CLIMATE CHANGE ALLIANCE of BOTANIC GARDENS

Landscape Succession for ‘Climate Ready’ Botanic Gardens

A LANDSCAPE SUCCESSION TOOLKIT

>

Contents

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Foreword

In 2016, Royal Botanic Gardens Victoria (RBGV) launched their pioneering Landscape Succession Strategy to guide the transition of Melbourne Gardens living collections through the impacts of future climate change, diminishing water supplies and ageing tree populations. Global interest in the Strategy grew, with invitations to present at international conferences and forums. By 2018, the growing momentum prompted RBGV's hosting of the inaugural Climate Change Summit, bringing together 13 like-minded botanic gardens and network organisations who declared that 'the time for action is now.' The Climate Change Alliance of Botanic Gardens was founded at this meeting.

One of the first actions of the alliance was to develop a toolkit for use by all botanic gardens to build their own strategic responses to climate change, regardless of their organisation's capacity or extent of their living collections.

In October 2019 the toolkit was presented at a workshop at the Botanic Gardens Australia and New Zealand (BGANZ) congress in Wellington, New Zealand. The workshop was so well received that all 30 draft copies disappeared! It was clear that botanic gardens were in immediate need of support to start the journey of adapting their gardens to a changing climate.

BGANZ, as a network that is founded on collaboration and partnerships, recognised the eagerness of gardens to act, and has funded the publication of this toolkit in support of the ongoing work of the Alliance.

Chris Russell
BGANZ President
June 2022

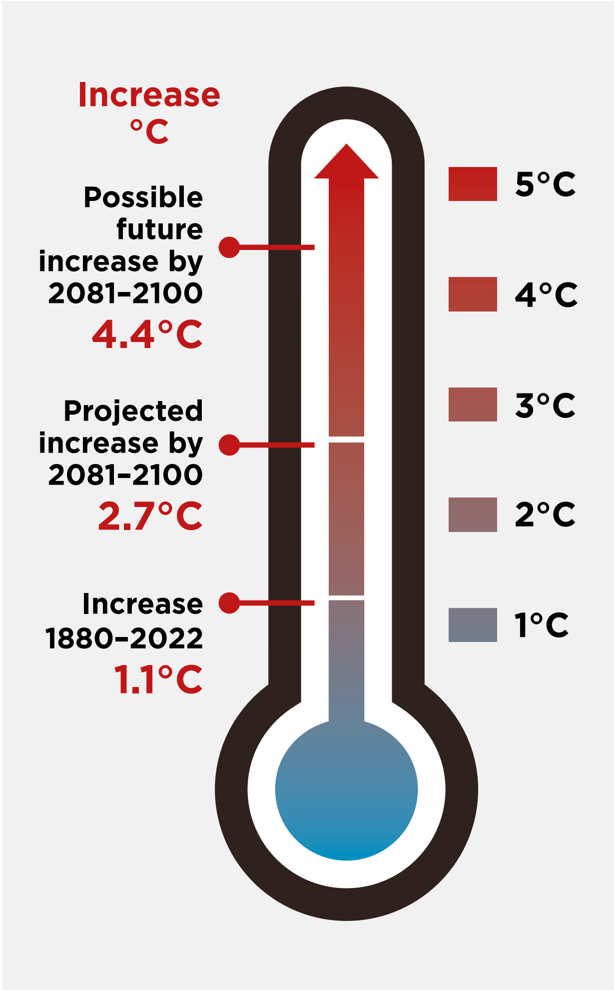
'One of the first actions of the alliance was to develop a toolkit for use by all botanic gardens to build their own strategic responses to climate change.'

1 Executive summary

Risks

Global surface temperature is estimated to have increased by 1.1 °C for the decade of 2011–2020 compared to the reference period of 1850–1900. Future projections suggest that if emissions of greenhouse gases can be constrained, land surface temperature may still increase by an average 2.7 °C by 2081–2100 but could increase as much as 4.4 °C for the same period if there is no mitigation of emissions (Arias et al., 2021).

It is likely that most plant species will not be able to adapt to survive these changes in the relatively short time available in most landscapes, especially when other factors such as habitat loss, invasive species and other human-mediated activities are also involved.



This presents enormous challenges to the managers of botanic gardens and arboreta around the world, who need to make decade-scale management decisions for long-lived species that will likely be exposed to a different climate future. These decisions could result in losses of rare and threatened plants, reductions in plant diversity and diminished landscape values if the impacts of the changing climate are not considered.

To minimise such risks, urgent action is required by gardens and arboreta to adapt their landscapes to climate change.

Goal of this toolkit

Our goal is to help botanic gardens and arboreta around the world adapt their landscapes and living collections in response to climate change. To do this, we have created a landscape succession toolkit containing content for developing strategies and actions for developing site-specific landscape adaptation plans.

This will help in managing the transition of a cultivated landscape to one that is dominated by plants more likely to be resilient under the projected climate for that landscape, while maintaining high botanic values and the desired landscape character. This toolkit is also relevant to parks and broader landscape management and can be used by all to support action and change.

Strategies and actions

We have developed the following strategies and identified accompanying actions to achieve this goal (see figure over page). These are applicable to any botanic garden, arboretum or other managed landscape around the world. The strategies are to:

1. Develop an understanding of climate change – starting now
2. Identify the risks to the organisation
3. Prioritise species selection for those at less risk from the future climate[1]
4. Collaborate and develop a diversity of partnerships
5. Adopt adaptive management and continuous improvement.

These strategies can then be used by individual gardens and arboreta to develop their own site-specific landscape succession or adaptation plan. To guide the creation of such a plan, we have included a proposed outline and suggestions for developing its content.

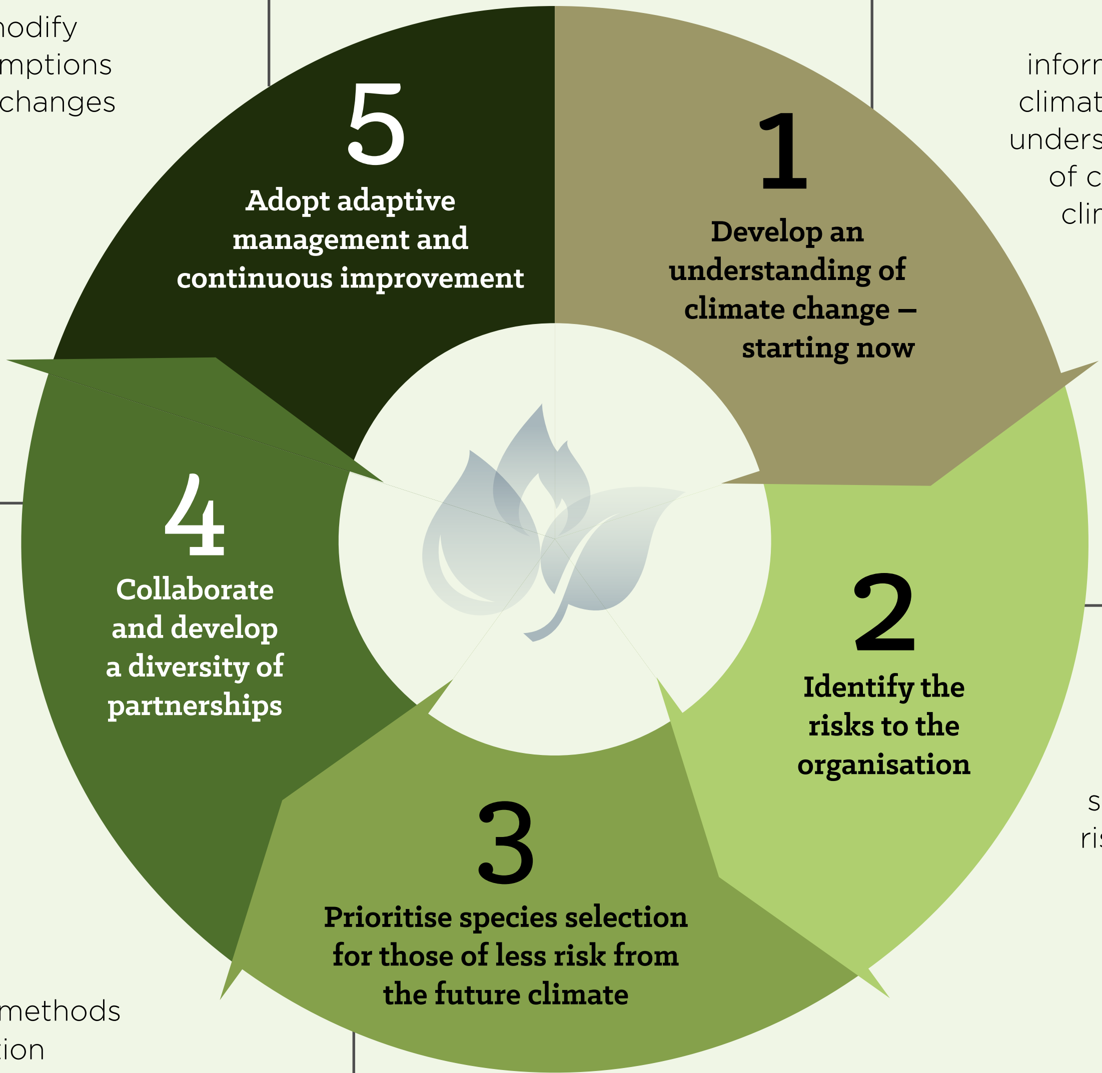
Above: Potted Christmas Island Fern *Pneumatopteris truncata* growing at the Australian National Botanic Gardens nursery nine months after spore germination.

Photo: Fanny Karouta-Manasse, Parks Australia.

1 Note that it is also important to identify species at risk and undertake protective actions – especially for species of conservation importance.

Action:
continuously modify plans and assumptions in response to changes

Actions:
collect baseline information on current climatic conditions and understand the impacts of climate change on climate variables for your site



Action:
engage with others

Action:
assess the significance of the risks of a changing climate to the organisation

Action:
use predictive methods for plant selection

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2 Introduction

'Climate Change is happening now. As a consequence, the issues our world faces are unprecedented and borderless. The world's botanic gardens are custodians of critically needed scientific and horticultural knowledge, and their landscapes a source of inspiration, learning and a place for positive social change.'

Declaration at the Climate Change Summit,
Royal Botanic Gardens Melbourne, December 2018

This toolkit can be used as a blueprint or starting framework for developing site-specific landscape adaptation plans.

This landscape succession toolkit was created by the Climate Change Alliance of Botanic Gardens (CCABG) to support climate action that protects and improves the resilience of botanic landscapes[2] and living collections. The goal of the toolkit is to guide organisations in developing their own climate adaptive landscape strategies through a step-by-step process.

There are gaps in our current knowledge of how botanic gardens and arboreta can prepare for, adapt to, and manage climate change (Symes, 2017). The focus of this toolkit is to help address these gaps, so that gardens and arboreta have a better understanding of the actions required. This toolkit does not directly deal with more sustainable management practices such as carbon-neutral schemes, low-carbon infrastructure and services, renewable energy, recycling and waste minimisation, as adequate information and examples of best practice are already available.

However, effective strategic planning for landscape succession will readily link to concerns such as sustainability. Implementation of the adaptation and succession plans is likely to improve the overall sustainability of an organisation. For ideas on how to make the infrastructure of your botanic garden sustainable and environmentally friendly, and the steps you can take to mitigate climate change, see climatetoolkit.org.

2 'Botanical landscapes' and 'botanic gardens' in this document refer to both botanic gardens and arboreta.

Climate change impacts can have the potential to increase the duration, frequency and severity of natural disasters such as fires, floods and storms. For ideas on how to prepare for such events, mitigate the damage and expedite recovery, see the BCGI Technical Review: The susceptibility of botanic gardens, and their responses, to natural and man-made disasters (Gratzfeld et al., 2021).

Substantial content for the toolkit is sourced from the learning in preparing the Royal Botanic Gardens Victoria's (RBGV) Landscape Succession Strategy – Melbourne Gardens 2016–2036 (LSS) (RBGV, 2016) and subsequent development of expertise within the CCABG.

The model for 'landscape succession' is borrowed from a living system of plant succession, that is, changes in the composition and structure of vegetation communities over various temporal scales following a disturbance threshold (Pickett et al., 1987; Serra-Diaz et al., 2015; Walker and Wardle, 2014).

For botanic gardens, landscape succession can be understood as:

'A managed transition of current landscapes towards those that are dominated by plants more likely to be resilient under the projected climate yet maintaining high botanic values and desired landscape character.'

'Landscape succession' is a management objective that is never finished, and continuous improvement is one of the strategies for effective landscape succession.

The Maze Garden at the Morton Arboretum, Illinois, US.

Like living systems, landscape succession should be approached as a continuous adaptive process and not as a static outcome.

3 Background

‘The last time it was four degrees warmer, there was no ice at either pole and sea level was 260 feet higher than it is today.’

Peter Brannen, The Ends of the World: Supervolcanoes, Lethal Oceans, and the Search for Past Apocalypses

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) will be completed in late 2022. Initial releases by the working groups highlight that human influence on the climate system is conclusive and recent climate changes have had widespread impacts on both human and natural environments. When measured globally, the combined land and ocean surface temperature show a warming of about 1.1 °C over the period from 1880 to 2022 (Pörtner et al., in press). However, of particular relevance for land plants, it should be noted that not all global warming is equal. A recent IPCC draft special report highlights (with high confidence) that following the pre-industrial period (1850–1900), ‘land surface air temperature has risen nearly twice as much as the global average temperature’ (land and ocean combined) (IPCC, 2019).

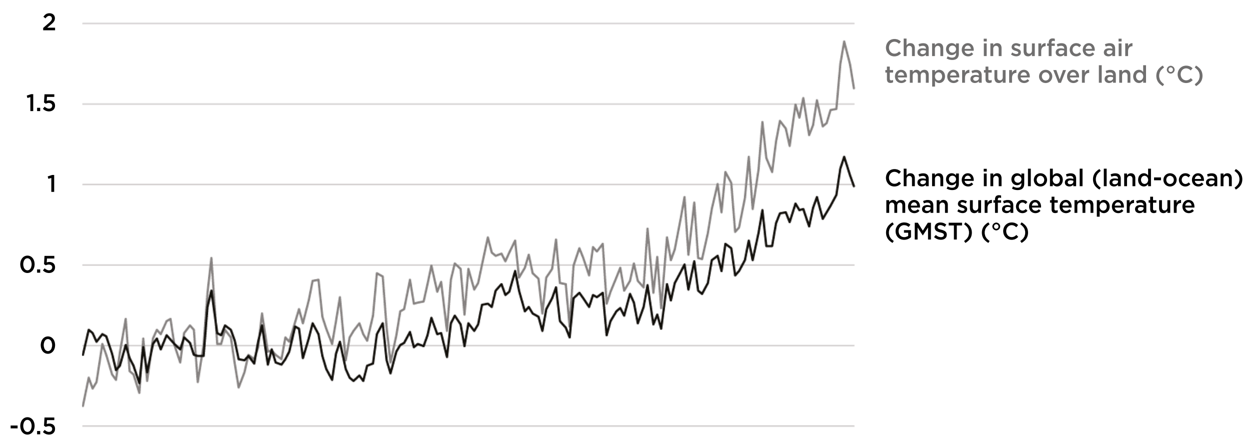

Figure 1: Change in temperature relative to 1850–1900 (°C)
Since the pre-industrial period (1850–1900) the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST).
From IPCC (2019)

Relative to the reference period of 1850–1900, future projections suggest that by 2081–2100 the global mean surface temperature is likely to increase by 2.1–3.5 °C under a SSP-4.5 scenario (intermediate emissions)[3], whereas under a SSP5-8.5 scenario (very high emissions) the temperature is projected to increase to between 3.3–5.7 °C (Arias et al., 2021). For both scenarios, an increase in the frequency and intensity of heat waves is projected and these conditions may also be compounded by drought affecting more areas of the world than typical. Most land regions are also expected to experience more intense and frequent precipitation events. In tropical regions, cyclones are projected to be more powerful and deliver significantly higher rates of precipitation.

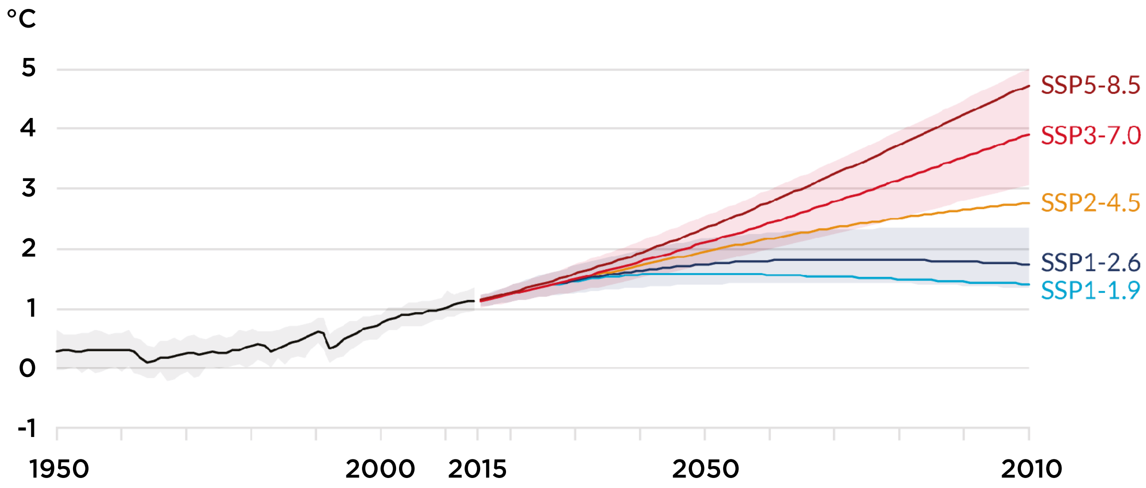

Figure 2: Global surface temperature change for five scenarios (central estimate solid, very likely range shaded for SSP1-2.6 and SSP3-7.0), relative to 1850–1900. From Arias et al. (2021)

A *Banksia* cone with open seed pods after a bushfire. Photo: Rebecca Harcourt

3 Shared Socioeconomic Pathways (SSPs). For more details see The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview (Riahi et al., 2017).

The Climate Change Alliance of Botanic Gardens

During 3–6 December 2018, in recognition of the climate change threats posed to living landscapes and plant collections, RBGV hosted the Inaugural Climate Change Summit in Melbourne, Australia of 13 like-minded botanic organisations from around the world.

These organisations established the CCABG through the 'Melbourne Declaration'.

During the summit, it was clear that the complexity and scale of addressing climate change requires global collaboration with a rich diversity of expertise – qualities that are intrinsic to the botanic gardens network (Symes and Hart, 2021). This toolkit is one product that is expected to support the wide capacity of botanic gardens for advocacy and protection of plant life that is so essential for the planet and its people (Smith, 2019).

The Melbourne Declaration states:

'...to safe-guard life by protecting landscapes' and '...the time for action is now.'

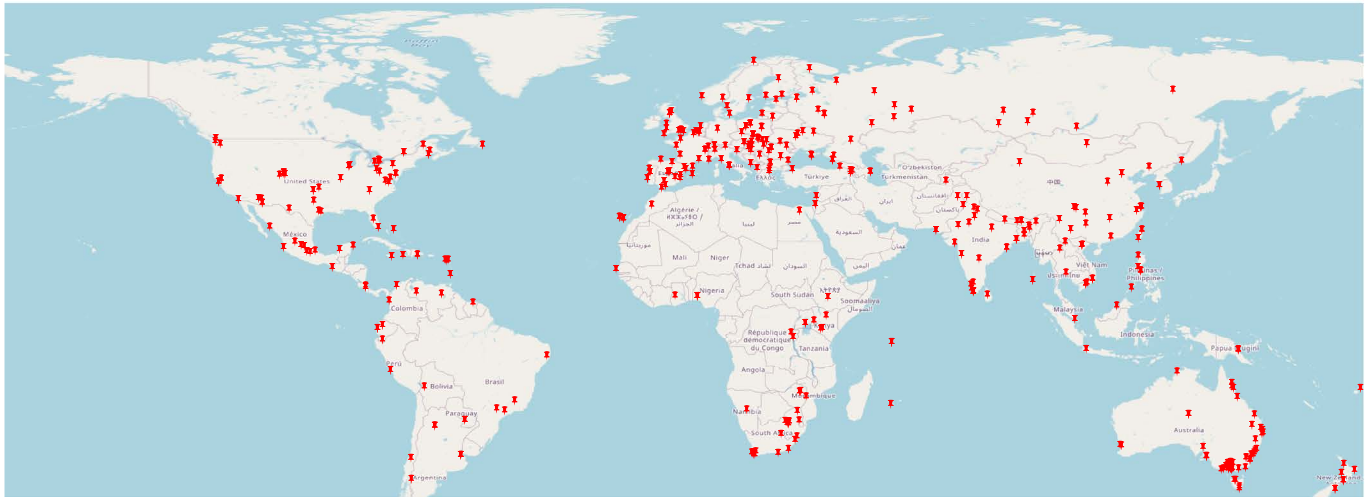

Figure 3: CCAGB members as of 5 July 2022: 499 founding partners, members, associates and supporters in 97 countries. Image: David Cash, RBGV

4 What are the risks?

'In the next 50 years, 20–50% of current plant species in botanic gardens and urban landscapes will likely confront temperatures those species have never experienced before.'

Dr Dave Kendal,
Senior Lecturer in
Environmental Management,
University of Tasmania

It has been estimated that over 20% of the world's plants are threatened with extinction. Much of this is due to habitat loss, invasive species and other human-mediated activities but climate change brings another threatening process to the fore (Pimm and Raven, 2017). The IPCC (2014b) outline indicates (with high confidence) that biodiversity richness faces significant threats to survival from climate change, and as quoted with special reference to plants, 'A large fraction of species faces increased extinction risk due to climate change during and beyond the 21st century, especially as climate change interacts with other stressors.' Even if global warming can be limited to 1.5 °C (which is only 0.4 °C above current levels) compared to pre-industrial levels, it is estimated that 8% of plants could lose half their climatically defined geographic range – this loss doubles if warming is actually 2 °C (IPCC, 2018). One study of 50,000 plant species suggested that 57 +/– 5% of these plants could lose over half their climatic range for a warming of approximately 3.6 °C above pre-industrial levels (Warren et al., 2013).

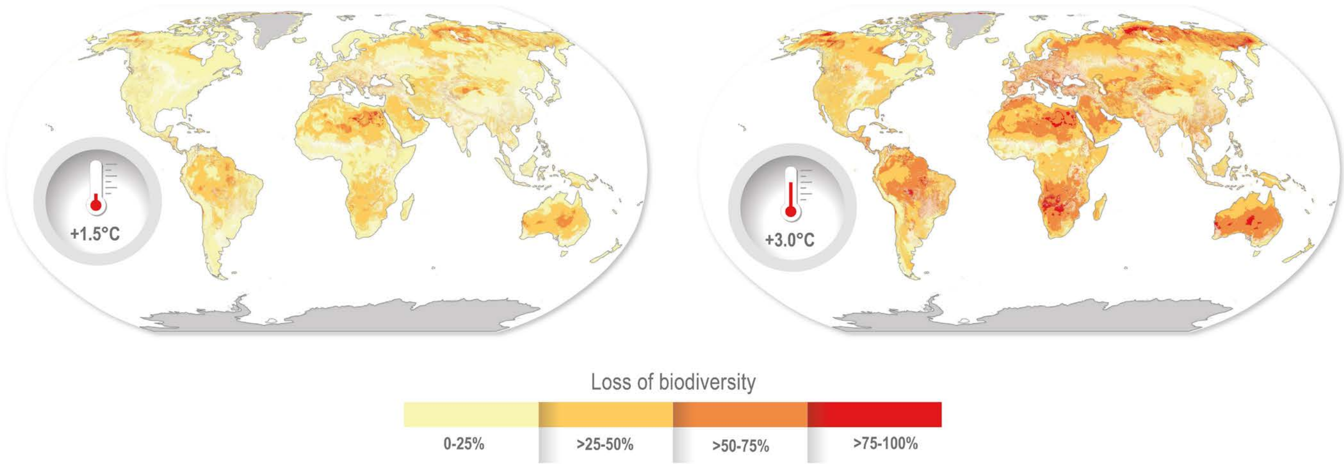

Figure 4: Biodiversity loss at different warming levels (Pörtner et al., in press)

Burley et al. (2019) report in Australia that under six different climate scenarios for 2030 and 2070, climatically suitable habitat would be reduced for 73% of urban trees that were studied. For 18% of these species there would be a greater than 50% reduction in climatic range. Urban areas face risks from air pollution, drought and water scarcity, additional heat stress, intense rainfall and storms, flooding and landslides. Risks such as these will likely impact people, assets and infrastructure, economies, ecosystems and natural systems (Pörtner et al., in press). These compounding factors present vast challenges for managers of botanic landscapes who need to make immediate decisions for decade-scale outcomes – decisions such as planting a tree, introducing new landscapes or plant collections, and planning plant conservation programs. Decisions like these are especially difficult to make, as responding to these changes can be like trying to hit a moving target. At a landscape level, this can result in losses of rare and threatened plants, reductions in plant diversity and diminished landscape values.

Some research indicates that the correlation between temperature and both natural and urban plant distributions is stronger than with precipitation (Jenerette et al., 2016; Kendal et al., 2018). Others have correlated tree losses with changes in temperature zones linked to urban heat and global warming (Lanza and Stone, 2016). A rise in mean temperatures also increases the probability of more extreme heat (Lewis and King, 2017) and associated heatwaves (Perkins-Kirkpatrick and Gibson, 2017), which have caused worldwide forest mortality especially when combined with droughts (Allen et al., 2015; Ruthrof et al., 2018).

RBGV commissioned research by Kendal and Farrar (2017) who found that around 25% of the current taxa in Melbourne Gardens will be at most risk of decline or death from the projected Mean Annual Temperature (MAT) of 19.3 °C under a RCP[4] 8.5 (business as usual) climate scenario by 2070. For comparison, the current MAT is 15.9 °C (RBGV, 2016).

4 Representative Concentration Pathways (RCPs). See https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html for more details.

'Most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change in most landscapes…(high confidence)' IPCC, 2014b

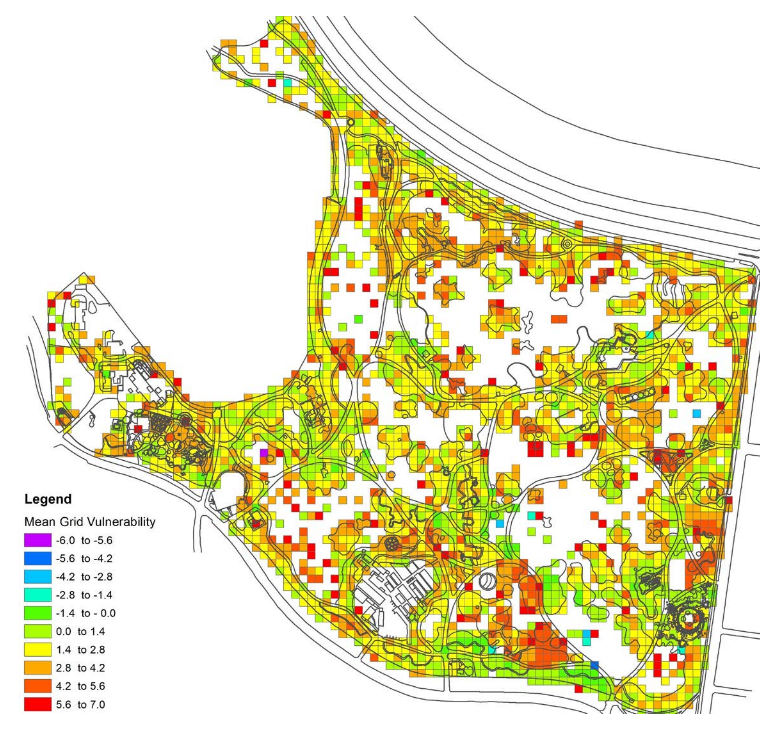

Figure 5: Plant vulnerability to climate change as shown via a gridded matrix in Melbourne Gardens, RBGV. 26% of species were considered least suitable for the projected 2070 climate under a high emissions scenario.

Map: Peter Symes. Data source: Kendal and Farrar (2017)

5 Benefits of landscape succession

> ‘Someone’s sitting in the shade today because someone planted a tree a long time ago.’
>
> Warren Buffett

The benefits of landscape succession planning (or landscape succession) are wide-ranging and could lead to unexpected advantages that are specific to each organisation. Some key benefits are discussed in detail below.

1. Plant conservation: protecting rare and threatened plants

Collectively, botanic gardens hold about 30% (around 106,000 species) of the world’s known plants. They contain 41% of threatened species through ex situ conservation, although there are significant collection gaps in plant groups, such as tropical species (Mounce et al., 2017).

An improved understanding of the risks posed to vulnerable plants in your collection assists the prioritising of further actions. If plants are at risk from climate change impacts, steps can be taken to protect these species, such as transferring duplicates or the entire collection to another, more suitable site.

Remember, you are part of a network of over 1775 botanic gardens and arboreta in 148 countries around the world (BGCI, 2016) and at least one of those sites may be suited to ex situ conservation of these plants. Further, even cultivating and monitoring the health of climate-susceptible species can be used to inform plant conservation initiatives in their countries of origin. The realisation of future climate conditions may also provide opportunities for botanic gardens to grow and display rare and threatened species that could not be curated previously. For example, RBGV commissioned a worldwide assessment of around 20,000 rare and threatened taxa. From the 12,145 taxa (60%) that were able to be assessed, almost 3,000 taxa were indicated as potentially suitable for cultivation in Melbourne by 2070 under a ‘business as usual’ climate scenario (Kendal, 2017). The cultivation and display of rare and threatened species in living collections provide a basis for research and monitoring, and for raising the community’s awareness about threats to plant biodiversity.

2. Informs integrated management

A focus on the impacts of climate change coupled with long-lived living assets demands a strategic perspective to landscape management – highlighting the need to practice precautionary principles and stewardship. Landscape succession planning provides an integrated framework or 'line-of-sight' between other organisational plans to respond to the changing climate, inform design development, support decision-making, and incorporate the cultural, educational, recreational and scientific roles of botanic gardens and arboreta. It is important that landscape succession plans are integrated into other management plans and policies of your organisation.

In practice, landscape succession planning allows you to identify and understand your management gaps, such as climatically unsuitable species, and can effectively address targets for improvement such as:

- plant conservation programs
- integrated water management
- human health and wellbeing
- plant assessment and selection
- biosecurity of botanic landscapes
- carbon sequestration
- environmental cooling
- research programs to inform management
- habitat for urban biodiversity
- landscape infrastructure.

Azorella macquariensis Macquarie Cushion, endemic to Macquarie Island, is the keystone species of the plateau uplands, or feldmark, which covers 45% of the Island. In 2008/09 an Island-wide dieback of *A. macquariensis* emerged, resulting in substantial and continuing loss. Since 2009 a multi-agency collaborative taskforce has been involved in the conservation of this species, involving the Tasmanian Parks and Wildlife Service, the Australian Antarctic Division, Natural Values Conservation Section of NRE Tas and the Royal Tasmanian Botanical Gardens.

This image shows the containerised *A. macquariensis* seed orchard on Macquarie Island.

Image: Andrea Turbett

3. Environmental improvements and urban greening

Nature-based (or in a botanical context, ‘plant-based’) solutions (Marselle et al., 2019a) have been used for more sustainable urban development, such as:

- increasing plant density in urban centres to support human wellbeing (Shanahan et al., 2015)
- landscape carbon storage (Webb, 2014)
- providing natural cooling against temperature rise (Ellison et al., 2017)
- provisioning habitat for urban biodiversity (Marselle et al., 2019b)
- reduction of noise and filtering of pollution (Haase et al., 2014)
- the application of ‘green infrastructure’ to reduce damage from flooding and stormwater run-off (Livesley et al., 2016).

The role of green space in cooling the urban environment by evapotranspiration and direct shading has been the particular focus of a substantial number of studies, as outlined by Symes (2017). Trees that transpire 100 litres of water per day have been equated to the cooling capacity of 70 kWh or the power of two residential air conditioners (Ellison et al., 2017). The cooling capacity of larger trees can theoretically exceed these levels several times over.

Preparing for future climates means effective landscape succession will continue to provide plant-based solutions for local, regional, national, and global arenas.

A living, or green, roof planted with a variety of succulents in the Potter Children's Garden at Auckland Botanic Gardens. A green roof is a way to capture rainfall as well as helping to cool its environment.
Photo: Auckland Botanic Gardens

4. Enhance human wellbeing: supporting overall physical, mental and social health

Evidence continues to build on the essential provision of nature and landscapes in supporting people's wellbeing (White et al., 2019). The urbanisation of populations around the world is reducing the availability of green spaces for communities (Cavender et al., 2019). Subsequently, there is a need to enhance plant density in urban centres (Shanahan et al., 2015). This likely increase in urban grey infrastructure and additional stresses from issues such as increased noise, heat waves, pollution, and social isolation (Marselle et al., 2019b), highlights the important role of biodiversity and living landscapes in urban centres to support the physical, psychological and social health of people (Marselle et al., 2019a; Sandifer et al., 2015). Of particular relevance to botanic gardens and their intrinsic plant diversity, some evidence suggests a connection between greater biodiversity (including plant richness) of green areas and an associated increase in psychological benefits (Aerts et al., 2018; Carrus et al., 2015; Fuller et al., 2007; Hand et al., 2016)

Through existing botanic and horticultural expertise, and developing capacity in landscape succession, botanic gardens and arboreta can continue to contribute to resilient urban greening (Cavender et al., 2019) and provide services for human wellbeing (Carrus et al., 2017; Krishnan and Novy, 2016).

Sustaining botanical landscapes in the face of climate change not only continues to provide health benefits. These assets also tangibly demonstrate the vital connections between plants and the ongoing survival of humanity.

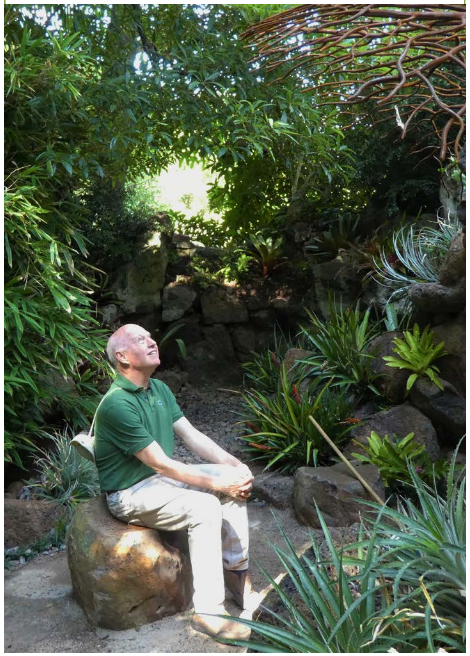

Photo: Peter Symes

5. Building scientific knowledge, professional development and community learning

Botanic gardens provide unique contexts for climate change research with:

- site-based, but geographically diverse plant holdings
- managed plant environments
- documentation from long-term monitoring and environmental modification of gardens and their associated living collections which often spans decades
- professional networks
- a body of considerable staff expertise (Primack and Miller-Rushing, 2009).

In botanic gardens many plants are readily grown outside their natural range. This can demonstrate the 'fundamental niche' (Booth, 2017) or the potential of a given species to grow beyond its natural distribution when competition and other inhibitory factors are removed (Bush et al., 2018). This may also be artificially supported by practices such as irrigation.

Living collections in botanic gardens have arguably untapped capacity to provide information to:

- improve models of potential plant distribution
- develop better predictions of species that are most at risk of extinction
- inform plant conservation programs.

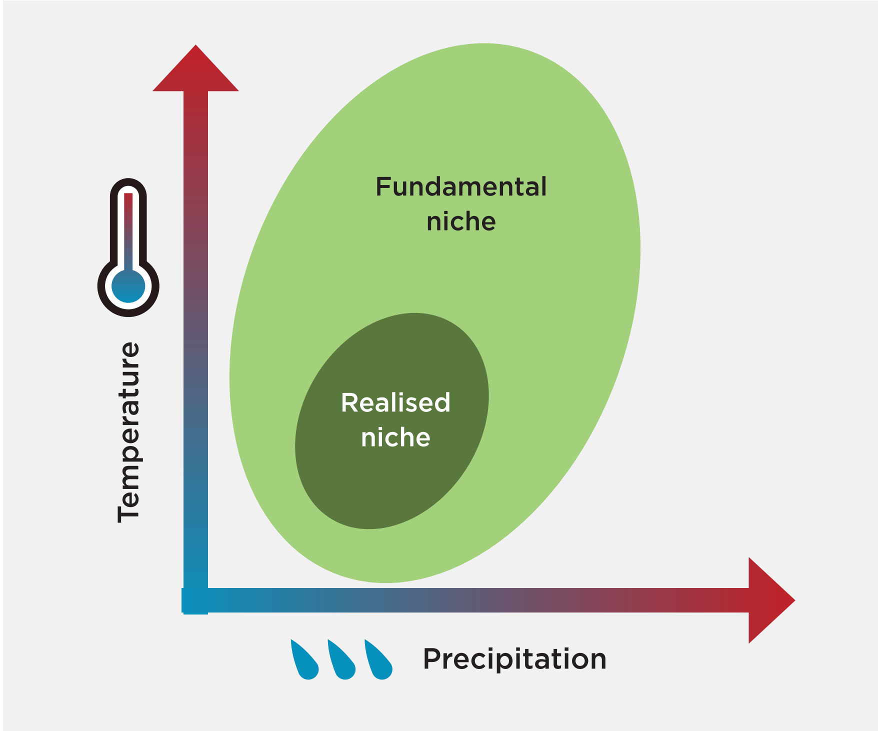

Figure 6: A simple example of a species' environmental envelope – mapped to axes of temperature and precipitation. Cultivation practices such as in a botanic garden may allow a plant to grow under warmer and drier conditions (fundamental niche) compared to what occurs in its natural habitat (realised niche).

Peter Symes (concept figure)

A changing climatic environment brings profound learning challenges but also opportunities for grappling with increased complexity, gaps in knowledge and an abundance of information systems to help stimulate creativity and innovation. For example, implementing landscape succession at Melbourne Gardens led to:

- improved strategic planning
- fine-tuned database management
- improved accuracy of plant records
- the development of better techniques to estimate plant growing environments.

Botanic horticulturists at RBGV have been active in suggesting innovative methods to improve living collections curation. They have expanded their professional skills through staff scholarships (including technical expeditions to other countries), presenting on landscape succession to both professional and public forums. The managing of living assets through climate change brings a focus to better systems, techniques and skills.

The Climate Change Alliance of Botanic Gardens is an ideal model of landscape succession. It has galvanised a botanical community and the professional capacity of this community to tackle climate change threats to living collections and botanical landscapes.

International participants sharing experiences with RBGV horticulturists at the Climate Change Summit in December 2018. Photo: RBGV

6. Mobilising support and funding for botanic landscape and living collection development

The production of a readily identifiable strategy with clear targets in response to climate change can catch the interest and imagination of the broader community. In the Melbourne Gardens experience, the RBGV Board has made responding to climate change one of the key pillars of the organisation.

International staff scholarships for collections development at RBGV have been supported by Friends groups and philanthropic donations. Further, and perhaps unusually (at least in Australia), private funding has also been provided for desktop analyses and technical reports that support landscape sustainability into the future.

For the RBGV, substantial philanthropic funding has made possible collecting expeditions – on a scale not seen for over 20 years – to improve the botanic value and resilience of living collections.

In Victoria, Australia, the State Government has recently made available substantial funding for regional botanic gardens that includes improving their climate change adaptation and resilience. Significant funding has also been partitioned for infrastructure improvements such as more efficient irrigation systems.

Having a climate adaptation plan already in place can aid your own efforts in securing funding to undertake the necessary work.

Summary of benefits

Developing and implementing your own climate change response will ensure you can continue to provide the benefits of your botanic gardens for future generations through more resilient, sustainable landscapes and protection of vulnerable plants. The non-limitative benefits of landscape succession include the following:

- ✔ integrated and intergenerational planning
- ✔ raised community and socio-political profile
- ✔ increased opportunities for funding and resources
- ✔ improved plant conservation
- ✔ continued provision of environment and habitat
- ✔ reduced operating costs
- ✔ better employee skills and organisational capacity
- ✔ enriched collaboration, partnerships and expertise transfer
- ✔ enhanced research, techniques and systems.

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6 Strategies for effective landscape succession

‘Act as if what you do makes a difference. It does. ‘

William James

We must act now. The need to respond is urgent due to constant and inevitable climate shift. Decade-scale management choices are required for long-lived species that will likely be exposed to a different climate future. Mobilising now to understand climate change risks to botanical assets will undoubtedly uncover information and practices to enable:

- better informed decision-making
- improved landscape planning
- more resilient living collections.

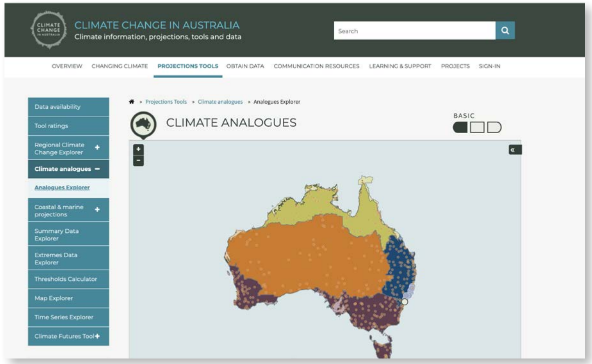
Everyone can make a difference, regardless of organisational capacity. Being personally agile means that improvements can always be made to improve your organisation’s resilience and climate change readiness.

Royal Botanic Gardens Victoria developed the technical content of its Landscape Succession Strategy mostly through its own horticultural staff – there was no expenditure on consultants or external studies to inform its creation.

1. Develop an understanding of climate change – starting now

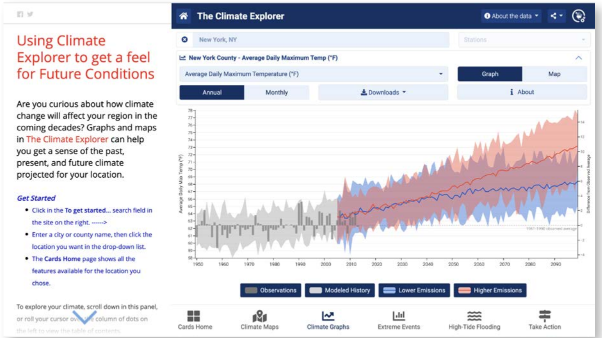
Action: Collect baseline information on the current climatic conditions

To obtain sources of data for current and historical climatic conditions, many countries have meteorological or equivalent organisations such as weather bureaus, climate observatories or climate centres. Some botanic gardens will be collecting their own site-specific records or even manage weather stations. If local climate data is not readily accessible, then the World Weather Information Service (operated by the World Meteorological Organization) is a useful website to access temperature and precipitation data for many localities around the world. Mean temperatures can be simply calculated as an average value from the mean minimum and maximum temperatures that are provided.



It is vital to become familiar with the future shifts that may occur from climate change and how these could impact the health of your living landscape and sustainability of your organisation. To support building your knowledge, there are diverse online resources that are freely available for informing management practices. Australia has useful tools and reports available through the Climate Change in Australia website, including the Analogues Explorer that provides reports based on simulations of various climate scenarios.

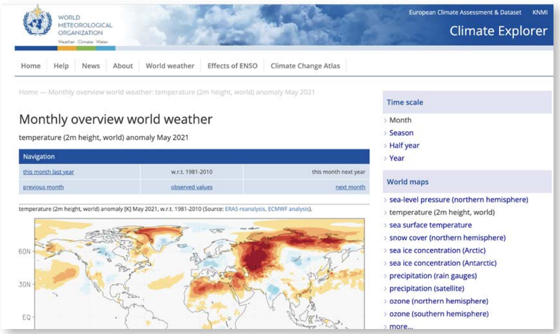
Other countries may have comparative resources specific to their region, especially those with access to more resources. The USA has comparative online products to Australia with user-friendly products online via its U.S. Climate Resilience Toolkit/the Climate Explorer webpage.



Ask your colleagues or nearby gardens for advice as well as checking the internet. You may be surprised at what is available.

If your location does not have a national set of tools, then there are still resources available to estimate changes in temperature, rainfall and other climatic variables.

The KNMI Climate Change Atlas is an online tool that is based on the physical science of the IPCC Fifth Assessment Report (WGI AR5) and provides maps and time series. A user can plot simulations of climate change scenarios for a range of variables such as evaporation, precipitation, relative humidity, solar radiation, and minimum, mean and maximum temperature.



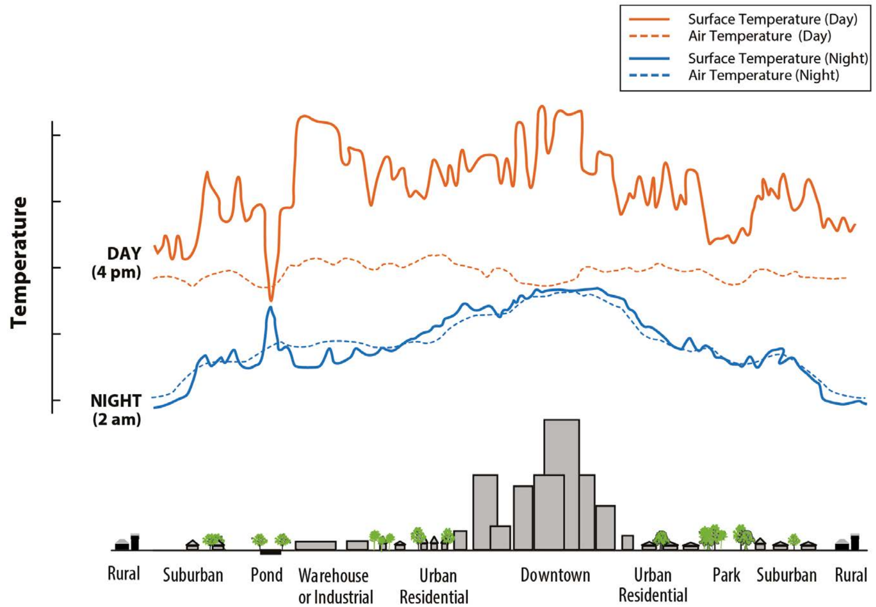
The Intergovernmental Panel on Climate Change has provided resources arising from the IPCC Sixth Assessment Report that include summary fact sheets for regions around the world. See www.ipcc.ch/report/ar6/wg1/resources/factsheets

Note that large-scale global climate change projections do not typically factor in the urban heat island effect (Oleson et al., 2018; Sachindra et al., 2016; see box). In addition, while changes over urban and nearby rural environments can be similar, the absolute climate is often significantly warmer in the urban setting, such as more days above 35 °C, and warmer nights (above 25 °C; D. Karoly, pers. comm., 5 August 2019). As many botanic gardens are in urbanised areas, you will likely need to consider the impact of this amplifying risk of higher temperatures and temperature extremes upon your landscape and organisation's operation.

The urban heat island effect

Urbanised areas can be warmer than surrounding rural areas. This is known as the urban heat island (UHI) effect. This UHI effect is due to factors such as the prevalence of heat-absorbing hard surfaces, greater density of buildings, higher heat generating activity and less cooling vegetation compared to rural and natural areas.

See www.epa.gov/heatislands/learn-about-heat-islands for more details.



From www.epa.gov/heatislands/learn-about-heat-islands

Action: Understand the impacts of climate change on climate variables for the site

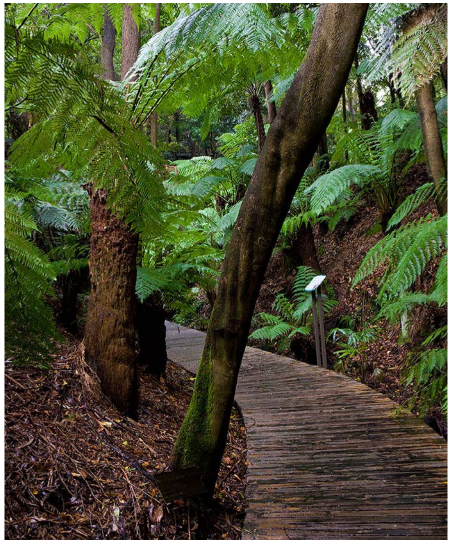
A key question is what are the subsequent changes to rainfall and temperature under selected climate change scenarios?

The range of climatic parameters and their seasonality influences the plant environment in complex ways: precipitation, relative humidity, solar radiation, temperature and wind are key parameters. Even small changes to these factors can interact to influence key processes. For example, a reduction in relative humidity combined with increased solar radiation and wind speed could result in significantly higher landscape evapotranspiration.

For landscape management, at least understanding Mean Annual Temperature (MAT) and Mean Annual Precipitation (MAP) is valuable for comparing climate baselines. Changes to temperature are one of the most difficult to manage in landscapes and should be prioritised for site responses and informing plant selection. Changes to precipitation are relevant as these may impact stormwater run-off and irrigation demand of collections. Preferably, you should also develop an understanding of potential seasonal shifts in these and other environmental variables as these can lead to profound differences. For example, in Melbourne, winter/spring rainfall is projected to be 19% less under future climates (Grose, 2015) and this can have a substantial impact on stormwater harvesting schemes for irrigation.

Using landscape microclimates to modify the plant environment is mainly limited to manipulating soil conditions, and exposure to solar radiation and wind. Research commissioned by RBGV indicates it is difficult to reduce MAT within the landscape by this approach, apart from modifying daily temperature extremes and this is often confined to very select sites (Lam et al., 2016; Symes, 2017).

Other changes, for example, may predispose your garden and arboreta to greater risks from flooding, high temperature extremes (or even low temperature extremes for some gardens), sea level rise and wind damage, and at less typical times of the year. These issues can compound other threats such as promoting conditions for new diseases and pests or worsening outbreaks of existing ones (Pautasso et al., 2015).



Top: The lush Rainforest Gully and boardwalks at the Australian National Botanic Gardens (ANBG).

Above: January 2020 – the littered Rainforest Gully at the ANBG after a hailstorm. Photos: Parks Australia

2. Identify the risks to the organisation

Action: Assess the significance of the risks of a changing climate to the organisation

Some investigation will likely be required to uncover these risks, and the enquiry could be informed by asking three simple questions (perhaps resulting in highly complex answers!).

Question 1: What plants are curated in the living collections and which ones are likely suited or not suited to future conditions?

Essentially, this involves carrying out an audit of your living collections against selected climate variables such as temperature and precipitation. The quality of this assessment relies on the accuracy of your plant census, plant identification and access to climate information. If your plant records are due for review, then action this as soon as possible. However, as this can be time-intensive, you may elect to work from what information is available and update this periodically. See also the approaches found in Section 6.3, *Prioritise species selection for those at less risk from the future climate.*

One challenging component is the availability of climate-linked data to include with the species assessment. In Melbourne Gardens, this was first approached by identifying plant distribution data with respect to Köppen-Geiger climate classifications[5] (Beck et al., 2018), defined by assumptions of

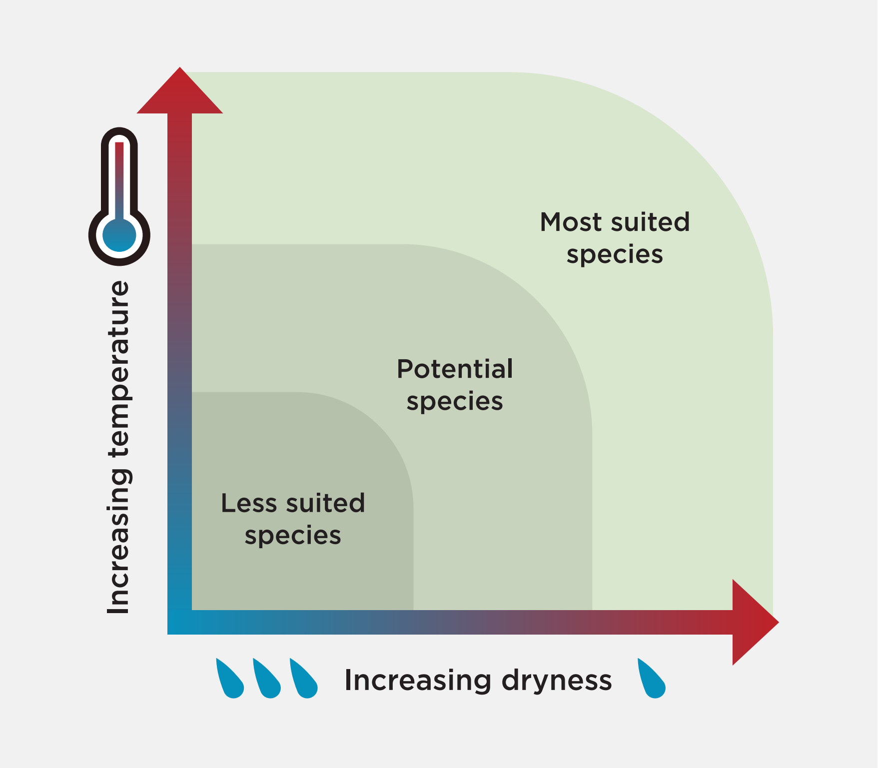


Figure 7: Plant selection under landscape succession

This schematic shows the future choices of plant selection that may be required under a warming and drying climate. Pending on the location, plants might need to be selected with tolerances to a warming and/or drying bias. For example, if the temperature increases, but moisture availability remains similar, then plant choices will come from 'bands' elevated along the y axis on this graphic.

Peter Symes (concept figure)

5 The Köppen-Geiger climate classification system divides the world into five climate zones based on local vegetation: A (tropical), B (dry), C (temperate), D (continental) and E (polar). Each zone is subdivided based on seasonal temperature and precipitation: the second letter indicates the type of seasonal precipitation and the third letter indicates temperature. See http://koeppen-geiger.vu-wien.ac.at/shifts.htm for more details.

future temperature and rainfall. By 2090, and under the RCP8.5 scenario, Melbourne's current Köppen-Geiger classification of 'Cfb' (C, temperate, f humid, b warm summer) is projected to shift to 'Cfa' or 'hot summer'. It was determined that 35% of taxa were 'less likely' suited to these 2090 conditions and that there was a substantial risk to manage (Symes, 2017). While such climate classifications are useful for identifying regions where suitable taxa are likely to be found, they are not a definitive indicator of suitability. For example, taxa that can tolerate an increase in heat may not be able to cope with a decrease in water availability. The expertise and familiarity with your collections that your horticulturists have will build upon these climate classifications.

Question 2: What existing management issues do we know about? How might these be affected by a changing climate?

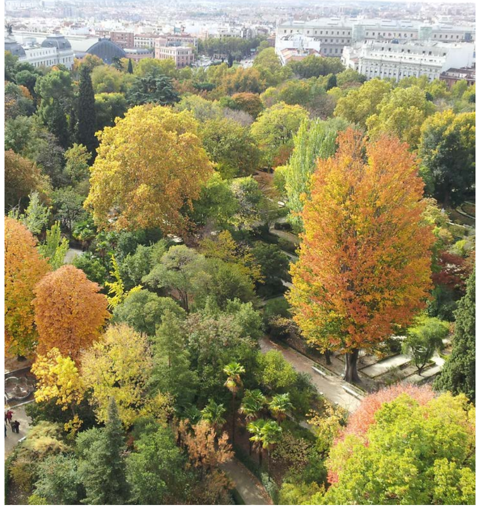
We have discussed the existing challenge of changing climatic parameters to your landscape. For example, effective water supply and security is an obvious issue for most (large) landscapes.

Some landscapes will have a dominance of mature and over-mature trees that are nearing the end of their useful life. If some of these plants are replaced with more climate-suited vegetation, what is your community and organisation's attitude to this and how will you engage them positively with the changes that may be required? Further, establishing new plants effectively in a mature landscape can be fraught with difficulty due to root competition, lack of available light and limited planting spaces. Complete renovations of areas may be required now for successful new plantings and collections.

However, while you may be aware of most existing management issues for your organisation, have these been tested against the impacts from the changing climate? For example, is increasing visitation causing more wear and tear on your lawns – how might this change in the future? Will the growth of cool-season grasses decline under increasing temperatures and/or will they require more intensive irrigation and other resources?

Could there be a magnitude change in visitation from people in an increasingly urbanised world seeking the wellbeing benefits of landscapes? In Melbourne Gardens, the projected visitation of 2.5 million visitors by 2036 in the LSS became close to realisation with about 2 million annual visitors in 2018!

The Climate Change Alliance of Botanic Gardens (CCABG) is developing a Climate Resilience Assessment Tool for plant assessment (CRAT) that provides a suite of climatic information and an indicative risk scale that will be available for CCABG members.



Real Jardín Botánico, Madrid.
Photo: Real Jardín Botánico, Madrid

Are there environmental issues on site that could become more difficult, such as higher rates of stormwater run-off (and carried pollutants), impacted water body quality, intrusion of salt water from rising sea levels, and increased dust and soil erosion? Can the existing infrastructure cope with the increased demands?

Managing existing pests or disease may become more intensive or new problems may arise. What about invasive plants – will some of your plants that are 'inclined to wander' become more unmanageable as they recruit more readily, or will completely new weeds appear?

New management issues may arise from interaction with existing ones and or can be compounded by impacts from the shifting climate. Where you can, these issues and risks need to be considered in your planning.

Question 3: Do we have future management challenges that we do not yet realise?

In Melbourne Gardens, one issue that came to light and was reinforced by a PhD study (Lam et al., 2016) was that some pathways are exposed to sunlight for long periods and the asphalt surface can emit high levels of sensible heat. The effect of future hotter conditions on visitors' thermal comfort was considered. As a solution, landscape planning proposes tree planting at key areas to provide shade and reduce this direct exposure for visitors but also to protect more vulnerable plant collections in some sites.

If you manage waterways, will an increase in temperatures favour blue-green algae (cyanobacteria) blooms or rampant water plant growth (macrophytes)? For low-lying sites, have you thought about future sea level rise and the associated risk of saline intrusion, and/or increasing storm frequency and intensity?

Top: The Gospers Mountain fire as seen from the front entrance of the Blue Mountains Botanic Garden Mount Tomah at 9 pm. This fire was one of many in Australia during 'Black Summer', December 2019–January 2020. Above: The Gospers Mountain fire as seen from the garden's deck two hours prior to impact. Photos: Blue Mountains Botanic Garden, Mount Tomah

During future heatwave conditions, maybe wildfires will enter urban and peri-urban areas and damage your botanical assets for the first time? Conversely, what is the risk of unseasonal or extreme cold events for your location that might damage your new warmer climate plantings?

Will future policy shifts in response to climate change or community values drastically change your access to resources such as reliance on groundwater supplies and/or river water for irrigation?

Access to plant genetic material is also becoming more complex due to concerns about invasive species and international developments in Access and Benefit Sharing (ABS) arrangements as under the Nagoya Protocol. Some countries have their own access legislation and the rights of traditional custodians are rightfully becoming more valued. How will you obtain new plant material in a timely manner under intricate legal and relationship arrangements, let alone navigate the layers of international quarantine for plant biosecurity?

Identifying future issues is probably best approached by organising dedicated workshops with peers and experts to canvass diverse perspectives so you can identify the relevant matters for integrating within your planning.

Victorian bushfires burned over 1.2 million hectares in the east of the State between late 2019 and early 2020, severely impacting both terrestrial and associated freshwater ecosystems such as this scene of the Genoa River.

(Godfree et al., 2021) Photo: Nick Clemann

Landscape succession: some examples of management challenges/risks and solutions

Challenge/risk	Possible solutions
Shifting climatic parameters	• document these changes and the strategic responses that are needed i.e. in a Landscape Adaptation/Succession Strategy • join the CCABG and other botanic networks for support.
Climatic extremes	• develop contingency and 'what if?' plans • give attention to the possible solutions in this table (and develop your own) to improve overall resilience.
Identifying plants at risk and suitable replacement species	• maintain your curiosity • make use of tools produced by the CCABG • engage your employee expertise and scientific experts • quantify the future temperature and precipitation requirements of your living collections. • protect vulnerable rare and threatened plants by duplicating or transferring material with your partners.
Water supply and security	• invest in professional development • identify required water demand and sustainable sources of water • reduce water demand i.e. via plant selection • develop landscape water-use efficiency programs.
Increasing visitation	• focus on turf selection, irrigation and soil management to prevent compaction/wear and tear • develop better control of pedestrian congestion points • provide spread of attractions and collections across the landscape to avoid concentrated intensity.
Established mature landscape	• identify taxa and landscape areas most at risk • staged matrix approach to tree replacements and bed renewal • community information and learning activities • demonstration garden areas to show that rejuvenation is a positive process • highlight wide opportunities to grow new plant species.

Landscape succession: some examples of management challenges/risks and solutions *continued*

Challenge/risk	Possible solutions
Pest and disease outbreaks	• maintain high genetic plant diversity • invest in continuous education • join the International Plant Pest Sentinel Network and take advantage of similar resources • develop relationships with local plant health authorities.
Invasive plants	• develop weed risk assessment and management policy and procedures • share observations with peers.
Limited access to new plant material	• develop your botanic garden network and examine what taxa are available nationally • build relationships with first nations/traditional custodians and authorities in countries of origin • evaluate existing collections and/or develop new ones.
Lack of resources	• do what you can, when you can, and with what you have: it can be surprising where any action can lead • focus on building partnerships with those who can assist you i.e. invite universities to undertake in-kind student research of elements of your landscape • join the CCABG • collaborate with other botanic gardens • take the attitude: 'how could we make this happen' rather than 'we don't have time for this.'
Inadequate infrastructure	• identify the risks and first look at integrated, plant-based solutions e.g. improving the permeability of the landscape and interception of water, or shading of paths to increase their life • carry out audits of infrastructure and develop asset management plans.

3. Prioritise species selection for those at less risk from the future climate

Action: Use predictive methods for plant selection

Much of our understanding of plant tolerances in cultivation is from past observations, and quality literature is often limited (Rayner and Williams, 2016). However, it appears that more anecdotal knowledge (some of this can be high quality expertise) is applied to plant selection rather than tested, verifiable results (Asgarzadeh et al., 2014).

However, this approach is not so effective when future conditions may be well beyond our experience. Historical knowledge may be relevant if we have worked within a warmer or drier environment with the same species or know a colleague that has this experience, or we have observed plant species in other botanic gardens or habitats with these conditions. In many cases, we need to try and predict plant performance for climatic conditions decades ahead to the future. It is especially important to improve this decision-making for valuable plants, such as rare and threatened taxa, and typically long-lived species, for example cycads, palms, shrubs and trees.

> **'Successful plant selection is a complex process on its own without the additional problems of a shifting climate.'**
>
> Roloff et al., 2009

Photo: Wendy Farley

Methods that might be applied include:

a. Comparing plant inventories of current locations that are performing under a similar projected climatic regime to your location for a selected timeframe, such as 2090. These taxa and corresponding locations could be used in an analogous manner to determine other possibly suitable species.

b. Applying species distribution modelling techniques against selected biologically meaningful climate parameters (bioclimatic), such as BIOCLIM (Booth, 2017). However, these ecologically based selections can be difficult and time-consuming to process (especially when individual botanic gardens can hold thousands of taxa). In addition, they tend to outline the realised ecological niche (environmental envelope) rather than the fundamental niche, the latter being what a species is capable of growing in when not inhibited by competition or other environmental conditions (Booth, 2017; Bulleri et al., 2016). However, due to the magnitude of plant diversity and time constraints for evaluating many botanic gardens, there is arguably a need to adopt techniques within a heuristic (practical) context rather than striving for absolute scientific certainty.

c. Developing risk-based systems that combine worldwide plant databases and elements of species distribution modelling – especially signature climatic variables with reasonable predictability of a given plant's vulnerability or resilience in a climate scenario. This approach will likely be improved by the inclusion of expert judgement through an adaptive management framework.

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Following on from risk-based systems, dramatic advances in computing power and the availability of mega datasets have enabled more effective workflows for plant selection and determining these climate risks. For example, the Global Biodiversity Information Facility (GBIF) can provide millions of occurrences for plant taxa linked to coordinates across the globe. These locations can be combined with modelled 'climate surfaces', that is, temperature as found at publicly available sites such as Worldclim (Fick and Hijmans, 2017) and used in GIS or other programs to estimate the 'environmental envelopes' or growing conditions of regions, or indeed individual species.

The CCABG is developing the Climate Resilience Assessment Tool (CRAT) to help botanic gardens. The tool uses the predictive modelling of the IPCC's emission scenarios, and datasets of known species occurrences, to provide taxa with a resilience score. By analysing the climates in which a species is known to grow, its future climate resilience can be modelled, thus providing guidance and allowing for more informed decision-making when managing long-lived assets such as trees.

One of the findings through implementing the climate assessments in Melbourne Gardens is that the risk from higher temperatures may be overstated for taxa that are:

- geographically isolated or unable to spread to warmer climates, so possibly not demonstrating their full climate tolerance
- species that are commonly cultivated in colder climates than their natural habitat, thus skewing the results
- taxa that have very broad distributions across many climates but dominate in colder ones, indicating potential susceptibility but may indeed be a mix of ecotypes (Ikeda et al., 2017) with wide tolerances
- species that are poorly known in cultivation.

The usefulness of such results comes from interrogating the risk conclusion according to the context of your site. For example, if your at-risk taxa have a wide natural distribution, then despite a result skewing towards colder climates, could specimens specifically from those plants growing in warmer climates be used as a new source of climate-appropriate material?

In summary, we recommend focusing on improving your landscape plant diversity and dominance with species that are more likely to be resilient under the future climate. This means it is less likely that you will have to manage reactively by removing trees unnecessarily or losing wide-scale plantings with subsequent losses in plant diversity, and landscape values.

Think in decade-time scales and adopt stewardship in protecting both natural biodiversity and plant collections (regional gardens play a vital role in advocating for and safeguarding local flora).

Climate change impacts all botanic landscapes regardless of their scale – therefore seek to understand the stresses and risks to your landscape from the impacts of climate change. How do we learn to change and maintain our values?

4. Adopt adaptive management and continuous improvement

Action: Continuously modify plans and assumptions in response to changes

Botanic gardens as typically urban landscapes can be defined as complex social-ecological systems (Martín-López et al., 2017; Steenberg et al., 2019a). This complexity is further challenged by a changing climate, uncertainty and a lack of understanding of the future dynamics of these shifting interactions.

'Adaptive management' is a systematic method taken by natural resource management to improve the effectiveness of dealing with uncertainty and complex environments over time (Bosomworth et al., 2015). It works on the premise of a continuous cycle of planning, implementing, monitoring, evaluating and is in effect, learning from the management practice, which in turn adjusts decision-making (Williams and Brown, 2016). However, adaptive management is not simply 'learning by doing,' it requires a management model, clear baseline targets, and careful attention to not only the monitoring of the inputs into the interventions but also the assumptions of the model (Ordóñez and Duinker, 2013; Steenberg et al., 2019b).

Continuous improvement usually occurs within shorter timescales than typical adaptive management but is a useful mechanism to portray organisational learning. A 'learning organisation' is one where individuals continuously learn through sharing ideas, skills and knowledge and adapt their work accordingly through a changing workplace environment. This approach can foster creativity and innovation and supports the resilience of an organisation (Dickson et al., 2019). Technical

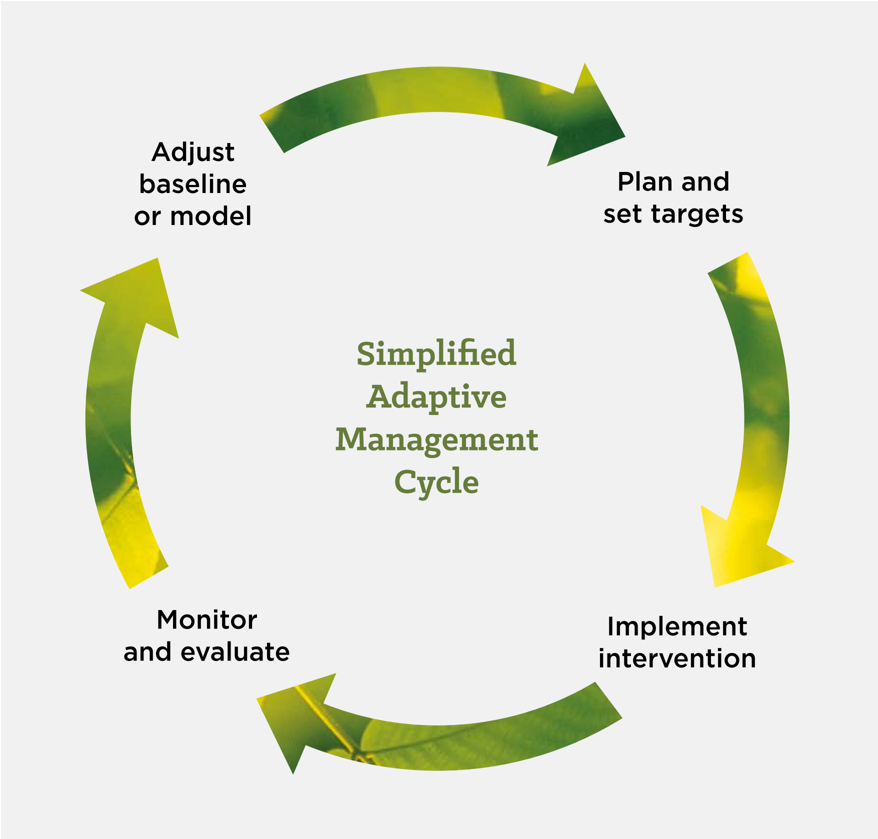

Figure 8: Adaptive management displayed as a continuous cycle of planning, implementing, monitoring, evaluating and learning from the process, which in turn adjusts decision-making.

improvements can be transferred and supported by 'social learning' (Dickson et al., 2019). Social systems of learning can foster creativity, innovation and resilience, demonstrating high plasticity to predict needs, adapt to circumstances and adopt new solutions within shorter time scales (Gonzales-Iwanciw et al., 2019).

This may all seem rather complicated but on a practical level it is worth encouraging this continuous learning approach by your teams in your day-to-day language. Using statements such as 'every new development will consider climate change' or 'every project is a landscape succession project' (C Hart, pers. comm., 2019) can really make a difference. The challenges are now set, and botanical horticulturists and other team members usually discover a way to overcome them.

Botanic landscapes are social-ecological systems – the products of complexity over time involving people, resources and the environment. The complex and changing world, challenges of shifting climate and future uncertainty require adaptive management and an 'always learning' focus. Botanic gardens have a depth of expertise and community of practice across the globe to meet these challenges. The ability to collaborate and develop partnerships with others will strengthen this capacity.

Are we doing the best we can, with what we have and where we can? Continuous improvement is not defined by the resources we have but by an act of our will.

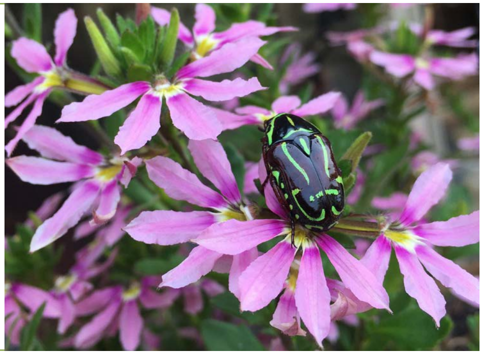

Photo: Rebecca Harcourt

Adaptive Management Case Study Melbourne Gardens Water Management

- After installation of an automatic irrigation system in 1993–94, irrigation training was implemented.
- Initial irrigation scheduling applied only two crop factors (plant water use factors) to gardens and turf that were not seasonally adjusted.
- Adaptive management principles were applied to fine-tune methods as there was little literature available for plant water use factors in complex landscapes.
- Today, there are 60 different scheduling regimes per annum (adjusted monthly) based on landscape coefficients (Symes and Connellan, 2013).
- Attention to irrigation water use efficiency resulted in up to 65% savings in potable water use.
- RBGV's expertise in water management was pioneered by horticultural employees with a focus on continuous improvement—saving about AUD5.4 million (1994–2019) in water costs.
- Learning from this example has been adopted for other landscape management initiatives i.e. the RBGV Landscape Succession Strategy.

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5. Collaborate and develop partnerships

Action: Engage with others

Climate change is a global problem that transcends the boundary of your botanic garden. The distribution of plants is not constrained by political limits with habitats across states and countries (Enquist et al., 2016). When this large spatial scale is combined with the complexity and uncertainty of the future, it requires a diversity of skills and perspectives, and many organisations working together to effectively respond to issues (Schulman and Lehvävirta, 2011). No organisation can fully tackle these problems on their own, especially even more so for those who have fewer resources. Collaboration provides a powerful mechanism to pool resources or share a diversity of skills and insights in tackling profound problems. The many alliances, associations and networks around the world bear testament to this.

Botanic gardens have developed partnerships with research institutions like universities to manage profound environmental or even social questions more effectively. The botanic garden provides the 'living laboratory' environment (Ballon and Schuurman, 2015; Smith, 2019) and the university provides the research expertise. RBGV has applied this approach in working with universities, for example, to assess community resilience under hot conditions, to improve environmental monitoring, soil and water management and plant evaluation and selection techniques.

Expertise, however, can also be developed by a botanic garden in partnerships with government agencies, industry or technological-based enterprises, such as:

- biosecurity departments wanting technical observations of plant health
- water supply authorities wanting to improve their educational reach on water efficiency
- enterprises with environmental instrumentation that require a testing location.

Participants engaged in the first Landscape Succession Workshop in October 2019 at BGANZ Congress, Wellington, New Zealand. Photo: Peter Symes

Seek to be the very best at collaboration and networking with others of diverse backgrounds! Focus on your relationships.

These relationships can result in more resources or in-kind support for your landscape and living collections management than would otherwise exist.

If you are resource-limited and do not have many partnerships other than networks in botanic gardens, then consider what opportunities you have to engage with other organisations. Can you work with schools (Sellmann and Bogner, 2013), local communities or universities to improve your profile and make an impact (Krishnan and Novy, 2016)? Maybe you can suggest research topics for students and researchers in your botanic garden?

Developing your own landscape adaptation response to climate change can also activate the potential for new partnerships with others. You may be surprised to find your botanic garden is suddenly seen as the leader in a new movement and people want to connect with you. The LSS of the RBGV has already attracted the interest of audiences beyond living collections management. Sustainability organisations, futurists, climate scientists and meteorologists, and urban planners, are some examples of engagement.

Ultimately, the ability and willingness to effectively collaborate with others is the most essential attribute that an organisation can have – especially when tackling a seemingly intractable problem like climate change. Richer relationships through partnering with others provide a greater scope of reach, expertise, and overall capacity (Entwisle, 2019).

The CCABG is a model example of expansive collaboration.

All botanic gardens and arboreta can connect to their communities to positively act towards protecting plant biodiversity. Always advocate for the benefits of botanic gardens – be visible!

Photo: Jo Brennan, RBGV

7 Prepare your own Landscape Succession Strategy

> 'Tiny Tasks or little actions are a key part of growing a Landscape Succession Strategy that thrives.'
>
> Mary T Burke, pers. comm., 2018

In this document we have generally covered a range of background material, risks, benefits of landscape succession and management strategies. However, each botanic organisation or those managing landscapes should have a strategic landscape plan that is specific to their circumstances, culture, environment and location. Every botanic garden will typically have climates so dissimilar to another that management of the respective landscapes would need to be significantly different, for example, meeting water demand.

An outline of major headings is provided with some suggestions for developing content that can guide the creation of your own landscape succession or adaptation strategy. The headings are:

1. **Executive summary**
2. **Background and context**
3. **Benefits of landscape succession**
4. **Issues, challenges and opportunities**
5. **Goals, strategies and targets**
6. **Appendices**

1. Executive summary

This is a high-level summary of the strategy with content carefully prepared to capture the attention of decision and policy makers, senior executives/managers and potential funding partners.

2. Background and context

This is an overview of the site and major items affecting its management, such as the current climate and summary of projected changes, location, visitation, heritage or historical overlays, living collections context and other management plans.

You may need to consider government reporting structures, policy settings and relevant external organisations such as botanic networks.

Define a strong narrative based on what is unique about your site/organisation. Is there a particular purpose that stands out? Maybe your site is best suited for something that others are not able to do, or do as well?

3. Benefits of landscape succession

This includes descriptions of the benefits and values that justify the formation of a strategic plan (this may require significant resources to complete). The toolkit provides a range of benefit examples, for example, environmental improvement, health and wellbeing, intergenerational legacies, plant conservation, planning and process improvement and urban greening which can help with ideas (don't skimp on the benefits!).

If you have other benefits to include, consider describing them in the strategy as these will be useful when preparing matters such as funding applications and if necessary, presenting your arguments to other people.

It is also important to highlight what will happen if no action is taken compared with the expected trajectory of improvement if interventions are put in place.

4. Issues, challenges and opportunities

You might think about this section as examining the risks to your landscape and living collections (and subsequently to your organisation) in depth. However, it is not all about difficult matters to resolve. In preparing the RBGV's LSS and subsequent developments, opportunities arose that could have been made more emphatic (see box). In your narrative, you may want to draw attention to these opportunities in parallel to the issues, for example, the risk to current plants can be compensated by prospective new plant collections.

This is a good topic to workshop with your teams and bring in additional expertise if you need it.

Examples of opportunities arising from the RBGV's LSS:

- The development of a 'metacollection' (networked plant collection) with national and international partners to protect plant genetic diversity by growing species not suited to seed banking, such as the Tropical Mountain Plant Science Project (TroMPS). This was created with the aim of establishing ex situ holdings of targeted Far North Queensland high mountain peak plant species. It involves a living metacollection of 86 at-risk species 'backed up' across seed banks and botanic gardens across Australia, including the Australian Tropical Herbarium, the Australian National Botanic Garden, Australian Rhododendron Society (Victoria), Brisbane Botanic Gardens, Cairns Botanic Garden, Earthwatch, RBGV, Royal Botanic Gardens and Domain Trust (Sydney), Western Yalanji (and other indigenous groups) and the Wet Tropics Management Authority.
- Melbourne's warming climate may provide the opportunity to grow taxa that are at risk in their normal environment, such as the rare and endangered *Quercus engelmannii* Engelmann Oak from southern California. Various factors have caused a reduction in its natural range, which is expected to further decline as climate change intensifies. The current projections suggest that Melbourne's mean annual temperature will likely become more suitable for growing this species whereas the temperature in its natural origin is projected to become less suitable. Oaks are not suited to seed banking as a conservation measure. Therefore, acorns were imported from the Los Angeles County Arboretum and Botanic Garden and will be planted in the RBGV and other well-suited botanic gardens, expanding the ex situ conservation of this endangered species (Brennan, 2022).

A *Quercus engelmannii* seedling at the RBGV grown from the imported acorns. Photo: Jo Brennan, RBGV

Issues and challenges will likely encompass climatic parameters and risks from changes to these across decadal timescales. Other items to consider may include:

- irrigation and water management
- site stresses, such as visitation capacity
- level of staff expertise to deliver changes
- community attitudes to landscape change
- effective plant introduction and establishment
- managing a mature landscape/tree population
- threats to plant biosecurity
- condition of infrastructure
- capacity to support landscape services
- financial and other resourcing needs
- site-specific environmental issues.

See more ideas in Section 6 – *Strategies for effective landscape succession.*

Botanic gardens are not only required to adapt to the changing climate for effective plant conservation but will also need to consider future community learning and design of landscape projects. This image is sourced from the Guilfoyle's Volcano landscape at RBGV Melbourne Gardens that includes interpretation, plant selection, protection of heritage legacy, and sustainable water management as organisational responses to climate change. Photo: Peter Symes

5. Goals, strategies and targets

Your strategy might be an interesting (or possibly alarming) read but it is not effective unless there are some meaningful goals, strategies, targets and actions that respond to the issues, challenges and opportunities. The work you have done to this point includes setting the scene, providing a sound basis for the strategy, and analysing the needs for change.

In a synthesis of the content of your strategy (and the learning in preparing your document), what is it that needs to be done now to prepare your invaluable living landscape for the future?

At a higher level, you might prepare an overall high-level qualitative goal that summarises your main objectives. In one sentence, what does success look like in 50 or even 100 years?

Strategies can unpack the overall goal and may begin with more active language, such as maximise, establish, protect, improve, foster, but can still be relatively qualitative statements.

Under your strategies section, you can begin to delve into the detail of what needs to be done (or continued) and these are the targets and actions of your LSS.

It is useful to consider setting goals, targets/objectives and actions against models for describing these that make them harder-hitting and effective. One framework that has been frequently used is based on the SMART (Doran, 1981) acronym and there are many variations of this (Rubin, 2002). Common current interpretations suggest that SMART can be indicated as follows:

S	Specific
M	Measurable
A	Achievable, attainable[6], (ambitious)
R	Relevant/realistic
T	Time-bound

Articulate the priorities for your site and maintain a focus on what is right, not what is easy!

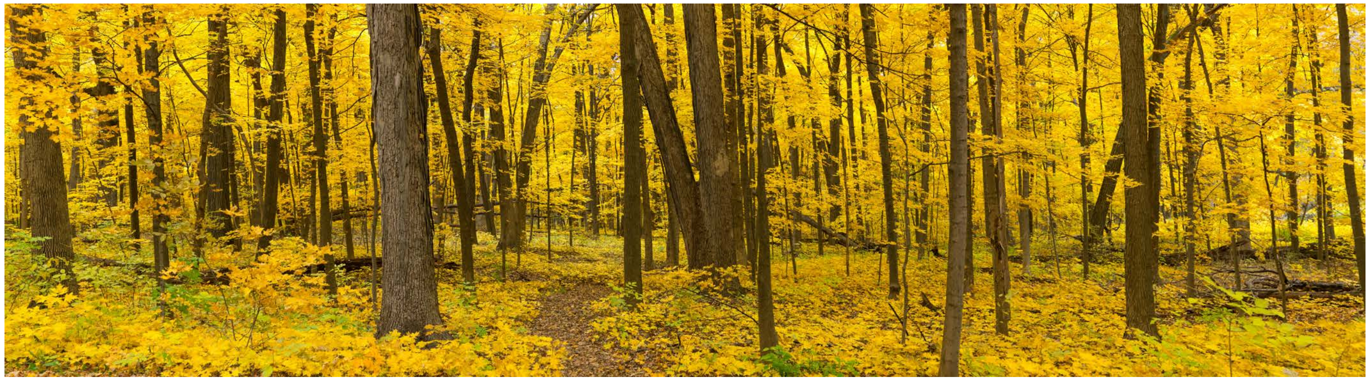
6 Some suggest that 'ambitious' can be substituted for 'attainable' as is the case with some targets in the RBGV's LSS – this has helped drive creativity and better management responses in Melbourne Gardens.

It has been suggested by some that the 'Achievable' category should be more challenging and instead encourage a 'stretch' in effort by substituting it with 'Ambitious' (Poister, 2008). It is a proposition worth considering as it is likely that ambitious effort is required to drive the necessary creativity, innovation and commitment to achieve your aims. However, your targets should not be so challenging that they are insurmountable and become disheartening due to a lack of progress. Here again, adaptive management principles can be applied to achieve regular review of status and adjustments that are needed so you are on the right path.

A simplified model framework called OITT (Outcome, Indicator, Target level and Timeframe) that is based on SMART and goal-setting theory (Ogbeiwi, 2017) is used for comparison here and this may be more practical. The following is an adapted example from the RBGV's LSS for illustration:

O	Specific Outcome	→	Taxa in the gardens are suited for the projected climate of 2090
I	Measurable Indicator	→	% of taxa
T	Attainable Target	→	75%
T	Realistic Timeframe	→	By 2036

This means that by 2036, 75% of taxa in the gardens are suited for the projected climate of 2090.



Morton Arboretum – Fall Colors 2018. Photo: Michael Hudson © 2022 The Morton Arboretum. All rights reserved.

6. Appendices (optional)

Under this section, you might include more additional supporting information, such as detailed analyses, maps, plant lists, and other items that inform the strategy, but these elements are not essential to understand the main body of the document. This additional information may also be provided to inform the reader's knowledge of the subject.

8 Conclusion

Botanic gardens and arboreta worldwide face significant challenges from a changing climatic environment. The transition of cultivated landscapes and collections towards those which are more resilient under the projected climate requires urgent action. This landscape succession toolkit has been produced to help organisations in developing their own site-specific adaptation strategies. As the first version, this toolkit is intended to be a living document that will be continuously improved as the science develops and our understanding of climate change improves.

The founding partners of the Climate Change Alliance of Botanic Gardens after signing the Melbourne Declaration.
Photo: RBGV

9 Resources, tools and sources of further information

Name	Description	Link
Landscape Succession Strategy (RBGV)	*The Landscape Succession Strategy – Melbourne Gardens 2016–2036* is available as a pdf file download. The site also has information on papers, climate risk reports, presentations and news on the CCABG.	https://www.rbg.vic.gov.au/initiatives/landscape-succession-strategy/
IPCC Sixth Assessment Report	Regional fact sheets: regional summary fact sheets across the world and for specific topics (Africa, Asia, Australasia, Central and South America, Europe, Mountains, North and Central America, Ocean, Polar regions, Small Islands, Urban areas).	https://www.ipcc.ch/report/ar6/wg1/resources/factsheets/
	Interactive atlas: a novel tool for flexible spatial and temporal analyses of much of the observed and projected climate change information and assessment findings in the report.	https://interactive-atlas.ipcc.ch/
	Frequently asked questions.	https://www.ipcc.ch/report/ar6/wg1/resources/frequently-asked-questions
The Adaptation Support Tool	Created by the European Climate Adaptation Platform (Climate-ADAPT) with the aim to assist policy makers and coordinators on the national level in developing, implementing, monitoring and evaluating climate change adaptation strategies and plans.	https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool
Climate Change in Australia	Easy access to the climate change projections information and data with multiple interactive tools for exploring data; a data download facility; a technical report describing the data sources, methods, observed changes and projections; reports and brochures that summarise the results for eight regions of Australia and selected cities.	https://www.climatechangeinaustralia.gov.au/en/

Name	Description	Link
US Climate Resilience Toolkit/The Climate Explorer	Offers customisable graphs and maps of observed and projected temperature, precipitation and related climate variables for every county in the contiguous United States.	https://toolkit.climate.gov/ https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=8b910d9c7b9744ea94e07d82f5420782
World Weather Information Service	This global website presents official weather observations, weather forecasts and climatological information for selected cities supplied by National Meteorological & Hydrological Services (NMHSs) worldwide.	http://worldweather.wmo.int/en/home.html
KNMI Climate Change Atlas	Online tool that is based on the physical science of the IPCC Fifth Assessment Report (WGI AR5) and provides maps and time series. A user can plot simulations of climate change scenarios for a range of variables such as evaporation, precipitation, relative humidity, solar radiation; and minimum, mean and maximum temperature.	http://climexp.knmi.nl/plot_atlas_form.py?id=someone@somewhere

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