewerage system accounts for an estimated annual flow of 100,000ML (60% of residential + 100% return of commercial and industrial). If we assume a similar leakage rate, this source provides another 10,000MLs of environmental water (i*bid.* p11). Efficiency gains will come at a cost to the urban environment and, in particular, to street trees.

The Cost of Drought and Water Price Rises

The years of drought in south-eastern Australia resulted in water restrictions for household gardens. As a consequence many street trees, relying on water from adjacent properties, became stressed. This could be considered a normal part of the Australian climatic cycle and one could contemplate that the ecosystem should return to its general equilibrium. However, with watering restrictions in place, the South Australian Government used the crisis to announce steep increases in the price of water.

Previous studies (2000) have shown that, while the price of water used internally is relatively elastic (Thomas and Syme,1979, Perth Aus., -0.04, Veck & Bill, Alberton & Thokaza, South Africa, -0.13), the price of water used outdoors is inelastic (Thomas and Syme,1979, Perth Aus., -0.31, Veck & Bill, Alberton & Thokaza, South Africa, -0.38). It would appear that with a price rise in the region of 10%, the volume of water used externally will drop 3.1% (or 1674 ML/annum using Water Proofing Adelaide figures).

The suburbs of Adelaide already exhibit many examples of abandoned gardens. Other householders have installed water wise plantings or subsurface irrigation. Some have installed synthetic lawns. Others have dramatically increased the areas of impermeable paved surfaces. Each of these actions deprives deep rooted plants of moisture.

The Cost of Urban Infill

Traditionally the suburbs of Adelaide have reflected the Australian dream: the modest house on the quarter acre block, ‘the home among the gum trees, with lots of plum trees’. The city epitomised the ‘garden city’ as conceived by Ebenezer Howard in his 1898 book, ‘Tomorrow: a peaceful path to real reform’. In reality, it is increasingly accepted that the concept is wasteful and inefficient in its use of land and infrastructure resources. Increased urban density has become a policy goal.

However, rather than pursue the vision of the Swiss-French architect Le Corbusier, who envisaged dense concentrations of people in high-rise condominiums, with 95% of the plot ratio being devoted to green spaces and urban forest, the South Australian Government has sought increased density through the subdivision of suburban blocks.

Where once one dwelling existed on a 600m² allotment, with a roof area occupying about a quarter of the area, there are now two and sometimes three homes. The roof area of each is generally larger than that of the original dwelling. The necessity of three driveways, patio areas etc results in an increase of impervious surfaces from about 30% to between 80 and 90% of the allotment. The consequences for subsurface moisture are as obvious as are the consequences for increased run off.

Higher urban densities remained elusive. Twenty years ago the original house would have provided a home for five or six people. Census data reveals that the occupancy rate of dwellings in Adelaide is around two. No more people are housed on the allotment, but a lot more resources have been used to house them.

Again this has a water consequence: single person households use more water per person than do multi person households. As the occupancy rate decreases, the demand for water will increase, price will increase and the elasticity of outdoor water use will again come into play.

The Cost of Capturing Stormwater Run-Off

The South Australian Government has recently committed to a storage and recovery program harvesting 80 gigalitres of potable water per annum. As total run-off is calculated to be in the order of 160 gigalitres (South Australia 2004), and as this run-off is not available to street trees, there would appear to be little problem.

If the previously mentioned policies deprive urban ecosystems of significant quantities of water, we may well reach a point which is catastrophic for street trees. The most logical solution, therefore, is to develop a management regime which assigns an adequate share of rainwater run-off to urban green spaces and, in particular, street trees.

David Lawry has been working on an innovative and cost effective solution for in situ tree plantings. It has the potential, not only to water the trees, but, because it this changes root patterns, to diminish the damage and consequently the costs associated with pavement and road paving repairs. It therefore increases the economic efficiency of the tree

He hopes to achieve this through a design which utilises two waste products; water treatment solids and old tyres. The water treatment solids exhibit compaction characteristics and free draining structures similar to structural soils. Additionally, the cation fixing properties of the medium will facilitate the removal of nutrients and heavy metals from roadway run-off, while its carbon component will contribute positively to the soil profile.

The proposed system can be engineered to collect given volumes of water during any rainfall event. It has the advantage of capturing, at least theoretically, first flush run-off. Importantly, this water contains all of the environmental "nasties". Because these can be captured by the medium and captured or processed in the root zone of trees, the ecosystem advantages and the smaller amount of remediation required to purify the remaining water in Wetlands is obvious.

Carbon Sequestration and its Economic Possibilities

Dispelling Some Myths

In 2007 Jeff Angel delivered a paper, 'Trees and Carbon Trading'. He acknowledged that 'the tree has been an enduring feature in the policy, rhetoric and symbolism of the environmental fight' (Angel 2007, p.1). He posits that the champions of carbon trading are 'leveraging off the last 30 years of environmental campaigning that made the trees so popular with the community' (*ibid.* p1).

He goes on to assert however that 'tree plantations are the least credible carbon offset' (*ibid.* p2) and quotes Cambridge University botanist Oliver Rackham as saying 'telling people to plant trees (to address climate change) is like telling them to drink more water to keep down rising sea levels' (Ibid,p.3). Indeed, studies reveal that over their lifecycle, all vegetation, including trees, are carbon neutral: while vegetation extracts carbon and synthesises it into organic compounds, when that vegetation dies, aerobic decomposition releases the sequestered carbon.

Kyoto and the Future

Under the Kyoto protocols, urban vegetation cannot be included in the calculations of greenhouse gas emissions, as either sinks or for the purposes of sequestration. Nor is it intended that urban vegetation can be used in carbon credit calculations or carbon trading. This is primarily because of difficulties that relate to verification of data and the relatively small scale of urban plantings in relation to the large scale of forests or plantations. Moore (2006) argues that 'this does not seem logical and it is difficult to imagine that under the more stringent post-Kyoto protocols, urban woody vegetation will not have some value after 2012. Again this should translate into an added recognition of the increased value of urban woody vegetation in real terms'. (*ibid.* p.5). This contention receives qualified support in a paper by McHalea (McHalea, McPhersonb et al. 2007).

From its genesis, policymakers have targeted major point sources of polluting products (e.g. oil refineries are held responsible, not only for the emissions of the refining process, but for the carbon emissions produced by consumers). Logic and equity[21] would suggest that either future protocols or the governments responsible for their management and implementation will hold urban centres[22] accountable for their emissions in a similar manner[23].

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[21] Taxing urban populations in respect to their "carbon footprint" is one methodology by which the developing world can be relieved of some of the burden of the first world's profligacy

[22] " With over 60% of world' population (nearly 5 billion people) expected to be living in urban areas by 2030 (compared with less than 15% in 1990 and 48% in 2002), cities are rising to the top of the policy agenda" Additionally, by " 2000 there were 388 cities with a million or more inhabitants(UN2002)….with 16 cities

Indeed, the work of Rees and others (Rees 1992) (Rees 1995; Rees 1996) could lead policymakers in the direction of an even more focused ‘user pays’ system: vis taxing urban centres for their carbon footprint.

While the way forward is uncertain, all signposts indicate that the urban forest will play an integral role in future plans for the bio sequestration of carbon.

Present Opportunities

In concentrating on the future, it is easy to ignore immediate opportunities. As has been mentioned, scientifically, trees represent an efficient means of bio sequestration in the short and medium term. The world must find long-term solutions. To do this we can have no better teacher than nature[24].

Vast reserves of coal, oil and natural gas, having locked carbonaceous material beneath the earth's crust for aeons, have given this planet its current climatology. Their release is universally attributed as the prime cause of global warming. These reserves were created by the anaerobic decomposition of carbonaceous material Vast quantities of green organics found their way into aqueous environments and, protected from the atmosphere, formed those reserves which, with heat, pressure and time would provide the fuel sources of the modern epoch. On its journey the detritus was critical in providing nutrients to estuarine ecosystems[25].

Why then, in a world which is desperately attempting to sequester carbon, are we lectured by Catchment Management Boards (behind whom stand water engineers) to sweep our gutters clean of leaves and never to dispose of green waste in our watercourses? I refer you back to Falkenmark’s comment ‘water resources management is taken as various ways of controlling and governing direct water use and related waste flows, not as managing water’s various functions in the landscape’ (Falkenmark 2003, p237). The purpose of stormwater drainage systems is to avoid flooding. Economic efficiency in such systems is measured by getting the maximum amount of water through the least amount of infrastructure in the shortest possible time. Leaves and other vegetable matter, block outlets and slow flow, creating inefficiency. In a world where the efficiency of a part is often regarded as more important than the well-being of the whole, leaves are to be avoided.

Unfortunately for us and for our environment, we are trapped by this error. Since most of the urban world is ‘stuck’ with stormwater systems engineered on the principles outlined, to ignore the engineer's advice is to court flooding and, at worst, systems failure. Nevertheless as old systems are replaced or new systems constructed, a holistic approach to urban ecological management which mimics natural systems should be developed. The efficiency of these new systems should be estimated by their lack of disruption to the ecosystem.

Possible Solutions

In the short term then, does this consign leaf litter to the debit column when measuring the economic value of street trees? The answer, according to Dr. Tim Flannery (Flannery 2008) and other distinguished academics, is no.

Urban leaf litter, and most particularly that of large deciduous trees, is a valuable fuel source for pyrolysis (often referred to as char burning). This process generates excess methane that can be used as a fuel. The waste product is carbon. Such carbon, unlike a growing forest, is tangible. It does not need to be estimated. It contains neither risk nor uncertainty. It can be weighed and

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becoming “megacities” in 2000 (a “megacity” has a population of 10 million or more)(2003). Water for People, Water for Life. The United Nations World Water Development Report. Barcelona, UNESCO: 575.
,p160.

[23] if petroleum product emissions are accounted at refineries and double dipping is to be avoided, the emissions for which the urban centre would be held responsible are "total emissions minus petroleum product emissions"

[24] George Santayana: “Those who cannot learn from history are doomed to repeat it”. H.G. Wells: “History is the race between education and catastrophe”

[25] the same process remains a primary part of a modified estuarine ecosystems and can be seen in such places as the Kimberley region of Australia and the Amazon river basin

measured, its credits sold. It has a stability which is measured in centuries. It has been demonstrated to enhance soil structure, fertility and water retention rates, especially in fragile soils (Lal 2004).

If we consider that a mature plane tree can sequester about 70kg of atmospheric carbon per annum and that a large amount of this carbon is used to form the leaves, the potential of urban forest as a major source of fuel for the bio charter industry is enormous. The economic value of each street tree would increase accordingly.

Further Possibilities

We cannot do justice to all the possibilities for enhancing the economic value of our urban forest within the limited confines of this paper. However, I would like to canvass one more.

In a recent address at the University of Adelaide, Associate Professor David Paton spoke of the loss of habitat for the birds of the Mount Lofty region and the consequent endangerment of a number of species. Properly planned, suitable plantings in urban green spaces could remediate this problem. Executed as a contractual arrangement between local government authorities, government or wildlife conservation trusts such plantings could generate revenue for their owners. The provision and management of urban habitat could prove a profitable business venture.

Summary

In concluding, we seek to avoid the pitfalls of oversimplification. We see the future of the management of urban green space as a myriad of possibilities. We see the work Stringer and others as establishing, beyond doubt, the rightful place of environmental managers in economic fora. We have not attempted to place a value on urban trees, for not only do these vary with species, site and size, but, as new uses are found for them and as the measures by which their values are assessed change[26] their economic value will increase. Rather we have attempted to argue a case for increasing the economic value of street trees through efficiency and through canvassing alternative possibilities for their use.

While environmental economics must grapple with the constructs of efficiency it should never succumb to the pitfall of 'one size fits all' solutions. Environmental efficiency is achieved holistically but is dependent on optimum solutions within the complexities of species, place and time. Changing any of the variables will result in different solutions for each place and each species at any particular time.

Though the solutions will be complex, we remain confident that they are achievable. A decade ago you came together because you believed that you have a part to play in saving street trees. I think that you should go from here believing that you have a part to play in saving our world. For as Robert Kennedy once said: 'Few will have the greatness to bend history itself; but each of us can work to change a small portion of events, and in the total of all those acts will be written in the history of this generation'.

[26] When Killicoat et al calculated their original values, the median house value was hundred and $174,000. It is currently $360,000 (Anthony Toop, 12/08/09). If street trees add, as asserted, 1% to house value the median value of those trees is $3600. Toop estimates the value of a garden to be 10% of the sale value of the property i.e. $36,000. Trees on properties could therefore be worth considerably more than $3600.

Reprinted from: Killicoat, P., E. Puzio et al. (2002) **"The Economic Value of Trees in Urban Areas: estimating the Benefits of Adelaide's Street Trees"**
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Table 1 summarises many tree benefits, including various estimates of the values associated with those benefits. *Table 1 An overview of tree benefits: selected studies.*

Temperature and Energy Use
a) Community heat islands (3o to 10^{o}F 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) 20^{o}F lower temperature on a site from trees.
b) 35^{o}F 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) 20^{o}F 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.

Active Evaporation
a) 65% of heat generated in full sunlight on a tree is dissipated by active evaporation from leaf surfaces. (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).
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 mould 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 48lbs particulates, 9lbs nitrogen dioxide, 6 lbs sulfur dioxide, and frac12; 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 60mg 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 centres 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 mask 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;
- •In estimating residential energy use for summer cooling we ignore commercial and industrial savings, but suggest additional savings of around 40% of total residential or $3.3 million or $25.60 per street tree (calculation table found in the original document)

Recalculating the Gross annual benefits for a typical Adelaide street tree

Household Benefits
Energy savings **$64**(Based on assessment of Killicoat et al. (2002))
Aesthetics/others **$65** (Based on assessment of Killicoat et al. (2002))
Capital appreciation **$72** (Based on a median house value of $360,000 and assuming 2% pa appreciation)

Local Government Benefits
Storm water **$6.50** (Based on assessment of Killicoat et al. (2002))
Repaving Savings **$180** (Moore 2009[27]

Community Value
Air Quality (reduced pollution) **$34.50** ((Based on assessment of Killicoat et al. (2002))
Reduced CO_2 Emissions **$1.00** (Based on assessment of Killicoat et al. (2002))
CO_2 sequestration **$1.40** (based on absorption figures for a mature deciduous tree with a CO2 trading price of $20.00 per tonne)

Estimated Gross Benefit, $424.40 pa

Assuming a 60 year average life cycle, estimated gross benefit per tree, $25,500
All assumptions mirror those made in the Killicoat paper. Where estimates have been revised or updated, extrapolations have been made from other studies. In the absence of adequate data on tree numbers, prices, and computer modelling, the numbers remain, at best, a revised 'guesstimate'. While the authors of the original document were 'confident that the gross benefits would actually be significantly higher if a proper study could be undertaken', the likelihood of underestimation is here compounded because many of the values used are in 2002 dollars. Hopefully, the increasing significance of the economic value of trees as community assets, will challenge others to a more accurate assessment of their worth.

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[27] This calculation is the value of road surface protection only. It assumes a tree with a canopy diameter of 6m set in a two metre nature strip, with a two metre paved footpath. Hence no savings are calculated re paving

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