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People, Trees, Landscapes and Climate Change

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Trees, Parks and People

Trees make major contributions to all urban landscapes, such as streetscapes, roadsides, parks and gardens, as well as private dwellings. The significance of trees comes not only from their large size, but also from their long life spans. Their size gives a sense of scale to built structures, the importance of which is magnified by the presence of multi-storey dwellings and large numbers of utility poles and signs. The longevity of trees can span decades and even centuries, and they may persist as monuments to human intervention or management of the landscape longer than the labours of any other human endeavour.

Often the 'liveability' of major cities is associated with the impressive trees found in parks, gardens, streets and boulevards, which have largely resulted from the involvement of horticulturists in urban planning over a century and a half ago (Spirn, 1984). The character and ambience of many major Australian cities were largely determined by decisions made by planners and decision-makers last century at a time when the role of the horticulturist in civil affairs was significant (Winzenreid, 1991). Many of these cities have as major aspects of their designs significant areas of open space that are dedicated as parks or gardens, as well as impressive avenues and boulevards. These attributes contribute much to the nature of these cities and to their reputations as fine examples of Victorian era design and development.

It is often assumed that the dedication of large tracts of land for parks, gardens, avenues and boulevards was done at a time when land was cheap and readily available. This does not do justice to the foresight of preceding generations, because in relative terms the cost of land at the time in many Australian cities was as high, if not higher, than today due to events such as gold rushes, pastoral wealth and commodity booms. Space was allocated and resources were expended because parks and gardens were rightly seen as civil assets worthy of appropriate investment and management.

The motivations of these early planners and decision-makers were as mixed as they are today. However, the decision to allocate land for parks and gardens was a conscious decision that reflected the social concerns of the time. While aesthetics were important, the public open spaces were also designed to fulfil various functional roles. Among the motivations were those dealing with the aesthetics of creating an attractive city, concerns about public health, which recognised the need for open space and adequate access to light for a healthy populace, and the economic imperatives associated with new crops and forestry. There was also the response to the Dickensian period, which reinforced the need for recreation and appropriate places for its provision; the realisation that basic human needs were met by the presence of parks and the provision of opportunity for people to interact with at least some components of nature.

Parks and gardens were provided not by chance, but because they were considered essential to the wellbeing of the citizens of a civilised and modern city. It was realised that parks and gardens came at a cost, but it was also recognised that the benefits that these parks and gardens provided simply outweighed these costs and so public open space was provided. It is interesting to note that today the provision of public open space is not assumed to be a benefit, and that in many instances the public open space provided by earlier generations is now being alienated for other purposes. It would seem that the future development of parks and gardens in Australian cities is at something of a crossroad. The responsibility for making proper decisions that will affect the future of our cities rests with us.

Trees and Public Open Space as Assets

Trees, parks and gardens are major community assets, which do not come free of cost to society. Considerable sums of public money are invested in their establishment and management, usually through local government or other public utilities. As assets they must be properly valued and managed, which requires an appropriate annual budget for their management and replacement.

Mature trees are significant assets to our environment and society, regardless of where they occur or whether they are native or exotic. A great deal of effort has gone into managing, conserving and preserving these trees. Considerable human effort and time has been expended on the trees, as well as a great deal of real energy in the form of fossils fuels that has underpinned their maintenance. There has also been significant water resource allocated to their growth and development. They are community assets in every sense of the word — society has invested resources in their establishment and management, and they have matured as assets and are now returning great and diverse benefits (Moore 1997) to society in return.

For trees growing in parks and gardens there must be proper inventories that are computer-based, providing full and comprehensive information on the specimen, including its identity, location, age, condition and monetary value among other important details. The monetary value must be assigned to a tree using an acceptable amenity tree-valuation program (Moore, 1995b). This value raises the status of the tree to that of an asset, and allows for the proper recognition of trees in the decision-making processes by those who may fail to recognise the inherent value of the tree.

In an analysis of urban tree cover in Melbourne, Mullaly (2000) used aerial photographs to estimate changes in the cover of an inner suburb — a part of Richmond, now in the City of Yarra — and an eastern suburb — a part of Balwyn, now in the City of Boroondara. Aerial photographs from 1993 were compared with those from the year 2000 (Table 1). There was a reduction in overall canopy cover of 2% in the City of Yarra and 7% in the City of Boroondara. While the reduction in cover was anticipated, it was not expected that the

Table 1
Changes in Tree Cover for Developed and Undeveloped Land in Richmond and Balwyn Between 1993 and 2000 (Modified from Mullaly 2000)

Land type	Ownership of land	Balwyn			Richmond		
Developed land		1993	2000	Change	1993	2000	Change
	Private	19.23	10.49	–8.24	7.01	5.17	–1.84
	Public	3.45	4.65	1.20	2.65	2.12	–0.43
	Total	22.68	15.64	–7.04	9.66	7.39	–2.27
Undeveloped land							
	Private	20.00	17.47	–2.53	5.89	5.78	–0.11
	Public	6.25	7.81	1.56	2.84	5.45	2.61
	Total	26.25	25.28	–0.97	8.73	11.23	2.50

reduction would be greater in the outer suburb compared with the inner suburb. These results suggest that while there is recognition of loss of cover in inner-city urban renewal, changes in the vegetation cover of other suburbs should not be underestimated.

Upon further analysis (Table 1) it was noted that the City of Boroondara had approximately 2.5 times more foliage cover per unit area in developed public space than the City of Yarra in 1993. This would suggest that there has been a significant loss of tree cover in Boroondara and that a 7% loss represents a substantial change in this part of Melbourne. This loss of trees, however, is not as noticeable as in many parts of the city as there are still many substantial trees remaining. A 2% loss in the City of Richmond may seem almost insignificant. However, given the relatively low levels of cover, even 2% can make a substantial difference.

The initial assumption that little had changed in the City of Yarra was proved to be further unjustified when the percentage of cover was related to land ownership. The analysis showed that there had been a considerable loss of cover in the City of Yarra on privately owned property, but that this had been compensated for by significant tree planting in the public open space (Mullaly 2000). Significant losses of trees on private property due to intense high-density housing development had been compensated for to some degree by the planting of trees in local streets and parks. However, many of the spaces suitable for planting larger-specimen trees on public land had already been utilised, and as further high-density inner-city development proceeds, the loss of trees on private open space is unlikely to be compensated for by public planting.

The significance of these changes in a mere seven years should not be underestimated. Should these trends continue they will have a profound influence in both inner and outer city suburbs, the impact of which could be even more profound given similar trends are likely in other Australian cities. It is ironic that at a time when the environment and climate change are major matters of public concern, in cities public and private open spaces are reducing and vegetation cover is depleted.

Cities and Tree Value

If our urban trees and landscapes are assets that require the expenditure of resources — labour, energy, and even water, on their proper management, the question might be asked, 'What is the value of the benefits that are provided by them?' What is the value of shade provided by trees that drop temperatures by up to 8°C, reduce air-conditioner use and reduce carbon emissions? Estimates put the savings at between 12 to 15% per annum. What is the value of reduced wind speeds of up to 10% due to the presence of trees under a climate change scenario when winds will be stronger? The presence of shady trees can increase the useful life of asphalt pavement by at least 30%, which can be of considerable value in the hot climate of Australia, where asphalt degrades quite rapidly. Little scientific research has been done in Australia on these benefits from vegetation, and there is even less economic data to inform decisions.

What is the value of the pollutants removed from the air of Australian cities? In New York in 1994 the value of the city's trees in removing pollutants was estimated at $US10 million per annum. Planting 11 million trees in the Los Angeles basin saves $US50 million per annum on airconditioning bills. In Australia, the only study of its kind by economists notes that an Adelaide street tree provides a minimum annual benefit of about $200 per year and they note that it is a gross underestimate of the real value (Killicoat, Puzio and Stringer, 2002). If you consider the value returned to the City of Melbourne by its approximately 70,000 public trees alone it would be more than $14 million per annum. Other studies show a cost to benefit ratio of 1 to 6 in favour of urban trees and landscapes.

There is also the role of trees and public open space under a changed climate in holding and absorbing water during more intense rainfall events. What is their value in reducing localised flooding? The benefits of urban trees and landscapes already mentioned have not included how gardens improve human heath, extend life spans, reduce violence and vandalism, lower blood pressure and save our society a fortune on medical and social infrastructure costs. So if urban trees and landscapes are lost because politicians don't think they are worthy of some of our resources, society could pay a very high price indeed. It is lucky that as we let all the turf in our parks and ovals die that we don't have a problem with children lacking exercise and becoming obese. If we did, we might be paying a far higher price than was ever dreamt possible — society won't know what its got until it's gone.

As the population of Australia and its major cities continues to grow approaching the year 2050, the pressure on public open space will be enormous. There will be a tendency by politicians and bureaucrats to see any open space, whether public or private, as ornamental and therefore up for development. However, these cities will only be sustainable if the open space is sufficient to balance the resource demands of a modern society.

It is often forgotten that the major and capital cities of Australia are often biodiversity hot spots. The parks, gardens, streets and front and back yards provide a very diverse range of plant species that generate a myriad of habitats and niches for wildlife such as birds and mammals, reptiles, spiders and insects. There is also a diverse range of soil types that contribute to massive soil microflora and fauna. High-density urban developments and inner-city renewal make it virtually impossible to grow trees in places that were once green and leafy. The real and full costs of such developments are rarely ever seen.

Trees, Gardens and Climate Change

> Humanity is conducting an unintentional, uncontrolled, globally pervasive experiment, whose ultimate consequences could be second only to a global nuclear war … It is imperative to act now! (World Conference on the Changing Atmosphere, 1988)

This statement from an international conference over 20 years ago emphasised the significance of global warming and associated climate change on the planet's environment. Sadly, the warning was not heeded in an Australian context as global warming was mired in a maze of poor media coverage, ignorance by senior politicians and a misunderstanding of the scientific method that saw the matter debated as controversial for far longer than was scientifically justifiable.

Today, the debate is not so much about whether there is climate change, but about the extent of change and how it might be managed (Table 2). Gases produced by human activity have changed the composition of the Earth's atmosphere and reduced the amount of radiation that is reflected from the Earth's surface. This extra radiation warms up the atmosphere.

The major gases responsible for these changes and global warming — the greenhouse gases — are carbon dioxide, methane, the oxides of nitrogen, and other gases in smaller amounts that are included under the Kyoto Protocol (Table 2). In the Australian context, the greatest contributor to the greenhouse gases is carbon dioxide. This is due to a complex of factors, including such things as transport infrastructure, methods of energy generation and the fact that there is a relatively small population occupying a large continent. In some States, such as Victoria, the greater significance of carbon dioxide as a greenhouse gas is due to the use of brown coal to generate electricity (Table 2).

This data is useful as it explains, or perhaps justifies, the current emphasis by scientists, politicians and environmentalists on dealing with carbon dioxide as a greenhouse gas and climate change priority.

Table 2

Greenhouse Gases Included Under the Kyoto Protocols, and Their Contributions to the Overall Greenhouse Effect (as a %) for the State of Victoria (Anon 2001)

Greenhouse Gas	Symbol	Contribution (%)
Carbon dioxide	CO_2	68.4
Methane	CH4	25.0
Nitrous Oxide	N2O	6.4
Hydrofluorocarbons	HFCs	Negligible or 0
Perflourocarbons	PFCs	0.2
Sulphur hexafluoride	SF6	Negligible or 0

If something can be done about reducing carbon dioxide emissions then it will have a significant impact; however, this is not to say that other gases are unimportant. There are terms used under the Kyoto Protocol that are not always clearly understood (Anon 2000, Anon 2001). A source is any process or activity which involves releasing any of the greenhouse gases, while a sink is any reservoir or process that stores carbon, thus lowering the amount of carbon dioxide in the atmosphere. Sequestration is any removal of greenhouse gases from the atmosphere by plants or technological measures over time. Thus carbon sequestration is the absorption of carbon, usually by biomass such as trees, soils and crops.

Under the Kyoto Protocol, urban vegetation cannot be included in calculations of greenhouse-gas emissions, as either sinks or for purposes of sequestration, primarily because of difficulties that relate to verification of data and the relatively small scale of urban plantings. It should also be remembered that the Protocol only deals with plants greater than two metres in height and that its term ends in 2012, and that prior to that date a successor protocol (post-Kyoto Protocol) needs to be developed. It is expected that such a protocol would be more demanding on nations that agree to it than the current arrangements. Australia has recently signed the Kyoto Protocol and is actively taking part in the preparatory discussions for the post-Kyoto protocols.

Managing Urban Landscapes Under Climate Change

Although the Kyoto Protocol does not apply to urban vegetation, it will alter the political environment surrounding urban vegetation, and see the value of urban vegetation increase. It is also possible that the post-Kyoto protocol will include urban vegetation. Either way, there will be an opportunity to increase the public awareness of trees in cities, an opportunity to have the real value of urban vegetation calculated and recognised, and the potential to significantly affect decision-making processes.

While the values of large trees are recognised by some people, others perceive trees as nuisances (Spirn 1984, Moore 1997). The costs associated with trees in urban landscapes are often well known but their real direct and indirect benefits are rarely fully valued. Economists driven by the huge real costs of damage to the environ-

Table 3
Climate and Environmental Values Associated With Mature Trees (Moore 1997)

Climate related values:	Environmental values:
• Shade	• Production of oxygen
• Shelter from the wind	• Fixing of carbon dioxide
• Thermal insulation	• Reduced soil erosion
• Temperature modification	• Edaphic environment
• Reduction in glare	• Protecting watersheds
• Humidification of the air	• Improved air quality
• Filtration of polluted air	• Altering ambient temperature
• Interception of rainfall	• Noise abatement
• Reduced water runoff	• Wildlife habitat
• Reduced stream turbidity	• Create ecosystems
• Altered effective precipitation	

ment, and the costs of attempting environmental amelioration and rehabilitation, are only now starting to redress this problem and put balance back into the economic models. The impacts of trees on the urban microclimate and city infrastructure are now being recognised (Table 3).

These mature trees are significant sinks of carbon and sequester atmospheric carbon dioxide for very long periods of time. Should the trees die the carbon that is the major element of their structure would be released into the atmosphere, making matters significantly worse (Table 4). Consider what this could mean in a city like Melbourne, using rounded estimates to calculate the masses involved.

Table 4
Carbon Fixed in Urban Trees in Inner Melbourne

Approximations used	Value
Estimated number of trees in private and public open space in inner Melbourne	100,000
Average weight of whole tree, including above and below ground components (t)	100
Water content (%) of tree (approximation)	80
Dry matter mass of trees (%; varies, so conservative estimate)	20
Carbon content of dry matter (%; varies, so conservative estimate)	50
Amount of carbon sequestered in each tree (t)	10
Approximate value of carbon AUD$ per tonne	20
Total carbon sequestered in urban trees of inner Melbourne (t)	1,000,000
Total $ value of carbon sequestered in Melbourne's trees	20,000,000

There are at least 100,000 mature trees in the inner-city area alone, and each weighs approximately 100 tonne. Of this weight about 80% is water, leaving about 20 tonne of structural mass, of which about 50% or 10 tonne is carbon. Thus there is about a million tonnes of carbon sequestered in these inner-city trees alone, not to mention that sequestered by associated organisms.

The value of carbon varies according to the market and economic conditions at the time of valuing. Back in 2006, the value was estimated at about $10 per tonne, but once the Federal Government under Kevin Rudd signed the Kyoto Protocol, the value on the Sydney Carbon Exchange rose to almost $20 in late 2008, which is the figure shown in Table 4. On the international market based in Europe, the value reached $E20 per tonne (almost $AUD50) in 2008, but has fluctuated considerably since due to the global economic crisis.

These calculations can be used to estimate what effect pruning mature trees for construction, or installation of utility services such as powerlines or communication cables, might have in terms of Carbon (Table 5). Different pruning regimes remove different proportions of the canopy and so data for 30, 20 and 10% canopy reductions are shown.

Given that pruning contracts and operations managed by local governments usually involve hundreds or perhaps even thousands of trees, it is worth estimating overall carbon losses for 100 trees (Table 6). Furthermore, if you value carbon at the 2008 rate of $20 per tonne, the significance of the losses becomes clearer. When these values are considered it becomes apparent that they could affect the economic value of pruning as a management tool, and could see the rapid move to undergrounding services. This is especially so when costs for three and five-year pruning cycles are calculated. When the economic

Table 5
Carbon Lost in Pruning Mature Urban Tree Canopies

Approximations used	Value
Average weight of whole tree, including above and below ground components (t)	100
Amount of carbon sequestered in each tree (t)	10
Amount of carbon sequestered in the canopy of each tree (t)	5
Amount of carbon lost if 30% of canopy pruned from each tree (t)	1.5
Amount of carbon lost if 20% of canopy pruned from each tree (t)	1
Amount of carbon lost if 10% of canopy pruned from each tree (t)	0.5

Table 6
Carbon Lost and Its Value for Pruning 100 Mature Urban Tree Canopies

Approximations used	Value
Amount of carbon lost if 30% of canopy pruned for 100 trees (t)	150
Amount of carbon lost if 20% of canopy pruned for 100 trees (t)	100
Amount of carbon lost if 10% of canopy pruned for 100 trees (t)	50
Value of one tonne of carbon $	20
Value of carbon pruned from 100 trees when 30% pruned ($)	3000
Value of carbon pruned from 100 trees when 20% pruned ($)	2000
Value of carbon pruned from 100 trees when 10% pruned ($)	1000

benefits associated with trees and urban vegetation are established in this way, they alter the economics of long-established practices and should lead to a more sustainable future.

It should be noted that similar calculations can be applied to root damage and loss when roots are severed for construction and utility installation. Clearly, installation of underground services must be done in a way that does not damage or remove root mass. Modern boring and tunnelling equipment allows such installation, especially when it is remembered that most mature trees do not have significant tap roots, and that in urban contexts there are usually very few roots below a depth of about 750 mm. Similarly, research could reveal the extent of root losses due to compaction, waterlogging and other urban stresses and the associated loss of carbon that results. Its economic impact could then be calculated.

The calculations above have involved the deliberate use of conservative estimates so that there can be no accusations of inflating values to serve the arguments in favour of urban trees. There are many algorithms that can be used for carbon calculations, including those available from the Australian Greenhouse Office, and most of these will give a higher carbon value than the calculations above. It should also be noted that there is growing evidence that there has been a general and significant undervaluation of the carbon fixed below ground by mycorrhizae and the other microbes associated with plant root systems. The value for tree-related carbon is likely to be considerable.

Water, Drought and Changed Weather Patterns

The current drought that has affected south-eastern Australia is now well into its 12th year. In Victoria, there has not been a dry period like it in the State's recorded recent history, and the duration of the drought is unprecedented over the period for which data is available. The current drought has not been of the type described as acute, but has been a chronic drought with below-average rainfall month after month, and year after year.

It is not known whether this drought is a part of a regular natural pattern that occurs over a longer period of time. It might be the once

Table 7

Current Data Trends on Global Warming and Predictions of the Likely Outcomes for Climate and Sea-Level-Related Changes

Factor	How we are tracking?	Prediction
Global temperature	The past 30 years have been the warmest of the past 200 years	Suggests that temperature rises will be at or above the worst-case scenario of 6–8°C
Australian terrestrial temperatures	Have increased by 1°C in the past 50 years	Is in line with higher rather than lower temperature predictions
Sea levels	Have risen by 3mm per annum for the past 15 years	Consistent with higher sea-level predictions
Atmospheric CO_2 levels	These are above the predicted worst-case scenario	This suggests atmospheric temperature rises of 6–8°C
Safe atmospheric CO_2 levels	The environmentally safe level seems to be about 350ppm, and for the past 200,000 years they have been at about 280ppm	Atmospheric CO_2 levels are likely to rise to between about 500 and 1000ppm, which could cause a major extinction event
Arctic ice cap	Melting more rapidly than expected. It seems the northern hemisphere is warming more rapidly than the south	Could melt as early as 2013 rather than 2040–2050 as was originally predicted
Melting polar ice caps	Melting more rapidly	Only 3% of the extra energy absorbed in global warming has gone into heating the atmosphere. Most has gone in melting the ice caps
Reflection of radiation by ice caps	As they diminish in size less radiation is reflected from earth	Heating of the planet will accelerate to or above the worst-case scenario

in 500 years or perhaps the once in a millennium drought, for example, but current meteorological data are too recent to reveal such patterns. However, the current dry period may be a result of global warming and may indicate the changes that are to come, and which could be a more permanent part of our environmental conditions (Table 7).

Regardless of how things eventually pan out, there is no doubt that chronic drought and the possibility of more permanent global climate change are changing the environments within which trees are growing. Such changes are also resulting in the rapid change of the political, economic and social environments within which tree managers operate, and the decision-making processes that ensue. There are likely to be more severe weather events more often in south-eastern Australia, which will be associated with stronger winds and more intense rainfall. Storm events that were once considered 1 in 100-year or 1 in 30-year events are likely to occur perhaps every decade, or even annually.

There has been huge public interest in efficient and effective water use and conservation. In many parts of south-eastern Australia, restrictions to water use have been applied to urban gardens, parks and streetscapes, and these have placed the vegetation under considerable stress. There have been debates about whether trees — native or exotic — should be irrigated over the summer, and suggestions that perhaps the drought should take its course and consequently trees could be left to die. This is neither asset nor environmental management! Our knowledge of trees and particularly their root biology can be applied to effective and efficient management practices (Table 8).

Table 8

Tree Management Imperatives at Times of Drought and Climate Change

- Absorbing roots are near the soil surface, use this knowledge in management
- Plant trees in large mulched beds
- Mulch of any type is beneficial, but organic mulches have much to offer
- Large old trees must use significant amounts of water
- A few irrigations over summer will see trees through the driest periods of the year
- Focus on younger trees so that there are new generations of trees for the future
- Select trees wisely for the particular landscape role that is intended
- Consider water efficiency as part of any urban tree-management program

Despite the current, popular view that turf and lawns are profligate water users and so are unsustainable in the Australian environment, natural turf is usually a much more sustainable option than artificial turf if you consider the bigger picture of the latter's fossil-fuel chemical base and imbedded energy. Turf is quite a complex ecosystem that has a significant effect on temperature and the heat island effect, and if properly managed also sequesters a considerable amount of carbon. Perhaps it is not the villain that many think it is when they consider only the water component of a more complex equation.

Consider the following scenario. In a small backyard the lawn (8 × 4 m) has been replaced with artificial turf at a cost of $6000. The owners have done so because they are getting older and they have heard that lawn is not good for water use or the environment. The artificial turf is made from fossil fuel, imported from overseas and has high embedded energy. The purchase and installation of a locally made 5000-litre tank would cost $1200 and provide enough water for such a small lawn year round. Already the owners miss the birds that used to come fossicking in the lawn. Their local council is also replacing a turf oval, which they cannot irrigate due to local water authority restrictions, with artificial turf. They are doing so as part of their water policy. However, the product is imported with high embedded energy and carbon. Furthermore, the council is not harvesting the water that runs off or passes through the new artificial turf surface. Efficient irrigation and water recycling and the use of a water-efficient native grass would be a far more sustainable option for a low-use oval. The council has also used couch grass on a number of its other sporting ovals, unaware that its high binding strength could cause serious knee injuries to teenage football, hockey or cricket players.

Trees and urban parks and gardens are assets in every sense of the word. As a consequence the labour, energy and resources for their proper and sustained management must be provided. Among these resources may be the need for an allocation of water, used wisely and sustainably. If the focus is solely on water and trees and other vegetation are left to die, then consequently the carbon that they sequester would be released into the atmosphere. Such an outcome would not be environmentally

Table 9
Characteristics and Benefits of Mulch for Urban Trees

Mixed particle size — coarse and fine matter:
• facilitates aeration
• prolongs the life of mulch in urban sites
• creates habitat for edaphic organisms
Depth of 75–100 mm (3–4 inches)
Benefits include:
• better water infiltration
• lower evaporation
• improved aeration
• better soil structure

responsible, and highlights the need for those managing urban vegetation to appreciate the larger environmental picture.

Mature trees will continue to have a significant place in urban landscapes of the future and they must be managed to ensure that they remain healthy and fulfill the full potential of their lifespans. In recognising tree structure, appropriate space must be provided for their canopies and root systems. This will reduce human interference with root systems in particular, leading to healthier, longer-lived trees and lowered maintenance costs. Larger spaces to accommodate trees must be a part of sustainable urban design.

Similarly, recognising that the absorbing roots of most trees growing in urban locations are shallow and spreading should dictate the proper use of mulch material (Table 9). Mulches should be organic wherever possible, of mixed particle size and between 75–100 mm in depth. Irrigation systems such as drippers or leaky pipes should be located under the mulch to deliver water effectively and with a minimum loss to where it is needed most by tree root systems.

Use of mulch cannot be an afterthought, which often leads to an eyesore, but rather an integral part of proper design. The needs of trees must be provided for in a way that is incorporated into the design of urban landscapes, so that the right mulch will be used and it will be integral to the ambience of the landscape. Already, there is a change in people's appreciation of the appropriateness of mulch, and their perceptions of trees growing in a green turf have changed.

As our climate changes, the impact of vegetation on stormwater runoff could save billions of dollars in infrastructure costs to Australia's cities. It is not economically possible to retrofit larger stormwater drains and alter the levels at which they enter waterways. However, trees not only hold rainwater on their canopies, but through transpiration significantly reduce the amount of water entering drains. Estimates suggest that trees may hold up to 40% of the rainwater that impacts on them and that as little as 40% of water striking trees may enter drains. Furthermore, the root systems may act as effective biofilters in improving the quality of the storm water before it enters watertables or river systems (Denman 2006).

Given that carbon dioxide is the most significant of the greenhouse gases, especially for the States of south-eastern Australia, its sources, sinks and sequestration will be particularly politically sensitive. Sources of carbon dioxide from the use of fossil fuels are often obvious, but many citizens fail to associate electricity with greenhouse-gas emissions. However, in Australia considerable electricity is derived from coal-powered generators, and as people become more aware of climate change, the focus on green issues associated with power generation will increase. This could have a profound impact on current powerline clearing practices in the eastern States.

The Kyoto Protocol recognises the value of carbon sequestration by trees as a means of locking up carbon for significant periods of time. While the Protocol does not recognise urban trees, the public is becoming increasingly aware that power generation is producing large volumes of greenhouse-gas emissions and that the clearing of trees for powerlines and general tree pruning is reducing the level of carbon sequestered in the canopy structures of urban trees. Thus the power-generating and distribution companies and authorities are compounding their contributions to the greenhouse effect and global warming. On the one hand they are major greenhouse-gas emitters, and on the other they are causing significant carbon losses by their line-clearing activities. Line clearing compounds the negative effects of power generation on greenhouse-gas production.

Governments through their agencies are still major clearers of trees, forests and ecosystems. In most States approaches to roadside vegetation at a time of climate change are inappropriate. Trees and roadside ecosystems are assets that fix carbon, provide shade, filter air and protect from wind, and provide wildlife corridors and habitat, just to mention a few of the obvious benefits. Are these benefits properly costed for road-related projects where a balance of safety, cost and the environment has to be achieved? It is to be hoped that an old-fashioned engineering philosophy to trees and the environment that is as inflexible in its approach as concrete is no longer the reigning paradigm at a time of climate change. However, such roadside vegetation is still being cleared right across the country, despite the fact that it sequesters massive amounts of carbon that could be used to partially offset the carbon produced by the vehicles that use the roads. Once again it is clear that the real and full economics of the situation have not been properly considered.

These circumstances could see citizens demanding an end to powerline and utility clearing and a significant change to roadside vegetation management to protect the carbon sequestered in urban trees. Under such a scenario, the Kyoto Protocol has no legal impact on urban trees management, but a changed political environment could provide an opportunity to press for undergrounding of services and the end to powerline and excessive roadside clearing. Once again this would see a rise in the real economic value of urban trees and landscapes.

Conclusion

Australia has signed the Kyoto Protocol, and it is highly likely that the Australian Government will become a signatory to the post-Kyoto successor. Consequently, it would seem logical that the present situation, which often substantially undervalues trees and urban vegetation, may change dramatically once the impact of the protocols on greenhouse-gas emissions are recognised. The economic algorithms and paradigms that have applied to the management of trees and public open space in urban environments are changing rapidly. As a consequence the economic imperatives that apply to managing trees will change under a thorough cost/benefit analysis. The future role of trees in the urban landscape, and indeed of public and private open spaces, are being redefined not by horticulturists, but by others who have little interest or expertise in urban-vegetation management and are driven by other imperatives. It is time to address some of these issues before changes are made that degrade the landscape, and which could take decades to remedy.

This is the century of the environment and the value of trees and vegetation will inevitably rise as people become more aware of the elements of a sustainable urban environment. There have been major changes over a short period of time in attitudes to water, climate change and the need for sustainability. However, will they be permanent? They herald the development of a truly Australian urban landscape that values trees and recognises the aridity and changed reality of the climate that affects the Australian continent.

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