Urban Tree Management Strategies for Climate Change

Greg Moore

School of Ecosystem & Forest Sciences

AAFBG Geelong

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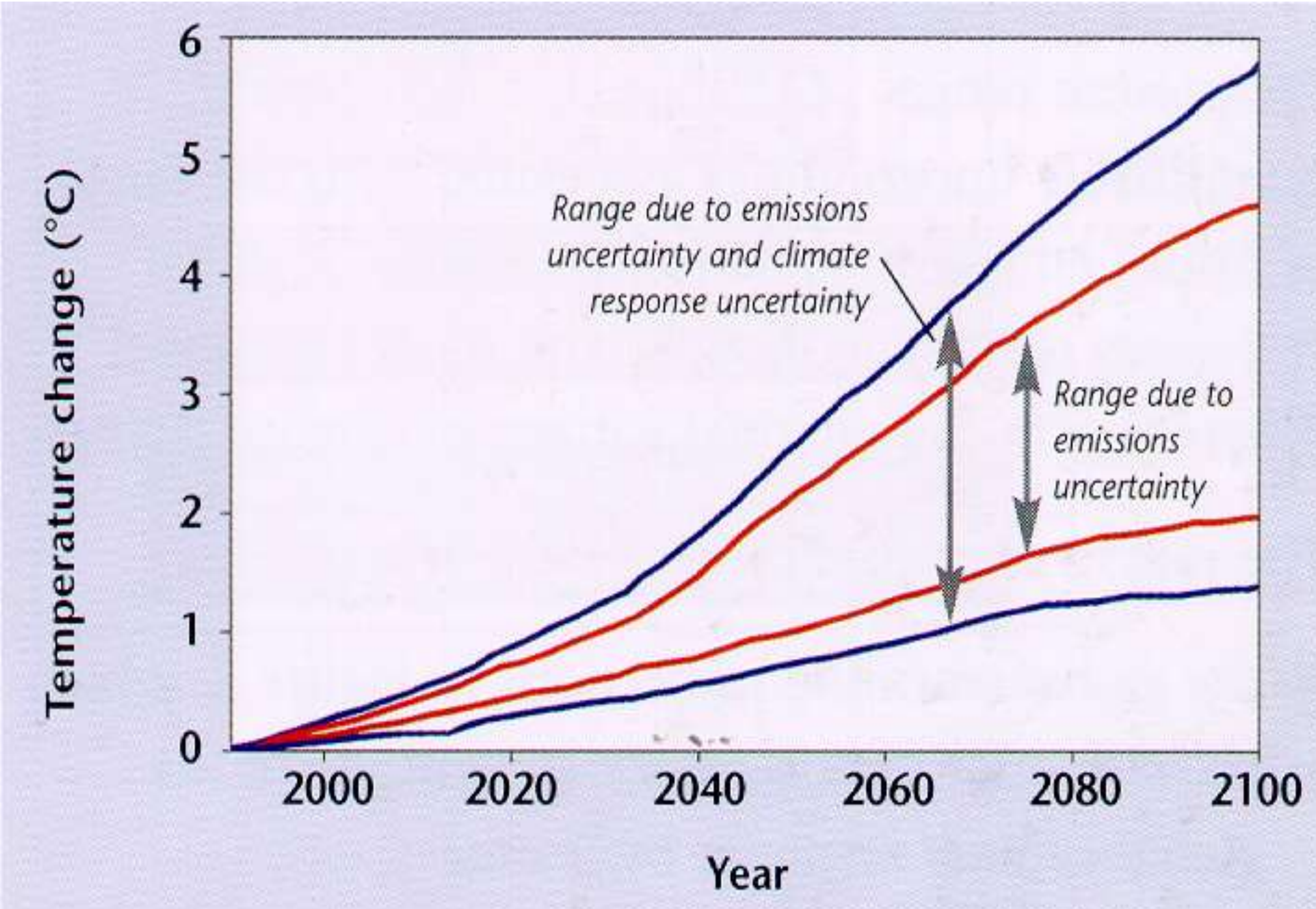
INTRODUCTION:

- All ecosystems, including urban forests, will be affected by climate change
- Higher global air temperatures and atmospheric CO_2
- Changes in the patterns and amounts of annual precipitation
- More frequent and intense storms
- Canges in the frequency and severity fires that affect peri-urban parts of cities

- In Australia the rises in temperature are likely to be in the order of 4^{o}C
- Decreases in rainfall in Victoria will be in the vicinity of 10-15%

These changes are significant but manageable and contrast temperature rises of up to 7-8^{o}C that are forecast for North America and parts of Europe


Temperature change (°C)
6
5
4
3
2
1
0
2000
2020
2040
2060
2080
2100
Year
Range due to emissions uncertainty and climate response uncertainty
Range due to emissions uncertainty

Projected future temperature rises (°C) for different geographic regions for 2020-9 and 2090-9 for low and high emission growth scenarios (IPCC 2007)

Emission Scenario	Low Emission Growth		High Emission Growth	
Projection Date	2020-9	2090-9	2020-9	2090-9
REGION				
North America	1.0	2.0-3.5	1.0-1.5	4.0-7.0
South America	0.5-1.0	2.0	1.0	3.0-4.0
Northern Europe	1.0-1.5	3.0	1.5-2.5	5.0-8.0
Mediterranean	1.0	2.0	1.0-1.5	4.0-4.5
Africa	1.0-1.5	1.5-2.5	1.0-1.5	2.5-4.0
Asia	0.5-1.0	2.0-3.0	1.0	3.5-4.5
Australasia	1.0	2.0-2.5	1.0	4.0-4.5

Effects of climate change on south eastern Australia

Generally warmer winters and hotter summers
A more tropical climate extending southward
More easterly winds leading to summer storms
More frequent major storm events
More days of extreme fire risk weather
More bushfire prone regions, extending to peri-urban parts of major cities
Changed weather and fire patterns
Fewer frosts, and in some places elimination of frosts completely

Effects of climate change on south eastern Australia

Many more days above 30C and double the number of days above 35c
Higher summer rainfall with more intense rainfall events
Flooding of lowland coastal areas – probably minor
For every one degree temperatures rise, the snowline rises 100m
Agricultural productivity will change, in some cases improving
Some crops will not be grown but others become viable
Housing and building construction processes will change
Energy demands and patterns of use will alter

Record high summer temperatures have already been experienced in many parts of Australia
Major storm events are increasing both in frequency and ferocity.
Trees regarded as safe have been windthrown /major limb failures resulting in damage and deaths

Images of fallen trees on homes and vehicles often lead to a call that trees be removed.
The moderating influence of trees on wind speeds preventing even greater damage rarely gets media exposure.

The value of shade from the urban forest canopy cover in reducing heat related illnesses and deaths is attracting the attention of both the media and health authorities. Heat waves are the greatest killers of people of any natural phenomenon, and the number of heat-related deaths, hospitalizations and ambulance call-outs will increase substantially, as will their costs

Health authorities are promoting an increase in urban tree cover as one of the remedies.

At the same time, however, intensive urban and inner city re-development is resulting in a decline in the tree cover in most Australian cities and regional centres.

There is a paradox emerging. There is a drive for tree clearing for development, better roadways and more dwellings as the Australian population, particularly in urban centres, grows rapidly. However, planners and health authorities recognise the need for greater canopy cover to reduce heat wave related deaths and for healthier lifestyles.

Several local government authorities have established challenging and increased tree cover targets, which would see canopy density double over a 20-30 year planning period. The major drivers of these targets are economic and health related.

Here is the conundrum: at the same time as the value of urban trees is being recognized by some sectors of Australian society, other are removing larger trees in increasing numbers.

The impacts of climate change on trees will not be uniform, making decisions related to planning and managing urban forests difficult.

There must be expanded and denser urban forests in future simply because they are our only sustainable weapons in dealing with climate change. Their significance in both the economic and environmental sustainability of cities will increase.

SOME STRATEGIES FOR MANAGING URBAN FORESTS AS CLIMATE CHANGES

One of the more obvious strategies in dealing with climate change is to do nothing.

Our urban forests may be more resilient to climate change than we think and we may not need to do anything, or at least avoid an uninformed knee-jerk reaction.

Many species that are widely planted in cities, from genera such as *Platanus*, *Linden*, *Pittosporum*, *Betula*, *Ulmus* and some coniferous genera, are renowned for their wide tolerance ranges (Table 1). They have become great urban trees because of their environmental resilience and tolerance of a wide range of soil, rainfall and temperature conditions and most should cope with the changes in temperatures and rainfall that are projected for many cities (Moore, 2009a).

However some such as *Betula* species and perhaps *Platanus x acerifolia* may be approaching the limits of their tolerance in south-eastern Australia, if their performance as ornamental trees during the dry period from 1997-2010 is considered.

Table 1: Simplified decision matrix for managing trees in the urban forest during climate change (expanded from Moore, 2016)

Table 1: Simplified decision matrix for managing trees in the urban forest during climate change (from Moore, 2016)

Species Characteristics	Tolerance of Higher Temperature	Tolerance of Drought or Lower Rainfall	Likely Impact of Climate Change	Management Implications
Widely dispersed over a broad range	High	High	Low	Select propagation material from appropriate provenance
Restricted range	Low	Low	High	Monitor performance and consider related species with tolerance of warmer, drier conditions
General stress tolerators	High	High	Low	Monitor performance and expand planting
General stress avoiders	Low	Low	High	Monitor performance and plant only where favourable management conditions allow survival
Drought prone	High	Low	High	May only survive if irrigated
Drought resistance	Low	High	Moderate	Grow in shaded, cooler parts of cities
Seed set	Low	Moderate	Moderate	May be an advantage when fruits or seeds are problematic in cities
Photosynthetic rate	Moderate	Moderate	Low	May be an advantage with higher establishment and growth rates. Could be enhanced with irrigation
Respiratory rate	High	Moderate	Moderate	Enhanced tree establishment and growth through efficient irrigation
Transpiration rate	High	Low	High	May only survive if irrigated
Frost sensitive when young	Moderate-High	Moderate	Low	Small, young trees may be grown without protection from frost
Sensitive to insect grazing	High	Moderate	Moderate	Increased pest control or select resistant cultivars
Changed growing season phenology	Moderate-High	High	Low	Earlier and longer growing season. May need to alter street sweeping regimes
Species prone to native mistletoe infection	High	Moderate	Moderate	There may be reduced mistletoe numbers due to hot windy days, which could be an advantage in mistletoe management
Narrow range of planted species	Low	Low	High	Plant a wider range of trees from different families and genera

Other common urban trees come from populations that have wide and extensive natural distributions.

This is the case for many species from Australia's two largest genera, *Eucalyptus* and *Acacia*, where there are large numbers of related species occupying a broad range of habitats.

Lophestemon confertus occupies a wide-range of habitats and differences in the provenances of the species are well-known for their different characteristics. Similarly *Acmena smithii* and *Tristainiopsis* species show a wide-range of environmental tolerances.

Careful provenance selection and breeding, which source specimens growing on appropriate soils but from lower rainfall or warmer regions could ensure that there are suitable intraspecific selections to meet urban planting demands (Table 1).

Even if species' ranges are limited, there may be the option of selecting different but closely-related species from within a genus where displacement series of species exist (Table 2). A displacement series consists of often related species, which replace each other over an ecotone that could be related to aridity, rainfall, soil nutrition, altitude or temperature (Table3)

Of particular interest for informing tree selection for climate change are displacement series of increasingly arid or warmer environments. Species show characteristics (Table 4) that adapt them to the drier conditions or generally more stressful environments, which could be used as a guide for which species might be successful for urban planting in drier conditions.

Often species that are tolerant of one environmental stress may be more generally stress tolerant, or perhaps capable of withstanding a related stress

It is not only abiotic stresses that can be dealt with via displacement series, but also biotic stresses, such as susceptibility to insect or fungal attack. Within the eucalypts, species from different subgenera show different general tolerances to fungal pathogens such as *Phytophthora cinnamomi* (Table 5). There emerges a pattern showing that in general, species within the subgenus Symphiomyrtus are more stress tolerant than species within the genus Corymbia which in turn are more stress tolerant than members of Monocalyptus (Table 5).

Table 2. Displacement series within eucalypt genera/subgenera, *Acacia* and *Atriplex* species.

Characteristic	Milder Environment	Harsher Environment
Eucalypt Subgenera/genera	Monocalyptus → Corymbia →	Symphyomyrtus
Monocalyptus Displacement series in Victoria's Central Highlands	*E.regnans* → *E.obliqua* →	*E.sieberi* → *E.radiata*
Monocalyptus Displacement series in Victoria's Southern Highlands	*E.delegatensis* → *E.fastigata* →	*E.radiata* → *E.dives* *E.pauciflora*
Salt Tolerance of Atriplex species	*A. leptocarpa* →	*A. cinerea*
Tolerance of soil moisture levels within Acacia species	*A. dealbata* → dense canopy	*A. mearnsii* sparse/open canopy
Tolerance of aridity within Acacia species	*A. catenulata* → larger phyllodes	*A. Aneura* → *A. harpophylla* smaller phyllodes

Table 3. Relationship Between Eucalypt species distribution and soil fertility in Queensland forests (developed from Florence, 1981)

High nutrient soil →			**Low nutrient soil**
Rainforest →	**Tall Open Forest**		**Open Forest**
	E saligna **S** *E microcorys* **S**	*E pilularis* **M** *E acmenioides* **M**	*E umbra* **M** *E signata* **M** *E piperita* **M**
	Lophostemon confertus	*Many ymphyomyrtus species* **S**	*E gummifera* **C**
			Angophora spp

Table 4: Characteristics of a eucalypt displacement series from wetter to drier environments (Pate and McComb, 1981)

Characteristics altered as environment dries
Greater root:shoot ratio
Increasing root:shoot ratio in response to water stress
Slower stomatal response to decreasing xylem water potential
Slower decline in leaf turgidity with increased water stress
Lower rate of transpiration in wetter soils

While growth and arboricultural data on Australian amenity trees grown in urban areas is generally unavailable, there have been studies on provenances of *Lophostemon confertus* (Williams, 1996), *Tristainiopsis laurina* (Looker, 2001) and *Corymbia maculata* (Bone XXXX)(Table 6). There are often good provenance data for important forestry and crop tree species, which can also inform decisions.

Horticulturists are adept at establishing, growing and managing trees outside their natural ranges and under adverse conditions (Table 1).

The role of Botanic Gardens in trialling plants through their various acclimatization plantings in the mid-1800s should not be undervalued. Many of these plantings were properly constructed trials that were well documented, and in the gardens in Melbourne for example von Mueller trialled plants for shelter, fibre and drought hardiness (Pescott, 1982). While many of the plantings and trials were short-lived, the remnant trees that have survived could prove to be invaluable in making informed plant selections as climate changes. Many of these sites have been widely photogarphed and I have used postcards from botanic gardens showing certain specimen trees from the early 1900s when inspecting the same trees in recent years (Figure 1).

Botanic Gardens Adelaide circa to 1969

Botanic Gardens Adelaide prior to 1949

Botanic Gardens Adelaide prior to 1909

Botanic Gardens Adelaide circa to 1910

Table 5 Tolerances of eucalypt species to the pathogenic fungus, *Phytophthora cinnamomi* (original table from many different soutrces)

HIGHLY TOLERANT	TOLERANT	SUSCEPTIBLE	HIGHLY SUSCEPTIBLE
Symphyomyrtus	**Symphyomyrtus**	**Symphyomyrtus**	**Monocalyptus**
sideroxylon	*resinifera*	*astringens*	*fastigata*
camaldulensis	*microcorys*	*cornuta*	*regnans*
grandis	*robusta*	*salubris*	*obliqua*
saligna	*cypellocarpa*	*campaspe*	
botryoides	*cladocalyx*	**Monocalyptus**	
	rubida	*sieberi*	
	crenulata	*baxteri*	
	occidentalis	*radiata*	
	viminalis	*consideniana*	
		muelleriana	
	Corymbia		
	maculata		
	citriodora		
	Monocalyptus		
	elata		

The range of microclimates and microhabitats that exist within urban environments can be used to advantage. Trees that are more sensitive to warmer temperatures could be grown in parts of cities that are subject to permanent shade, while frost-sensitive species may be grown more easily (Table 1). In the urban environment, restricting water availability to trees which may limit growth or foliage density may also restrict the benefits that trees provide, such as their capacity for providing shade, sequestering carbon and transpirational cooling

Many Australian tree genera are sclerophyllous and maintain cellular volume as conditions dry. It is often assumed that sclerophylls are low water users, but paradoxically many have poor stomatal control and will use whatever water is available until they start wilting (Ladiges *et al*, 2005). However, there are many other native species that do have the capacity for surviving in environments where water is limited, and managers could proactively minimise the supply of water in low water environments using sclerophyllous trees.

The use of species with high tolerances of low rainfall may come at a cost. Some native trees, such as *Casuarina littoralis, Eucalyptus calophylla, Eromophila macgillivrayii, Pittosporum phylliraeoides and Myoporum floribundum* have stomatal control and efficient water use, but if water is limiting their growth rates are very slow and ineffective for urban planting (Table X).

Acacia melanoxylon or Eucalyptus grandiflora, reduce water use through reduction in leaf surface area, and so lack the canopy density required of an effective urban tree.

Coping with lower rainfall in the urban forest may require more sophisticated and efficient irrigation that balances limited water availability against the need for an effective urban forest canopy

As climate changes, there will be a demand from landscape architects and urban planners for native winter deciduous trees, which provide shade during summer but allow access to light and warmth during winter.

Such species are in demand for urban sustainability which seeks to maximise the efficient use of energy and other resources.

Winter deciduous Australian native trees are relatively rare, with *Melia azedarach*, *Nothofagus gunnii*, and *Brachychiton acerifolius* being notable examples.

A few northern species including some eucalypts, such as *E. clavigera*, *E. grandiflora* and *E. brachyandra*, are facultatively deciduous during dry periods

There has been very little breeding and selection of these native winter deciduous tree species for urban use, and even less research on whether breeding might allow deciduousness to apply to southern winters, expanding the potential use of any of these or related species

Table 6: Australian Tree species with full or facultative deciduousness, usually in response to a dry period (Moore, 2013).

Species	**Common Name**	**Species**	**Common Name**
Brachychiton rupestris	bottle tree	*Gmelina leichhardtii*	white beech
Brachychiton discolor	lacebark tree	*Lysiphyllum cunninghamii*	native bauhinia
Brachychiton bidwillii	rusty kurrajong	*Lysiphyllum carroni*	native bauhinia
Brachychiton australis	large leaf bottle tree	*Lysiphyllum hookeri*	white bauhinia
Ehretia acuminata	koda	*Nauclea orientalis*	leichhardt tree
Erythrina vespertilio	bat wing tree	*Peltophorum pterocarpum*	yellow poinciana
Ficus supera	deciduous fig	*Sterculia quadrifida*	peanut tree
Ficus virens	white fig	*Terminalia catappa*	sea almond
Ficus fraseri	sandpaper fig	*Toona australis*	red cedar

Our island status has spared Australia of many of the pests and diseases

As conditions warm and dry periods extend there has been an increase in tree deaths from biological causes. Many older conifers such as *Pinus radiata* and *Cupressus macrocarpa* have died, urban populations of *Platanus x acerifolia* have been deleteriously affected and thousands of the most widely-distributed eucalypt, *Eucalyptus camaldulensis* died.

When this period ended, some trees such as *Ulmus* species recovered and the surviving *E. camaldulensis* rapidly re-foliated.

Cypress canker has taken a steady toll on older stressed conifers and a number of pines succumbed to *Diplodia*, *pinea*.

Recently there have been outbreaks of the exotic insect, giant pine scale.

Myrtle rust has also cut a swathe down the east coast of Australia.

Botanical Gardens Ballarat prior to 1911

Botanical Gardens Ballarat prior to 1908

The role of botanic gardens in early detection and in providing information on species' susceptibilities to these pest and diseases is invaluable.

Many of the botanic gardens in Australia are near the major cities and ports and they can act to some extent as the *canary in the mine* as part of early warning systems of climate-related pest and disease attack.

This role is more likely to bear fruit as the staff working in botanic gardens are well-trained and have expertise in particular species and so are likely to detect unusual symptoms early.

There may also be the need for action in relation to insect grazers. Insect predation could lead to increased tree mortality and a reduction in urban forest. High temperatures and extended heat wave conditions can impact on insect life-cycles and survival rates which can significantly reduce insect numbers. This highlights the need for careful monitoring of insect pests and adopting an **adaptive management** approach to pest management in the urban forest.

There will be tree species that benefit from a warmer dryer climate.

Trees that have been frost sensitive may be considered for planting or planted at an earlier age as the frequency of frosts and their intensity reduces (Table 1).

Species with temperature dependent fruit or seed set, higher temperatures may result in trees that flower but which do not produce fruits which are a nuisance in cities.

For many tree species, higher temperatures will allow more rapid and easier tree establishment and growth if water is available which is advantageous for municipal tree planting.

The warmer temperatures allows more rapid root growth, either from more rapid growth rates or from longer growing seasons. This would be beneficial for street trees where rapid early growth and establishment are considered advantageous as trees have an earlier landscape impact and planting would be more cost-effective (Table 5).

CONCLUSION:

As climate changes and cities expand, the pressure upon urban trees and forests will increase.

The ameliorating benefits provided by trees will be seen as essential urban infrastructure and their economic worth will be established.

To capture the major benefits of the urban forest requires a cover of between 30-35%.

Urban forest managers have the expertise to achieve high levels of cover and will have many tree selection options available to them, if they use the data that are available on the adaptations of many tree species to warmer, drier environments.

The role of botanic gardens in providing data where there is a history of growing species beyond their normal range of growing conditions cannot be over-valued.

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- *A. mearnsii* could lose 261kg of water per day compared to *A. decurrens'* 44kg, but this was largely due to a difference in foliage density with *A. mearnsii* having a foliage mass of 69kg while *A. decurrens* had a foliage mass of 9kg

- In an urban forest a choice between these species may come down to a decision about canopy appearance, density and impact versus water use.

- However, there are major research gaps in the use of Australian native species, as well as exotic species, growing under Australian environmental conditions

- Many eucalypt species seem to remain physiologically active using water under conditions of moderate to severe water stress

- In Western Australia *E. calophylla* has better stomatal control than *E. marginata*, which is a luxury water user

- Similarly in eastern Australia *E. regnans* is a profligate water user with little capacity for stomatal control while *E. obliqua* behaves similarly to *E. calophylla*

- In eucalypt dominated forests, it is common for different species to occupy environments that become increasingly drier.

- The leads to a displacement series, of often related species, which replace each other over an ecotone of increasingly arid environments.

- As this happens species tend to show characteristics that better adapt them to the drier conditions.

- These characteristics could be used by urban forest managers as a guide for what species might be successful for urban planting in drier conditions, but very little research has been applied to the urban context.

Melbourne Botanic Gardens prior to 1908


View of Melbourne

School of Ecosystem & Forest Sciences- Burnley