Conserving plants in a changing climate – an Australian perspective

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Abstract

Climate change is projected to significantly affect south-eastern Australia, with current assessments indicating lower rainfall and higher temperatures. The effects will be compounded by the concentration of urban development in coastal areas, relative aridity of the existing climate, and limited altitudinal and or geographical 'escape paths' for flora. Successful adaptation strategies for *ex situ* plant conservation must address both temperature rise and uncertain water supply. Individual botanic gardens should consider specific climatic projections for their location to ensure that collection planning and conservation activities are well informed and effective. Sourcing plants from current and projected homoclimes (geographic regions of similar climate) is essential to ensure that plants are well matched to the local environment. Microclimate variability and diverse landscape styles in botanic gardens offer prospects for the protection of taxa sensitive to the effects of climate change. It is anticipated that robust regional partnerships embracing landscape management, plant curation and research will enhance *ex situ* plant conservation programmes.

Key Words

Climate change, collections, conservation, homoclimes, microclimate, rainfall, temperature

Current situation and problems

Increased temperatures and number of hotter days on average are commonly projected across south-eastern Australia. Decreases in average rainfall are projected for most south-eastern Australian cities including Adelaide, Melbourne and Sydney (Suppiah *et al*., 2006; CSIRO 2007; CSIRO 2008; SEACI 2009).

The current situation in Australia (Figure 1), with decreasing rainfall in the west, south and south-east, has to a large extent driven increasing public awareness of climate change. Most major cities have had, or continue to experience, water use restrictions.

Northern hemisphere examples (Figure 2) show the amplitude and speed of temperature change in the past 100 years, compared to the last 1,300 y. However, all Australian Botanic Gardens are less than 200 years old and were largely designed and developed on the basis of European landscape interpretation in a different climatic period. This resulted in plant selections that need significant resources to survive and raises the question of what these landscapes would look like if developed under current or projected conditions.

Current climate change models are generally following the higher emission scenarios as projected by the Intergovernmental Panel on Climate Change (IPCC), but in some cases the projected changes are taking place more quickly than anticipated – showing more rapid and serious change (Climate Change in Australia 2009; Steffen 2009).

In this context, the need to consider 50+ year scenarios of worst case temperature and rainfall changes, lends weight to a precautionary approach to botanic garden planning as the prime risk management strategy. Contemporary risk management doctrine (Standards Australia, 1999) is not as applicable when considering the protection of dynamic living systems and the extensive lead time required to protect plants by translocation of genotypes and development of more climate-resilient collections.

Global climate changes are combined with existing threats to plants *in situ*. For example, in the Sierra Nevada Mountains, California, ecological niches of montane flora and fauna appear to be shifting to higher altitudes (*Pinus ponderosa* has retreated upwards about 200 metres, linked to an increase in minimum monthly temperatures of 3^{o} C over the last 100 years, Moser *et al.,* 2009).

Australia is particularly vulnerable to changing climatic conditions as there are limited escape paths for flora. Its mean altitude is the lowest in the world at 330 metres and montane regions, such as the Great Dividing Range, average just 600–900 metres in height (http://www.ga.gov.au/education/geoscience-basics/landforms/elevations.jsp). Flora in southern Australia also cannot migrate readily over ocean to adapt to increasing temperatures (CHABG 2008; CSIRO 2008; Hawkins *et al.,* 2008).

Managers of biodiversity must consider extreme weather events. The projected increase in annual average temperatures may also result in increases of individual, or flushes of consecutive, extreme temperature days (Figure 3). While this extreme can occur at daily or monthly temporal scales, there are also yearly considerations. In January 2009, a heat wave was experienced in Melbourne (Figure 4) where three consecutive days above 45° C (eight days above 40° C for the year) resulted in significant damage to many taxa across the Royal Botanic Gardens Melbourne (RBG Melbourne), especially to cool temperate species. Of concern is that the current trend indicates an annual increase in hot days (Table 1).

The shift in average temperature bandwidth can also be compared to rainfall changes. Long-term annual average reduction in rainfall for Melbourne is projected to be up to 11 per cent less (CSIRO 2008). However, there may be an amplified reduction for the average 10th percentile (that is, the 1 in 10 driest) rainfall years. It is reasonable to assume that one year of extremely reduced rainfall is enough to be severely detrimental to plant health.

Projected seasonal changes to climate may already be impacting upon regions in south-east Australia, and may be related to projected trends for the Southern Hemisphere (Figure 5). Murphy and Timbal (2007) found that there had been a 61 per cent decline in autumn rainfall between 1997 and 2006, and that there is likely to be an influence from global warming on the climate of south-east Australia, at least for temperature.

For many major botanic gardens, the urban heat island (UHI) effect is expected to magnify temperatures projected under climate change scenarios as UHI influences are not factored into long term projections (Coutts *et al*., 2009). In Melbourne, the UHI effect shows an increase in the average temperature of between 2 and 4^{o} C, with daily peaks to 7^{o} C in certain areas of the city (Coutts *et al*., 2009). The UHI phenomenon in the past has assisted the curation of warmer climate taxa, but in the future is likely to become a collection management problem.

While reductions in annual rainfall for south-east Australia are projected, changes to daily rainfall intensity and duration also have considerable effects on the precipitation actually reaching the soil for plant growth, or that which is ‘effective’. Rainfall in RBG Melbourne is strongly attenuated by canopy interception (Figure 6) (60 per cent coverage) and wet-canopy evaporation. Interception losses of 60 per cent have been recorded, falling to 30 per cent in the largest rainfall events. Current research indicates that Melbourne is experiencing an increasing trend towards low rainfall intensities (Dunkerley pers.comm, 2009), and therefore increasing interception rates.

Solutions

The early adoption of water efficiency programmes has shown immediate benefits in climate change resilience through savings in energy, materials and labour, and water (Figure 7).

Fluency in climatic and soil information is an underdeveloped skill-set for botanic gardens. There is a higher imperative to understand the soil environment (or edaphic) and to invest in researching and testing. Assessment of microclimates and soil types should be factored into landscape planning and collection development (Figure 8). Soil moisture sensing (Figure 9) is one technology to inform plant water use, soil hydraulic performance and assess rainfall effectiveness. Current research in RBG Melbourne is establishing baselines for the influence of the current climate on plant water use (Symes *et al*., 2008), and in assessing future trends.

Other useful technology includes site-specific automatic weather stations. These have considerable benefits for collections planning and management, such as:

- tracking temperature changes
- evapotranspiration estimation
- degree day estimation (heat accumulation)
- cross-referencing of plant phenological studies.

Comparative climatic assessments are one of the large challenges to overcome. The simplest models use comparisons between evaporation, temperature and rainfall to predict a soil-water balance. RBG Melbourne is currently adapting climate matching methodology (Gentilli, 1971) for future plant selection and landscape succession (Figure 10). It can be seen clearly that it would be very difficult to support the health of Kunming flora and that our current irrigation practice is well outside Melbourne’s existing, let alone projected, climate.

On the presumption that long lead times are required to establish more resilient living collections, then worst case scenarios in both temperature and rainfall changes need to be applied to landscape planning. A delayed response, combined with worst projections, will likely result in greater losses of plants and biodiversity.

The benefits of proactive strategic planning are obvious, but specifically include:

- an increased understanding of biodiversity risks
- greater investment in plant conservation
- transition of many living landscapes to more sustainable states
- enhancement of employee skills, and
- further development of botanic gardens networks and partnerships.

Plant selection of the future must become increasingly provenance-based, not only because of important conservation value, but also due to specific ecotypic variation for tolerances to drought and heat. However, there are large information gaps for many of the plants we grow – especially climatic preferences, environmental tolerances, and natural habitats. Consequently, it is crucial to up-skill curators in *both* climate and plant knowledge. This plant knowledge should also be stored in readily accessible national/global databases to reduce duplicated research.

In 2007, RBG Melbourne considered climate change projections in its review of the landscape Masterplan and Living Plant Collections Plan, leading to recommendations that vulnerable species be strategically replaced by those more suited to the projected climate. The focus is now on selecting plant species for their suitability to the local climatic, edaphic conditions and projected homoclimes, while maintaining the style of the respective landscapes.

Recent living collection developments at RBG Melbourne, such as the Californian Garden, the Water Conservation Garden, the Lower Yarra River Habitat (indigenous flora of Melbourne) and Guilfoyle's Volcano (Figure 11) are more likely to be suited to the projected drier and hotter conditions of the future. The Guilfoyle's Volcano project integrates heritage, climatic plant selection, water re-use, water treatment, efficient irrigation and education.

RBG Melbourne is the custodian of important collections not well adapted to Melbourne's homoclime. At least some of the taxa in these collections will need to be duplicated with other botanic gardens. RBG Melbourne and the Botanic Gardens Trust, Sydney, are examining the possibilities for duplication/transfer of wild-collected Southern Chinese flora.

In summary, we must take a precautionary and long-term approach in planning for climate change. Climatic extremes must be considered, and flexible planning policy developed for changing conditions. Collection planning should begin from an edaphic and microclimate perspective, and current collections should be evaluated for suitability under future climates. Protection of plants needs integration on both regional and global scales. Finally, we must continue to build knowledge of plant environments, to pursue an understanding of climate science, and the impacts of these changes for our respective botanic gardens and plant habitats.

References

(CHABG) Council of Heads of Australian Botanic Gardens (2008) *National Strategy and Action Plan for the Role of Australia's Botanic Gardens in Adapting to Climate Change.* Council of Heads of Australian Botanic Gardens: Canberra.

Climate Change in Australia Science update 2009 issue one http://www.climatechangeinaustralia.gov.au/resources.php (accessed June 2009).

Coutts, A.M., Beringer, J., Jimi, S. and Tapper, N.J. (2009) The urban heat island in Melbourne: drivers, spatial and temporal variability, and the vital role of stormwater*.* In: *Proceedings of Stormwater 2009, 7th–10th July 2009. Albury-Wodonga*, http://www.gemspl.com.au/Stormwater/ (accessed June 2009).

CSIRO (2007) *Climate Change in the Sydney Metropolitan Catchments*. Department of Environment and Climate Change, New South Wales Government. http://www.environment.nsw.gov.au/resources/climatechange/070216SydneyDetailedFinal1.pdf (accessed July 2009).

CSIRO (2008) *Climate Change in Victoria.* Department of Sustainability and Environment, The State of Victoria, Melbourne, June 2008. http://www.climatechange.vic.gov.au (accessed May 2009).

Dunkerley, D. (2009) pers. comm. David Dunkerley, Associate Professor, School of Geographic and Environmental Sciences, Monash University.

(FAO) Food and Agriculture Organisation of the United Nations (2005) *New_LocClim: Local Climate Estimator*. Food and Agriculture Organisation of the United Nations: Rome, Italy. http://www.fao.org/nr/climpag/pub/en3_051002_en.asp (accessed April 2009).

Gentilli, J. (1971) *World Survey of Climatology Volume 13, Climates of Australia and New Zealand.* Elsevier Publishing Company: Amsterdam-London-New York.

Hawkins, B., Sharrock, S. and Havens, K. (2008) Plants and climate change: which future? Botanic Gardens Conservation International, Richmond, UK
http://unfccc.int/essential_background/convention/background/items/1355.php (accessed July 2009).

Moser, S., Franco, G., Pittiglio, S., Chou, W. and Cayan, D. (2009) *The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California.* California Energy Commission, PIER Energy-Related Environmental Research Program: California.

Murphy, B.F. and Timbal, B. (2007) A review of recent climate variability and climate change in southeastern Australia. *International Journal of Climatology* **28**, 859–79*.*

South East Australia Climate Initiative (SEACI) (2009) Answering questions about climate in South Eastern Australia Poster
http://www.mdbc.gov.au/subs/seaci/docs/factsheets/090402-SEACI-foldout-poster-copy.pdf (accessed July 2009).

Standards Australia (1999) *Risk Management AS/NZS 4360:1999*. Standards Association Australia: Strathfield NSW.

Steffen, W. (2009) *Climate Change 2009, Faster Change and More Serious Risks*. Australian Government, Department of Climate Change. http://www.climatechange.gov.au/science/publications/faster-change-more-risks.html (accessed July 2009).

Suppiah, R., Preston, B., Whetton, P.H., McInnes, K.L., Jones, R.N., Macadam, I., Bathols, J. and Kirono, D. (2006) *Climate change under enhanced greenhouse conditions in South Australia – an updated report on: Assessment of climate change, impacts and risk management strategies relevant to South Australia.* Climate Impacts and Risk Group, CSIRO Marine and Atmospheric Research. http://www.climatechange.sa.gov.au/index.php?page=climate-change-in-sa
(accessed June 2009).

Symes, P., Connellan, G., Dalton, M. and Buss, P. (2008) Developing water management strategies for complex landscapes. In: *Irrigation Association of Australia National Conference Proceedings*: Melbourne Exhibition Centre, 20–22 May, Irrigation Association of Australia: Melbourne.

Van Rees, H., Jackman, A., Williamson, J. and Cummings, D. (1993) *Royal Botanic Gardens soil survey.* Centre for Land Protection Research, Department of Conservation and Natural Resources: Bendigo, Vic.

Figure 1 Climate change awareness driven by water scarcity

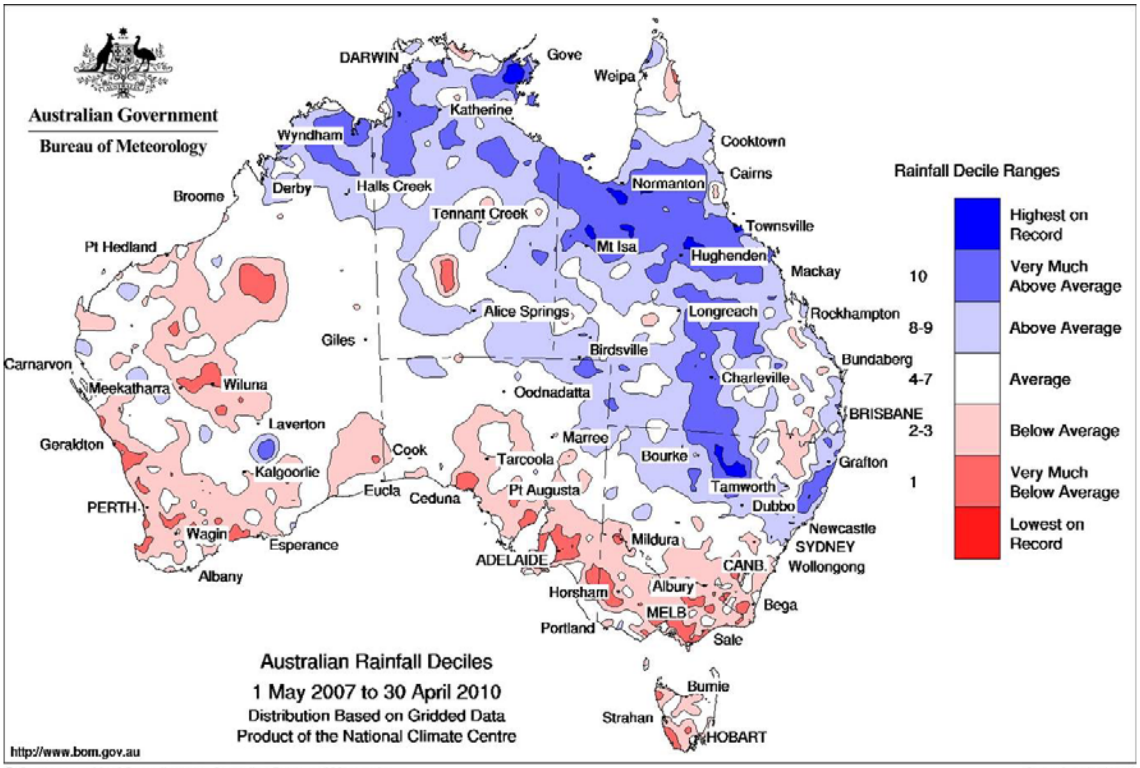

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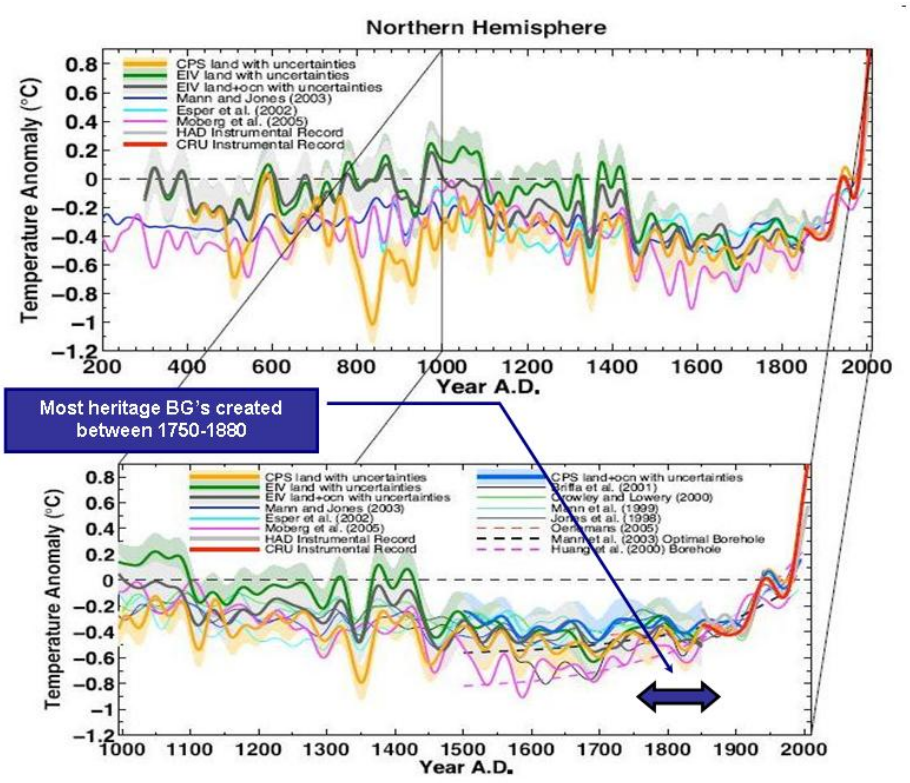
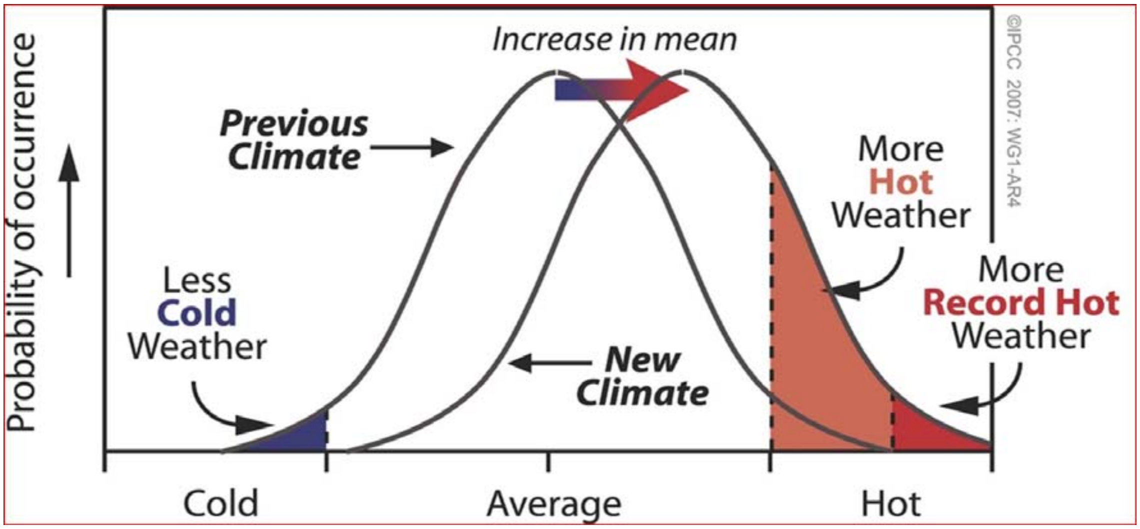
Figure 2 Reconstructions of hemispheric and global surface temperature variations



Source: *Proceedings of the National Academy of Sciences*, Vol 105, No 36, pp 13252-13257, 9 September 2008.

Figure 3 Consider the dangers of applying ‘average’ climate data in landscape planning



Source: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf.

Figure 4 Extreme temperatures trend – RBG Melbourne

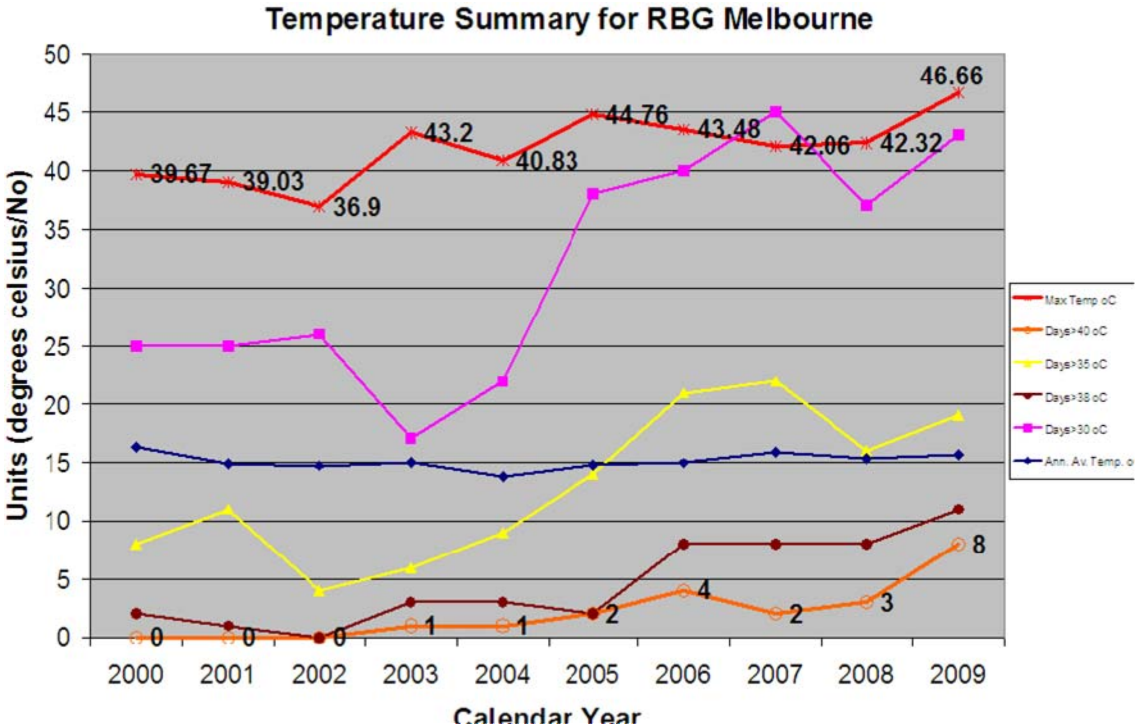
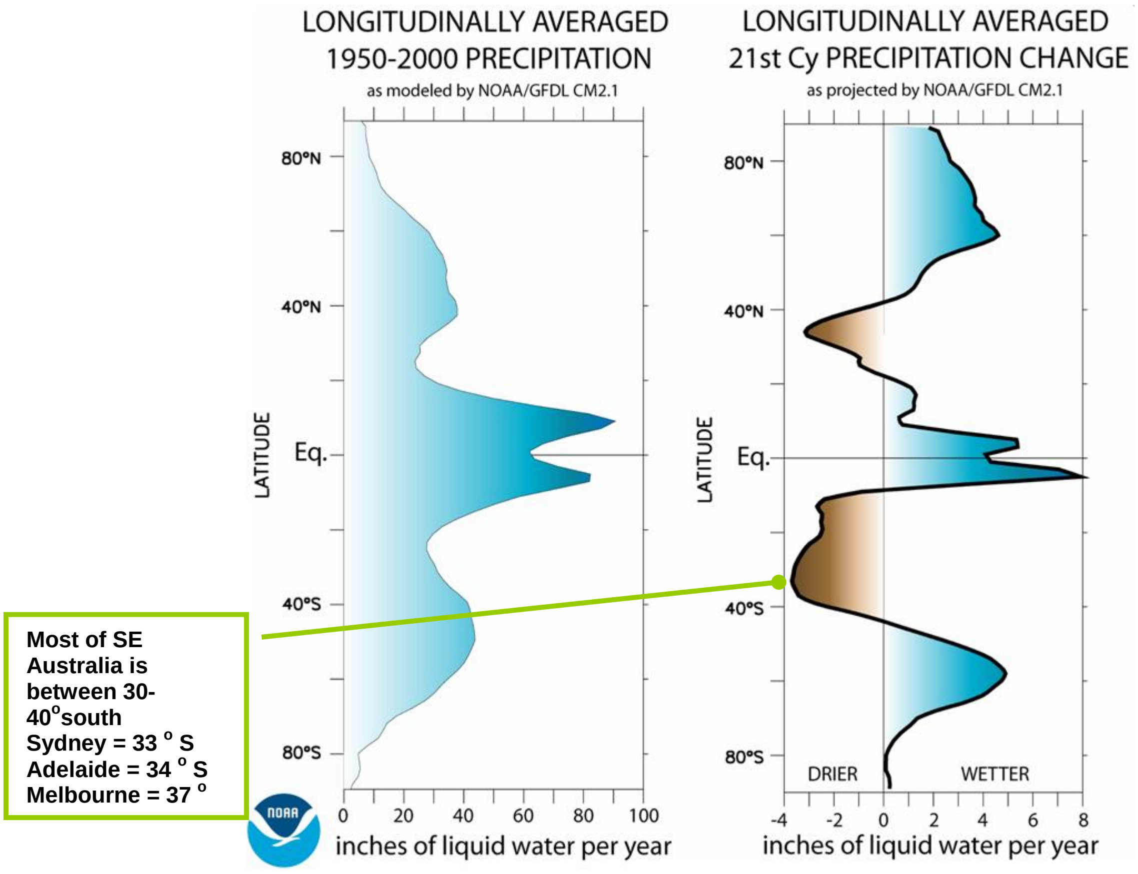


Table 1 Selection of projected climatic variables for Melbourne compared to RBG Melbourne Automatic Weather Station (AWS) records

Parameter	*Current*	*Average RBG AWS 2000–2009*	*2009*	*2030*	*2070*
Frosts	3	0.2	0	2 to1	1 to 0
Temperature change	15	15.1	15.58	+0.6 to +1.1	+0 to +3.7
Annual average evaporation	1241	1278	1359	-1 to +5%	-1 to +17%
Average annual rainfall	648	498 (-23%)	407 (-38%)	0 to -8%	-6 to -24%
Days over 30°C	30	**31.8**	**43**	**33—37**	**35—62**
Days over 35°C	9	**13**	**19**	**10—13**	**12—26**
Days over 40°C	1	**2.1**	**8**	**2**	**2—8**

Figure 5 Changes to longitudinal precipitation

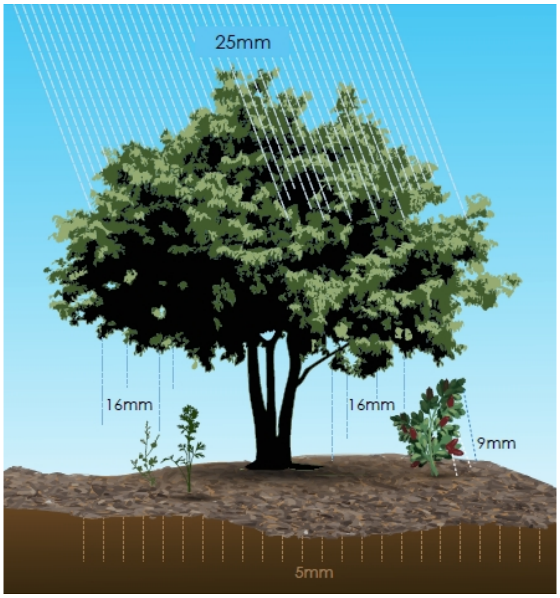


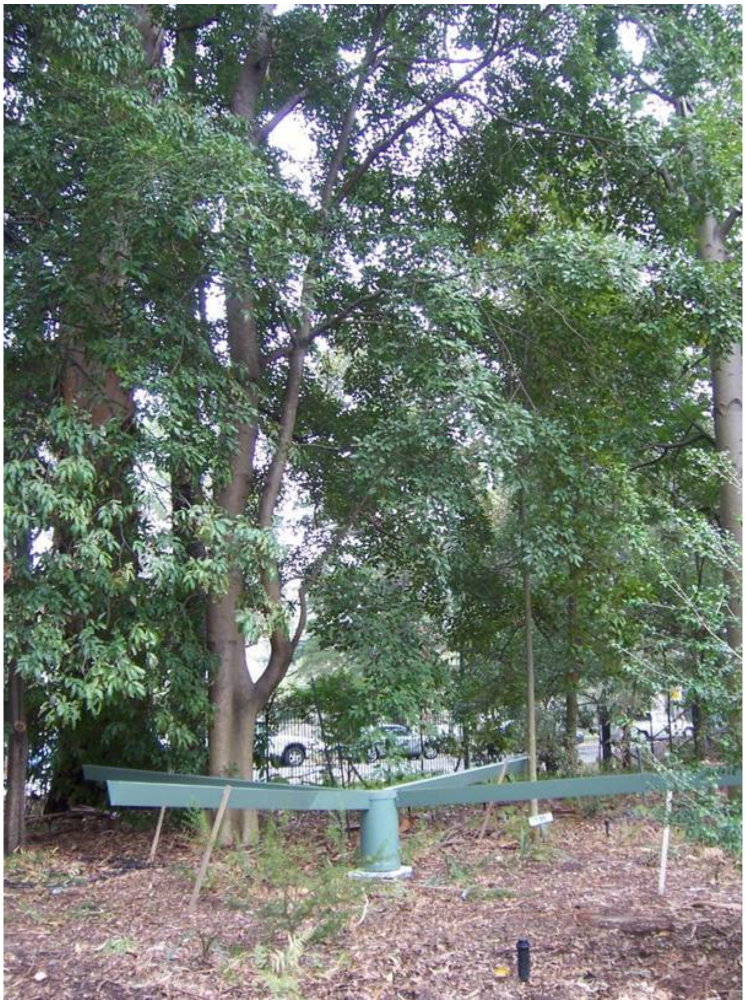
Most of SE Australia is between 30-40°south
Sydney = 33 ° S
Adelaide = 34 ° S
Melbourne = 37 °

Source: http://www.gfdl.noaa.gov/will-the-wet-get-wetter-and-the-dry-drier.

Figure 6 Up to 60 per cent of rainfall can be intercepted by the canopy per month

Throughfall measurement in the Australian Forest Walk Collection, RBG Melbourne





Schematic of rainfall interception by vegetation canopy
(used with permission – D. Dunkerley, Monash University)

Figure 7 Continuous improvement in water management efficiency

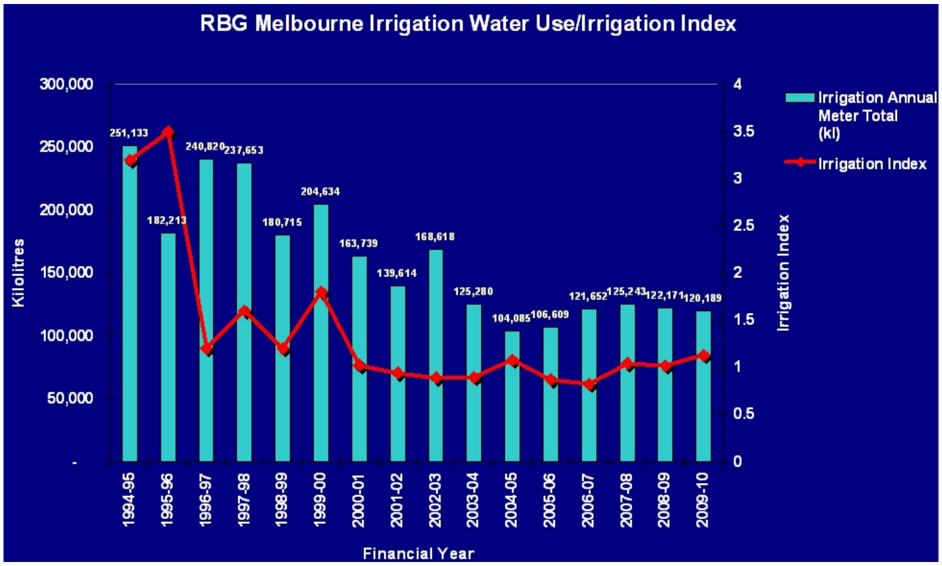


Figure 8 Soil and Microclimate Mapping

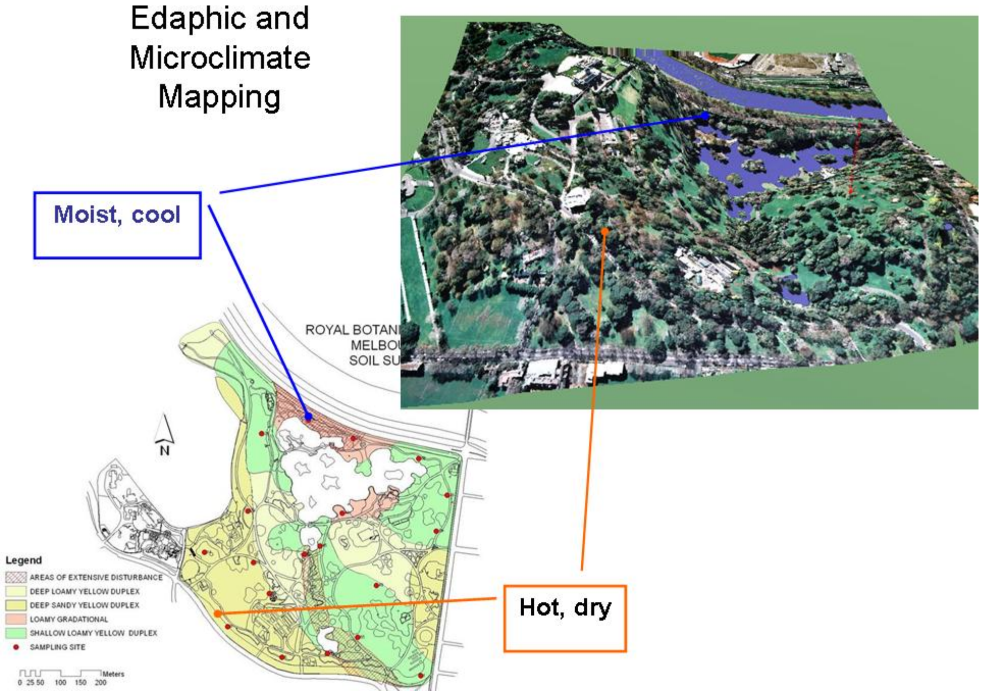


Figure 9 Soil moisture sensing

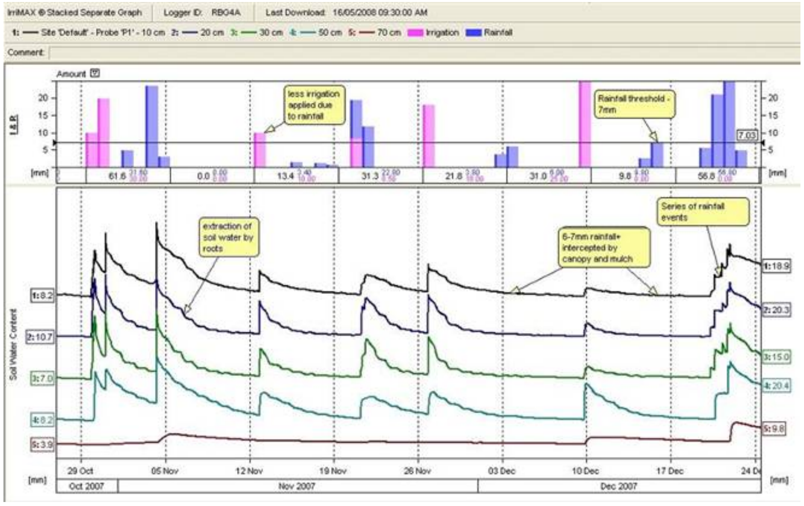
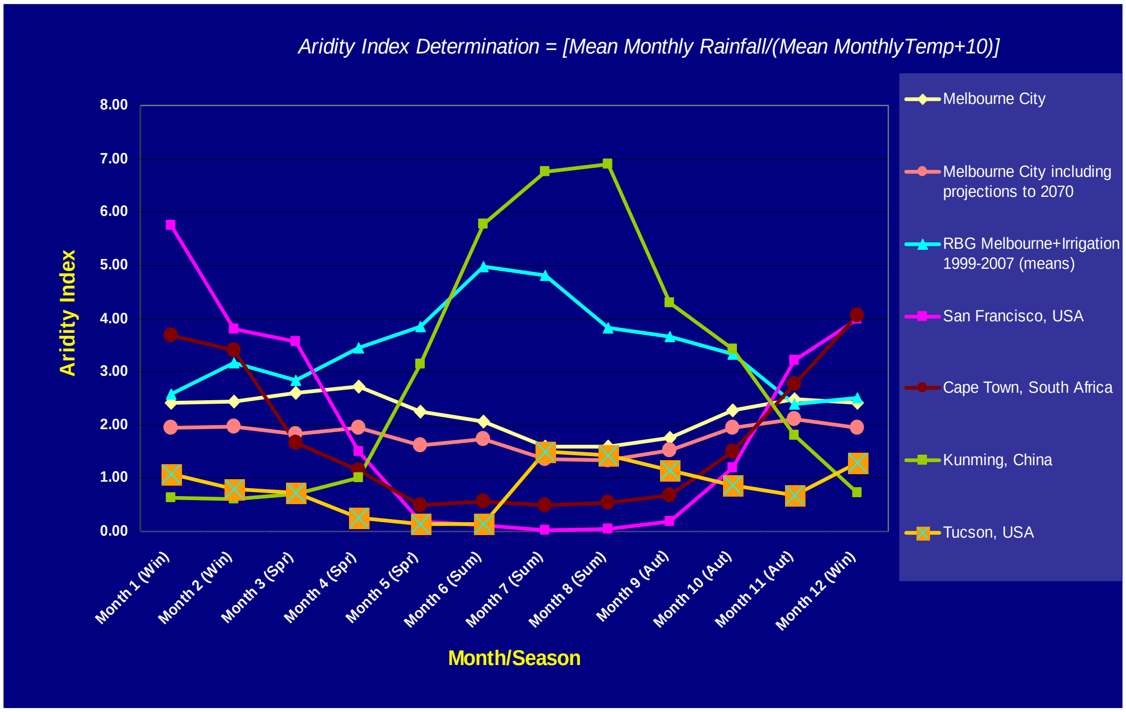


Figure 10 Climatic assessments (Aridity Index)



(Month 1 is equivalent to July ((winter)) in Melbourne.)

Figure 11 Guilfoyle's Volcano Project – long-term, climate suited collections