Managing Trees in a Changing Environment

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INTRODUCTION

"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 nearly twenty years ago emphasizes the significance of global warming, and associated climate change on the planet's environment. The debate today is about the extent of change and how it might be managed. Since most urban tree managers have a firm grasp of these issues, a brief synopsis of the causes of the greenhouse effect is presented here, which highlights elements relevant to urban tree management (Moore, 2006). 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 (Figure 1).

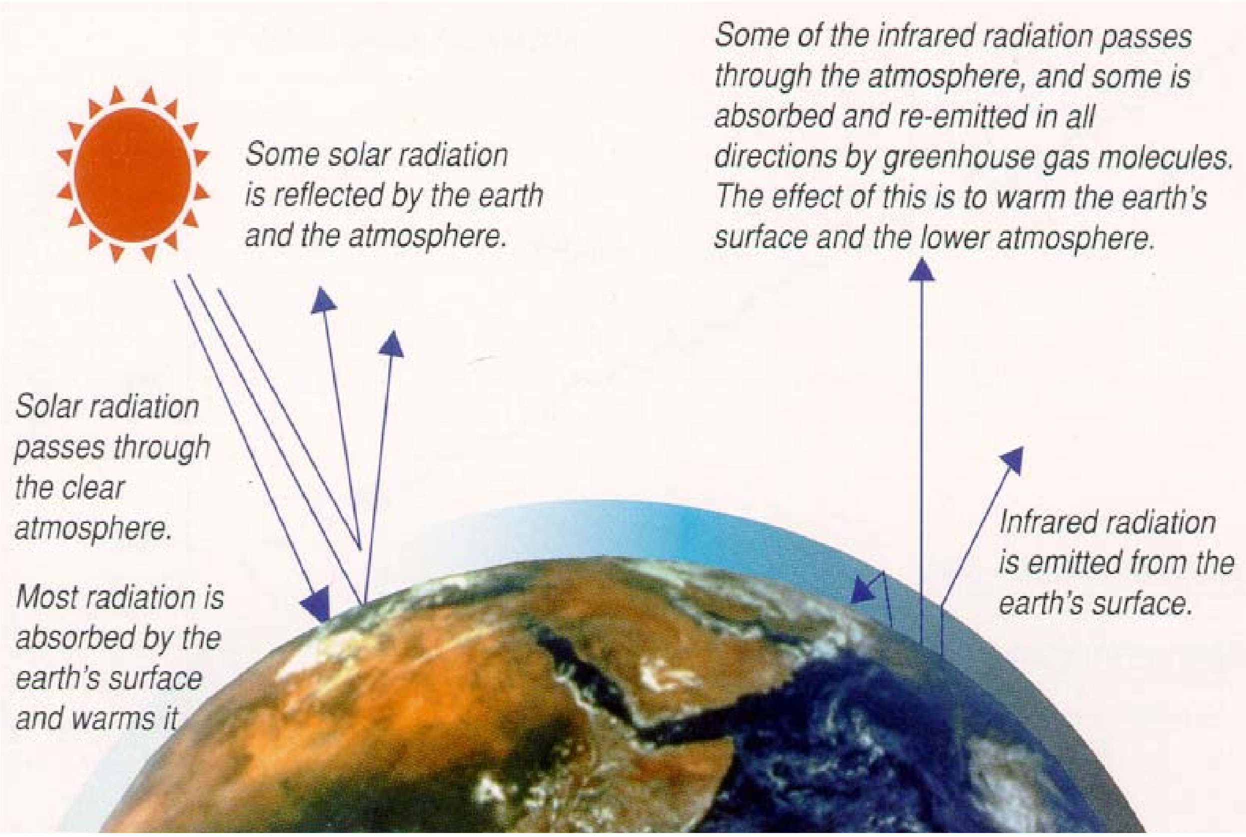

Figure 1 Causes of the Greenhouse Effect and the Subsequent Global Warming, which is responsible for climate change (Anon, 2001)

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 protocols (Table1). In the Australian and Victorian 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 Victoria, the significance of carbon dioxide as a greenhouse gas is due to the use of brown coal to generate electricity (Table 1).

Table 1: 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	CO2	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

These data are useful as they explain, or perhaps justify, the current emphasis by scientists, politicians and environmentalists on dealing with carbon dioxide as a greenhouse gas and climate change priority. 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, which 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 Protocols, 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 term of the Kyoto Protocol 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. Now that Australia has signed the Kyoto protocol, it should impact on all aspects of vegetation management, including urban landscape management. Furthermore, Australia can now actively take part in the discussions for the post-Kyoto protocols.

MANAGING TREES UNDER THESE CHANGING CONDITIONS

Although the Kyoto Protocol does not apply to urban vegetation, it does alter the political environment surrounding urban vegetation, and should see the value of urban vegetation increase. It is 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 recognized, 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 environment, 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 impact of trees on the urban microclimate and city infrastructure are being recognized (Table 2). The

Table 2: Climate and environmental values associated with mature trees (After Grey and Deneke, 1978: Anon, 1989: Harris, 1992: Finnigan, 1994, 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	• Ameliorating windflow
• Filtration of polluted air	• Improved air quality
• Interception of rainfall	• Altering ambient temperature
• Reduced water runoff	• Noise abatement
• Reduced stream turbidity	• Wildlife habitat
• Altered effective precipitation	• Create ecosytems

role trees as filters for pollutants, improving the quality of air, reducing wind speed and influencing water infiltration and absorption are the subject of research (Finnigan 1994). The presence of shady trees can increase the useful life of asphalt pavement by 30% (Killicoat, Puzio and Stringer, 2002).

Mature trees are significant assets to our environment and our society regardless of where they occur or whether they are native or exotic. A great deal of effort has gone into managing and conserving and preserving the trees. In the urban context of this conference, 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.

These mature trees are significant sinks of carbon and sequester this atmospheric carbon dioxide for very long periods of time. Should the trees die the carbon which is the major element of their structure would be released to the atmosphere making matters significantly worse (Table 3). Consider what this could mean in a city like Melbourne, using rounded estimates to calculate the masses involved. There are at least 100,000 mature trees in the inner city area alone, and each weighs approximately 100t. Of this weight about 80% is water, leaving about 20t of structural mass, of which about 50% or 10t 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.

Table 3: 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
Total carbon sequestered in urban trees of inner Melbourne (t)	1,000,000

If we take these calculations further, it can be calculated what effect pruning such mature trees for construction, or installation of utility services such as powerlines or communication cables, might have in terms of Carbon (Table 4). Different pruning regimes remove different proportions of the canopy, and so data for 30, 20 and 10% canopy reductions are shown.

Table 4: 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**

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 5). Furthermore, if you value carbon at AUD$10.00 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 underground services. This is especially so when costs for 3 and 5 year pruning cycles are calculated.

Table 5: 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 tree (t)	**100**
Amount of carbon lost if 10% of canopy pruned for 100 tree (t)	**50**
Value of 1tonne of carbon $AUD	**10**
Value of carbon pruned from 100 trees when 30% pruned (AUD$)	**1500.00**
Value of carbon pruned from 100 trees when 20% pruned (AUD$)	**1000.00**

Value of carbon pruned from 100 trees when 10% pruned (AUD$)	**500.00**

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. Similarly, research could reveal the extent of root loss due to compaction and waterlogging and the 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 carbon fixed below ground by mycorrhizae and the other microbes associated with plant root systems. In short, values for tree related carbon are likely to be considerably higher than any of the algorithms currently in use have so far revealed.

DROUGHT AND CHANGED WEATHER PATTERNS

The current drought that has affected Victoria, and more generally the south eastern part of Australia is now well into its ninth year. 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 we have data. The current drought has not been of the type described as acute, like that of 1983, 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 one in five hundred year 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.

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 is no doubt that they are managing trees in a changing environment.

There has been huge public interest in efficient and effective water use and conservation. 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 6).

Table 6: Tree management imperatives at times of drought and climate change

- Since absorbing roots are near the soil surface, use this 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

Mature trees will 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. Through recognizing 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. Use of mulch cannot be an afterthought, which often leads to an eyesore, but rather must be an integral part of proper design. The needs of trees will be provided for in a way which is incorporated into the design of urban landscapes, so that the right much will be used and it will be integral to the ambience of the landscape.

Similarly, recognizing that the absorbing roots of most trees growing in urban locations are shallow and spreading should dictate the proper use of mulch material (Table 7). Mulches should be organic wherever possible, of mixed particle size and between 75-100mm in depth. Irrigation systems such as drippers or leaky pipe should be located under the mulch to deliver water effectively and with a minimum of loss to where it is needed most by tree root systems

Table 7: Characteristics and benefits of mulch for urban trees

- Mixed particle size – course and fine matter
  * Facilitates aeration
  * Prolongs the life of mulch in urban sites
  * Creates habitat for edaphic organisms
- Depth of 75-100mm (3-4 inches)
- Benefits include:
  * Better water infiltration
  * Lower evaporation
  * Improved aeration
  * Better soil structure

Use of mulch will not be an afterthought, which often leads to an eyesore, but rather an integral part of proper design. The needs of trees will be provided for in a way which is incorporated into the design of urban landscapes, so that the right much 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 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 drains and alter the levels at which they enter waterways, but trees not only hold rainwater on their canopies, but through transpirational water use reduce water entering drains significantly. Estimates suggest that trees may hold up to 40% of the rain water 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 recognizes the value of carbon sequestration by trees, as a means of locking up carbon for significant periods of time. While the protocol does not recognize urban trees, the public will soon be aware that power generation is producing large volumes of greenhouse 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. These circumstances see citizens demanding an end to line clearing to protect the carbon sequestered in urban trees. Under such a scenario, the Kyoto protocol has no legal impact on urban tree management but a changed political environment could provide an opportunity to press for undergrounding of services and the end to powerline clearing. Once again this would see a rise in the real economic value of urban trees and landscapes.

A CASE STUDY FOR LANDSCAPE DESIGNERS:

By way of concluding this paper, a short hypothetical case study is presented. A local school has recently briefed a well-known firm of architects for the construction of its new school buildings. The school has a very strong environmental ethos, and employed the architects who are known for their environmental and energy expertise. The design has been presented and the architects have done a fine job in taking into account climate, energy use and recycling. The building and its landscape have been integrated, and the architects are relying on the proper choice of trees to shade buildings in Sumer, but allow sunlight to warm the school in Winter. Their calculations show that this could save between 12-15% of the building’s heating/cooling and lighting energy budget.

The architects have thus sought horticultural advice on which species of deciduous trees they can consider for planting to meet their design requirements, but at the same time meeting the school’s policy of planting only indigenous trees. The school has planted Australian native plants in the past and may consider native plants, if appropriate local indigenous trees are not available, and so the architects have alerted horticulturists that this may be an acceptable option.

The architects have already had *Brachychiton* species, *Melia azedarach* and perhaps some *Nothofagus* species suggested as possibilities. However, they have considered the list to be too short; the *Nothofagus* seems inappropriate because of its slow growth rate, the *Melia* problematic because of its hard fruits in a school environment and they have heard reports that *Brachychiton* often has uneven canopy development. A number of other species tend to be sumer deciduous which is far from desirable under these circumstances. So they want a wider range from which to choose.

Here the issues of native versus exotic, efficient energy use in urban design and the role of trees in urban landscapes under changing climatic conditions collide.

CONCLUSION

Having signed the Kyoto Protocol, it is highly likely that the Australian Government will become a signatory to the post Kyoto successor. These are profound changes and Australia will meet its targets, so that it does not suffer the sanctions and trade barriers that failure to comply would entail. Consequently, it would seem logical that the present situation, which often substantially undervalues woody vegetation, may change dramatically once the impact of the protocols on greenhouse gas emissions are recognised.

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 in attitudes to water, climate change and the need for sustainability in a short period of time, but they will be permanent. They herald the development of a truly Australian urban landscape which values trees, but recognizes the dryness of the Australian continent.

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