

# Investigating Potential Mornington Peninsula Environmental Impacts of a Warming and Drying Climate

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## Contents

1. Summary .....	1
2. Climate Baseline.....	2
3. Discussion.....	3
Mornington Peninsula Flora’s Sensitivity to Climate Change .....	3
Temperature and Growth Rate .....	4
Eucalyptus Recovery Following Droughts of Varying Intensity .....	4
An Australian Example of Dieback from Linked/Compound Events .....	5
4. Potential Role of Plant Stomata .....	7
5. Appendix 1: Caveats.....	8
6. Appendix 2: Data and Analytic Approach .....	9

## 1. Summary

Local flora have evolved to past climatological drought and heatwave periods, insect invasions, and bushfires - albeit with some overall damage to leaves and xylems that may take several months or even years for recovery.

Increasing local climatological temperatures and lowering rainfall from climate change are associated with increasing frequency, severity, and length of droughts and heatwaves. Direct and indirect processes associated with these changes may take local flora beyond a tipping point and into mass dieback. Compound or linked drought and heatwave events are particularly dangerous.

Indirect effects have been well documented, they include:

- Warming and lengthening seasons may support rapid increases in diseases and pest insects. Pests may consume foliage to a level where photosynthesis is insufficient to provide the sugars needed to grow new leaves. Trees may not be able to produce sufficient sap to deter borers, which then cause increasing xylem damage, less sap production, and death.
- Warmer conditions coupled with shorter, but heavier rain in the growing season, may substantially increase understory plant density. The resulting more intense summer fires may become capable of killing flora outright or causing damage that can take years to repair. The extended repair period leaves the plant vulnerable to attacks by insects, and to subsequent droughts and heatwaves.

- Already adapted weeds may expand rapidly, weakening and perhaps seriously degrading indigenous plant communities.

Direct effects include the inability of plant stomata to adjust sufficiently to maintain a balance between dehydration and canopy overheating, together with loss of the photosynthesis required to provide materials to repair resulting damage.

This analysis examines the direct impacts of drought and heat waves from a plant stomata perspective, an analysis that includes a recent Australian example of damage that has already occurred. **It paints a grim climate-change scenario for many of our indigenous flora.**

It includes evidence that the level of impact and response is not uniform across all flora species. For example:

- There is strong evidence that Kangaroo Grass (*Themeda triandra*) may be largely unaffected by expected drought and heatwave extremes, and it being green and active during summer helps protect it from bushfire.
- **The available evidence does point towards our eucalypts being very vulnerable.**
- Taller trees have lower leaf mass compared to smaller plants in the same species, and require considerable energy to pump fluids from their roots to the canopy. Canopy or xylem damage that would not destroy smaller plants may take these giants past the tipping point.

Canopy trees such as eucalypts, are major ecological engineer species in that they provide lower-level plants with shade and protection from weather extremes such as high temperature and winds, and heavy rain. **Mass loss of these eucalypts can be expected to lead to substantial ecological rearrangements, perhaps to the level of extinction and creation of new ecosystems.**

These notes are released to generate discussion on this important topic, discussion that has been largely absent to date and should include consideration of at least the following:

- Are our current revegetation programs adequate; should we be considering non-indigenous species as a buffer? Perhaps a new mix of indigenous and non-indigenous?
- What ecosystems and flora are the most vulnerable; should we leave these to evolve to a new state; or is there potential for introducing already adapted species to maintain an approximation of the status quo?

## 2. Climate Baseline

The Vic Future Climate Tool (see Appendix) indicates that their current baseline (1979-2018) annual rainfall and annual mean temperature for the Shire are approximately 800 mm and 15°C. Typical values across the shire vary from 640-817 mm, and 14-15°C .

We use projections to the period 2080-2099 based on two scenarios: RCP4.5 (moderate emissions) and RCP 8.5 (high emissions). The scatter of projections across the different models are shown in Table 1. From these we choose indicative rainfall reductions of 10 and 20%, and indicative temperature increases of 2 and 3°C. As will be seen, the results are not sensitive to the precise values of these choices.

Projected Climate: Change - Rainfall (Precipitation) % change						Projected Climate: Change - Avg Temperature (°C)					
Local Government Areas: MORNINGTON PENINSULA						Local Government Areas: MORNINGTON PENINSULA					
Climate Model: Multi Model Mean						Climate Model: Multi Model Mean					
Climate Variable: Rainfall (Precipitation)						Climate Variable: Avg Temperature					
Projection Horizon: 2090s (2080 - 2099) Variability across climate models						Projection Horizon: 2090s (2080 - 2099) Variability across climate models					
Percentiles						Percentiles					
Scenario	10th Percent	25th Percent	50th Percent	75th Percent	90th Percentile	Scenario	10th Percent	25th Percent	50th Percent	75th Percent	90th Percentile
Annual RCP4	-20.9	-16.61	-8.43	-4.33	-0.5	Annual RCP4	1.29	1.4	1.72	1.8	2.07
Annual RCP8	-27.3	-26.94	-22.57	-15.35	-2.38	Annual RCP8	2.38	2.45	2.82	3.35	3.73

Table 1: Projected changes in annual rainfall (left) and annual mean temperature (right).

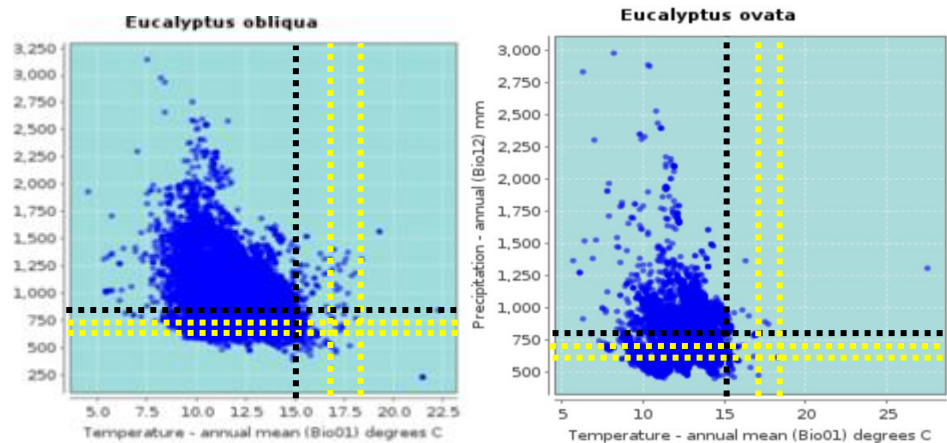
### 3. Discussion

#### Mornington Peninsula Flora’s Sensitivity to Climate Change

We use Messmates (*Eucalyptus obliqua*) and Swamp Gums (*E. ovata*) as indicative examples. The scatter plots of observed rainfall and temperature ranges for all Australian observations of these species are shown in Fig. 1 (Derived from ALA, see Appendix for details).

Figure 1 indicates that expected reductions in rainfall from local climate change probably will not take messmates and swamp gums outside their current climate range. But the degree of warming will take them outside their observed climate range (note that a check found that many of the temperature outliers in Fig. 1 are incorrectly located or in house gardens).

Figure 1: Range of observed annual rainfall and mean temperature for *E. obliqua* (left) and *E. ovata* (right) based on ALA. Black dotted lines indicate current Peninsula values, and the yellow lines indicate the projected RCP4.5 and RCP8.5 ranges for 2080-2099.



The sensitivity of several other species were checked, with the following results:

- Sensitive to all temperature projections: Coastal Manna Gum (*E. viminalis pryoriana*), Peppermint Gum (*E. radiata radiata*), Swamp Sheoak (*Allocasuarina paludosa*).
- OK to 2°C warming: Black Wattle (*Acacia mearnsii*), Prickly Teatree (*Leptospermum continentiale*), Prickly Currant Bush (*Coprosma quadrifida*).
- Probably safe to beyond 3°C warming: Blackwood (*Acacia melanoxylon*), Silver Banksia (*Banksia marginale*), Sweet Bursaria (*Bursaria spinulosa spinosa*), Black Sheoak (*Allocasuarina littoralis*), Common Cassinia (*Cassinia aculeata*), Poa Lab (*Poa labillardierei*), Kangaroo Grass (*Themeda triandra*).

Entering this analysis, I expected there to be a degree of sensitivity to reductions in rainfall. Although our flora are expected to remain within their climatological rainfall range, the expected drying does make them more vulnerable to droughts and other heat-driven events.

I was particularly surprised to find the vulnerability to relatively small climatological changes in mean temperature. The narrow temperature ranges for Eucalypts have been noted previously by [Hughes et al \(1996\)](#), who also commented on the small habitat range of most eucalypts.

A reasonable hypothesis for this temperature vulnerability lies in the close association between increasing temperatures and increasing extremes across all but extreme cold. For example, at higher mean temperatures ([IPCC](#)):

- Droughts are longer, more intense, and occur more frequently.
- Heatwaves also are more intense and occur much more frequently.
- Mean rainfall typically decreases, but when rain occurs it tends to be more intense.

These outcomes also increase the potential for concurrent or linked extremes to occur. Concurrent extremes are those that overlap to produce a more severe impact than either event could cause by itself - an example is an extended heatwave during a drought. Linked extremes occur one after the other, and include, for example:

- The first extreme sets up the conditions for the second to be more severe, such as a second drought or heatwave following a moderate drought.
- Plants damaged from the first extreme have not had sufficient time to recover and thus may be severely impacted by even a moderate second extreme.

Several studies have predicted, or observed reductions in extent, growth rate, and viability of Eucalyptus species from climate changes. Following are three.

## Temperature and Growth Rate

We have seen that eucalypts are particularly sensitive to temperature change and are thus normally constrained to relatively small climatic zones. Many studies also have found that the optimal annual temperature for our temperate Peninsula eucalypts lies around 11°C, and that their growth rate and height declines as the mean temperature increases or decreases. [Bowman et al \(2014\)](#) modelled this changing eucalypt growth rate as environmental temperatures and found, for example, that a messmate that would take 187 years to reach a diameter of 100 cm when growing at 14°C, would require 430 years to reach the same size at 20°C!

## Eucalyptus Recovery Following Droughts of Varying Intensity

Impact and recovery from a drought has been reviewed by [Ruehr et al \(2019\)](#). They combined modelling and experimental work to examine the period following droughts of varying intensity, with the results illustrated in Fig. 2. Note this is mostly a European perspective, but their study did include eucalypts.

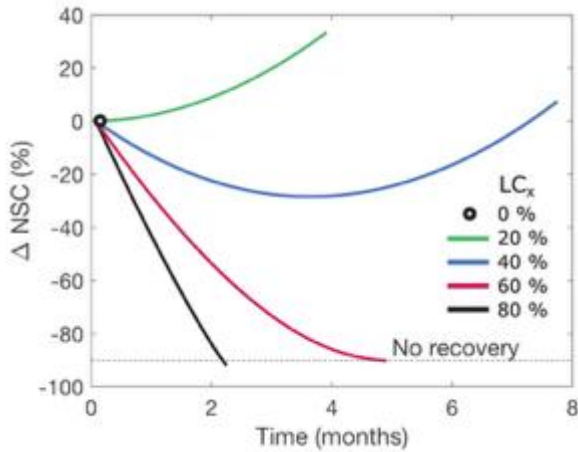


Figure 2: Tree recovery following a drought, where: NSC represents change in non-structural starches etc (sugars), and LCx represents the xylem’s ability to transport essential fluids up from the roots. The starches are used to repair damage to leaves and the xylem (Ruehr et al 2019).

Following a mild drought (circle at 0%, no line), trees recovered immediately with no loss of function. Trees leaving a moderate drought also recovered quickly (20% line). In both these cases, leaf survival and photosynthesis was sufficient to

support regrowth. For a severe drought (40%), the trees initially continued to decline, but then recovered over several months. At more extreme drought levels, the damage was too severe for the trees to recover - they gradually died.

Extreme events that decades ago would have done little damage may therefore become destructive when occurring in a warmer and drier climate-change environment. As an example, adding a 20% climate drying to the above graph, takes the existing 40% curve to 60% and loss of the plant. Increases in frequency and intensity of droughts add even greater impact. An example of this process is proved in the next section.

### An Australian Example of Dieback from Linked/Compound Events

An extended heatwave following a winter drought, severely impacted forest areas in the Perth Hills and Swan Coastal Plain during 2010-2011 (Brouwers et al, 2015, Ruthroff et al 2018). The 2010 winter drought had been preceded by a drying trend of 14% since 1960, to which it added a further 40-50% drop below the long-term rainfall average. A subsequent summer heatwave increased mean temperatures by >2.5°C over a large area, and by >5°C near Perth.

*These conditions are well within the bounds of what we may expect at the Peninsula in the future.*

The following damage resulted: canopy tree mortality averaged ~25%; Jarrah (*Eucalyptus marginata*) in the Perth Hills died at 10.5 times the normal loss rate over an area of 16,000 ha; on the



Figure 3: Extent of the Banksia Woodlands in the Swan Coastal Plain (DEE, 2016).

coastal plains, 70-80% of Giant Banksias (*Banksia grandis*) were lost and 500 ha of Tuart (*Eucalyptus*

*gomphocephala*) collapsed. Knock on effects included a 34% decline in the near-extinct Carnaby's Black Cockatoo (*Zanda latirostris*), and permanent damage to some ecosystems.

We concentrate on ecosystem damage along the coastal plain. Applying the ALA analysis approach to the giant banksias (Fig. 4) found that these exist across a wide range of mean temperatures and rainfall, despite their relatively small geographical range.

The winter drought was sufficient to take the majority below their lower climate rainfall limit (all those below the dashed line on the left panel - red observations in the middle panel). That most of these did not die, indicates a resilience to such rainfall deficits. This is consistent with the experimental results in Fig. 2.

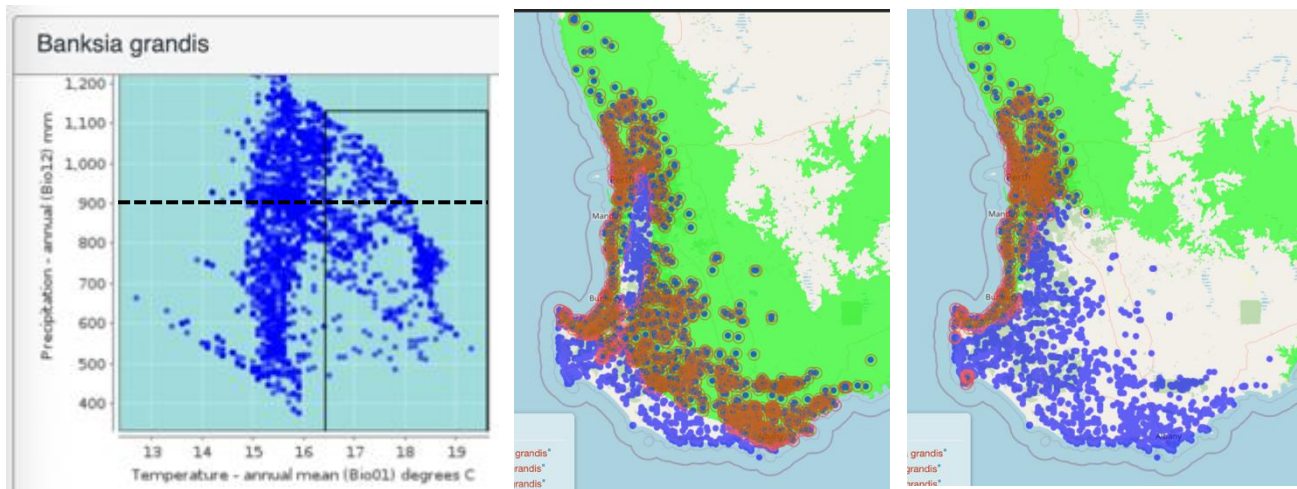


Figure 4: Scatter plot observed annual temperature and mean precipitation for Giant Banksia (*Banksia grandis*, left panel) based on ALA. The red dots on the map relate to those observations that were drier than the dashed line on the scatter plot (middle panel); and warmer than the solid rectangle (right panel).

The solid rectangle encloses those for which the observed summer heatwave of 2.5°C was warmer than their upper climatic temperature limit. The associated red observations in the right panel, closely follow the area of banksia woodlands in Fig. 3. where giant banksias experienced 70-80% die back.

This analysis emphasises the importance of heatwaves, even when the observed rainfall remains adequate.

We next consider Tuart (*Eucalyptus gomphocephala*), which in Western Australia are constrained largely to the coastal zone (Fig. 5).

In contrast to giant banksias, all local Western Australian tuarts have >600 mm annual rainfall (the plants below the dashed line were nearly all in eastern Australia). Tuarts thus were unlikely to have been directly impacted by the drought alone (no red observations in the centre panel). But the heatwave took most of them outside their climate zone – compare the solid rectangle in the left panel and red observations in right panel. This points strongly to the combined drought and heatwave being the major factor in the observed damage.

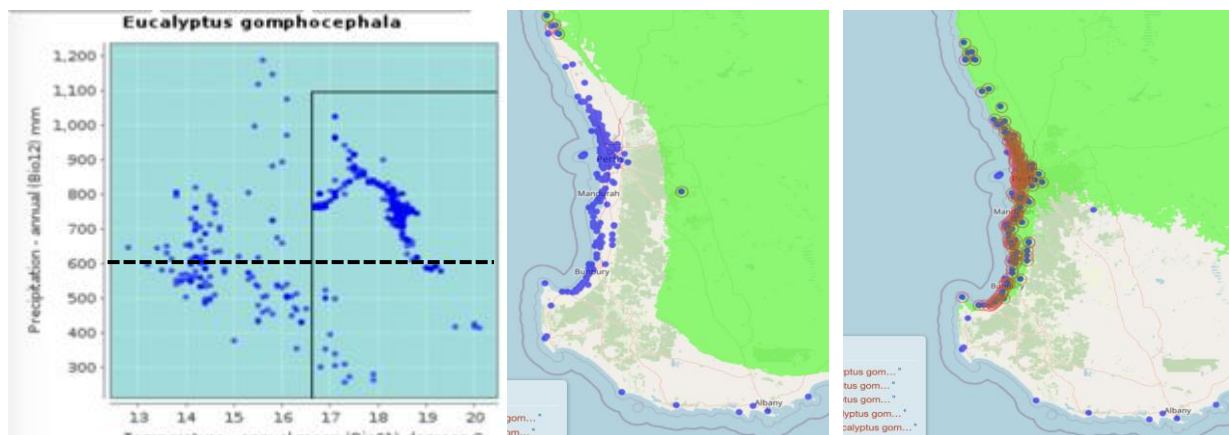


Figure 5: As for Fig. 4, except Tuart (*Eucalyptus gomphocephala*). Note that the maps only show southwest Western Australia, whereas the scatter plot is for all Australia.

#### 4. Potential Role of Plant Stomata

The previous analysis provided strong evidence of the direct and indirect roles of heat on plant mortality, especially when combined with a rainfall deficit that was insufficient to have led to dieback by itself. Here we discuss how these results may arise from the responses of plant stomata to drought and heat.

Stomata are the tiny pores (mouths) scattered across all leaves, which are the plants' breathing mechanism (Fig. 6). During the day, stomata open up to allow CO<sub>2</sub> to flow in and oxygen and moisture to be removed.

Evaporation is a powerful mechanism that cools the leaves and the immediate environment from the debilitating heat effects of sunlight or hot air. Energy derived from this sunlight enables plants to break the CO<sub>2</sub> into carbon and oxygen. The carbon is converted to sugars that are ducted around the plant for growth and repair of damaged tissue.

All plants have a critical temperature at which they are in danger of dieback due to overheating and loss of moisture in the leaves. Most plants adjust their stomata to balance the impact of approaching this critical temperature.

Given a plentiful water supply, stomata tend to stay open. They thus can sustain full photosynthesis and evaporative cooling.

If water is scarce, such as in a drought, some plants will partially or completely close their stomata as their critical temperature approaches, and leave them closed. These isohydric plants are risking

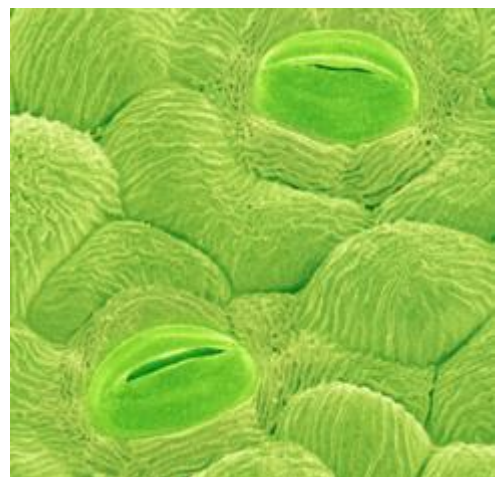


Figure 6: Two stomata, one partially open, the other closed (Chambers 2022).

short-term leaf damage from overheating in order to prevent longer-term damage from dehydration. Photosynthesis also stops as the stomata close, reducing the plants' capacity to grow or repair damage. This can be seen by the straggly and stunted plants that often result from extended dry and hot periods

As their leaves heat up in dry conditions, other (anhydric) plants initially close their stomata, then reopen them cool the leaves and prevent canopy dieback. The trade-off here is that the leaves are saved to continue photosynthesis, with the hope that this will be sufficient to repair the resulting dehydration damage to both leaves and xylems (regions under the bark where sap flows up and down).

Some plants have evolved leaves designed to counter overheating, such as needles, thick waxy surfaces, or facing away from the sun. They are capable of keeping their stomata closed under higher temperatures.

Note that his analysis provides just one mechanism to explain the sensitivity of our eucalypt overstory to climate drought and heat extremes. There almost certainly will be other contributors.

## 5. Appendix 1: Caveats

**CO<sub>2</sub> Fertilisation.** Under current climatic conditions, elevated CO<sub>2</sub> typically leads to enhanced photosynthesis, faster growth rates, and improved water use efficiency, which may increase flora robustness to climate change. However, recent studies (see the review by [Booth et al, 2015](#)) have found that environmental warming results in decreasing responses to the associated CO<sub>2</sub> fertilisation, at least for eucalypts. Negative effects include later flowering and leaf die back from increasingly frequent heatwaves and droughts.

The mechanisms involved are quite complex and not well understood. It is possible that CO<sub>2</sub> increases still may reduce the heatwave and drought impacts, but the degree of such reduction is unknown. A more rigorous answer awaits further research.

**Species Adaptation:** This analysis and the quoted studies use pre-existing ranges as a proxy for future conditions. It could be that some or all of these species are capable of adjusting to future conditions outside their current ranges.

There are documented examples of species growing well beyond their natural range in plantations, but these still remain constrained to their original quite narrow temperature and rainfall bands – for example, the Western Australian drought and heat wave above led to a general collapse of local pine plantations.

[Wardlow \(2024\)](#) noted that eucalypts in the cool, moist conditions of Tasmania demonstrate a stronger response to warming than those on the mainland, indicating there may be potential for adaptation to climate change.

The long life and slow turnover of eucalypts, their ability to only move over relatively small distances in decades, and the rapid rate of climate change, points to a low probability of adaptation.

[Booth \(2024\)](#) provided an analysis of potential issues here, and concluded that eucalypt evolution to withstand a warming climate is not possible in a natural environment, although it may be possible in a plantation context.

Natural variations in microclimate across the Peninsula can reasonably be expected to ensure that some areas will retain their canopy trees, especially if the trees lie in protected gullies and can help maintain a benevolent microclimate. But this still leaves large areas that are vulnerable.

**Soil Type Impact:** I could not find any substantial information on the role of soil type in plant survivability to projected climate change.

**Author Credentials:** I am a climate and weather scientist who has no formal ecological training. I can read and assimilate reports and scientific papers by experts, but there always is the possibility that some important aspects have been missed, or misinterpreted.

## 6. Appendix 2: Data and Analytic Approach

The approach adopted here was to use current known species distributions to assess likely changes as the climate warms and dries. An approach often referred to as Species Distribution Modelling (SDM). Our approach closely follows that described by [Booth \(2014\)](#):

- Plant observations were from those archived on [Atlas of Living Australia](#) (ALA).
- Plant species scatterplots were derived using the ALA analysis engine, as described in the [April 2025 MPLN Newsletter](#).
- The annual mean temperature and rainfall data used come from the [Copernicus Bioclimatic Indicators Data Archive](#). This use the global ERA5 reanalysis from the European Centre for Medium Range Weather Forecasting averaged over the period 1979-2018. It has a 50 km grid spacing, which may have been statistically downscaled to a smaller scale in some areas (details could not be found). We used Bio01 (annual mean temperature), and Bio12 (annual rainfall).
- Current and future climate data were derived from the [Vic Future Climate Tool](#). This is based on projections from several climate models statistically downscaled to a 5 km grid. Current climate is based on the model averages for the period 1986-2005, which is considered to be statistically the same as the 1979-2018 period used by ALA. Note that the base period from 1979-2018 used by the Vic Future Climate Tool already contains a significant component of ~1°C climate warming (on average). So converting the changes here to a pre-1900 base requires the addition of 0.5-1°C.

### Species:

- The ALA archive contains data from citizen scientist observations either directly to ALA or through their partner iNaturalist. Only spatially validated data were used here.
- Shorter-lived and rapidly growing species will either be able to undergo natural evolution to adjust to climate change, or if not, can easily be replaced. A further analysis will be made for these as time permits.
- Longer-lived and slowly growing species, such as eucalypts, typically take over 100 years to reach full ecological capacity and adapt slowly, hence these are the focus of this analysis.

**Sensitivity to Other Parameters:**

I have not made a detailed analysis of other climate parameters such as cool or warm season rainfall. But a check by plotting annual mean temperatures vs summer mean temperatures found a very high correlation (Fig. A1), which indicates little sensitivity in choosing between the two. A plot of summer rainfall vs summer temperature (Fig A1) also indicated similar temperature sensitivity to that found for annual mean temperatures in Fig. 2, albeit at a higher base temperature.

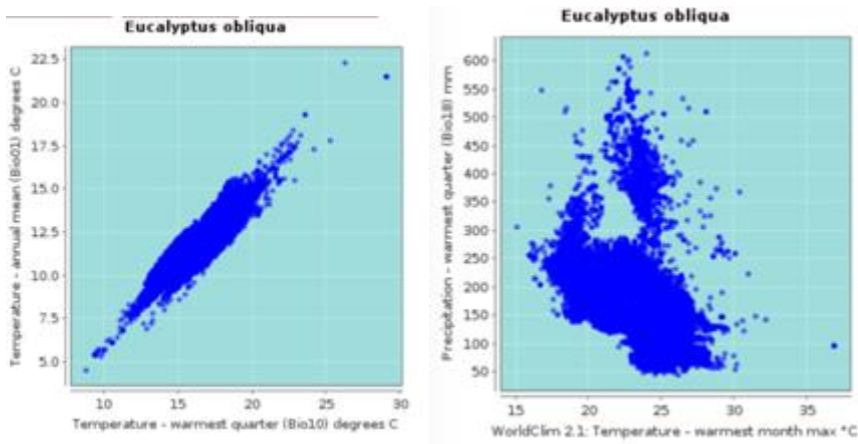


Figure A1: Relationship for *E. obliqua* between annual mean and summer temperatures (left), and summer precipitation and temperatures (right).