A Comparative Climate Vulnerability Assessment for Key Agricultural Industries in the Adelaide and Mount Lofty Ranges Region

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Government of South Australia

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Australian Government

This project is supported by the Adelaide and Mount Lofty Ranges Natural Resources Management Board, through funding from the Australian Government.

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Preferred way to cite this publication:

Thomas, D., Hayman, P. and Bachar, Z. (2016) A Comparative Climate Vulnerability Assessment for Key Agricultural Industries in the Adelaide and Mount Lofty Ranges Natural Resource Management Region. Adelaide and Mount Lofty Ranges Natural Resources Management Board, Adelaide.

Acknowledgments

The authours wish to thank the following individuals for their advice, help and support in preparing this report:

- Cathy Phelps and Monique White of Dairy Australia
- David Basham of the South Australian Dairy Farmers' Association
- Kendra White of the McLaren Vale Grape, Wine and Tourism Association
- Mardi Longbottom and Paul Petrie of the Australian Wine Research Institute
- Michael McCarthy of the South Australian Research and Development Institute (SARDI)
- Nicki Robbins of the Barossa Grape and Wine Association
- Nicole Bennett of Natural Resources Adelaide and Mount Lofty Ranges, Department of Environment, Water and Natural Resources
- Paul James of the Lenswood Cold Stores Co-operative Society
- Paul Shanks of Barossa Infrastructure Limited (BIL)
- Richard Hamilton of the Adelaide Hills Wine Region
- Wendy Allan of Pindarie Wines.

Executive Summary

This report provides background information to support planning for climate change for primary industries within the Adelaide Mount Lofty Ranges region (AMLR NRM). Planning for climate change in the Adelaide and Mount Lofty Ranges is challenging because it's a highly diverse region with a range of primary industries, facing multi-faceted aspect of climate change.

This report considers six key primary industries that occur in the region (viticulture, perennial horticulture, annual horticulture, annual cropping, livestock and dairy) by the five rural subregions (Northern Coast and Plains, Northern Hills, Central Hills, Willunga Basin and the Fleurieu Peninsula). Viticulture is the only primary industry found in all subregions; other industries are more restricted; for example annual cropping in Northern Coast and Plains and Northern Hills and dairy in Central Hills and the Fleurieu Peninsula. There are 18 combinations of sub-region and primary industry and for each combination the impact of moderate (1°C warming and 10% drying) or severe (2°C warming and 20% drying) changes in climate were considered.

The Adelaide and Mount Lofty Ranges (AMLR) region (the region) can be seen as a relatively cool and high rainfall island surrounded by hotter and drier regions to the north and east. As most of the primary industries found in the region are successfully practiced in warmer and drier locations, this report uses space (warmer and drier regions) as a proxy for time to consider the potential impacts of key projected climatic changes and the appropriate adaptation responses. The report concludes that even with more severe changes (of 2°C warming and 20% drying) it will still be possible to grow grapes, fruit, wheat and vegetables, and have livestock graze on pasture in the AMLR region. Importantly however, warmer and drier regions use different plant varieties and management practices, as well as different business structures and operational scales.

This report's key findings are as follows:

1. Warmer summers will hasten the development of wine grapes and perennial fruit. In some cases this is expected to shift ripening from milder autumn and late summer conditions towards hotter mid-summer conditions. Although there are some management options available, in the longer term some variety changes may be advisable.
2. Winter warming will reduce chilling, required for perennial horticulture. This will be especially challenging for high-chill crops such as cherries.
3. The 'cool climate' classification currently used by the Adelaide Hills wine region may be lost due to warming, representing a marketing risk for the region.
4. Extreme heat events are a greater concern than the increase in average temperatures. Crop damage is most likely when these events correspond with critical phenological stages, such as flowering in wheat, verasion to harvest in wine grapes and ripening in apples.
5. Extreme heat events in the AMLR region are usually associated with very low humidity which exacerbates the damage for plants and increases the risk of bushfires. At the same time, that low humidity reduces the impact of heat on well watered livestock.
6. A decline in winter and spring rainfall would reduce the production of crops and pastures growing over winter. It would also increase the irrigation requirement for summer growing crops (e.g. grapevines), which rely on water stored in the soil over winter.
7. It is prudent to expect a water constrained future for the AMLR region. One of the factors leading to water scarcity will be the extra irrigation needed to counteract the higher evaporation associated with warmer conditions. An additional requirement for water supplies will be for irrigation to manage an expected increase in extreme heat events.
8. Viticulture and perennial horticulture enterprises have multi-decadal planning horizons, and variety choices made now will have consequences throughout the coming decades. This contrasts with annual cropping and horticulture enterprises, where variety choice decisions can be adjusted year to year.
9. Modest warming over summer will be a problem for cool climate grape varieties such as Pinot Noir, but may improve the ripening conditions for longer season varieties such as Cabernet Sauvignon.

10. While there is some uncertainty about changes to summer rainfall, wetter summers would increase disease and harvest problems for viticulture and perennial horticulture, but may present opportunities for annual crop and livestock managers.

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Chapter 1. Introduction

Climate change will interact with other environmental, economic and social drivers to shape primary industries in the Adelaide and Mount Lofty Ranges (AMLR) region. The latest climate change projections for southern Australia are available at www.climatechangeinaustralia.gov.au. While there is high confidence that the future climate will be warmer with more heatwaves, there is less confidence on projected changes to rainfall. Most global climate models suggest that autumn, winter and spring will be drier; there is less agreement on changes to summer rainfall. Given the competing demands for water, it seems prudent to plan for a warmer, and water constrained future.

In the largely warm and dry South Australian landscape, the AMLR region is an island of relatively high rainfall and cooler conditions (Figure 1.1). There are two key implications of this. Firstly, primary industries in the AMLR region will be competing for land and water resources with other primary industries moving into the area for other areas significantly affected by warming and drying. Biodiversity and residential development will also be competing for these land and water resources. Secondly, primary producers in the region who wonder what a warmer and drier future might look like, do not have to travel very far to see an area currently experiencing a similar climate.

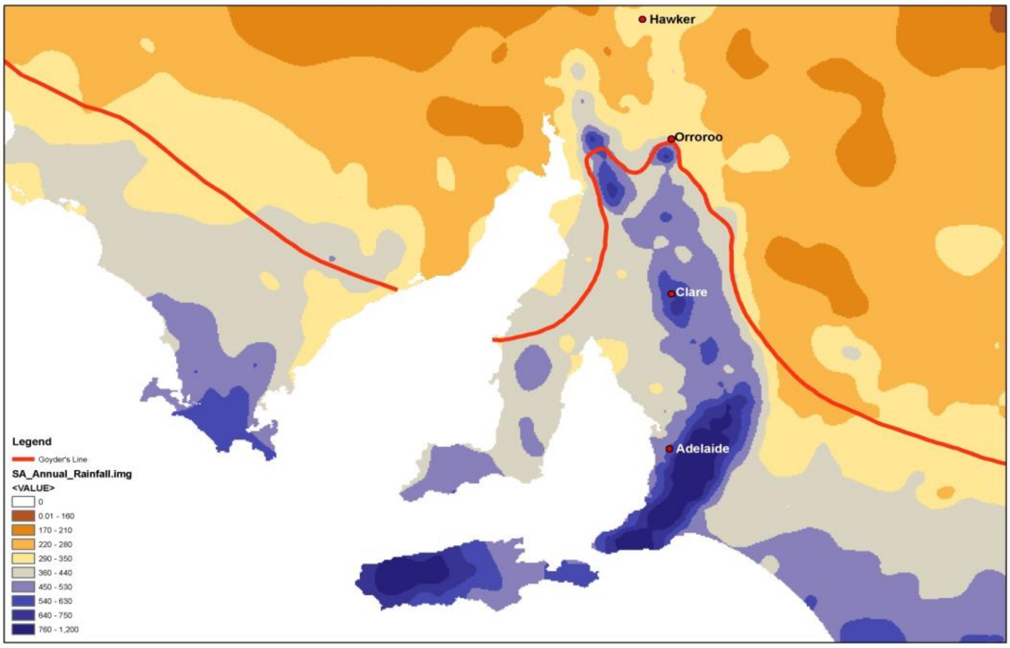

Figure 1.1. *Average annual rainfall in southern South Australia, with Goyder's Line shown in red*

The AMLR region is divided into seven subregion. Of these there are five with significant primary industries:

1. Northern Coasts and Plains (including the significant vegetable growing area around Virginia)
2. Northern Hills (Including the Barossa Valley wine region)
3. Central Hills (notable for both viticulture and perennial horticulture)
4. Willunga Basin (including the significant food and wine region of McLaren Vale)
5. Fleurieu Peninsula (including the large regional centre of Victor Harbor).

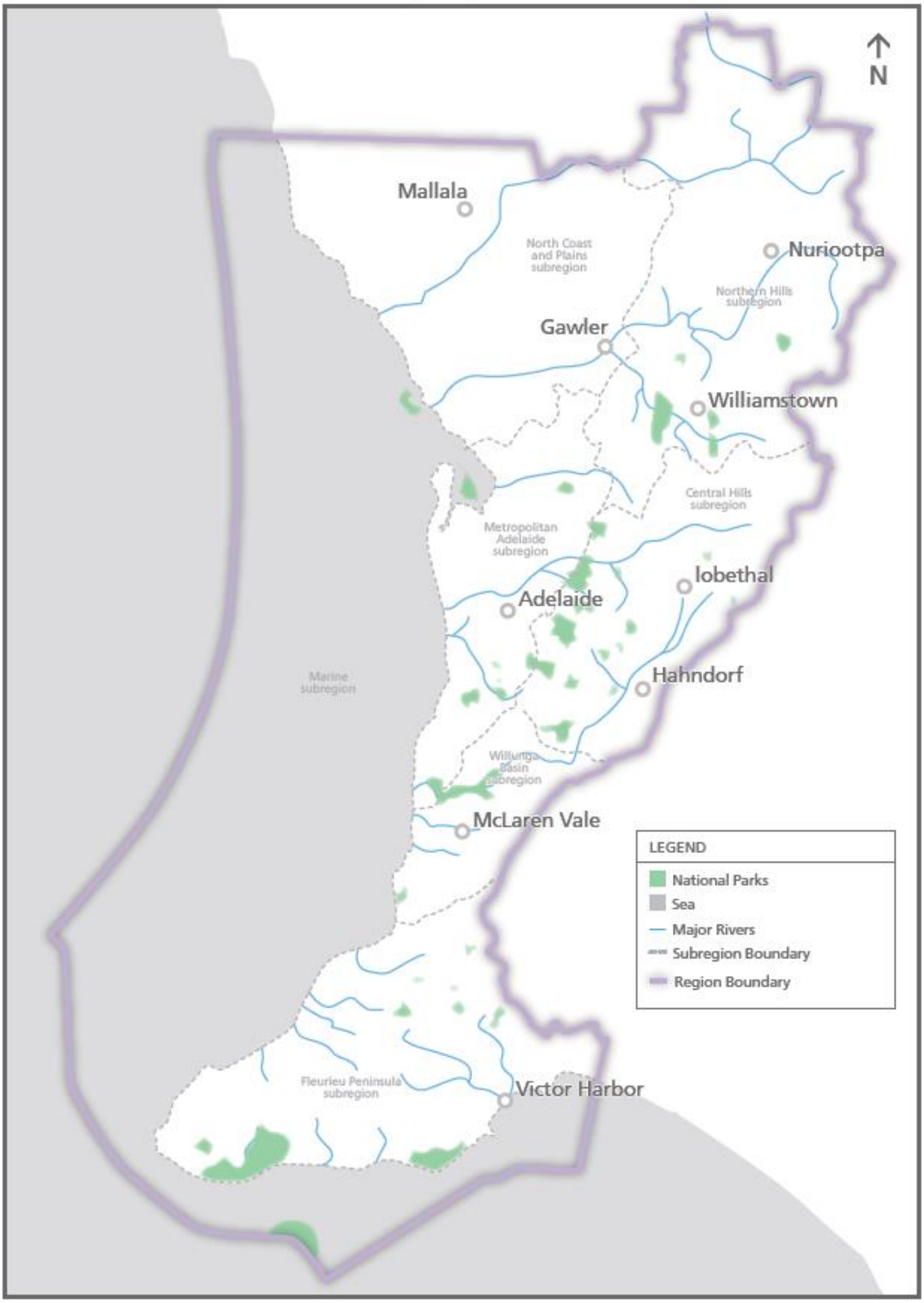

Figure 1.2. *The Adelaide and Mount Lofty Ranges Natural Resources Management region and its subregions*

This report considers agro-climatic vulnerabilities for key primary industries within the AMLR region, namely:

1. viticulture (grape production, mostly for wine)
2. perennial horticulture (fruit and nut production)
3. annual horticulture (the production of vegetables and vegetable-like fruit)
4. annual cropping (the production of field crops such as wheat and barley)
5. grazing (grazing of cows and sheep for meat production)
6. dairy (cow grazing for milk products).

Not all of these primary industries occur in each subregion.

Although it is useful to consider these six sectors separately, they fall within three main land uses, namely:

1. Perennial horticulture (including grapevines, tree and berry crops)
2. Annual cropping (broad acre cropping or vegetables)
3. Grazing (sheep, cattle and dairy).

With the 20 year period centred on 2030 taken as the projection timeframe, the agro-climatic risk factors explored in detail in this report are:

1. increased mean temperature (assumed to be a warming of 1°C or 2°C)
2. increased frequency/duration of extreme heat events (as a result of overall warming)
3. reduced autumn, winter and spring rainfall (as a consequence of a 10% or 20% reduction in annual rainfall)
4. Increased irrigation demand and decreased water quality/availability (as a result of both increased temperatures and reduced rainfall)
5. increased summer rainfall (by 10% or 20%).

The following additional agro-climatic issues have been acknowledged as relevant, and are briefly summarised in Chapter 2. They have not been further explored or ranked throughout this report, on the assumption that they are of lesser overall importance in the AMLR region:

1. Reduced extreme low temperature events
2. Increased atmospheric carbon dioxide concentrations
3. Increased rainfall intensity.

In this report we have considered a temperature increase of 1°C or 2°C, and a 10% or 20% change in rainfall for the 20 year period centred on 2030 (compared to the base period of 1980 to 1999). These possible climate futures were chosen to avoid a sense of false precision and to focus planning on the general expected trend of warming and drying. Although there will still be cooler than average, and warmer than average years into the future, we now expect each decade to be warmer than the preceding one. A winter drying trend will manifest as more dry years than wet years, but the year to year, and decade to decade, variability in Australian rainfall is much higher than the variability in temperature and is expected to remain so. It is also still possible that there will be a 'step change' drop in rainfall at some stage, as seems to have occurred in south western Western Australia in recent years. More local detail and updates are available from CSIRO and the Bureau of Meteorology at www.climatechangeinaustralia.gov.au

The vulnerability of primary industries in the AMLR region can be considered as a balance between the potential impact of climate change and the adaptive capacity at the field, farm and regional levels. Figure 1.3 shows a common framework which considers sensitivity (response of a system to climate event such as a heatwave) and exposure (degree to which a system is subject to the event). The vulnerability is more fully defined as the residual vulnerability, which is the vulnerability after cost effective climate risk management steps have been taken. Primary industries are exposed and sensitive, but responses to droughts and heatwaves in recent years show that there is also a high level of adaptive capacity[1].

Just as the climate is changing now and will change into the future, adaptive capacity will also change. The exercise of developing climate ready NRM plans for primary industries and the process of identifying risks, vulnerabilities and adaptation pathways will improve adaptive capacity.

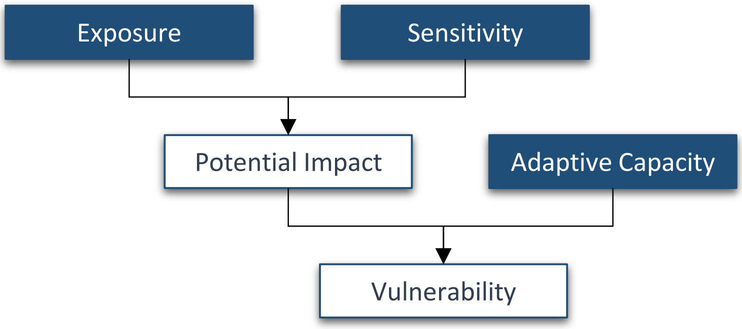

Figure 1.3. *Climate vulnerability as a function of exposure, sensitivity and adaptive capacity*

Climate impact and adaptive capacity are difficult to assess across a region, as to a large extent they are unique to each individual farm, vineyard or orchard. Even within a single vineyard there could be varieties which may actually benefit from some warming and others that will suffer, as there would be some blocks on shallow soils or with poorer irrigation structure which are at greater risk than others.

There has been a substantial amount of work on climate change impacts and adaptation undertaken for the AMLR region and some of it has focussed on primary production. It is important to build on this work. There is also work on sustainable agricultural production that covers climate change as one of a number of issues and this is clearly presented for each subregion in the Adelaide and Mount Lofty Ranges Regional Plan. Furthermore, each of the major primary industries (e.g. viticulture, grazing, perennial and annual horticulture, grain farming) have national and state level research development and extension activities on climate impacts and adaptation options. Figure 1.4 (derived from Bardsley *et al.*, 2006) shows an example of early work on climate change in the region, where the vulnerability framework shown in Figure 1.3 is applied to a range of areas within the AMLR region.

[1] The ability of a system to change in a way that makes it better equipped to deal with external influences

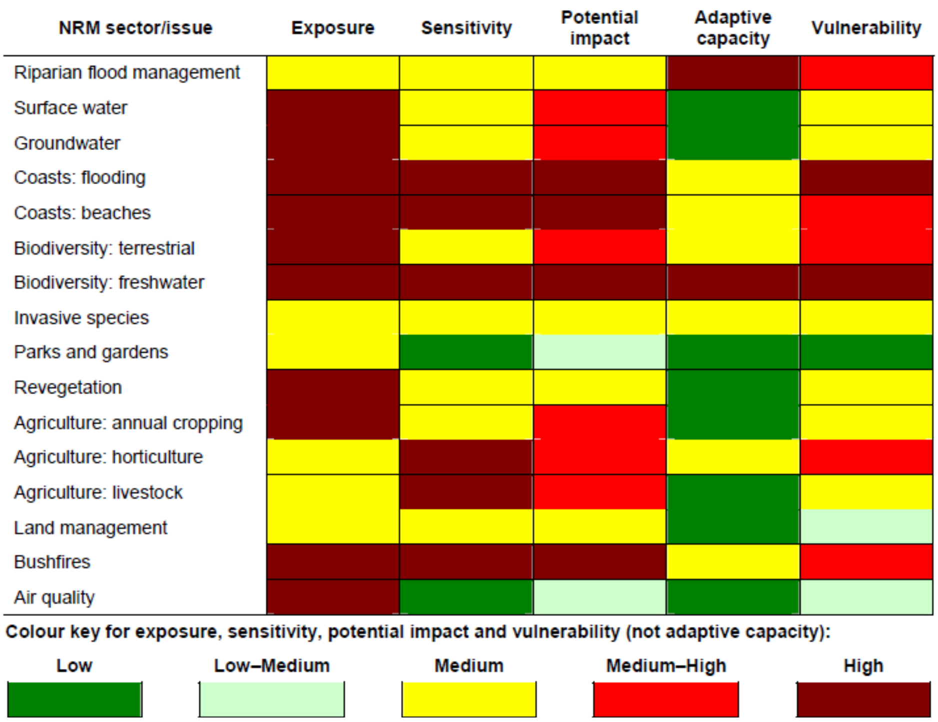

Figure 1.4. *A climate vulnerability matrix for key areas within the AMLR NRM region (Bardsley et al., 2006)*

This report uses a similar five point scale and modified ‘traffic lights’ to rate vulnerability of industries in different subregions for different climate risks. A low vulnerability score may result from a benign impact or because the adaptation measure is a relatively low cost one, such as replacing a wheat variety with a longer season one. A high vulnerability score may result from heatwaves under a 2°C warming scenario, as these will be difficult to manage, may in many cases be associated with heightened bush fire risk and may require the application of additional water for management.

Throughout the report spatial analogues (locations in Australia whose current climates are similar to the climates projected for the region) have been used to consider the types of vulnerabilities and adaptation options which may face the AMLR region in the future. The spatial analogues approach needs to be used carefully, as analogous locations may feature soils, distances to market, management strategies and cost structures which are all very different from the Adelaide and Mount Lofty Ranges locations they’re being compared to. Nonetheless, it is important to recognise that all primary industries in the region can be currently found in warmer and drier locations throughout Australia. Similarly, other regions deal with much wetter summers than the AMLR region’s (e.g. the Mornington Peninsula and the Yarra Valley in Victoria, outer Sydney, and South East Queensland), so there are opportunities to apply management practices used in those regions to reduce the region’s projected summer rainfall vulnerabilities.

Within the AMLR region, viticulture conditions and practices can be compared between the cooler and warmer subregions. Viticulture can also be compared to warmer and drier South Australian regions such as the Riverland, and with interstate locations such as the Swan valley (a much warmer area at Perth’s peri-urban fringe) and the Hunter Valley in New South Wales (which like the AMLR region, combines viticulture and tourism from a nearby capital city).

Similarly, the AMLR region’s annual and perennial horticulture industries can be compared with those of the Riverland (South Australia) and Mildura (Victoria), but also with those of the peri-urban fringes of Sydney and Perth (Camden and Pearce respectively). Cropping and livestock farmers in the AMLR region can look north and east to see similar industries operating in warmer and drier locations.

The rest of this report is organised as follows:

Chapter 2 outlines the five main climate risks considered in this report, and their respective scientific confidence levels, with a brief summary of related impacts and adaptation options. It also includes a brief overview of the potential implications of reduced frost events, increased carbon dioxide concentrations and increased rainfall intensity.

Chapter 3 provides primary industry vulnerability ratings across the subregions (by agro-climatic risk factor), using a colour coded vulnerability matrix.

Chapter 4 discusses the key climate vulnerabilities facing each primary industry (by agro-climatic risk factor). This chapter will therefore be of most use to the reader particularly interested in the vulnerability each agro-climatic risk factor poses for a given industry.

Chapter 5 provides the same vulnerability information presented in Chapter 4, but is organised by subregion. This chapter will therefore be of most use to the reader particularly interested in the vulnerability each agro-climatic risk factor poses for a given subregion.

For a detailed explanation of the agro-climatic analysis methods used in the preparation of this report refer to Appendix 1, and for detailed climate data sets used refer to Appendix 2.

A small number of relevant agricultural stakeholders were consulted regarding their views on climate vulnerability and resilience factors in the dairy, viticulture and perennial horticulture sectors within the AMLR region. Views of representatives of these sectors were sought as this report suggests they are the relatively more climatically vulnerable sectors (see Table 3.1).

Table 1.1 lists the names of stakeholders consulted, and Appendix 3 provides a summary of key comments received from each sector regarding key relevant climatic risk factors.

Table 1.1. *Industry stakeholders consulted for this report*

Sector	Name of stakeholder	Organisation
Dairy	Monique White	Dairy Australia
	Cathy Phelps	Dairy Australia
	David Basham	South Australian Dairy Farmers' Association
Perennial Horticulture	Paul Shanks	Barossa Infrastructure Limited (BIL)
	Paul James	Lenswood Cold Stores Co-operative Society
Viticulture	Nicki Robbins	Barossa Grape and Wine Association
	Kendra White	McLaren Vale Grape, Wine and Tourism Association
	Paul Petrie	The Australian Wine Research Institute
	Mardi Longbottom	The Australian Wine Research Institute
	Richard Hamilton	Adelaide Hills Wine Region
	Michael McCarthy	South Australian Research and Development Institute (SARDI)
	Wendy Allan	Pindarie Wines

Finally, the authors of this report acknowledge that some readers may disagree with individual vulnerability ratings presented herein, and wish to stress that their intention was for this analysis to facilitate an ongoing and informed debate, rather than be viewed as a definitive statement.

Chapter 2. Overview of key agro-climatic risks to primary production in the AMLR Region

There has been much written about climate change and agricultural production. Recent reviews of Australian circumstances include Howden *et al.*, 2010; Miller *et al.*, 2010; Stokes *et al.*, 2010; Webb *et al.*, 2010; and Webb and Whetton, 2010, while Jones (2010) reviews the expected impacts on water resources.

The five main agro-climatic risk factors deemed most relevant to agricultural production in the AMLR region are:

1. Warmer mean temperatures
2. More hot days and an increase in the frequency and length of heatwaves
3. Decline in autumn, winter and spring rainfall
4. Increased irrigation demand and decreased water quality/availability
5. Summer rainfall increases.

Table 2.1 provides more detail on these changes and summarises the degree of confidence of climate science in their magnitude and timing. It also summarises the current understanding of the impact of each climate factor on agricultural production. Most of the management strategies outlined in Table 2.1 are already being widely used by farmers, in the AMLR region and elsewhere.

The agro-climatic factors of reduction in frost events, increase in carbon dioxide concentrations and increased rainfall intensity are deemed less important and are therefore briefly summarised later in this chapter.

Table 2.1. *Overview of key agro-climatic risks and adaptation strategies for primary production in the AMLR region*

1. Warmer mean temperatures		
Scientific confidence	**Impacts**	**Adaptation and management strategies**
High confidence of warmer mean temperatures. Expect each decade to be warmer. Lower confidence in the seasonal pattern of warming. Nights have warmed more than days, but this may not remain a strong trend into the future.	Ripening of perennial horticulture/viticulture shifts to warmer periods. Possible de-coupling of sugar and flavour ripening in wine grapes. Impacts on harvest logistics. Insufficient chill accumulation for budburst. Increased winter growth of pasture, weeds and native vegetation, so reduced groundwater/dam storages. Changed spectrum of weeds and diseases.	Switching to longer season varieties and to warmer climate crops. Some opportunities for new varieties. Managing crop load and pruning In horticulture and viticulture. Use of chemicals to reduce chill accumulation requirements (shorter term option); or variety change, shift to cooler location within the region (longer term option). Continually monitoring pests, diseases and weeds. Monitoring effectiveness of chemical control measures.
2. More hot days and an increase in the frequency and length of heatwaves		
Scientific confidence	**Impacts**	**Adaptation and management strategies**
High confidence in general increase in frequency and intensity of summer heatwaves. Lower confidence in the timing of individual heatwaves.	Very dependent on the timing relative to stage of development. Reduced yield and product quality, e.g. sunburn damage. Increased demand for irrigation. Animal comfort related production impacts.	Changed sowing / planting schedules to avoid risky periods. Using weather forecasts to trigger pre-heatwave irrigation. Providing extra irrigation during the heatwave. Shade provision (trees and structures for animals, canopy for vines and fruit trees).
3. Decline in autumn, winter and spring rainfall		
Scientific confidence	**Impacts**	**Adaptation and management strategies**
Low to medium confidence in rainfall projections. Generally anticipating drier winters and springs. Lower confidence in summer projections. Medium to high confidence in increased evaporative demand (ETo) projections	Reduced production and increased risk of low groundcover. Reduced replenishment of surface (dam) water and groundwater. Altered pest and disease range and dynamics. Reduced average yields due to rainfall seasonality changes and increased drought.	Maximising water use efficiency by: - retaining crop residues/mulching to reduce evaporation and manage inter-row cover crop - monitoring soil moisture to optimise irrigation timing. Selecting drought tolerant varieties and rootstocks. Directing surface water run-off and increasing water infiltration through ground works. Reducing evaporation from dams through the use of covers and through dam design. Reducing erosion risks by: - retaining stubble - reducing grazing pressure - establishing contour banks where appropriate.

4. Increased irrigation demand and decreased water quality/availability		
Scientific confidence	**Impacts**	**Adaptation and management strategies**
High confidence that crops will require more irrigation in a drier, warmer environment.	If increased demand is not met – reduced product quality, especially in dairy and in annual and perennial horticulture. If increased demand is met – salts present in the additional irrigation water may increase root zone salinity, potentially leading to crop and soil quality reduction.	Water efficiency measures as outlined in Section 3. Water trade is possible (as regulated by Water Allocation Plans), but volumes traded are currently relatively small. Stormwater/wastewater storage and reuse.

5. Summer rainfall increases		
Scientific confidence	**Impacts**	**Adaptation and management strategies**
Low to medium confidence in rainfall projections. Lower confidence in projections for summer.	Altered pest and disease dynamics. Reduced product (fruit and vegetable) quality.	Using spring and summer seasonal forecasts to prepare ahead of time (e.g. the wet summer of 2010/11 was partly explained by a forecast La Nina event). Selecting better adapted varieties. Considering water proof crop covers, when economical.

Additional agro-climatic factors for consideration

Increased rainfall intensity

Rainfall intensity is a measure of the amount of rainfall over a given time, often millimetres per hour. High intensity rainfall is a problem for soil erosion and localised flooding. Winter rainfall in the AMLR region is associated with frontal weather patterns and is typically of relatively low intensity. In contrast, summer rainfall, especially when associated with convective thunderstorms, is typically of higher intensity. Because a warmer atmosphere holds more water, the intensity of rainfall in all seasons is likely to increase with climate change. Rainfall intensity in the AMLR region is lower than in many other locations in Eastern and Northern Australia where similar agriculture is practiced. However any increase from what is currently seen as normal could create challenges for management and design.

A reduction in frost events

In the long term, the number of frost events is likely to decrease with the increase in minimum temperatures. A reduction in frost would present opportunities because a longer frost free period will allow plants to be grown for a longer period within each year. A reduction in frost events would also be directly beneficial to the viticulture, perennial horticulture and annual cropping sectors, all of which typically sustain serious economic losses due to frost events. Nonetheless, the following frost related risk factors should be kept in mind:

1. Although maximum and minimum temperatures are expected to increase, it is harder to be definitive about frost events. As the AMLR region's frosts are radiation frosts, and are strongly associated with clear night skies, winter and spring drying could see the frequency of frost actually increasing. Furthermore, the changes in weather patterns associated with climate change may lead to more frequent inflows of dry cold polar air over the region.
2. Even if frost frequency changed very little, altered phenology due to warming may increase the risk of frost damage to some crops, because early spring buds (for example in grapevines) and flowers (for example in wheat) are exposed to colder night temperatures than those developing in later spring (when conditions are slightly warmer). In annual crops like wheat, this can be simply managed by changing to a longer season variety. In perennial crops like grapevines, sprinklers and wind turbines

are commonly used in frost prone areas. Other management options that may reduce the level of frost damage include changes to inter row ground cover, including presence and type of cover crops and irrigation of the inter row area. Some viticulturists delay pruning to delay budburst and hence reduce the risk of frost damage, and this is currently an active area of research.

3. Freezing temperatures can play an important role in keeping pest and disease levels down, and while many crops will benefit from less frequent frost events, pests and diseases may similarly benefit.

Overall, it is likely that in the coming decades, untimely frosts will remain a low frequency but high consequence problem in parts of the region.

An increase in carbon dioxide concentrations

There is very high confidence in the scientific community that atmospheric concentrations of carbon dioxide will continue to increase over the coming decades. It is also well known that higher levels of carbon dioxide increase transpiration efficiency[2], in effect increasing plant growth per unit of water received. This increased efficiency may well compensate for some of the expected increase in plant water demand and the concurrent decrease of water supply associated with a warmer and drier future. However there are some risk factors to bear in mind:

1. The impacts of increased carbon dioxide concentrations are much better understood at the single leaf and plant level than at the whole crop and ecosystem level. More vigorous growth may require different pruning techniques and a revision of irrigations coefficients used for different crop stages.
2. There are some uncertainties regarding the interactions between increased carbon dioxide concentrations and risk factors such as frost and extreme heat events, with some concern that increased carbon dioxide levels will increase the sensitivity of plants to such stresses.
3. Weeds and pests may also benefit from higher carbon dioxide levels, which may require new control and management methods.

[2] Transpiration efficiency is the amount of water transpired for a given amount of carbon accumulated through photosynthesis.

Chapter 3. Rating the climate change vulnerability of key agricultural industries in the AMLR NRM region

Table 3.1 is a matrix summarising the five main agro-climatic risks for primary industries in each subregion at two levels of warming (1°C warming and 2°C warming) and at two levels of rainfall change (10% dryer and 20% dryer autumns winters and springs, as well as 10% or 20% wetter summers).

Table 3.1. *Matrix of vulnerability of the AMLR region's main primary industries to projected climate change, with coloured dots representing degree of vulnerability*

	Viticulture				
Increase in mean temperature	Most current winegrape varieties near or beyond accepted thresholds. Altered management or changes in variety are possible. Loss of 'cool climate' status may affect some areas.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●	●	●	●
2°C warmer	●	●	●	●	●
More hot days, higher frequency and longer heatwaves	Potential loss of quality/ flavour. High reputation wine regions (e.g. Barossa) more vulnerable.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●	●	●	●
2°C warmer	●	●	●	●	●
Decline in autumn, winter and spring rainfall	Dependent for filling profiles over winter and major source of water through growth period. Irrigation requirements will increase.				
Subregion	NP	NH	CH	WB	FP
10% drier	●	●	●	●	●
20% drier	●	●	●	●	●
Increased irrigation demand, decreased water quality/availability	High value crop. Yield and quality may suffer. Irrigation used to manage heatwaves.				
Subregion	NC	NH	CH	WB	FP
10% drier	●	●	●	●	●
20% drier	●	●	●	●	●
Increased summer rainfall	May reduce fruit quality.				
Subregion	NP	NH	CH	WB	FP
10% wetter	●	●	●	●	●
20% wetter	●	●	●	●	●

	Perennial Horticulture				
Increase in mean temperature	Insufficient chill accumulation in perennial horticulture unlikely with 1°C warming but near threshold with 2°C warming.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●		●	●	
2°C warmer	●		●	●	
More hot days, higher frequency and longer heatwaves	Potential losses in quality (visual for cherry, apple, stonefruit, less so for almonds)				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●		●	●	
2°C warmer	●		●	●	
Decline in autumn, winter and spring rainfall	Major source of water for growth period. Irrigation requirements will increase.				
Subregion	NP	NH	CH	WB	FP
10% drier	●		●	●	
20% drier	●		●	●	
Increased irrigation demand, decreased water quality/availability	High value crop. Yield and quality may suffer. Irrigation used to manage heatwaves.				
Subregion	NP	NH	CH	WB	FP
10% drier	●		●	●	
20% drier	●		●	●	
Increased summer rainfall	May reduce fruit quality.				
Subregion	NP	NH	CH	WB	FP
10% wetter	●		●	●	
20% wetter	●		●	●	

	Cropping				
Increase in mean temperature	Can be partially managed with changes in variety or sowing time.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●			
2°C warmer	●	●			
More hot days, higher frequency and longer heatwaves	Concern of warmer temperatures near flowering.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●			
2°C warmer	●	●			
Decline in autumn, winter and spring rainfall	Yields related to rainfall quantity and seasonality. There will be a yield penalty, but crops can be grown with 10 or 20% less rainfall.				
Subregion	NP	NH	CH	WB	FP
10% drier	●	●			
20% drier	●	●			
Increased irrigation demand, decreased water quality/availability	Not applicable				
Subregion	NP	NH	CH	WB	FP
10% drier					
20% drier					
Increased summer rainfall	May add to summer weed control requirements.				
Subregion	NP	NH	CH	WB	FP
10% wetter	●	●			
20% wetter	●	●			

	Annual Horticulture				
Increase in mean temperature	Can be partially managed with changes in species, variety or sowing time.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●		●		
2°C warmer	●		●		
More hot days, higher frequency and longer heatwaves	Potential major losses in quality from extreme heat events.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●		●		
2°C warmer	●		●		
Decline in autumn, winter and spring rainfall	Some concern as crops rely less on rainfall and more on irrigation from groundwater and treated water.				
Subregion	NP	NH	CH	WB	FP
10% drier	●		●		
20% drier	●		●		
Increased irrigation demand, decreased water quality/availability	High value crop with high water requirements.				
Subregion	NP	NH	CH	WB	FP
10% drier	●		●		
20% drier	●		●		
Increased summer rainfall	Low impact unless intensity increases.				
Subregion	NP	NH	CH	WB	FP
10% wetter	●		●		
20% wetter	●		●		

	Livestock Sheep/cattle				
Increase in mean temperature	Small benefits from slightly increased winter pasture growth. Summer growth affected at higher temperatures.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●	●		●
2°C warmer	●	●	●		●
More hot days, higher frequency and longer heatwaves	Sheep less susceptible than cattle with milking breeds more susceptible than meat breeds.				
Subregion	NP	NH	CH	WB	FP
1°C warmer	●	●	●		●
2°C warmer	●	●	●		●
Decline in autumn, winter and spring rainfall	Dependent on spring rainfall for pasture production. Limited opportunities for irrigation of pastures.				
Subregion	NP	NH	CH	WB	FP
10% drier	●	●	●		●
20% drier	●	●	●		●
Increased irrigation demand, decreased water quality/availability	Lower value crop; usually rain-fed				
Subregion	NP	NH	CH	WB	FP
10% drier	●	●	●		●
20% drier	●	●	●		●
Increased summer rainfall	Overall likely to be beneficial.				
Subregion	NP	NH	CH	WB	FP
10% wetter	●	●	●		●
20% wetter	●	●	●		●

	Livestock Dairy				
Increase in mean temperature	Small benefits from slightly increased winter pasture growth. Summer growth affected at higher temperatures				
Subregion	NP	NH	CH	WB	FP
1°C warmer			●		●
2°C warmer			●		●
More hot days, higher frequency and longer heatwaves	Small increase in days with moderate THI.				
Subregion	NP	NH	CH	WB	FP
1°C warmer			●		●
2°C warmer			●		●
Decline in autumn, winter and spring rainfall	Very dependent on spring rainfall for pasture production. Although it will come at a cost, it can be supplemented with irrigation.				
Subregion	NP	NH	CH	WB	FP
10% drier			●		●
20% drier			●		●
Increased irrigation demand, decreased water quality/availability	High value enterprise with high water requirements.				
Subregion	NP	NH	CH	WB	FP
10% drier			●		●
20% drier			●		●
Increased summer rainfall	Overall likely to be beneficial.				
Subregion	NP	NH	CH	WB	FP
10% wetter			●		●
20% wetter			●		●

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge. NP - Northern Coasts and Plains, NH - Northern Hills, CH – Central Hills, WB - Willunga Basin; FP – Fleurieu Peninsula.

Chapter 4. Vulnerability of Main Primary Production Industries

4.1 Viticulture

With nationally important wine regions such as the Barossa Valley and McLaren Vale, viticulture has a distinct place in the AMLR region, which goes beyond its direct economic contribution to less quantifiable qualities such as regional character and heritage values. Table 4.1 shows climate vulnerability rankings for the viticulture sector across agro-climatic risk factors, by subregion.

Table 4.1. *Vulnerability of viticulture to projected climate change, by subregion*

Viticulture		**Northern Plains**	**Northern Hills**	**Central Hills**	**Willunga Basin**	**Fleurieu Peninsula**
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Warmer mean temperatures

The production of high quality wine grapes is sensitive to changes in mean temperature, as temperature influences the timing of plant development and the rate of accumulation of sugars, colour and complex flavours. An increase in mean temperature will influence individual vintages and then overall styles of wine, and past a certain point may finally threaten the suitability of a region for certain grape varieties (see Table 4.2). It is important to note that many in the wine industry will disagree with the figures presented in Table 4.2, and obviously there are viable wine grape industries in warm sites such as Mildura and Griffith. Warmer summers may hasten fruit development, which could result in ripening occurring in late summer (i.e. February) rather than under cooler autumn conditions (i.e. in March). This shift will not only have an impact on quality, but will also increase the chance of a heatwave coinciding with the sensitive stages of fruit ripening and harvest (as heatwaves are more likely in February than in March). Warmer conditions can also lead to a compression of ripening periods between varieties, creating logistical pressures for wineries. The risk of warmer mean temperatures resulting in insufficient chill accumulation is however minor, as grapes have low chill requirements.

While warming is likely to reduce the chance of lower night temperatures (and the potential for frost), this does not necessarily mean that the risk of damage to plants will also be reduced, because earlier budburst due to spring warming could mean the plants are vulnerable at an earlier time of the year when temperatures are still low. Another consideration is that a warmer mean temperature may alter a wine region's climate classification (for example Adelaide Hills' cool climate classification) and hence affect the marketing of the regions' wines. This is an issue especially for the Central Hills subregion.

Table 4.2. *A classification of common wine grape varieties by growing season temperature, using northern hemisphere benchmark wine regions (Jones et al., 2005)*

	Growing Season Temperature (°C)											
Varieties	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Pinot Gris	X	X	X									
Riesling	X	X	X	X	X							
Pinot Noir		X	X	X								
Chardonnay		X	X	X	X							
Sauvignon Blanc			X	X	X	X						
Semillon			X	X	X	X						
Cabernet Franc			X	X	X	X	X					
Tempranillo				X	X	X	X					
Merlot				X	X	X	X					
Malbec				X	X	X	X					
Viognier				X	X	X	X					
Shiraz			X	X	X	X	X					
Table Grapes				X	X	X	X	X	X	X	X	X
Cabernet Sauvignon				X	X	X	X	X				
Grenache				X	X	X	X	X				
Carignane					X	X	X	X				
Zinfandel					X	X	X	X	X			
Nebbiolo					X	X	X	X	X			
Raisins						X	X	X	X	X	X	X

2. More hot days and an increase in the frequency and length of heatwaves

Recent years have highlighted the vulnerability of wine grape production to heat waves. Factors that will affect the impact of a heat event include the maximum and minimum temperatures experienced, the event's duration, and the stage of the plants' development at the time of the event. For example a hot November day may affect the total number of grapes on the vine through an impact on pollination of those varieties flowering at the time, but may not affect varieties that have already completed their flowering or are yet to flower. Similarly heatwaves in March may have dramatic effects on berry quality if fruit is yet to be harvested.

3. Decline in autumn, winter and spring rainfall

Although most wine grapes are irrigated, drought and reduced autumn, winter and spring rainfall do pose risks for viticulture. The majority of the AMLR region's annual rainfall occurs during autumn and winter, a time when grapevines are dormant and their water requirements are nil or low. This winter and autumn rainfall is stored within the soil, runs off to on-site dams, or replenishes groundwater. While rainfall during periods of active plant growth (in spring and summer) is used by the plants, most of their water needs are met by these stored water supplies, hence the plant's medium to high vulnerability to reduced autumn, winter and spring rainfall. Additionally, winter rainfall often plays an important role leaching salt out of the root zone, so its reduction may lead to higher root zone salinity and hence to crop and soil quality reduction.

4. Increased irrigation demand and reductions in quality and quantity of water

As the soil is not able to store enough water in the wetter season to provide all the vine's water requirements during the drier (plant growth) season, most viticulture enterprises depend for their viability on the availability of high quality irrigation water. The risk to viticulture from restricted irrigation availability is therefore medium to high for a 10% drier future, and high for a 20% drier future.

5. Summer rainfall increases

While summer rainfall can increase disease risk for leaves and fruit, other regions deal with much wetter summers than the AMLR NRM region (e.g. the Mornington Peninsula and the Yarra Valley in Victoria, outer

Sydney, and South East Queensland), and there are opportunities to apply management practices used in those regions (e.g. spraying of fungicides and canopy management for quicker drying after rainfall).

For a summary of viticulture sector stakeholder comments refer to Appendix 3.

4.2 Perennial Horticulture

Deciduous fruit crops cover the bulk of perennial horticulture in the AMLR region. Apple, pear and cherry production is mainly located in the Adelaide Hills, and apricots, nectarine, peaches and almonds are mainly produced in the warmer subregions.

Table 4.3 shows climate vulnerability rankings for the perennial horticulture sector across agro-climatic risk factors, by subregion.

Table 4.3. *Vulnerability of perennial horticulture to projected climate change, by subregion*

Perennial Horticulture		Northern Plains	Northern Hills	Central Hills	Willunga Basin	Fleurieu Peninsula
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Warmer mean temperatures

The main impact of a warmer mean temperature on deciduous fruit crops is a reduction in winter chill accumulation, which is required to complete dormancy. If the buds do not receive sufficient chilling temperatures during winter to completely release dormancy, trees will develop one or more of the physiological symptoms associated with insufficient chilling, namely:

- delayed, erratic or uneven bud break (vegetative and floral)
- reduction in flower quality and fruit set
- reduction in fruit size and crop yield
- reduced fruit quality.

As different varieties within a species vary significantly in their chill requirements, there is scope to overcome the risk of insufficient chill accumulation through appropriate variety selection. For some industries, particularly those that rely on only a few varieties and those that rely on cross-pollination of the main crop with pollinator varieties (e.g. almond), the opportunity to change varieties is more limited. Another approach is to reduce chill requirements by using rest breaking agents [3].

Another impact of warmer mean temperatures is the hastening of phenological development after budburst (in spring and summer), which may cause fruit to ripen earlier (i.e. in February instead of in

[3] Compounds such as mineral oil, Giberellic Acid, potassium nitrate , Thiourea, hydrogen cyanamide and fatty acids and their esters have rest breaking properties which could alleviate insufficient chill accumulation, however they should be used cautiously due to their associated environmental impact concerns (such as toxicity).

March), when extreme heat conditions are more likely to occur. This may increase the risk of hot northern winds and heatwaves damaging fruit just before picking time, when it is generally most vulnerable to such conditions.

2. More hot days and an increase in the frequency and length of heatwaves

Perennial horticulture is already affected by heatwaves and high temperature events in the AMLR region. Extreme heat can affect the current crop by damaging fruit appearance and quality and by damaging the leaf canopy. It may also affect the buds (present on the trees at the time of fruit harvest, say around March) that will produce the following years' crop. Almonds for example may suffer non-infectious bud failure (i.e. failure not related to disease) of the following years' buds if exposed to extremely high summer temperatures.

3. Decline in autumn, winter and spring rainfall

As in viticulture, the majority of annual rainfall occurs at a time when the water requirements (of these largely deciduous trees) are nil or low, due to nil or low leaf area and low evaporative demand. This rainfall is not wasted as it gets stored (in soil, dams, groundwater) and is subsequently utilised during periods of more active plant growth, lower rainfall and higher evaporative demand. Reduced autumn, winter and spring rainfall will affect these stored water supplies. Additionally, winter rainfall often plays an important role leaching salt out of the root zone, so its reduction may lead to higher root zone salinity, and hence to crop and soil quality reduction.

4. Increased irrigation demand and reductions in quality and quantity of water

Water stored within the soil profile during periods of higher rainfall and lower evaporative demand is typically insufficient to meet the plant's summer water demands, and so the perennial horticulture industry requires reliable irrigation water to produce high quality fruit and remain viable. As many crops and stages of crop growth have low tolerance to saline water, that irrigation water must also be of high quality (i.e. low salinity), as salts present in irrigation water may increase root zone salinity, potentially leading to crop and soil quality reduction.

5. Summer rainfall increases

The cherry, almond and soft fruit (apricot, peach, nectarine) industries are more vulnerable to summer rainfall increases than the apple and pear industries. Cherry fruit which are generally produced in the region from early summer to mid-summer are susceptible to cracking after rainfall, but just how much rainfall is required for cracking to occur is not currently known (Measham *et al.*, 2009). The extent of fruit cracking also depends on factors such as the level of irrigation stress that the tree and fruit have experienced, air humidity, and length of time fruit is wet, with fruit nearer to development being more susceptible to cracking. In the almond industry, summer rainfall can cause infection of the kernels prior to harvest, and soil hygiene is another risk factor. Almond kernels are harvested from mid to late summer by shaking the trees and collecting the kernels from the soil surface. While in contact with the soil surface, the kernels are potentially susceptible to fungal infection (which if contracted renders them unsaleable), a risk which is increased by soil wetness.

In addition to the impacts on fruit, summer rainfall can increase risk of leaf diseases and damage to the canopy. These are low to moderate risks that could probably be managed through altered canopy management (to increase air flow and reduce opportunities for disease infestation), or through chemical controls. As in the viticulture industry's case, other fruit growing regions (e.g. in southern Victoria, New South Wales and Queensland) deal with much wetter summers than the AMLR region, so there are opportunities to apply management practices used in those regions.

For a summary of perennial horticulture sector stakeholder comments refer to Appendix 3.

4.3 Annual Horticulture

Annual horticulture in the AMLR region is largely centred on vegetable and associated fruit (solanaceae and cucurbit) production in the Northern Adelaide Plains (within the Northern Coast and Plains subregion), although this industry sector also exists within other subregions. These crops are grown in short rotations and comprise numerous varieties, and thus many opportunities exist to change species or variety to better suit conditions during particular times of the year. In addition, some production occurs in modified environments (semi or fully controlled greenhouses), where weather extremes can be managed. Nonetheless, continual production throughout the year means plants may be exposed to unfavourable conditions at any stage of their lifecycle.

Table 4.4 shows climate vulnerability rankings for the annual horticulture sector across agro-climatic risk factors, by subregion.

Table 4.4. *Vulnerability of annual horticulture to projected climate change, by subregion*

Annual Horticulture		**Northern Plains**	**Northern Hills**	**Central Hills**	**Willunga Basin**	**Fleurieu Peninsula**
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Warmer mean temperatures

Warmer mean temperatures will encourage faster growth and possibly allow for earlier harvest or for more rotations per year, but may also:

- disadvantage root and tuber growth as compared to stem and leaf growth (which may be of concern in crops such as potato and carrot)
- speed up plant development to the flowering stage in some vegetable crops (i.e. cause 'bolting'), resulting in insufficient biomass accumulation and the production of an unsaleable product.

2. More hot days and an increase in the frequency and length of heatwaves

Extreme heat events significantly increase the risk of visual damage to leaves and fruit, which may cause products to be downgraded or make them altogether unmarketable. Management options such as increased irrigation and shading will reduce these risks and the associated damages, however they both carry additional costs, which may be both upfront and ongoing (maintenance related).

Components of the plant's reproductive system (in charge of pollination/fertilisation) are even more sensitive to extreme heat than the leaves and fruit. Damage to those reproductive components may result in reduced pollination and hence fewer fruit, and may also cause uneven harvests, which complicate harvest logistics and increase costs to farmers.

3. Decline in autumn, winter and spring rainfall

The region's annual crops depend on a high and steady water supply (through a combination of rainfall and irrigation) to meet the market's growth and quality demands. Reduced rainfall increases the demand for irrigation, and hence irrigation costs (such as pumping costs in the case of groundwater use).

4. Increased irrigation demand and reductions in quality and quantity of water

The annual horticulture industry requires reliable irrigation water to produce high quality products and remain viable. Irrigation water may be sourced from groundwater and/or from treated/reclaimed water piped in from outside the enterprise area. As many crops and stages of crop growth have low tolerance to saline water, that irrigation water must also be of high quality (i.e. low salinity), as salts present in irrigation water may increase root zone salinity, potentially leading to crop and soil quality reduction.

Increased Irrigation demand and reduced availability has been deemed in this report as the highest vulnerability factor for the region's annual horticulture.

5. Summer rainfall increases

Any untimely rainfall can interfere with sowing, pest control and harvest operations. Rainfall during the warmer summer months may increase leaf and fruit disease risk, but this is likely to be controlled with small modifications to current management practices. Intense rain (at all times) that creates flooding can damage infrastructure such as glasshouses and packing sheds, as well as increase the spread of soil borne diseases and weeds.

4.4 Annual Field Crops

Annual field crops are grown in the Northern Coast and Plains subregion as well as at the margins of the Northern Hills subregion. Common crops are cereals (wheat, barley, oats), canola and pulses (legume crops). These are all crops sown in autumn and typically harvested in early summer (or sometimes in late spring).

Table 4.5 shows climate vulnerability rankings for the annual field crops sector across agro-climatic risk factors, by subregion.

Table 4.5. *Vulnerability of annual horticulture to projected climate change, by subregion*

Annual Field Crops		**Northern Plains**	**Northern Hills**	**Central Hills**	**Willunga Basin**	**Fleurieu Peninsula**
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Warmer mean temperatures

The mean temperature during the crop growing season (1st April - 31st October) in the AMLR region is lower than many other locations where these crops are grown, both within South Australia and elsewhere in Australia and overseas. This implies cropping in the AMLR is not directly limited by warm temperatures and that there is a level of resilience to increasing mean temperature. Developmental phenology will be faster with a warmer mean temperature, which may mean that sensitive stages of plant development will shift to times when the risk of extreme cold events is higher, such as late winter or early spring. Farmers are, however, well aware of these risks and are already managing them. Two management options are shifting sowing times to ensure flowering does not occur when frost risk is high, and selecting later maturing varieties. However the current rules of thumb used to decide the interaction between sowing time and plant maturity type [4] will need to be modified to account for faster plant phenological development and hence changes to the expected time of flowering when plants of a particular maturity type are sown at specified dates. This is especially the case where there is a risk of frosts which can greatly reduce crop yield, as the flowering process and early grain development are both very sensitive to low temperatures.

2. More hot days and an increase in the frequency and length of heatwaves

Field crops are typically grown in the cooler parts of the year (sowing in autumn, flowering in spring, harvest in later spring/early summer). High temperatures will continue to impact on growth and production, particularly if they coincide with flowering or with the early stages of grain fill (which may occur from September to November, depending on sowing date and plant maturity type). Even just one or two very warm spring days (with maximum temperature above 30°C) can affect flowering and reduce wheat yields.

3. Decline in autumn, winter and spring rainfall

While many grain growing farms outside of the AMLR region manage to remain viable under warmer and drier conditions, viable grain production in the region typically follows a high input – high yield model, and a crop failure can therefore be very expensive. The yield of field crops is strongly related to cool season (April to October) rainfall, while November to March rainfall is only useful (for the current or subsequent crop) if stored in the soil and not lost as soil evaporation or used up by weeds. Management practices such as stubble retention and summer weed control can increase the amount of rainfall stored within the soil.

4. Increased irrigation demand and reductions in quality and quantity of water

Most field crops are not irrigated, and are therefore not vulnerable to irrigation water restrictions.

5. Summer rainfall increases

In some varieties of wheat, high rainfall in late spring/ early summer has been associated with pre-harvest seed germination, resulting in a quality downgrade for the final product.

Late spring rain may increase the risk of diseases in crops, but existing chemical disease control measures should continue to be useful for the foreseeable future. An increase in summer rain may however allow some diseases to persist over summer on a 'green bridge'[5], thus increasing risks to the following crop. The green bridge is often created when grain left behind from harvest receives enough water to germinate and grow. This water would come from rainfall, but the amount required will depend on soil conditions and the balance between the gain in soil water (through rainfall) and its loss (through evaporation and plant transpiration). As the ratio of evapotranspiration to rainfall over summer in the region is currently very high, large summer rainfall increases would be needed to change the current balance and significantly increase the risk of some diseases using the 'green bridge' to persist over summer.

[4] The term 'maturity type' refers to the categorisation of plants according to the length of time they require to progress through the phenological stages. Thus a longer maturity type plant will flower later and be harvested later than a shorter maturity type (if sown on the same day in the same location).

[5] The term 'green bridge' refers to any plants (crops as well as weeds) growing in the field between harvest and sowing of the subsequent crop.

4.5 Livestock Enterprises - Grazing and Dairy

Within the AMLR region, grazing occurs mainly in the Northern Hills, Central Hills and Fleurieu Peninsula subregions, while dairy occurs mainly in the Fleurieu Peninsula subregion, and to a lesser extent through the Central Hills. Both enterprise types require adequate pasture, which may be provided through on-farm production and supplemented with off-farm supply of hay, grain and silage.

Tables 4.6a and 4.6b show climate vulnerability rankings for the grazing and dairy industries across agro-climatic risk factors, by subregion.

Table 4.6 a and b. *Vulnerability of the grazing (Table a, upper) and dairy (Table b, lower) industries to projected climate change, by subregion*

Livestock - grazing		**Northern Plains**	**Northern Hills**	**Central Hills**	**Willunga Basin**	**Fleurieu Peninsula**
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Livestock - dairy		**Northern Plains**	**Northern Hills**	**Central Hills**	**Willunga Basin**	**Fleurieu Peninsula**
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Warmer mean temperatures

While warmer winter temperatures may increase pasture growth, past a certain point warmer summer temperatures may reduce pasture production or its quality. Changes in the seasonality of feed quality and availability may necessitate changes to pasture composition, as well as changes to grazing systems, for example:

- increased use of cell grazing to more efficiently grow and utilize available pasture
- increased feedlotting
- increased purchasing of off-farm feed.

The Thermal Humidity Index (THI) measures the combined effects of heat and relative humidity, and is used to assess animal heat stress risks. Dairy Australia's Cool Cows website [6] provides information on the effects on dairy cows at different THI values, and outlines management strategies for dealing with excessive heat

[6] http://www.dairyaustralia.com.au and http://www.coolcows.com.au

loads. THI figures will increase in a warmer climate, meaning that the risk of heat stress to livestock will increase. However, even under a warmer climate, THI figures are likely to remain below critical thresholds on most days, due to humidity in the AMLR region remaining generally low. This contrasts with subtropical and tropical regions where increased heat may be associated with higher humidity, and therefore with very high THI conditions, leading to severe animal stress or animal death.

2. More hot days and an increase in the frequency and length of heatwaves

As extreme heat events in the AMLR region are usually associated with extremely low humidity, THI figures are not likely to reach the most severe category, associated with animal death. Nonetheless, production may suffer through reduced fertility and milk supply. Management options include providing cattle with adequate shade, water, access to evaporative cooling, and sufficient high quality feed. Dairy Australia's Cool Cows website [6] provides advice on managing the impact of high temperatures on dairy cow comfort.

3. Decline in autumn, winter and spring rainfall

An increase in the year-to-year variation in annual rainfall, along with the gradual decline in rainfall, may adversely impact pasture production (considering that optimal pasture composition and management is difficult to achieve at all times). Pasture production will decrease in years with lower rainfall, requiring altered management (such as reduction in cattle numbers or increased hand feeding) to avoid over-grazing, reduced land cover and soil erosion. Feed gaps may become more extensive and may necessitate changes in feed allocation and increased reliance on irrigation. Species composition within the pasture may have to be altered to make more efficient use of the available water resources.

4. Increased irrigation demand and reductions in quality and quantity of water

Reduced irrigation will translate into reduced pasture growth, and hence reduced carrying capacity and an increase need to feed lot cattle or purchase off-farm feed supplies.

5. Summer rainfall increases

Summer rainfall increases would actually be overall beneficial to livestock enterprises, as current pasture growth over summer is limited by low rainfall. In cases of pasture being normally irrigated throughout summer, higher summer rainfall would decrease irrigation requirements and the associated costs.

For a summary of dairy sector stakeholder comments refer to Appendix 3.

Chapter 5. Vulnerability of Subregions

5.1 Northern Coasts and Plains

The Northern Plains and Coast subregion supports the main annual horticulture enterprises that supply Adelaide. Perennial horticulture, viticulture, annual cropping and livestock enterprises are also present. The locations analysed to represent this subregion were the Edinburgh RAAF and Roseworthy (see appendix 2).

The Northern Plains and Coast is the AMLR region's warmest and driest subregion. As shown in Appendix 2, a warming of 1°C for Edinburgh will make the average year in the future climate warmer than the 9 in 10 warmest year [7] in the current climate. A warming of 2°C would shift the subregion to a new temperature regime. Increased temperatures will impact all primary industry types, but (as shown in Table 5.1), the authors estimate that perennial horticulture will be most severely affected, followed by viticulture and then annual horticulture before cropping and livestock.

Table 5.1. *Vulnerability of the Northern Coasts and Plains subregion to agro-climatic risks, by industry type*

Northern Coasts and Plains		Viticulture	Perennial Horticulture	Cropping	Annual Horticulture	Livestock Grazing
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. **The Northern Coasts and Plains subregion already has low winter chill levels, and these will drop further with warming**

Winter chill accumulation [8] is important for fruit trees, and warmer winters will result in lesser chill being accumulated throughout winter. The Dynamic Chill Model [9] shows Edinburgh to have a relatively low winter chill of 48 chill portions, dropping 8 or 9 chill portions per degree of warming. As shown in Figure 5.1, the current level of chill in Edinburgh is much lower than in fruit growing regions such as Lenswood or Tatura (Vic), but is also lower than the inland irrigated areas of Loxton (SA), Mildura (Vic) and Griffith (NSW).

[7] The '9 in 10 warmest year' refers to the 90% point in the temperature distribution curve, that is to say the year which is warmer than 90% of all years and only cooler than 10% of all years considered (which in this case are the baseline period years, from 1980 to 1999). Similarly, the '2 in 10 warmest year' is a reference to a relatively cool year, warmer than only 20% of years considered and cooler than 80%.

[8] Winter chill is a cumulative measure of cold temperatures over winter. Accumulation of sufficient winter chill is required to break bud dormancy and allow normal flowering to proceed. In seasons where winter chill accumulation is insufficient light flowering and low yields may result.

[9] The most biologically accurate method of calculating winter chill accumulation currently available, see Appendix 1 for more information.

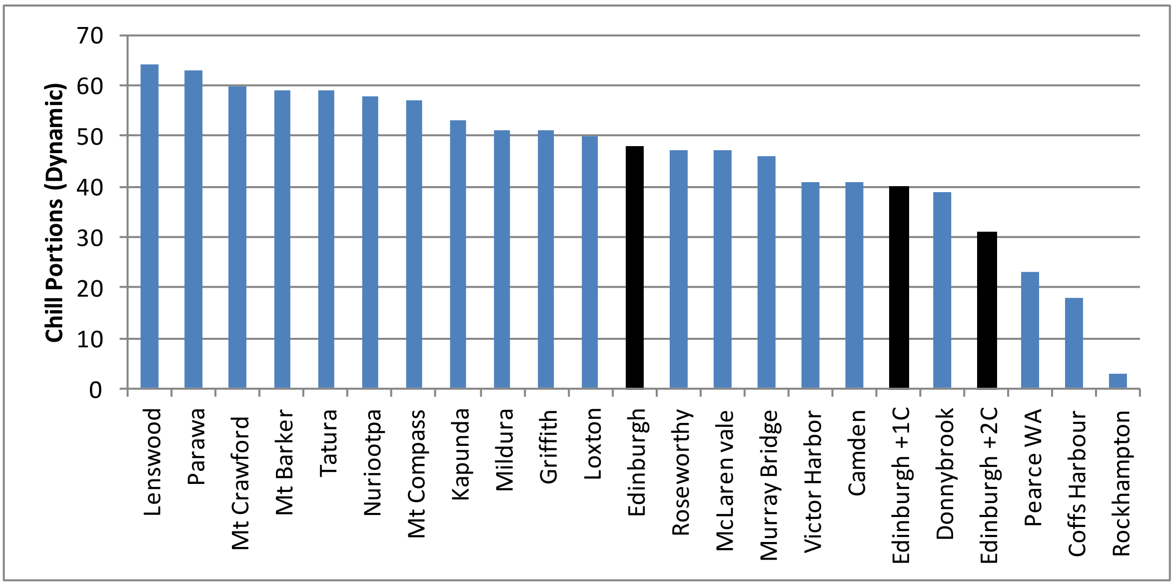

Figure 5.1. *Chill accumulation measured by the Dynamic Model during the baseline period (1980-1999) at locations within the AMLR NRM region and for Edinburgh RAAF with projected mean temperature increases of 1°C and 2°C, and for several homologue locations in Australia*

2. Edinburgh's summer is already warmer than Loxton's, and 1°C warming would make it warmer than Mildura's.

As shown in Figure 5.2, the Northern Coasts and Plains subregion already has comparatively hot summers, and any warming would shift them to what we currently consider very warm sites for horticulture.

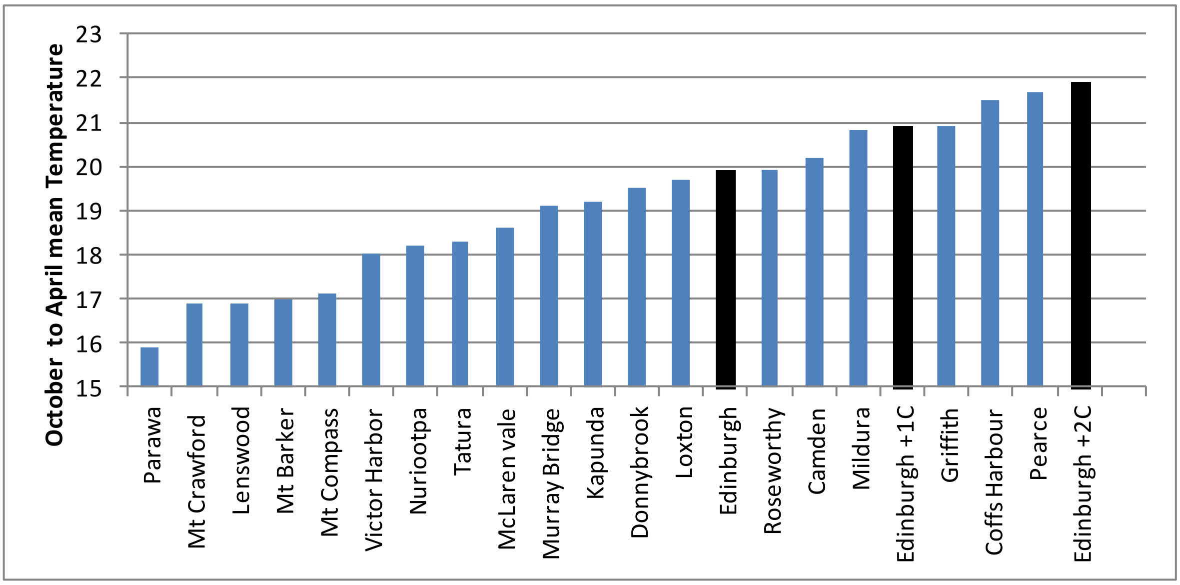

Figure 5.2. *The mean temperature from 1st October to 30th April during the baseline period (1980-1999) at locations within the AMLR NRM region and for the Edinburgh RAAF with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia*

Table 4.2 (page 12) shows that an October to April average temperature of 20°C is at the upper edge of ideal conditions for quality wine production, even for long season varieties such as Cabernet Sauvignon. It is important to note that many in the wine industry will disagree with the figures presented in Table 4.2, and obviously there are viable wine grape industries in warm sites such as Mildura and Griffith.

Wine grapes, fruit trees and vegetables develop relatively quickly in the current climate and will be even quicker in a warmer climate. This will lead to changes that in some cases will be detrimental. As seen in Figure 5.2, Edinburgh will become warmer than Camden (on Sydney's fringe) with a 1°C warming, and warmer than Pearce (on Perth's fringe) with a 2°C warming. The authors estimate that a 1°C warming is probably within management scope for annual vegetables, whereas a 2°C warming would involve significant changes in the composition of crops grown.

3. **Hot days and heatwaves are already a challenge in the current climate, and are expected to be more challenging in future climates**

The Northern Coasts and Plains subregion experiences more hot days than other AMLR subregions. Hot days will impact yields of annual crops such as wheat, barley, field peas and canola, which while grown mainly in the cooler months can be affected by warm days, particularly if those occur at sensitive stages of plant development (such as flowering, which occurs in spring). As annual horticulture is a continuous cropping system, hot days at any time of the year will be damaging. Hot days at key stages of flowering and fruit ripening are particularly damaging for perennial horticulture and viticulture. The increase in the number of days warmer than 35°C at Edinburgh in a 2°C warmer climate brings the occurrence to a similar frequency to that experienced at Pearce (outer Perth) during the baseline period, while the number of days warmer than 40°C would increase to more than that experienced at Pearce during that period. Very few viable horticulture and viticulture enterprises occur in locations with such high frequencies of extremely hot days.

A feature of heatwaves in the AMLR region is not only the temperatures but also the strong northerly winds and the extremely low humidity. Heatwaves also coincide with extreme fire danger. These desiccating conditions are damaging to most plants, and especially to high quality grape, fruit and vegetable crops. Recent experience has shown that the solution is shade and water provision. In some cases (such as with vegetables) artificial shade structures can be supplied, but these are costly to build and maintain. In other cases (such as in viticulture), extra crop canopy can provide additional shade, however growing that extra canopy requires additional water, and therefore it too imposes additional costs.

4. **An increase in evaporative demand and a decrease in rainfall will lead to a more water constrained future for agriculture in the region**

The Northern Coasts and Plains subregion is the AMLR region's driest subregion, and activities such as vegetable production require high levels of water use. Even though most industries have access to irrigation, any reduction of rainfall in catchment zones will impact on the long term availability of irrigation water. Winter rain can also play an important role in leaching salts out of the rootzone, so its reduction may lead to higher root zone salinity.

Heatwaves are commonly managed with the application of extra water, and the subregion's total water demand can therefore be expected to increase. Some farms may face infrastructural constraints and may not be capable of applying enough water across the farm (both before and during heatwaves) with their existing irrigation systems.

Evapotranspiration is expected to increase by about 3% if mean temperatures increase by 1°C, and by 5% if mean temperatures increase by 2°C. The 3% to 5% projected increase in annual evapotranspiration will increase the number of days with evapotranspiration greater than 6mm [10] at Edinburgh RAAF by about 7% and 15% respectively (compared with the baseline period). The increase in the number of days with

[10] The 6mm threshold was used to highlight days with slightly higher than average evapotranspiration, while the 8mm threshold was used to signify quite rare events. For example, in Nuriootpa during the period 1961-1990 (a standard weather averaging period used by BOM and WMO), evapotranspiration greater than 6mm occurred on about one third of November to February days (these are the year's four high evaporative months), while evapotranspiration greater than 8mm occurred only on about 5% of days during this same period.

evapotranspiration greater than 8mm (which are usually associated with extreme heat days) is small at 2 or 3 additional days per year. However, this seemingly small increase places the number of high irrigation demand days (that is days with evapotranspiration of 8mm and above) in the average year for the projected 2030 climate as near or above the maximum number experienced during the baseline period. That number of high irrigation demand days also becomes similar to that experienced at Pearce during its baseline period.

5. **Warming and drying will reduce broad acre crop and pasture production, however there are many viable mixed crop-livestock farms in warmer and drier regions of South Australia**

The mean temperature from 1st April to 30th October can be related to a site's suitability to annual cropping. At Roseworthy that mean temperature is 13.5°C and projected to increase to 15.5°C with a 2°C warming. This mean temperature is lower than many other locations where these crops are grown both within South Australia and elsewhere in Australia and overseas, which suggests cropping in the subregion is not directly limited by warm temperatures and that there is a level of resilience to increasing mean temperature.

Yields of annual crops are directly related to rainfall. According to the APSIM simulator [11], the expected wheat yield decline at Roseworthy is around 10% for each 10% decline in rainfall. However, when increased CO_2 concentrations were factored into the simulation (350ppm used for the baseline period, 450ppm used for 2030), declines in pasture production were reversed by 10% (that is from 20% to 10%, and from 10% to no decline).

Some viable cropping locations (in South Australia and elsewhere in Australia) are more than 20% drier than Roseworthy, however enterprises in those locations are typically larger and have different management and cost structures to those common in the Northern Plains and Coast subregion.

Sheep pasture productivity was simulated to be 10% lower for each 1°C increase in mean temperature, and 15% lower for each 10% reduction in rainfall. However the simulated beneficial effects of increased CO2 (at 450ppm) overcame both the initial 1°C temperature increase and the initial 10% rainfall reduction. In the case of 2°C temperature increase and 20% rainfall reduction, the modelled impact of a 450ppm CO2 concentration reduced the negative impact of the warmer climate to a 10% decline in productivity, and reduced the negative impact of the drier climate to a 20% decline in productivity.

While there is strong evidence regarding the positive impact of increased CO_2 concentrations on crop and pasture growth, it is important to keep in mind that weeds and pests are also likely to benefit from such an increase.

6. **An increase in summer rainfall could be problematic for viticulture and horticulture, but beneficial for dryland crop and pasture production**

Viticulture and many annual and perennial crops have the potential to suffer from excessive summer rain, as leaves and fruit which remain wet for extended periods during warmer weather are susceptible to fungal diseases. This potential was examined using the index of moisture positive days[12]. If rainfall increases (by either 10% or 20%) and evapotranspiration increases (by either 3% or 5%), then the number of moisture positive days in the Northern Coasts and Plains subregion is projected to slightly increase. It should be remembered that viticulture, perennial horticulture and annual horticulture are practiced in locations with much wetter summers than that experienced in the AMLR region (e.g. Mornington Peninsula and Yarra valley in Victoria, Outer Sydney, and South East Queensland).

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[11] APSIM is the Agricultural Production Systems Simulator, an advanced simulator of agricultural systems used in this study to simulate the effects of climatic changes on pasture and grain production. All references to simulated figures in this chapter refer to APSIM simulations.

[12] Moisture positive days were calculated as days when rainfall (below 10mm) in the preceding three days was greater than evapotranspiration over the same period. Days with rainfall over 10mm are not counted, as at that level of wetness water is considered to be running off the plants.

5.2 Northern Hills

The Northern Hills subregion is home to the significant wine regions of Barossa and Eden Valley, as well as to various annual cropping and livestock enterprises. Locations analysed for this report are Kapunda (for crops and livestock), Nuriootpa (for viticulture, representing the Barossa valley floor), and Mount Crawford (for viticulture, representing Eden Valley).

Table 5.2 shows the vulnerability of those agricultural sectors to key agro-climatic risks, with colours representing extent of vulnerability.

Table 5.2. *Vulnerability of the Northern Hills subregion to agro-climatic risks, by industry type*

Northern Hills		Viticulture	Cropping	Livestock Grazing
Increase in mean temperature	+1°C			
	+2°C			
More hot days and an increase in the frequency and length of heatwaves	+1°C			
	+2°C			
Decline in autumn winter and spring rainfall	-10%			
	-20%			
Increased irrigation demand and decreased water quality/availability	-10%			
	-20%			
Increase in summer rainfall	+10%			
	+20%			

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. Because the Barossa is at the warmer edge of premium wine growing regions, warming will present adaptation challenges

A warming of 1°C seems to be a small amount compared to daily and even monthly temperature variability. However such warming in the 20 year growing season (1st October to 30th April) mean temperature (known as mean GST) will shift the locations of Nuriootpa and Mt Crawford to a new climate. As shown in Figure 5.3 (and see Appendix 2 for more detail), the new mean GST for Nuriootpa with 1°C warming will be 19.2°C (as the current average is 18.2°C), warmer than what is currently the 9 in 10 warmest vintage years. What is now the 82nd percentile vintage (i.e. one of the warmest vintages) would become the 10th percentile vintage (i.e. the coolest 10% of vintages) in that 1°C warmer future. These simple calculations indicate that the mean GST envelope of experience is quite tight, and hence any warming will bring noticeable changes, requiring some adaptation actions.

Figure 5.3 shows that a warming of 2°C would shift Nuriootpa to warmer than the current climate at Loxton, but it would still be cooler than Griffith and Mildura. Table 4.2, based on Jones *et al.* (2005), indicates that 18°C is the upper boundary for ideal conditions for Sauvignon blanc (which accounts for 2% of current Barossa and Eden Valley production) and Semillon (which accounts for 6% of current Barossa and Eden Valley production), and is warmer than the ideal range for Riesling (5% of current Barossa and Eden Valley production) and Chardonnay (7% of current Barossa and Eden Valley production). A 19°C mean GST is the upper ideal range for Shiraz (50% of current Barossa and Eden valley production), while a 20°C mean GST (2°C warmer than the Nuriootpa mean during the baseline period) is the upper range for Cabernet Sauvignon (12% of current Barossa and Eden valley production) and Grenache (6% of Barossa and Eden valley production).

In this context it's important to note that:

- Many experts in the Australian wine industry have good reason to challenge the applicability of the figures presented in Table 4.2 (as some varieties are widely grown in warmer places than Table 4.2 suggests is suitable).
- The region has many complex mesoclimates[13] with conditions which differ from those at the Nuriootpa meteorological station.

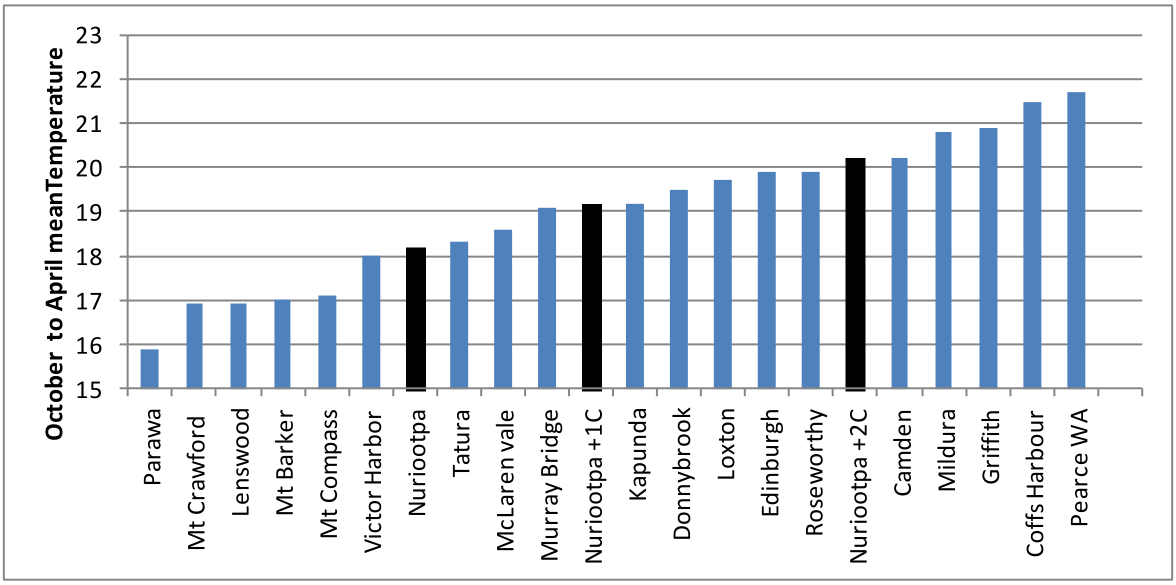

Figure 5.3. *Mean GST (average temperature from 1st October to 30th April) during the baseline period (1980-1999) at locations within the AMLR NRM region, for Nuriootpa with a projected mean temperature increase of 1°C and 2°C, and for several homologue locations in Australia*

Higher mean temperatures lead to quicker development, which would shift sensitive stages, such as berry ripening, to less desirable, warmer periods of the year (e.g. from March to February). Adaptation strategies may include canopy management (to provide better fruit protection through shading) and variety changes in existing vineyards, and heat load minimisation through row orientation in new vineyards.

2. Hot days and heatwaves are a challenge in the current climate, and are expected to become more challenging in future climates

Perhaps more worrying than mean temperature changes will be changes in the extremes. Locations within the Northern Hills subregion show considerable variation in the number of days per year with maximum temperature above 35°C and 40°C. In the southern location of Mt Crawford the number of days warmer than 35°C averaged 14 days per year during the baseline period, while at Nuriootpa it was 17 days per year and at Kapunda 23 days per year. The number of days above 35°C are expected to increase by 30% for each 1°C increase in mean temperature.

The number of days warmer than 40°C averaged 2 per year at Mt Crawford and Nuriootpa and 4 per year at Kapunda, and at Nuriootpa and Kapunda are expected to double in frequency in a 1°C warmer climate and triple in a 2°C warmer climate, with about half this increase at Mt Crawford. The number of days warmer than 40°C in a 2°C warmer climate at Nuriootpa is similar to that at Loxton or Mildura.

[13] For more information on microclimates and mesoclimates see Appendix 1

Extra irrigation is commonly used to mitigate heat impacts on viticulture, but the resultant increased irrigation demand would place additional strain on the supply of irrigation water and the ability of on-farm irrigation systems to apply it.

A feature of heatwaves in the AMLR region is not only the temperatures but also the strong northerly winds and the extremely low humidity. These desiccating conditions are damaging to most plants, let alone to high quality grape production. They are also associated with increased fire danger, a risk already present in some parts of the Northern Hills subregion, where fire may affect viticulture both directly and through the effects of smoke taint[14].

3. Hot days are of concern to livestock but the low humidity will lessen the impact

The thermal humidity index (THI) is a measure of animal comfort calculated from environmental temperature and relative humidity and used by the dairy industry, while also being applicable to other livestock enterprises. As shown in Figure 5.4, THI values are lower at Mt Crawford than Kapunda, although both are higher than those in the southern subregions. At Mt Crawford the number of days with THI values greater than 78, a value where heat stress occurs and weight gain is reduced (Cowie and Martin, 2009)[15] , would increase in a 2°C warmer climate to similar levels as experienced at Mt Compass during the baseline period. At Kapunda, a 1°C warmer climate would increase the number of days per year with THI greater than 78 from 36 during the baseline period to 46, while a 2°C warmer climate would increase it to 57 days, similar to the relatively high levels experienced at Griffith during the baseline period. Dairy Australia's Cool Cows website [16] provides information on the effects on dairy cows at different THI values, and on management options for dealing with excessive heat loads.

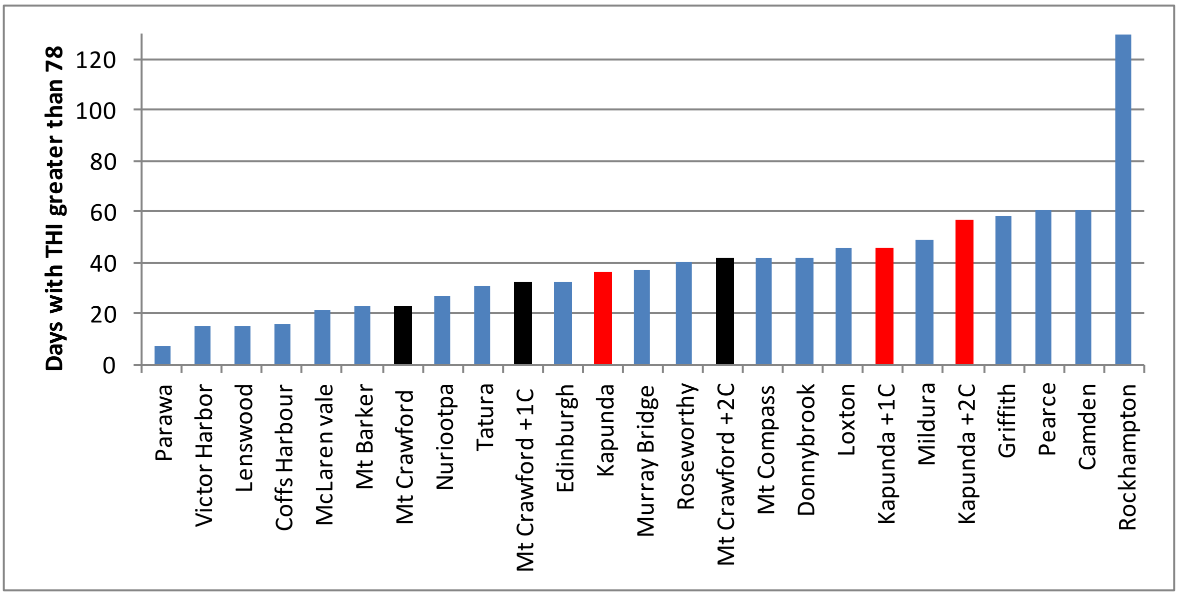

***Figure 5.4**. Number of days per year when the THI (thermal humidity index) was greater than 78 during the baseline period (1980-1999) at locations within the AMLR NRM region and at several homologue locations in Australia, and for Mt Crawford and Kapunda with 1°C and 2°C projected mean temperature increases.*

[14] Wines made from grapes exposed to smoke during sensitive growth stages are said to be 'smoke tainted'. They can exhibit unfavorable characteristics, which at high concentrations can render them unpalatable to consumers, resulting in financial losses to producers. The 2003 Canberra bushfires are estimated to have cost the Alpine Valley wine industry $4 million, while also causing smoke damage to vineyards in northeastern Victoria and in southwestern New South Wales. For more information see for example http://archive.agric.wa.gov.au/objtwr/imported_assets/content/foods/bulletin_4847.pdf

[15] Also see USA sites of http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef5157 and http://glossary.ametsoc.org/wiki/Livestock_safety_index

[16] http://www.dairyaustralia.com.au and http://www.coolcows.com.au

4. **An increase in evaporative demand and a concurrent decrease in rainfall will lead to a more water constrained future for agriculture in the Northern Hills region**

Most primary industries currently have access to irrigation, but any reduction of rainfall in catchment zones may reduce the long term availability of irrigation water. Winter rain can also play an important role in leaching salts out of the rootzone, and lower rainfall might therefore lead to higher rootzone salinity.

Extra irrigation is commonly used to mitigate the impact of heat on agricultural crops, but the resultant increased irrigation demand would place additional strain on the supply of irrigation water and the ability of on-farm irrigation systems to apply it.

A projected increase in evapotranspiration of either 3% or 5% (which is expected if mean temperatures increase by 1°C or 2°C respectively) will increase the number of days at Mt Crawford and Nuriootpa with evapotranspiration greater than 6mm[17] by about 10% and 20% respectively. While the increase in the number of days with evapotranspiration greater than 8mm (usually associated with extreme heat days) is small, at 2 or 3 additional days per year on average, this seemingly small increase places the number of high irrigation demand days in the <u>average</u> year for the projected 2030 climate at <u>near or above the maximum</u> number experienced during the baseline period.

5. **Warming and drying will reduce broadacre crop and pasture production, however there are many warmer and drier viable crop livestock farms in South Australia**

The mean temperature from 1st April to 30th October can be related to a site's suitability to annual cropping. At Kapunda the mean GST for the baseline period is 12.6°C, and is projected to increase to 14.6°C with a 2°C warming. This mean temperature is lower than many other locations where these crops are grown both within South Australia and elsewhere in Australia and overseas, which suggests cropping in the subregion is not directly limited by warm temperatures and that there is a level of resilience to increasing mean temperatures. Annual crop yields are directly related to rainfall, with the decline in simulated wheat yield at Kapunda to be about 10% for each 10% decline in rainfall. However the expected increase in CO_2 concentration (450ppm used for 2030 compared to 350ppm used for the baseline period) is simulated to compensate for this initial 10% rainfall decline. These declines are expected to be greater in locations with a lower baseline rainfall, such as more northern and lower elevation parts of the subregion. Some viable annual cropping locations in South Australia and elsewhere in Australia are more than 20% drier than Kapunda, but enterprises in those locations typically have different management and cost structures to those common in the AMLR region.

A 1°C warming or 10% drying was simulated to have minimal impact on pasture production at the cooler and wetter location of Mount Crawford, but showed a 10% reduction at the warmer and drier location of Kapunda. A 2°C warming or 20% was simulated to reduce pasture production by about 20% at Kapunda but only by about 10% at Mount Crawford. However, when increased CO_2 concentrations were factored in (from 350ppm during the baseline period to 450ppm for the projected 2030 climate), declines in pasture production were reduced by 10% (that is from 20% to 10%, and from 10% to no decline).

6. **The changes in summer rainfall could be problematic for horticulture, but should be beneficial for pasture production**

The index of moisture positive days [18] was used to examine the potential impact of increased summer rain on the viticulture sector. If rainfall increases (by either 10% or 20%) and evapotranspiration increases (by either 3% or 5%, which is expected if mean temperatures increase by 1°C or 2°C respectively), then the number of moisture positive days in the Northern Hills subregion is projected to increase slightly, but not to levels beyond those experienced in the baseline period. It should be remembered that horticulture is practiced in locations with much wetter summers (e.g. Mornington Peninsula and Yarra Valley in Victoria in Victoria).

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[17] For an explanation of daily evapotranspiration thresholds see footnote in Section 5.1
[18] For an explanation of moisture positive days see footnote in Section 5.1

Summer rainfall increases would actually be overall beneficial to livestock enterprises, as current pasture growth over summer is limited by low rainfall. In cases of pasture being normally irrigated throughout summer, higher summer rainfall would decrease irrigation requirements and the associated costs.

5.3 Central Hills

The Central hills subregion contains a wide range of industries and has high economic values owing to its proximity to Adelaide, with viticulture, perennial and annual horticulture and livestock industries particularly prominent. The region is recognized as a cool climate wine region, and the perennial horticulture industry includes many pome (apple, pear) and stone fruit (most significantly cherry) enterprises.

The locations analysed in this report are Lenswood and Mount Barker, and while the latter is positioned just outside the AMLR region's boundary, it can be taken as climatically representative of much of the region and has the advantage of long and detailed climate records.

Table 5.3. *Vulnerability of the Central Hills subregion to agro-climatic risks, by industry type*

Central Hills		Viticulture	Perennial Horticulture	Annual Horticulture	Livestock Grazing	Livestock Dairy
Increase in mean temperature	+1°C					
	+2°C					
More hot days and an increase in the frequency and length of heatwaves	+1°C					
	+2°C					
Decline in autumn winter and spring rainfall	-10%					
	-20%					
Increased irrigation demand and decreased water quality/availability	-10%					
	-20%					
Increase in summer rainfall	+10%					
	+20%					

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. A warming may present a greater reputational challenge than biological challenge for the cool climate Central Hills wine growing region

A 1°C warmer mean temperature places the climate of both Lenswood and Mt Barker into an unknown future where the average year is as warm as the current 9 in 10 warm year. In a cool region such as the Central Hills such warming may bring about opportunities to more confidently ripen some longer season red varieties, as well as threats to some short season varieties, associated with ripening in the warmer months (when heatwaves are more likely to occur).

The Adelaide Hills region currently has a mean January temperature of 19.2°C (as measured in Lenswood), with a range from 1 in 10 years as cool as 17.1°C and as warm as 21.1°C, and is commonly classified as a cool climate wine region.

This cool region classification, important in marketing terms, is therefore under threat in the Central Hills subregion, while comparable regions in New Zealand and Tasmania would still have a mean January temperature below 19°C with 1°C warming. The central hills region does however have some unique features as a wine growing region, such as its large diurnal range and cooler nights (thought to be related to desirable grape flavour and wine quality traits).

As shown in Figure 5.5 (and in reference to Table 4.2), Lenswood and Mt Barker are at the warmer end of Chardonnay and Riesling production, which respectively account for 21% and 2% of the Adelaide Hills' current wine grape production. Lenswood and Mt Barker are already warmer than the ideal for Pinot Noir (17% of Adelaide Hills' current wine grape production), and a 1°C warming will bring the growing season temperature to the edge of that considered ideal for Sauvignon blanc production as well (27% of Adelaide Hills' current wine grape production).

In this context it's important to note that:

- Many experts in the Australian wine industry have good reason to challenge the applicability of the figures presented in Table 4.2 (as some varieties are widely grown in warmer places than Table 4.2 suggests is suitable).
- The region has many complex mesoclimates [19] with conditions which differ from those at the Nuriootpa meteorological station.

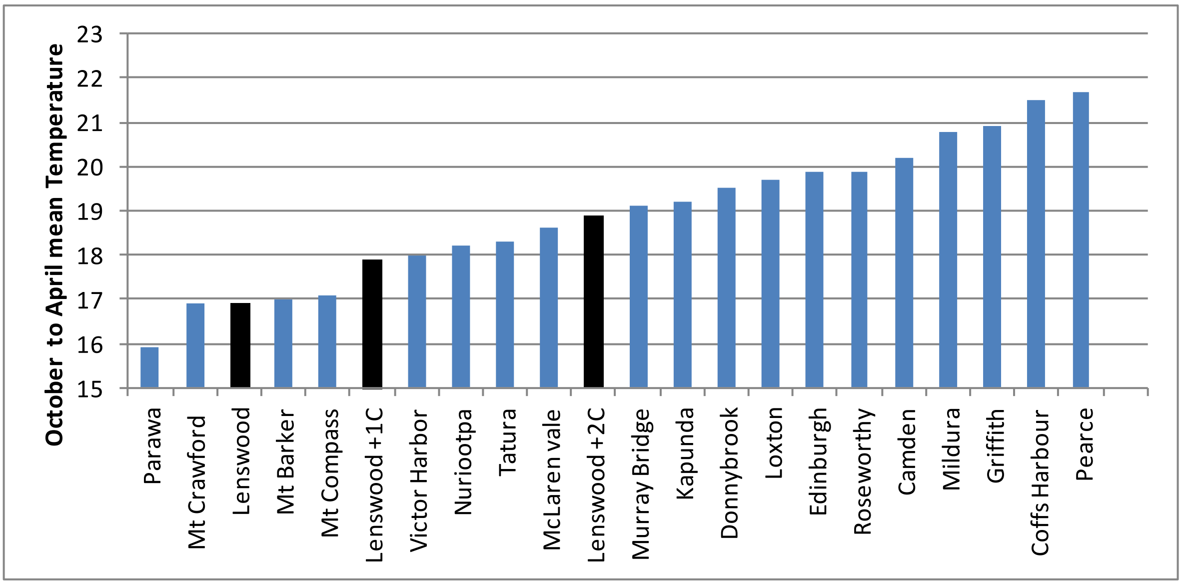

Figure 5.5. *The mean temperature from 1st October to 30th April during the baseline period (1980-1999) at locations within the AMLR NRM region, for Lenswood with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia*

Higher temperatures may hasten fruit development, which could result in ripening occurring in late summer (i.e. February) rather than under cooler autumn conditions (i.e. in March). This shift will not only have an impact on quality, but will also increase the chance of a heatwave coinciding with the sensitive stages of fruit ripening and harvest (as heatwaves are more likely in February than in March). Adaptation strategies may include changes to pruning and fruit crop loads to encourage shoot vigour and canopy development and thereby provide natural bunch shading to protect the fruit from excessive heat loads, and variety/rootstocks changes. Further details can be found in Dry (2009) and Hayman *et al.* (2012).

2. Chill accumulation is currently high in the Central Hills subregion, but may become insufficient for some crops in warmer years

As shown in Figure 5.6, the Central Hills subregion has the AMLR region's highest chill accumulation values, although many other Australian locations producing stone and pome fruit have higher values still (see Darbyshire *et al.*, 2011).

Chill accumulation during the baseline period was 64 and 59 chill portions at Lenswood and Mt Barker respectively. These were projected to decline by 10% for each 1°C warming, which would mean a 2°C increase in mean temperature would result in similar or slightly lower chill accumulation as that currently experienced in Loxton, but higher than that at Donnybrook (WA). In a projected 2°C warmer climate the

[19] For more information on microclimates and mesoclimates see Appendix 1

chill accumulation in the 1 in 10 warmest year at Lenswood and Mt Barker is at 44 and 40 chill portions respectively, a similar chill accumulation as Donnybrook's baseline period average. This means that chill accumulation under this warming scenario would be met in most if not all years. However other data (for example see Table 5.4, and Darbyshire *et al.*, 2012) suggest that such a level of chill accumulation may be insufficient for many varieties of cherries and apples, and that the use of alternative varieties or active adaptation measures (such as the application of rest breaking agents[20]) may be required to guarantee reliable and ongoing production.

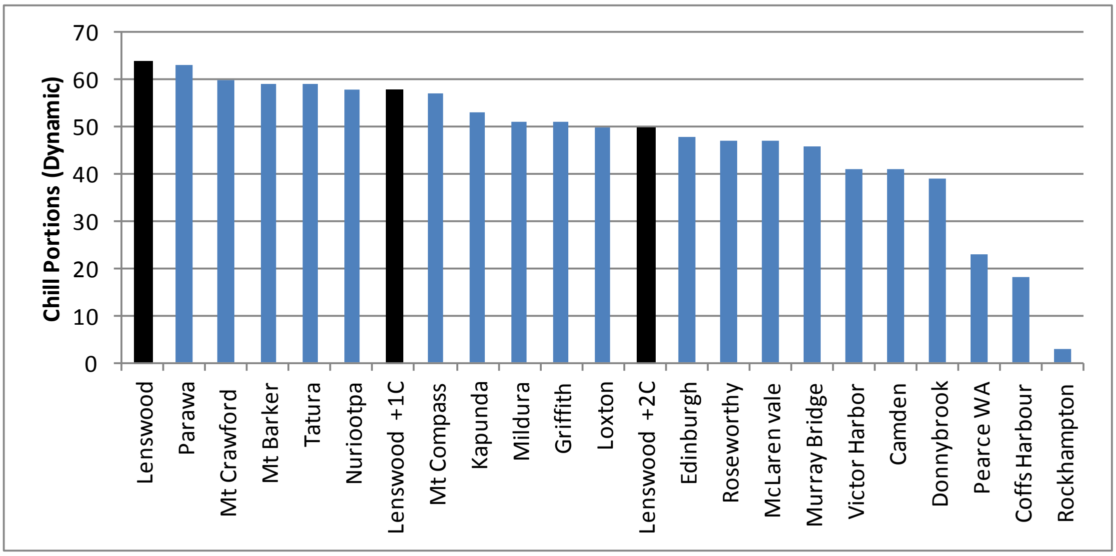

Figure 5.6. *Chill accumulation measured by the Dynamic Model during the baseline period (1980-1999) at locations within the AMLR region, for Lenswood with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia*

[20] For an explanation of rest breaking agents see footnote in Section 4.2

Table 5.4. *Chill portion requirements of a selection of crops, according to the Dynamic Model*[21]

Crop	Cultivar	Chill Portions
Almond	Desmayo Largueta	28
	Ferragnes	32
	Nonpareil	22-23
Apple	Golden Delicious	50
Apricot	Bergeron	62-65
	Búlida	54-56
	Canino	30-25
	Currot	34-40
	Dorada	56-58
	Goldrich	62
	Murciana	56
	Orange Red	55-69
	Palsteyn	32-37
	Rojo Pasion	48-51
	San Castrese	55
	Selene	57
Cherry	Brooks	37
	Burlat	48-53
	Cristobalina	30
	Lapins	35
	Marvin	58
	New Star	54
	Rainier	45
	Ruby	48
	Sam	70
	Somerset	48
Nectarine	Aprilglo	12
	Fantasia	42
	Flavortop	41
	Mayglo	18
	Sunlite	33
Peach	Andross	63
	Big Top	63
	Earligrande	12
	Flordaprince	8
	Maravilha	12
	O'Henry	63
	Redhaven	75
Pistachio	Kerman	54-58
	Mateur	36
	Peters	58-65
	Sirora	60
Prune	Improved French	55-60
Walnut	Chandler	45-50
	Hartley	54
	Payne	38

[21] Table compiled by Katherine Jarvis-Shean, Department of Plant Sciences, UC Davis, 28/4/2011. Accessed 7 April 2016 from http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/CropChillReq/.

3. Hot days and heatwaves are already a challenge in the current climate, and are expected to become more challenging in future climates

Perhaps more worrying than changes in mean temperature are changes in the extremes. The small number of hot days per year at locations in the Central Hills subregion (7 and 11 at or above 35°C, 0.2 and 0.8 at or above 40°C in Lenswood and Mt Barker respectively) is projected to increase by 50% with a 1°C warmer climate and double with a 2°C warmer climate. Such a scenario for the Central Hills region is comparable to Nuriootpa's baseline period conditions, which suggests that these hot days could be managed, for example through the following measures:

- canopy management to reduce evaporative demand and protect fruit from heat damage
- the upgrading or redesign of irrigation systems to meet the expected increase in irrigation demand to alleviate heat stress
- greater use of mulch to reduce soil evaporation.

A feature of heatwaves in the AMLR region is not only the temperatures but also the strong northerly winds and the extremely low humidity. These desiccating conditions are damaging to most plants, and are also associated with increased fire danger, a risk already present in some parts of the Central Hills subregion, where fire may affect viticulture both directly and through the effects of smoke taint[22].

4. Annual Horticulture can alter crop and sowing times to adapt to increased temperatures

Annual horticulture has many options to adapt to an increase in mean temperature owing to the ability to alter sowing times, species and varieties to make best use of the expected weather conditions. Hastened growth is expected in the winter months, but the length of the growing season could be reduced in the summer months due to excessively hot conditions.

5. Irrigation requirements and high evaporative demand days will increase

A projected increase in annual evapotranspiration of 3% or 5% (corresponding to 1°C and 2°C increase in mean temperature respectively) will increase the number of individual days with evapotranspiration greater than 6mm[23] by about 10% and 20% respectively. The projected increase in the number of days with evapotranspiration greater than 8mm (which are usually associated with extreme heat) is quite small (1-2 additional days per year on average), yet it places the number of high irrigation demand days in the average year for the projected 2030 climate at near or above the maximum number experienced during the baseline period (being 4 days per annum).

6. Hot days are of concern to livestock, but the low humidity will lessen the impact

The thermal humidity index (THI) is a measure of comfort calculated from temperature and humidity and used by the dairy industry, while also being applicable to other livestock enterprises. THI values are low in the Central Hills, with Lenswood and Mt Barker experiencing 15 and 23 days per year (respectively) with THI greater than 78, a value where heat stress occurs and milk production and weight gain are reduced (Cowie and Martin, 2009) [24]. Dairy Australia's Cool Cows website [25] provides information on the effects on dairy cows at different THI values, and on management options for dealing with excessive heat loads. The number of days with THI greater than 78 in those locations increases by about 50% for a 1°C warmer climate, and almost doubles in a 2°C warmer climate (to 21 and 29 days at Lenswood and to 32 and 40 days at Mt Barker respectively). Such conditions are similar to those experienced in other dairy farming areas during the baseline period, with Murray Bridge experiencing an average of 37 days where THI was greater than 78 while Mt Compass experienced an average of 42 such days. For comparison, Rockhampton (Qld) had an average of 145 days where THI was greater than 78 and 52 days per annum where THI was greater than 82. Obviously the livestock in Rockhampton are different breeds to those used

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[22] For an explanation of smoke taint see footnote in Section 5.2
[23] For an explanation of daily evapotranspiration thresholds see footnote in Section 5.1
[24] Also see USA sites of http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef5157 and http://glossary.ametsoc.org/wiki/Livestock_safety_index
[25] http://www.dairyaustralia.com.au and http://www.coolcows.com.au

in the Central Hills subregion, but the comparison highlights the much milder heat stress experienced in southern Australia due to the prevailing low humidity conditions

7. **Warming and drying will reduce pasture production, but there are many warmer and drier crop livestock farms in South Australia**

Modeled cattle pasture production at Lenswood was unaffected by a 1°C warmer climate or a 10% decline in rainfall, but declined by almost 10% in a 2°C warmer or a 20% drier climate. Production was stimulated by 10% when the atmospheric CO_2 concentration was assumed to be 450ppm CO_2 (as compared to the 350ppm CO_2 concentration used for the baseline period).

Irrigated dairy pasture production declined by 5% for each 1°C increase in mean temperature, but the 20% stimulation in production caused by elevated CO_2 concentrations overcame these reductions. An additional 4% irrigation water was needed to compensate for the effect of each 10% reduction in rainfall and achieve baseline period production levels.

8. **The changes in summer rainfall could be problematic for horticulture but beneficial for dryland crop and pasture production**

The index of moisture positive days [26] was used to examine the potential impact of increased summer rain on the viticulture sector. If rainfall increases (by either 10% or 20%) and evapotranspiration increases (by either 3% or 5% with a 1°C or 2°C increase in mean temperature respectively), then the number of moisture positive days in the Central Hills region is projected to increase slightly, but not to levels beyond those experienced in the baseline period. It should be remembered that viticulture is practiced in locations with much wetter summers (e.g. Mornington Peninsula and Yarra Valley in Victoria).

5.4 Willunga Basin

Viticulture was the main industry examined for the Willunga Basin subregion, home to the important wine region of McLaren Vale. Perennial horticulture was also examined, with analysis based on the town of McLaren Vale. Table 5.5 shows vulnerability rankings for those two industries by agro-climatic risk factor.

Table 5.5. *Vulnerability of the Willunga Basin subregion to agro-climatic risks, by industry type*

Willunga Basin		Viticulture	Perennial Horticulture
Increase in mean temperature	+1°C		
	+2°C		
More hot days and an increase in the frequency and length of heatwaves	+1°C		
	+2°C		
Decline in autumn winter and spring rainfall	-10%		
	-20%		
Increased irrigation demand and decreased water quality/availability	-10%		
	-20%		
Increase in summer rainfall	+10%		
	+20%		

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

[26] For an explanation of moisture positive days see footnote in Section 5.1

1. **Because McLaren Vale is at the warmer edge of premium wine growing regions, warming will present adaptation challenges**

A warming of 1°C seems to be a small amount compared to daily and even monthly temperature variability. However a warming of 1°C in the 20 year average of the (1st October to 30th April) growing season temperature (mean GST) will shift the Willunga Basin subregion to a new climate. As shown in figure 5.7 (and see appendix 2), the new GST for McLaren Vale with a 1°C warming will be 19.6°C (as the current average is 18.6°C), warmer than what is currently the 9 in 10 warmest vintage. The 1 in 10 warmest vintage (that is, one of the coolest vintages in a 10 year period) in that 1°C warmer climate will be what is currently the 88th percentile, (i.e. close to what is currently the 9 in 10 warmest vintage). These simple calculations indicate that the GST envelope of experience is quite tight, and hence any warming will bring noticeable changes, requiring some adaptation actions.

Figure 5.7 shows that at mean GST of 18.6°C, McLaren Vale is warmer than other viticulture areas within the AMLR NRM region (e.g. the Adelaide Hills and the Barossa Valley, and see appendix 2 for more detail). Figure 5.7 also shows that a 2°C warming would make McLaren Vale warmer than the current Loxton, but not as warm as Griffith (Qld) and Mildura (Vic). According to Table 4.2 (sourced from Jones *et al., 2005*) a GST of 19°C is the upper ideal range for Shiraz (which accounts for 51% of McLaren Vale's current wine grape production) and a GST of 20°C the upper range for Cabernet Sauvignon (17% of McLaren Vale's current wine grape production) and Grenache (6% of McLaren Vale's current wine grape production).

In this context it's important to note that:

- Many experts in the Australian wine industry have good reason to challenge the applicability of the figures presented in Table 4.2 (as some varieties are widely grown in warmer places than Table 4.2 suggests is suitable).
- The region has some mesoclimates [27] that differ from that of the McLaren Vale meteorological station. This is especially the case for higher elevation sites which tend to be cooler and are climatically more similar to the Central Hills than to the town of McLaren Vale.

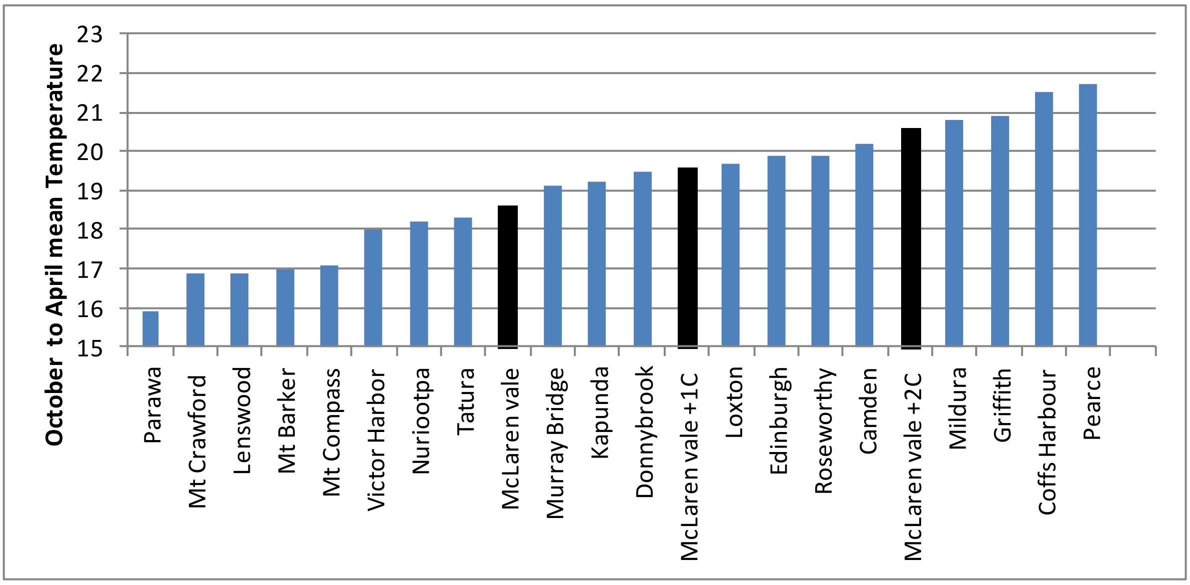

Figure 5.7. *GST (average temperature from 1st October to 30th April) during the baseline period (1980-1999) at locations within the AMLR NRM region, for McLaren Vale with a projected mean temperature increase of 1°C and 2°C, and for several homologue locations in Australia*

[27] For more information on microclimates and mesoclimates see Appendix 1

Higher mean temperatures lead to quicker development, which would shift sensitive stages (such as berry ripening) to less desirable, warmer periods of the year (e.g. from March to February). Adaptation strategies may include changes to pruning to encourage use of the canopy to protect the fruit from excessive heat loads, and variety/rootstocks changes. Further details can be found in Dry (2009) and Hayman *et al.* (2012).

2. Hot days and heatwaves are a challenge in the current climate and expected to be more challenging in future climates

Perhaps more worrying than change in mean temperature will be changes in the extremes. The number of days per year at McLaren Vale with maximum temperature above 35°C and 40°C (11 and 1.5 days respectively) is projected to increase in a warmer climate to frequencies above those experienced during the baseline period. However the number of days in a 2°C warmer climate is about the same as that experienced in the baseline period in other fruit growing regions, such as Loxton (SA), Mildura (Vic) or Donnybrook (WA). This suggests that these additional hot days can be tolerated and managed. Extra irrigation is commonly used to mitigate heat impacts on viticulture and higher value horticultural enterprises, but the resultant increased irrigation demand would place additional strain on the supply of irrigation water and the ability of on-farm irrigation systems to apply it.

A feature of heatwaves in the AMLR region is not only the temperatures but also the strong northerly winds and the extremely low humidity. These desiccating conditions are damaging to most plants, and are also associated with increased fire danger, a risk already present in some parts of the Willunga Basin subregion, where fire may affect viticulture both directly and through the effects of smoke taint[28].

3. McLaren Vale currently has low chill levels and these will drop further with warming

Another aspect of warmer mean temperatures is a potential loss of chill accumulation. Chill accumulation is already relatively low at McLaren Vale (47 chill portions, as measured by the Dynamic Model) and will decrease at the rate of about 10 chill portions for each 1°C warming (Figure 5.8). These reduced levels are however still expected to meet the requirements for viticulture. Chill accumulation for the lower chill commodities (e.g. stone fruit, almonds) in the Willunga Basin may not be attained in every year in a warmer future, and management actions such as the application of rest breaking agents 29 or the use of different varieties may be required.

[28] For an explanation of smoke taint see footnote in Section 5.2
[29] For an explanation of rest breaking agents see footnote in Section 4.2

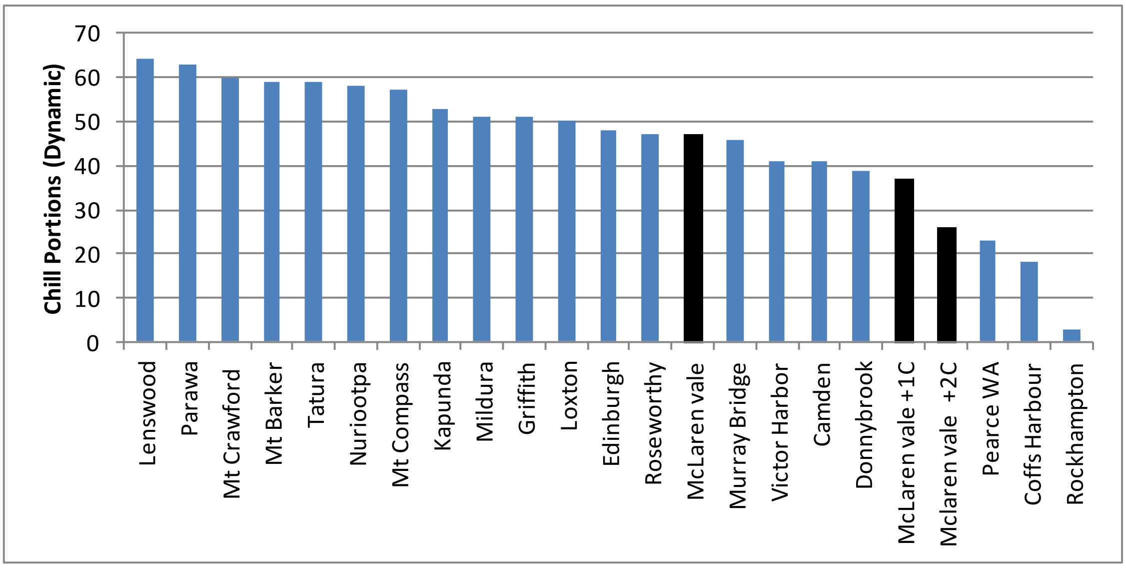

Figure 5.8. *Chill accumulation as measured by the Dynamic Model during the baseline period (1980-1999) at locations within the AMLR NRM region, for McLaren Vale with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia*

4. A decrease in rainfall and increase in evaporative demand will lead to a more water constrained future for agriculture in the region.

Viticulture and other perennial horticulture industries rely on rainfall and irrigation water to meet their yearly water demands. A decline in rainfall is of course undesirable, but even a 20% decline in average rainfall would mean that annual rainfall in some years will remain within the range experienced during the baseline period. The region's industries are somewhat protected from the effects of reduced rainfall due to the historic use of treated irrigation water (supplied to farmers by Willunga Basin Water[30]), a water source not available in most other subregions. However not all growers in the region are willing or able to make the upfront infrastructure investment required to connect their irrigation systems to this treated water source.

A projected increase in evapotranspiration of 3% or 5% (corresponding with a 1°C and 2°C mean temperature increase respectively) will increase the number of individual days with evapotranspiration greater than 6mm[31] by about 10% and 20% respectively. The increase in the number of days with evapotranspiration greater than 8mm (usually associated with extreme heat days) is small at 1 or 2 additional days per year, but this seemingly small increase places the number of high irrigation demand days in the average year for the projected 2030 climate at the level experienced in the baseline period in about 2 out of 10 years.

5. The increase in summer rainfall could be problematic for horticulture

The potential of the subregion's viticulture to suffer from excessive summer rain was examined using the index of moisture positive days[32]. If summer rainfall increases (by either 10% or 20%) and evapotranspiration increases (by either 3% or 5%), then the number of moisture positive days in the Willunga Basin subregion is projected to increase slightly, but not to levels beyond those experienced in the

[30] Willunga Basin Water takes treated water from SA Water's Christies Beach Wastewater Treatment Plant, 10 kilometres north of the Willunga Basin, and pumps it via 120 kilometres of pipeline to growers in the McLaren Vale region. For more information see http://www.wbwc.com.au/what-we-do/what-we-do

[31] For an explanation of daily evapotranspiration thresholds see footnote in Section 5.1

[32] For an explanation of moisture positive days see footnote in Section 5.1

baseline period. It should be remembered that viticulture is practiced in locations with much wetter summers (e.g. the Mornington Peninsula and the Yarra Valley in Victoria).

5.5 Fleurieu Peninsula

As shown in Table 5.6, the industries examined in the Fleurieu Peninsula subregion were viticulture and livestock, including dairy on irrigated pasture and beef cattle or sheep on unirrigated pasture.

The locations analysed were Parawa (Sharon), Victor Harbor and Mount Compass. The latter is not located within the AMLR Region but is close to the region's boundary, and its surrounding areas support a considerable dairy industry.

Table 5.6. *Vulnerability of the Fleurieu Peninsula subregion to agro-climatic risks, by industry type*

Fleurieu Peninsula		Viticulture	Livestock Grazing	Livestock Dairy
Increase in mean temperature	+1°C			
	+2°C			
More hot days and an increase in the frequency and length of heatwaves	+1°C			
	+2°C			
Decline in autumn winter and spring rainfall	-10%			
	-20%			
Increased irrigation demand and decreased water quality/availability	-10%			
	-20%			
Increase in summer rainfall	+10%			
	+20%			

Colours represent extent of vulnerability: dark green – low vulnerability; light green – low to medium vulnerability, manageable with low cost modifications; yellow – medium vulnerability, leading to some changes in current system; orange – medium to high vulnerability, leading to significant changes in current system; red- high vulnerability, major challenge.

1. The Fleurieu Peninsula's generally cooler conditions will reduce the impact of a warmer climate

For the viticulture sector, a 2°C warmer climate will see the mean Growing Season Temperature (mean GST) at Parawa, Mount Compass and Victor Harbor reach 18°C, 19°C and 20°C respectively[33], meaning that those locations would still be considered acceptable for continued production of most of the regionally important wine grape varieties (as shown in Table 4.2). This is despite the fact that a 1°C or 2°C warmer mean temperature would shift the region into a very different climatic regime, with the projected average year's mean temperature becoming as warm as the baseline period's 1 in 10 warm year.

Pasture production is simulated to decline in a warmer climate, but these declines in the Fleurieu Peninsula subregion are towards the lower end of those simulated for the ALMR region. Irrigated pasture production was simulated to decrease by 3% and 7% with a projected increase in mean temperature of 1°C and 2°C respectively, a lesser decline than those modelled for other subregions. Furthermore, an additional 3% and 7% of irrigation water would be required to achieve this production. In comparison, pasture production in the less productive unirrigated pastures was simulated to decline by 3% and 9% in a 1°C and 2°C warmer climate respectively. Importantly pasture production changes were not uniform in all seasons, with larger declines in the warmer summer months and smaller declines (or increases) in winter time production. Pasture production when the atmospheric CO_2 concentration was the projected elevated 450 ppm was simulated to be roughly 10% higher than when the atmospheric CO_2 concentration was the baseline 350 ppm. These simulated increases in pasture production due to elevated CO_2 (at 450 ppm) would offset or exceed the simulated declines in pasture production due to warming or drying.

[33] Each with a range of about 1.5°C from a decile 1 to a decile 9 year

2. Hot days and heatwaves are already a challenge in the current climate, and are expected to become more challenging in future climates

The Fleurieu Peninsula's small number of hot days per year (3 and 7 days above 35°C at Parawa and Victor Harbor respectively), is projected to increase quite significantly in a 2°C warmer climate (to 7 and 12 days at Parawa and Victor Harbor respectively). These figures bring the future Parawa very close to Lenswood of the baseline period, and the future Victor Harbor to the McLaren Vale of the baseline period. This suggests that the projected higher frequency of hot days at locations within the Fleurieu Peninsula subregion can be managed. Extra irrigation is commonly used to mitigate heat impacts on viticulture and higher value horticultural enterprises, but the resultant increased irrigation demand would place additional strain on the supply of irrigation water and the ability of on-farm irrigation systems to apply it.

A feature of heatwaves in the AMLR region is not only the temperatures but also the strong northerly winds and the extremely low humidity. These desiccating conditions are damaging to most plants, and are also associated with increased fire danger, a risk already present in some parts of the Fleurieu Peninsula subregion, where fire may affect viticulture both directly and through the effects of smoke taint[34].

3. Hot days are of concern to livestock, but the low humidity will lessen the impact

The thermal humidity index (THI) is a measure of comfort calculated from temperature and humidity and used by the dairy industry, while also being applicable to other livestock enterprises. THI values vary from very low in locations such as Parawa and Victor Harbor, to moderate at locations such as Mt Compass. As shown in Figure 5.9, at Victor Harbor the number of days with THI values greater than 78, a value where heat stress occurs and milk production is reduced (Cowie and Martin, 2009; Dairy Australia's Cool Cows website[35]) would increase in a 2°C warmer climate to similar levels as experienced at Mt Crawford during the baseline period. At Mt Compass, a 1°C warmer climate would increase the number of days per year with THI greater than 78 from 42 during the baseline period to 54, while a 2°C warmer climate would increase it to 68 days, similar to the relatively high levels experienced at Camden, NSW but lower than experienced in Rockhampton (Qld) during the baseline period. Obviously the livestock in Rockhampton are different breeds to those used on the Fleurieu Peninsula, but the comparison highlights the much milder heat stress experienced in southern Australia due to the prevailing low humidity conditions. Dairy Australia's Cool Cows website[36] provides information on the effects on dairy cows at different THI values, and management options to deal with excessive heat loads.

[34] For an explanation of smoke taint see footnote in Section 5.2

[35] http://www.dairyaustralia.com.au and http://www.coolcows.com.au

[36] http://www.dairyaustralia.com.au and http://www.coolcows.com.au

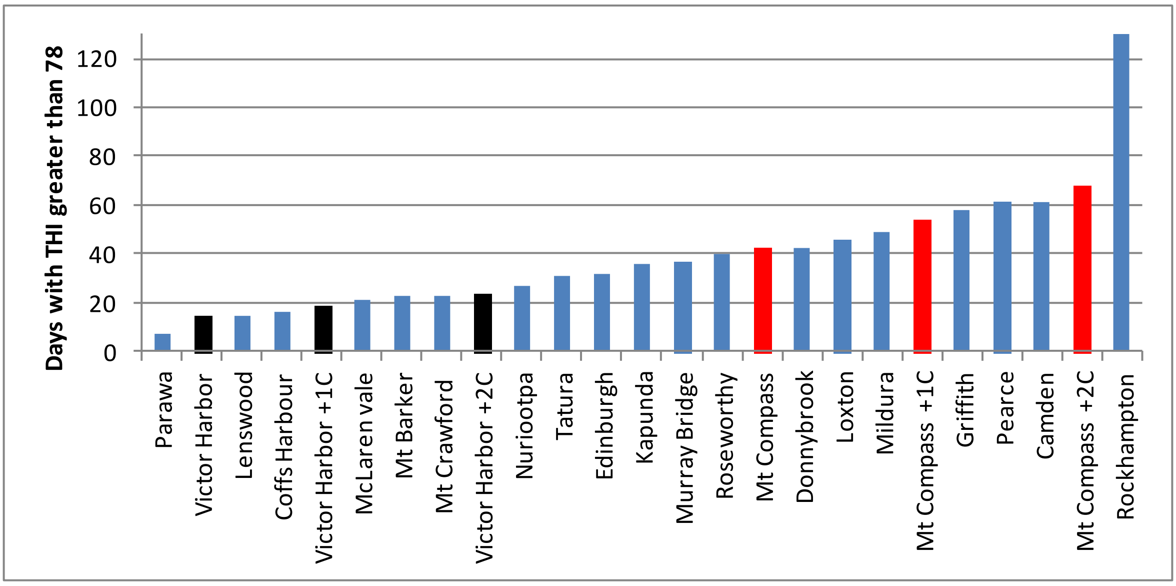

Figure 5.9. *Number of days per year when the THI (thermal humidity index) was greater than 78 during the baseline period (1980-1999) at locations within the AMLR NRM region and for several homologue locations in Australia, and for Victor Harbor and Mount Compass with the projected 1°C and 2°C mean temperature increases*

4. Autumn, winter and spring rainfall declines will affect productivity

Viticulture and pasture growth (particularly for dairy, but also for meat cattle production in some instances) typically rely on both rainfall and irrigation water to meet year-round water demands. While a decline in rainfall is certainly not desirable, even a 20% average decline will not be outside the range experienced on the Fleurieu Peninsula during the baseline period. The combination of reduced rainfall and increased evapotranspiration will however increase reliance on irrigation water, while the decrease in rainfall in catchment zones may affect the long term availability of that irrigation water, and potentially its quality. Additionally, unirrigated pasture production was modelled (by APSIM Agpasture) to decline by 5% for each 10% rainfall decline at Parawa and Mount Compass.

The Fleurieu Peninsula subregion has a wide rainfall range (with annual amounts of over 900mm at Parawa and a little over half this at Victor Harbor), but a much more uniform evaporative demand (at about 1000mm). This means that reliance on irrigation is much higher at Victor Harbor than in Parawa, but a future drier climate will increase irrigation demand at both locations.

5. There will be a greater overall demand for irrigation, as well as an increase in high irrigation requirement days

An increase in irrigation demand can arise from an increase in evapotranspiration, to overcome rainfall shortfalls or to manage changes in plant production. Modelled pasture production at Parawa and Mount Compass (using APSIM Agpasture) showed a 4% increase in irrigation water was required for each 10% reduction in rainfall in order to reach baseline period production levels.

An additional aspect of irrigation demand is the daily demand for irrigation. This is possibly of more interest to farmers involved in horticultural enterprises than those involved in pasture production, as horticultural enterprises typically experience greater stress/quality issues as a consequence of insufficient irrigation. Changes to the daily demand for irrigation may affect farmers because the irrigation system (related to the on-farm design of the irrigation system and also to the supply of irrigation water to the farm) has to be able to supply sufficient irrigation to meet the daily demand. A projected increase in evapotranspiration of 3% or 5% per annum (corresponding to 1°C and 2°C mean temperature increases respectively) will increase the number of individual days with evapotranspiration greater than 6 mm[37] from 14 days at both Parawa and Victor Harbor by about 10% and 20% respectively. Days with evapotranspiration greater than 8 mm are rare in the baseline period, at less than 2 days in the average years and at 4 days in the 9 in 10 warm years. A 10% or 20% drying will increase the expected number of days with more than 8 mm evapotranspiration by about 1 day per annum, meaning these will still remain rare events by regional standards.

6. The (uncertain) increase in summer rainfall could be problematic for horticulture but beneficial for pasture production

During the baseline period, the number of moisture positive days[38] was generally higher on the Fleurieu Peninsula than in other subregions (the exception being locations in the Central Hills subregion and in Mt Crawford, near the boundary with the Northern Hills subregion). The number of moisture positive days will increase if summer rainfall increases, but even these higher amounts are less than currently experienced throughout many viticultural regions, suggesting the impacts to the industry can be managed using well known, existing industry practices.

An increase in summer rainfall is likely to be small, and may therefore be slightly beneficial to pasture growth.

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[37] For an explanation of daily evapotranspiration thresholds see footnote in Section 5.1

[38] For an explanation of moisture positive days see footnote in Section 5.1

Appendix 1. Methods used for agro-climatic analysis of the current climate for locations in each subregion

The AMLR region is complex with significant variations in elevation, soil type, and climate. There is reasonable coverage for rainfall, but locations that have long term temperature records are more infrequent (although coverage is greater than for many other regions). This means that locations which can be historically analysed may be located some distance from many primary producing industries. Farmers are however generally aware that different microclimates and mesoclimates[39] are at play in their areas and within their properties. Given the high cost of farming land, sites are carefully selected not only for soil but also for elevation, aspect, slope and air drainage. In undulating areas, which comprise much of the AMLR NRM region, the differences in mesoclimate between nearby locations can be greater than the mean temperature changes projected for 2030. This means that careful site selection is a major source of resilience against the early stages of climate change.

The difference in actual temperature between a given farm location and its meteorological station can be estimated from differences in elevation, aspect, slope, air drainage and proximity to water bodies, and this is commonly done in the viticulture sector. Gladstones (1992) suggests changes for the farm location relative to the relevant meteorological station should include the following:

- For each 100m of elevation increase maximum and minimum temperature by 0.6°C.
- A north facing location should adjust minimum temperatures up by 0.2°C for a moderate slope and 0.4°C for a steep slope whereas a south facing location should adjust minimum temperatures down by the same amounts.
- As cold air is denser than the surrounding air, minimum temperatures at a location with cold air ponding should be 0.8 to 1.6°C lower than the comparable flat location, and temperatures of a free draining slope should be adjusted to be 0.4 to 0.8°C warmer than the flat location.
- Locations closer to water bodies will have higher (warmer) minimum temperature and lower (cooler) maximum temperatures. A larger water body (e.g. an ocean) will have a larger effect than a smaller water body (e.g. a lake). Gladstones suggests temperature adjustments of 0.4°C for sites moderately close to a lake, 0.8°C for sites closer to a lake or moderately close to an ocean, and 1.2°C for sites much closer to an ocean.

Climate data used in this report

Historical climate data for selected locations were obtained from the SILO database (http://www.nrw.qld.gov.au/silo/). Those data consisted of daily values for maximum and minimum temperatures, rainfall, evaporation, and potential evapotranspiration (ETo) as Patched Point Data (PPD). The PPD contains 'Observed' data (data as measured) from historical weather records and 'Patched' data. Patched data are used where no observed data exist, due for example to intermittent days when weather data were not observed, periods prior to opening a meteorological station or after its closure, or patching data for a climate variable that is not directly measured at the meteorological station (e.g. most stations do not record evaporation, and some stations do not record temperature). Information on which data are 'Observed' and which are 'Patched' (i.e. interpolated) at each location is available from the SILO website.

[39] Mesoclimates and microclimates are regional and local climates, respectively. They typically differ from the overall prevailing macroclimate due to small scale differences in topography, aspect, land cover and distance to water courses. Microclimates typically affect stretches of land at a scale smaller than 2 km (e.g. a forest may have a different microclimate to an adjacent cleared area), while mesoclimates cover larger areas (but not as large as a macroclimate). In viticulture, a microclimate typically refers to the specific environment in a small restricted space such as a row of vines, while a mesoclimate refers to the climate of a particular vineyard site (for more information see for example http://en.wikipedia.org/wiki/Regional_climate_levels_in_viticulture)

Climatic data from the 20 year period 1980 - 1999 were used to represent the historic baseline period, as this period is commonly used by climate scientists when assessing and projecting climatic changes (for further information see the IPCC website - http://www.ipcc.ch). Simplified climate change projections were used to represent warmer and drier 2030 climate scenarios, with the following key assumptions:

- 1°C mean temperature increase (with both daily minimum and daily maximum increasing)
- 2°C mean temperature increase (with both daily minimum and daily maximum increasing)
- 10% annual rainfall decrease, with a corresponding 3% evapotranspiration increase
- 20% annual rainfall decrease, with a corresponding 5% evapotranspiration increase
- 10% summer rainfall increase
- 20% summer rainfall increase.

These changes in climate of warming and drying are within the likely range for the AMLR region for 2030 with the milder conditions more likely and the more severe scenarios towards the extremes of possible projections (see CSIRO and Bureau of Meteorology, 2007). These simplified climate projections were used to avoid misrepresenting the certainty of a projected future climate scenario that can be affected by uncertainty in the rate of warming, the rate of increase in greenhouse gas emissions, the choice of general circulation models (GCM), the downscaling method used to calculate seasonal, monthly or daily time periods and the spatial resolution.

Changes to the baseline climate (1980 to 1999) were made to each days' value and climate variables recalculated for the projected climate futures. The mean and range of the climate variables in the projected future climates were compared to the mean and range of the baseline climate. We calculated climatic indices using daily data with the exception of indices of chill accumulation that require hourly data. Hourly data were generated from daily maximum and minimum temperature using the methods outlined in Linvill (1990) and Hennessy and Clayton-Greene (1995).

The indices

Indices relating to temperature included:

- mean annual temperatur,
- mean January temperature
- mean temperature during the period 1st April - 31st October, which was used to represent 'winter' growing crops such as wheat
- mean temperature during the period 1st October - 30th April, which was used to represent 'spring/summer' growing crops such as viticulture and perennial horticulture
- Growing Degree Days (GDD), with a base of 10°C
- Biologically Effective Degree Days (BEDD), calculated using the method outlined by Gladstones (2011).

Chill accumulation was calculated using four widely used chill models. These included Wienberger's 0-7.2°C model (Wienberger, 1950), the Utah model (Richardson *et al*., 1974) and its derivative the Positive Utah model (Linsley-Noakes *et al*., 1994), and the Dynamic model (Erez *et al*., 1990).

Unlike the Utah model, The Positive Utah model does not factor in the negation effects of high temperatures. It has been found to perform better than the Utah model in mild weather locations in South Africa (Linsley-Noakes *et al*., 1994), and to describe walnut phenology well in California (Luedeling *et al*., 2009).

Unfortunately there is limited conversion between chill models as shown by Luedeling and Brown's (2010) study into the comparability of chill models on a global scale. Darbyshire *et al*. (2011) support this global assessment in an Australian setting. The Dynamic model (Erez *et al*., 1990) is considered the most biologically accurate model. It calculates chilling accumulation as 'chill portions' and accounts for chill cancellation due to fluctuating warm temperatures. The dynamic model assumes that chill results from a two-step process, whereby cold temperatures initially form an intermediate product in the buds, and warm temperatures can then destroy this intermediate product. When a certain quantity of the intermediate product has accumulated, it is transformed irreversibly into a chill portion, which can no longer be destroyed (Erez *et al*., 1990) Recent studies comparing the ability of several chill models to simulate chill requirements in several species and locations have indicated the 0-7.2°C is least effective, with the Dynamic model being slightly more accurate than the Utah model (Alburquerque *et al*. 2008 in Cherry; Perez *et al*. 2008 in Grape; Ruiz *et al*. 2007 in Apricot; Viti *et al*. 2010 in Apricot; Zhang and Taylor, 2011 for Pistashio). Consequently we justify a locations vulnerability to chill accumulation based on the Dynamic model and relate these levels to reported chill requirements for species of interest. These include cherries, apples and pears, summerfruit (apricots, peaches, nectarines), and almonds (See Table 5.4).

Extreme hot temperature was examined by calculating the number of days when daily maximum temperatures was warmer than 35 or 40°C. We also examine the index for excessive heat days and heatwaves according to the method of Nairn and Fawcett (2011).

The thermal humidity index (THI) was calculated as Dry bulb temperature (°C) + 0.36*Dew point temperature (°C) + 41.2

Frost potential is deemed by the Bureau of Meteorology to occur when minimum temperature is less than 1°C. This is because temperatures are recorded at a height of 1.2m and inside an enclosure, whereas plants are not enclosed and temperatures are cooler closer to ground level. Climate change is likely to cause greater warming at night which may reduce risk of frost. However frost depends not just on night temperature; other factors such as weather patterns, soil conditions, topography which can affect if a frost occurs. We used the occurrence of minimum temperatures less than 1°C to examine the impact of warmer mean temperatures on reduction in extreme low temperatures.

Rainfall and evapotranspiration indices included:

- mean annual rainfall
- mean rainfall during the period 1st April to 31st October (used in reference to 'winter' growing crops such as wheat)
- mean annual evapotranspiration
- mean evapotranspiration during the period 1st April to 31st October

In addition, the 6mm threshold was used to highlight days with slightly higher than average evapotranspiration, while the 8mm threshold was used to signify quite rare events. For example, in Nuriootpa during the period 1961-1990 (a standard weather averaging period used by BOM and WMO), evapotranspiration greater than 6mm occurred on about one third of November to February days (these are the year's four high evaporative months), while evapotranspiration greater than 8mm occurred only on about 5% of days during this same period.

The number of days taken to deplete the readily available water (RAW) of 25mm if the crop coefficient was 0.6 was calculated. The water lost per day was calculated as crop coefficient (Kc) * evapotranspiration.

Moisture positive days were calculated as days when rainfall (below 10mm) in the preceding three days was greater than evapotranspiration over the same period. Days with rainfall over 10mm are not counted, as at that level of wetness water is considered to be running off the plants.

The use of a projected CO_2 concentration of 450ppm for the 2030 projections in the APSIM simulations of wheat growth and agriculture pasture growth was taken from extrapolation of observed data sourced from http://www.climateprediction.eu/cc/Main/Entries/2011/6/27_Prediction_of_CO2_Concentration_till_2030.html

Locations and homologues analysed

AMLR locations analysed in this report are shown in Table A1, along with their corresponding subregions and the relevant primary producing industries they accommodate. Figure A1 shows the arrangement of locations according to mean temperature and rainfall. Figure A1 shows there are spatial homologues of a warmer and/or drier climate for many locations used for analysis of the industries within the AMLR NRM subregions, both within and outside the region.

Detailed climate descriptions for the locations in the subregions during the baseline period (1980-1999) and for the projected future climate scenarios are shown in Appendix 2, which also shows comparable climatic data for these homologue locations during the baseline period.

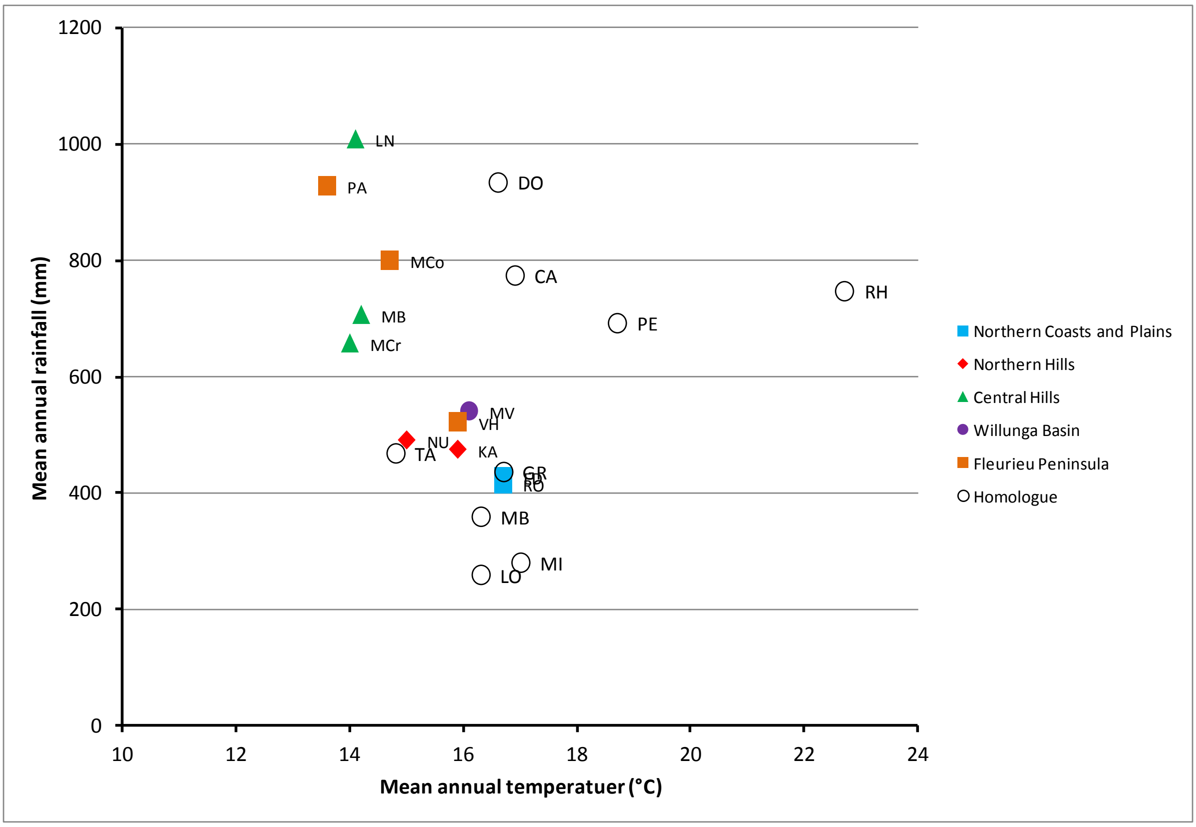

Figure A1. *Relationship between mean annual temperature and mean annual rainfall for selected locations in the AMLR subregions of Northern Coasts and Plains, Northern Hills, Central Hills, Willunga Basin and Fleurieu Peninsula. Abbreviations for the locations are shown in Table A1*

Table A1. Meteorological stations used in analysis

Subregion	Station name and abbreviation		Industry	Station number	Latitude	Longitude	Elevation (m ASL)
Northern Coasts and Plains	Edinburgh RAAF	ED	Annual horticulture Perennial horticulture Viticulture	23083	-34.71	138.62	16
Northern Coasts and Plains	Roseworthy Agricultural college	RO	Annual cropping Livestock	23020	-34.53	138.69	68
Northern Hills	Kapunda	KA	Annual cropping Livestock	23307	-34.34	138.92	245
Northern Hills	Nuriootpa comparison	NU	Viticulture	23321	-34.48	139.00	274
Northern Hills	Mt Crawford Forest Headquarters	MCr	Viticulture Livestock	23763	-34.718	138.95	395
Central Hills	Lenswood Research Centre	LE	Perennial horticulture Viticulture Annual horticulture Livestock	23801	-34.95	138.81	480
Central Hills	Mt Barker	MB	Perennial horticulture Viticulture Annual horticulture Livestock	23733	-35.065	138.85	360
Willunga Basin	McLaren Vale	MV	Viticulture Perennial horticulture	23729	-35.225	138.54	65
Fleurieu Peninsula	Mt Compass	MCo	Livestock Viticulture	23735	-35.35	138.62	232
Fleurieu Peninsula	Parawa (Sharon)	PA	Livestock Viticulture	23761	-35.56	138.34	361
Fleurieu Peninsula	Victor Harbor	VH	Livestock Viticulture	23751	-35.56	138.62	5
Homologue	Camden, NSW	CA	Annual horticulture Livestock	68192	-34.04	150.69	73
Homologue	Donnybrook, WA	DO	Perennial horticulture	9534	-33.574	115.82	63
Homologue	Griffith, NSW	GR	Annual horticulture Perennial horticulture Viticulture	75041	-34.25	146.07	134
Homologue	Loxton, SA	LO	Annual horticulture Perennial horticulture Viticulture Livestock	24024	-34.44	140.60	30
Homologue	Mildura, Vic	MI	Annual horticulture Perennial horticulture Viticulture Livestock	76031	-34.24	142.09	50
Homologue	Murray Bridge, SA	MB	Livestock	24521	-35.124	139.26	33

Subregion	Station name and abbreviation		Industry	Station number	Latitude	Longitude	Elevation (m ASL)
Homologue	Pearce, WA	PE	Annual horticulture Perennial horticulture Viticulture	9053	-31.67	116.02	40
Homologue	Rockhampton, Qld	RO	Livestock	39083	-23.38	150.48	10
Homologue	Tatura, Vic	TA	Perennial horticulture Viticulture	81049	-36.44	145.27	114

Appendix 2. Climatic data for locations.

The stations used in the analysis are shown in Table A1 (Appendix1). The period from 1980 to 1999 was used as the baseline period. The mean and the range from the 1st decile (D1; 1 in 10 warmest year, that is a relatively cool year for the location) to 9th decile (D9; 9 in 10 warmest year) during this period are shown. The mean, 1st decile and 9th decile of the climate indices and how these values relate to the values during the baseline period are shown for an increase in mean temperature (both daily minimum and daily maximum temperature were increased) of 1°C and of 2°C; and a moderately drier future represented by a 10% decrease in rainfall with a corresponding 3% increase in evapotranspiration and a more severe drier future represented by a 20% decrease in rainfall with a corresponding 5% increase in evapotranspiration. The impact of a10 and 20% increases in summer rainfall were also examined.

The frequency indicates how the values in a future climate for the 20 year period surrounding 2030 relate to the values during the baseline period (the 20 year period surrounding 1990). For example, using Edinburgh RAAF as an example, the mean January temperature during 1980-1999 was 22.6°C, the 1st decile (D1; 1 in 10 warmest year) was 20.6°C and the 9th decile (D9; 9 in 10 warmest year) was 24.9°C. A 1°C warmer climate would increase the mean January temperature from 22.6°C to 23.6°C which is equivalent to the 76% percentile of the baseline (1980 to 1999) period. This is the same as saying a year with a mean January temperature of 23.6°C was about the 7th or 8th warmest out of 10 years during this period. In other words, a 1°C increase in mean temperature would mean that a year that was considered the 7th or 8th warmest year during a 10 year period would become the average year (and likely to be warmer in half the years) for the 20 year period surrounding 2030).

Similarly a 2°C increase in mean temperature would increase the mean temperature from 22.6°C to 24.6°C. A mean temperature of 24.6°C is equivalent to the 86th percentile in the baseline period. This is about half way between the 8th or 9th warmest year during a 10 year period in the baseline period. In other words, a 2°C increase in mean temperature would mean that a year that was considered the 8th or 9th warmest year during a 10 year period would become the average year (and likely to be warmer in half the years) for the 20 year period surrounding 2030).

This same 1°C warming would increase the 1st decile from 20.6°C to 21.6°C which is equivalent to the 30th percentile of the base period. In other words, what was formerly a 3 in 10 warmest year during the 1980 to 1999 baseline period becomes the 1 in 10 warmest year for 2030. A 2°C warmer future would increase the 1st decile from 20.6°C to 22.6°C which is the 49th percentile, indicating what was an average year during 1980 to 1999 would become the 1 in 10 warmest year in 2030.

A 1°C warming would increase the 9th decile from 24.9°C to 25.9°C which is equivalent to the 99th percentile for the 1980 to 1999 period. In other words, it is equivalent to the warmest year on record. A 2°C warming would increase the 9th decile from 24.9°C to 26.9°C which is beyond the baseline period (indicated by ">BL"). In other words the warmest mean January temperature recorded during the baseline of 1980 to 1999 is cooler than the 26.9°C projected to occur in 1 in every 10 years for the period surrounding 2030.

Location	EDINBURGH RAAF				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	16.7									
Mean Annual Rainfall (mm)	427									
Mean Annual Evapotranspiration (mm)	1299									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	16.7	16.2 - 17.1	17.7	*>BL*	17.2 - 18.1	>BL , >BL	18.7	*>BL*	18.2 - 19.1	>BL , >BL
Mean "winter" (April to October) temperature (°C)	13.4	12.9 - 14.1	14.4	*>BL*	13.9 - 15.1	78 , >BL	15.4	*>BL*	14.9 - 16.1	>BL , >BL
Mean "summer" (October to April) temperature (°C)	19.9	19.4 - 20.5	20.9	*>BL*	20.4 - 21.5	85 , >BL	21.9	*>BL*	21.4 - 22.5	>BL , >BL
Mean January temperature (°C)	22.6	20.6 - 24.9	23.6	*76*	21.6 - 25.9	30 , 99	24.6	*86*	22.6 - 26.9	49 , >BL
GDD (October to April) (°C days)	2099	1997 - 2223	2311	*>BL*	2209 - 2435	86 , >BL	2524	*>BL*	2421 - 2647	>BL , >BL
BEDD (October to April) (°C days)	1605	1568 - 1645	1700	*>BL*	1671 - 1735	>BL , >BL	1774	*>BL*	1750 - 1805	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	48	43 - 53	40	*<BL*	34 - 46	<BL , 29	31	*<BL*	24 - 37	<BL , <BL
Utah model (chill units)	780	603 - 909	513	*<BL*	321 - 697	<BL , 32	219	*<BL*	28 - 440	<BL , <BL
Positive Utah model (positive chill units)	1007	909 - 1110	839	*<BL*	730 - 967	<BL , 32	668	*<BL*	546 - 812	<BL , <BL
Chill Hours (0 to 7.2 °C)	391	276 - 550	266	*6*	160 - 404	<BL , 55	167	*<BL*	78 - 285	<BL , 13
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	22	17 - 28	28	*95*	23 - 34	68 , 99	34	*100*	29 - 40	95 , >BL
Days when maximum temperature warmer than 40 °C	4.4	1 - 8.1	6.5	*71*	2.9 - 12	31 , >BL	9.2	*96*	3 - 16.2	32 , >BL
Excess heat temperature (°C)	27.7									
Severe heat threshold (°C)	33.4									
Excess heat factor (annual total) (°C^2)	177	51 - 327	274	*78*	117 - 478	29 , >BL	400	*97*	215 - 641	71 , >BL
Maximum daily value of Excess heat factor (°C^2)	41	17 - 64	52	*76*	24 - 75	19 , 96	62	*88*	31 - 87	27 , >BL
Number of days with positive Excess heat factor	11	7 - 18	16	*81*	9 - 23	45 , >BL	22	*>BL*	16 - 29	81 , >BL
Number of days with positive Severe heat factor	0	0 - 0	0.1	*>BL*	0 - 0.1	0 , >BL	0.6	*>BL*	0 - 2.1	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	142	131 - 159	164	*>BL*	150 - 178	68 , >BL	187	*>BL*	171 - 204	>BL , >BL
Days THI greater than 72 units	86	76 - 95	102	*>BL*	92 - 114	73 , >BL	121	*>BL*	108 - 135	>BL , >BL
Days THI greater than 78 units	32	25 - 40	41	*93*	33 - 49	47 , >BL	53	*>BL*	45 - 62	>BL , >BL
Days THI greater than 82 units	11	5 - 19	17	*85*	9 - 24	37 , >BL	23	*>BL*	16 - 30	83 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	3.3	0 - 8.1	1	*37*	0 - 3.1	0 , 66	0.2	*32*	0 - 0	0 , 0
First day of year when minimum temperature colder than 1°C	118	0 - 230	66	*35*	0 - 209	0 , 82	8	*32*	0 - 0	0 , 0
Last day of year when minimum temperature colder than 1°C	147	0 - 240	76	*34*	0 - 218	0 , 50	10	*32*	0 - 0	0 , 0
Frost risk duration (days)	30	0 - 77	10	*54*	0 - 28	0 , 57	2	*47*	0 - 0	0 , 0
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	322	247 - 393	289	*16*	222 - 354	8 , 80	257	*11*	198 - 315	6 , 38
Mean "winter" (April to October) evapotranspiration (mm)	482	441 - 522	496	*62*	454 - 538	18 , >BL	506	*81*	463 - 548	26 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	56	49 - 63	60	*57*	51 - 68	17 , 97	63	*91*	54 - 71	29 , 98
Days when evapotranspiration greater than 8 mm	9	4.9 - 12.4	11.2	*85*	6 - 14.4	21 , 93	12.6	*90*	7.9 - 18.2	36 , 97
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	7	6 - 7	7	*43*	6 - 7	<BL , 77	6	*22*	6 - 7	<BL , 75
RAW = 25mm, Kc = 0.6, in January	6	6 - 7	6	*26*	6 - 7	<BL , 79	6	*20*	5 - 7	<BL , 69
RAW = 25mm, Kc = 0.6, in December	7	6 - 8	7	*33*	6 - 8	1 , 83	6	*28*	6 - 7	<BL , 81
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	6.3	0.9 - 9.4	5.8	*52*	0.9 - 9.3	10 , 90	5.1	*52*	0.9 - 9.1	10 , 90
Moisture positive days in December and January	4.9	0 - 9.4	4.5	*69*	0 - 8.4	0 , 88	3.9	*69*	0 - 7.3	0 , 85
Moisture positive days in February and March	4.5	0 - 9	4.3	*56*	0 - 9	0 , 79	4	*56*	0 - 8.1	0 , 77

Location	ROSEWORTHY AGRIC COLLEGE				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	16.7									
Mean Annual Rainfall (mm)	415									
Mean Annual Evapotranspiration (mm)	1290									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	16.7	16.2 - 17.3	17.7	*>BL*	17.2 - 18.3	82 , >BL	18.7	*>BL*	18.2 - 19.3	>BL , >BL
Mean "winter" (April to October) temperature (°C)	13.5	12.8 - 14.3	14.5	*>BL*	13.8 - 15.3	68 , >BL	15.5	*>BL*	14.8 - 16.3	>BL , >BL
Mean "summer" (October to April) temperature (°C)	19.9	19.3 - 20.6	20.9	*100*	20.3 - 21.6	76 , >BL	21.9	*>BL*	21.3 - 22.6	>BL , >BL
Mean January temperature (°C)	22.6	20.4 - 24.8	23.6	*71*	21.4 - 25.8	33 , 98	24.6	*88*	22.4 - 26.8	41 , >BL
GDD (October to April) (°C days)	2098	1989 - 2242	2310	*100*	2200 - 2454	83 , >BL	2522	*>BL*	2413 - 2666	>BL , >BL
BEDD (October to April) (°C days)	1573	1481 - 1641	1673	*>BL*	1602 - 1725	72 , >BL	1753	*>BL*	1703 - 1791	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	47	42 - 52	38	*<BL*	33 - 44	<BL , 29	29	*<BL*	21 - 37	<BL , <BL
Utah model (chill units)	740	549 - 916	466	*<BL*	273 - 664	<BL , 29	169	*<BL*	-46 - 383	<BL , <BL
Positive Utah model (positive chill units)	990	849 - 1100	812	*<BL*	671 - 940	<BL , 25	641	*<BL*	496 - 769	<BL , <BL
Chill Hours (0 to 7.2 °C)	355	222 - 493	233	*13*	135 - 357	<BL , 56	142	*<BL*	70 - 247	<BL , 16
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	27	22 - 32	33	*95*	27 - 39	50 , >BL	40	*>BL*	35 - 49	98 , >BL
Days when maximum temperature warmer than 40 °C	5.4	2 - 9.1	8.2	*80*	3 - 14	32 , >BL	11.5	*99*	4.9 - 16.4	44 , >BL
Excess heat temperature (°C)	27.7									
Severe heat threshold (°C)	33.3									
Excess heat factor (annual total) (°C^2)	177	47 - 323	276	*78*	105 - 463	26 , 98	408	*96*	196 - 618	68 , >BL
Maximum daily value of Excess heat factor (°C^2)	41	11 - 68	51	*72*	18 - 82	15 , 98	61	*77*	26 - 94	25 , >BL
Number of days with positive Excess heat factor	11	5 - 20	17	*79*	11 - 24	52 , >BL	23	*>BL*	17 - 30	79 , >BL
Number of days with positive Severe heat factor	0	0 - 0	0.3	*>BL*	0 - 1	0 , >BL	0.6	*>BL*	0 - 1.3	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	154	145 - 167	177	*99*	166 - 190	89 , >BL	198	*>BL*	186 - 212	>BL , >BL
Days THI greater than 72 units	98	86 - 108	115	*>BL*	102 - 127	72 , >BL	136	*>BL*	121 - 150	>BL , >BL
Days THI greater than 78 units	40	35 - 48	52	*>BL*	45 - 58	79 , >BL	63	*>BL*	55 - 71	>BL , >BL
Days THI greater than 82 units	16	9 - 22	22	*92*	16 - 28	42 , >BL	31	*>BL*	24 - 36	>BL , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	3.4	0 - 10.2	0.9	*41*	0 - 3.1	0 , 61	0.2	*38*	0 - 0.2	0 , 38
First day of year when minimum temperature colder than 1°C	101	0 - 190	60	*40*	0 - 207	0 , 97	21	*38*	0 - 20	0 , 38
Last day of year when minimum temperature colder than 1°C	137	0 - 293	73	*40*	0 - 249	0 , 80	21	*38*	0 - 20	0 , 38
Frost risk duration (days)	36	0 - 109	13	*55*	0 - 57	0 , 75	0	*38*	0 - 0	0 , 38
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	319	254 - 391	287	*24*	229 - 352	5 , 69	255	*10*	203 - 313	2 , 58
Mean "winter" (April to October) evapotranspiration (mm)	477	438 - 514	492	*57*	452 - 529	25 , >BL	501	*63*	460 - 539	31 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	56	47 - 65	59	*57*	49 - 68	22 , 97	63	*68*	51 - 72	25 , 99
Days when evapotranspiration greater than 8 mm	9.4	4 - 14.1	11.9	*81*	5 - 18.1	21 , 97	13.1	*83*	5 - 18.2	21 , 97
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	7	6 - 8	7	*50*	6 - 7	<BL , 78	6	*22*	6 - 7	<BL , 76
RAW = 25mm, Kc = 0.6, in January	6	6 - 7	6	*30*	6 - 7	<BL , 72	6	*21*	6 - 7	<BL , 60
RAW = 25mm, Kc = 0.6, in December	7	6 - 8	7	*45*	6 - 8	<BL , 87	7	*37*	6 - 8	<BL , 84
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	6.1	0.9 - 11	5.6	*55*	0.9 - 10.1	10 , 79	4.9	*55*	0.9 - 9.1	10 , 74
Moisture positive days in December and January	5	0 - 11	4.5	*70*	0 - 9.2	0 , 85	3.7	*70*	0 - 6.2	0 , 79
Moisture positive days in February and March	4.2	0 - 10	4	*59*	0 - 9	0 , 84	3.7	*59*	0 - 9	0 , 84

Location	KAPUNDA				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	15.9									
Mean Annual Rainfall (mm)	474									
Mean Annual Evapotranspiration (mm)	1274									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	15.9	15.4 - 16.4	16.9	*>BL*	16.4 - 17.4	93 , >BL	17.9	*>BL*	17.4 - 18.4	>BL , >BL
Mean "winter" (April to October) temperature (°C)	12.6	12 - 13.2	13.6	*>BL*	13 - 14.2	75 , >BL	14.6	*>BL*	14 - 15.2	>BL , >BL
Mean "summer" (October to April) temperature (°C)	19.2	18.7 - 19.8	20.2	*>BL*	19.7 - 20.8	79 , >BL	21.2	*>BL*	20.7 - 21.8	>BL , >BL
Mean January temperature (°C)	22.1	20.1 - 24.6	23.1	*71*	21.1 - 25.6	33 , >BL	24.1	*88*	22.1 - 26.6	58 , >BL
GDD (October to April) (°C days)	1953	1847 - 2077	2164	*>BL*	2057 - 2289	79 , >BL	2376	*>BL*	2269 - 2501	>BL , >BL
BEDD (October to April) (°C days)	1491	1431 - 1540	1604	*>BL*	1547 - 1647	94 , >BL	1697	*>BL*	1642 - 1727	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	53	48 - 58	47	*<BL*	41 - 52	<BL , 38	38	*<BL*	33 - 44	<BL , <BL
Utah model (chill units)	985	850 - 1077	750	*<BL*	603 - 903	<BL , 30	482	*<BL*	327 - 668	<BL , <BL
Positive Utah model (positive chill units)	1162	1079 - 1222	1000	*<BL*	911 - 1094	<BL , 13	833	*<BL*	725 - 951	<BL , <BL
Chill Hours (0 to 7.2 °C)	539	378 - 697	386	*12*	236 - 546	<BL , 54	264	*<BL*	136 - 410	<BL , 15
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	23	17 - 27	30	*94*	25 - 36	68 , 100	36	*99*	30 - 44	95 , >BL
Days when maximum temperature warmer than 40 °C	3.7	0 - 7.1	6.1	*79*	2 - 11	26 , >BL	9.2	*>BL*	3.9 - 17.1	55 , >BL
Excess heat temperature (°C)	26.8									
Severe heat threshold (°C)	31.9									
Excess heat factor (annual total) (°C^2)	165	33 - 310	260	*78*	81 - 454	24 , 99	389	*96*	171 - 615	61 , >BL
Maximum daily value of Excess heat factor (°C^2)	37	10 - 56	46	*67*	18 - 66	23 , 96	56	*90*	25 - 78	31 , 98
Number of days with positive Excess heat factor	11	5 - 21	17	*79*	10 - 26	52 , >BL	25	*>BL*	17 - 33	79 , >BL
Number of days with positive Severe heat factor	0.1	0 - 0.1	0.4	*91*	0 - 1.1	0 , >BL	1	*95*	0 - 3.2	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	144	131 - 162	166	*>BL*	153 - 178	77 , >BL	187	*>BL*	172 - 200	>BL , >BL
Days THI greater than 72 units	92	82 - 101	107	*>BL*	95 - 121	61 , >BL	129	*>BL*	113 - 143	>BL , >BL
Days THI greater than 78 units	36	30 - 43	46	*94*	39 - 56	72 , >BL	57	*>BL*	48 - 66	>BL , >BL
Days THI greater than 82 units	13	7 - 21	19	*79*	12 - 26	46 , >BL	25	*>BL*	18 - 32	77 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	7.7	1 - 12.2	3.4	*18*	0 - 8.1	BL , 58	0.9	*BL*	0 - 3.2	BL , 17
First day of year when minimum temperature colder than 1°C	177	150 - 223	133	*3*	0 - 216	BL , 85	57	*BL*	0 - 202	BL , 76
Last day of year when minimum temperature colder than 1°C	240	211 - 270	163	*BL*	0 - 240	BL , 63	62	*BL*	0 - 217	BL , 17
Frost risk duration (days)	63	1 - 92	31	*18*	0 - 76	BL , 64	5	*11*	0 - 7	BL , 12
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	367	294 - 421	331	*22*	264 - 379	7 , 42	294	*10*	235 - 337	3 , 24
Mean "winter" (April to October) evapotranspiration (mm)	464	430 - 500	478	*58*	443 - 515	27 , >BL	487	*74*	451 - 525	39 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	56	45 - 66	59	*62*	51 - 69	19 , 97	63	*74*	56 - 71	54 , 99
Days when evapotranspiration greater than 8 mm	7.3	1.9 - 12.3	10.3	*77*	4.9 - 13.5	34 , 92	11.8	*88*	6 - 17.2	37 , 97
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	7	6 - 7	7	*46*	6 - 7	<BL , 78	6	*16*	6 - 7	<BL , 74
RAW = 25mm, Kc = 0.6, in January	6	6 - 7	6	*32*	6 - 7	<BL , 80	6	*19*	6 - 7	<BL , 69
RAW = 25mm, Kc = 0.6, in December	7	6 - 8	7	*42*	6 - 8	<BL , 83	6	*31*	6 - 7	<BL , 81
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	6.6	1.8 - 11.1	5.4	*63*	0.9 - 10	8 , 87	4.8	*63*	0.9 - 7.3	8 , 70
Moisture positive days in December and January	4.7	0 - 8.2	4.1	*74*	0 - 6.4	0 , 85	3.5	*74*	0 - 6.1	0 , 84
Moisture positive days in February and March	5.4	0 - 9.2	4.4	*59*	0 - 8.1	0 , 79	4.1	*59*	0 - 7.2	0 , 69

Location	NURIOOTPA COMPARISON				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	15.0									
Mean Annual Rainfall (mm)	490									
Mean Annual Evapotranspiration (mm)	1216									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	15	14.4 - 15.5	16	*>BL*	15.4 - 16.5	73 , >BL	17	*>BL*	16.4 - 17.5	>BL , >BL
Mean "winter" (April to October) temperature (°C)	11.7	11.1 - 12.3	12.7	*>BL*	12.1 - 13.3	67 , >BL	13.7	*>BL*	13.1 - 14.3	>BL , >BL
Mean "summer" (October to April) temperature (°C)	18.2	17.7 - 18.9	19.2	*>BL*	18.7 - 19.9	82 , >BL	20.2	*>BL*	19.7 - 20.9	>BL , >BL
Mean January temperature (°C)	21.1	19.5 - 23.7	22.1	*74*	20.5 - 24.7	38 , 100	23.1	*88*	21.5 - 25.7	61 , >BL
GDD (October to April) (°C days)	1752	1640 - 1882	1961	*>BL*	1849 - 2091	82 , >BL	2173	*>BL*	2061 - 2303	>BL , >BL
BEDD (October to April) (°C days)	1380	1341 - 1429	1505	*>BL*	1469 - 1548	>BL , >BL	1615	*>BL*	1579 - 1656	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	58	53 - 61	52	*<BL*	48 - 55	<BL , 15	45	*<BL*	40 - 50	<BL , <BL
Utah model (chill units)	1118	999 - 1207	921	*<BL*	784 - 1032	<BL , 20	690	*<BL*	504 - 832	<BL , <BL
Positive Utah model (positive chill units)	1244	1154 - 1318	1101	*<BL*	1012 - 1181	<BL , 13	945	*<BL*	824 - 1056	<BL , <BL
Chill Hours (0 to 7.2 °C)	651	504 - 775	505	*11*	334 - 652	<BL , 52	376	*<BL*	213 - 513	<BL , 12
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	17	13 - 22	22	*88*	17 - 26	56 , 96	28	*98*	23 - 37	91 , >BL
Days when maximum temperature warmer than 40 °C	1.8	0 - 3.3	3.3	*90*	0.9 - 6.1	26 , 95	5.5	*94*	1.9 - 10.1	68 , >BL
Excess heat temperature (°C)	25.8									
Severe heat threshold (°C)	31.1									
Excess heat factor (annual total) (°C^2)	157	34 - 270	248	*79*	88 - 408	22 , 99	371	*96*	154 - 574	62 , >BL
Maximum daily value of Excess heat factor (°C^2)	36	11 - 58	45	*64*	18 - 68	21 , 97	55	*85*	26 - 79	26 , >BL
Number of days with positive Excess heat factor	12	5 - 21	17	*80*	7 - 26	21 , >BL	24	*98*	13 - 34	65 , >BL
Number of days with positive Severe heat factor	0.1	0 - 0.1	0.3	*91*	0 - 1.1	0 , >BL	0.6	*92*	0 - 1.3	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	125	112 - 144	145	*94*	133 - 162	75 , >BL	165	*>BL*	153 - 180	>BL , >BL
Days THI greater than 72 units	77	67 - 86	91	*>BL*	79 - 103	58 , >BL	107	*>BL*	94 - 122	>BL , >BL
Days THI greater than 78 units	27	19 - 34	35	*93*	27 - 45	52 , >BL	45	*>BL*	37 - 58	96 , >BL
Days THI greater than 82 units	8	3 - 13	13	*90*	6 - 21	45 , >BL	19	*>BL*	12 - 26	74 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	17	6.9 - 25.1	9.4	*18*	2.8 - 19.1	BL , 58	4.4	*BL*	1 - 8.4	BL , 14
First day of year when minimum temperature colder than 1°C	139	117 - 158	160	*91*	132 - 218	30 , BL	170	*94*	140 - 215	60 , BL
Last day of year when minimum temperature colder than 1°C	259	238 - 288	239	*13*	211 - 265	BL , 69	203	*BL*	164 - 240	BL , 16
Frost risk duration (days)	121	90 - 155	80	*6*	22 - 129	BL , 54	34	*BL*	1 - 67	BL , 2
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	380	275 - 461	342	*25*	247 - 415	7 , 63	304	*17*	220 - 369	<BL , 43
Mean "winter" (April to October) evapotranspiration (mm)	435	396 - 468	449	*60*	408 - 482	23 , 96	457	*75*	416 - 491	25 , 100
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	48	38 - 57	52	*63*	41 - 61	13 , 97	55	*86*	45 - 64	28 , 99
Days when evapotranspiration greater than 8 mm	5.4	1.9 - 10.2	7.5	*75*	2 - 12.3	11 , 96	8.8	*78*	4 - 14.3	42 , >BL
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	7	6 - 8	7	*47*	6 - 7	<BL , 77	7	*21*	6 - 7	<BL , 72
RAW = 25mm, Kc = 0.6, in January	7	6 - 7	7	*35*	6 - 7	<BL , 83	6	*21*	6 - 7	<BL , 79
RAW = 25mm, Kc = 0.6, in December	7	6 - 8	7	*43*	6 - 8	<BL , 83	7	*30*	6 - 8	<BL , 81
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	6.8	0.9 - 9.2	6.4	*47*	0.9 - 9	10 , 68	5.8	*47*	0.9 - 8.1	10 , 64
Moisture positive days in December and January	5.4	0.9 - 9.1	5.1	*66*	0.9 - 9	10 , 89	4.7	*66*	0.9 - 8.1	10 , 87
Moisture positive days in February and March	4.9	0 - 8.1	4.5	*47*	0 - 8.1	0 , 90	4	*47*	0 - 8	0 , 79

Location	MOUNT CRAWFORD FOREST HEADQUAR				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	14.0									
Mean Annual Rainfall (mm)	657									
Mean Annual Evapotranspiration (mm)	1141									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	14	12.8 - 15.9	15	*79*	13.8 - 16.9	71 , >BL	16	*92*	14.8 - 17.9	79 , >BL
Mean "winter" (April to October) temperature (°C)	11	9.8 - 12.6	12	*77*	10.8 - 13.6	60 , >BL	13	*96*	11.8 - 14.6	76 , >BL
Mean "summer" (October to April) temperature (°C)	16.9	16 - 19.1	17.9	*82*	17 - 20.1	79 , >BL	18.9	*85*	18 - 21.1	82 , >BL
Mean January temperature (°C)	19.6	17 - 22.3	20.6	*72*	18 - 23.3	27 , 95	21.6	*83*	19 - 24.3	43 , 99
GDD (October to April) (°C days)	1468	1286 - 1924	1673	*82*	1489 - 2134	79 , >BL	1882	*85*	1699 - 2346	82 , >BL
BEDD (October to April) (°C days)	1200	1106 - 1485	1342	*82*	1254 - 1604	80 , >BL	1472	*87*	1391 - 1693	83 , >BL
Chill accumulation										
Dynamic model (chill portions)	60	54 - 64	55	*16*	48 - 61	<BL , 60	48	*<BL*	40 - 55	<BL , 17
Utah model (chill units)	1160	952 - 1313	1004	*17*	763 - 1178	<BL , 42	804	*<BL*	512 - 1036	<BL , 20
Positive Utah model (positive chill units)	1269	1121 - 1383	1160	*13*	1016 - 1285	<BL , 49	1026	*<BL*	885 - 1193	<BL , 17
Chill Hours (0 to 7.2 °C)	736	600 - 890	600	*10*	442 - 733	7 , 41	473	*7*	329 - 592	<BL , 10
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	14	6 - 26	18	*72*	9 - 32	31 , >BL	23	*82*	15 - 35	63 , >BL
Days when maximum temperature warmer than 40 °C	2.1	0 - 6.1	3	*74*	0 - 7.3	0 , 96	4.2	*82*	0 - 12	0 , >BL
Excess heat temperature (°C)	24.3									
Severe heat threshold (°C)	29.8									
Excess heat factor (annual total) (°C^2)	177	14 - 510	263	*78*	39 - 681	24 , 98	375	*85*	85 - 873	49 , >BL
Maximum daily value of Excess heat factor (°C^2)	36	7 - 79	46	*71*	15 - 89	24 , 98	56	*77*	23 - 100	34 , >BL
Number of days with positive Excess heat factor	12	3 - 27	17	*79*	5 - 36	25 , 99	24	*84*	11 - 44	62 , >BL
Number of days with positive Severe heat factor	0.3	0 - 0.1	0.5	*92*	0 - 1.2	0 , 95	0.8	*94*	0 - 2.2	0 , 96
Comfort and productivity of animals										
Days THI greater than 68 units	114	96 - 144	134	*87*	111 - 166	54 , >BL	153	*98*	129 - 188	86 , >BL
Days THI greater than 72 units	70	53 - 88	83	*81*	67 - 104	44 , >BL	99	*99*	82 - 132	80 , >BL
Days THI greater than 78 units	23	14 - 41	32	*79*	22 - 49	63 , >BL	42	*98*	31 - 58	78 , >BL
Days THI greater than 82 units	8	1 - 19	12	*77*	4 - 25	31 , >BL	17	*87*	10 - 31	73 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	34.2	6.6 - 56.4	22.6	*25*	1.9 - 35.7	BL , 47	12.9	*19*	0 - 23.4	BL , 26
First day of year when minimum temperature colder than 1°C	121	90 - 168	122	*67*	90 - 178	10 , 95	120	*65*	0 - 179	BL , 96
Last day of year when minimum temperature colder than 1°C	297	236 - 341	261	*19*	183 - 324	BL , 74	222	*0*	0 - 282	BL , 32
Frost risk duration (days)	178	69 - 239	139	*23*	3 - 214	BL , 58	103	*18*	0 - 165	BL , 33
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	527	280 - 655	474	*30*	252 - 590	3 , 59	421	*24*	224 - 524	<BL , 39
Mean "winter" (April to October) evapotranspiration (mm)	408	362 - 459	420	*70*	373 - 473	22 , 96	429	*75*	380 - 482	26 , 97
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	36	24 - 56	39	*65*	27 - 58	24 , 96	43	*75*	29 - 63	29 , >BL
Days when evapotranspiration greater than 8 mm	3.2	0 - 8	4.9	*76*	1 - 11	21 , >BL	5.6	*78*	1 - 12.1	21 , >BL
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	7	7 - 9	7	*36*	6 - 8	6 , 86	7	*32*	6 - 8	1 , 81
RAW = 25mm, Kc = 0.6, in January	7	6 - 8	7	*36*	6 - 8	5 , 73	7	*34*	6 - 8	2 , 69
RAW = 25mm, Kc = 0.6, in December	8	7 - 9	7	*55*	6 - 9	5 , 83	7	*44*	6 - 9	3 , 81
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	9.2	2 - 15.2	8.2	*64*	1.9 - 14.2	5 , 87	7.3	*64*	1.9 - 12.2	5 , 75
Moisture positive days in December and January	7.6	1.8 - 12.3	6.8	*57*	0.9 - 11.3	8 , 86	6.1	*57*	0.9 - 10.4	8 , 76
Moisture positive days in February and March	5.7	0 - 12.1	5.3	*52*	0 - 11.1	0 , 88	4.7	*52*	0 - 11	0 , 88

Climate analysis for Central Hills Subregion: Lenswood

Location	LENSWOOD RESEARCH CENTRE				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	14.1									
Mean Annual Rainfall (mm)	1008									
Mean Annual Evapotranspiration (mm)	1100									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	14.1	13.6 - 14.5	15.1	*>BL*	14.6 - 15.5	94 , >BL	16.1	*>BL*	15.6 - 16.5	>BL , >BL
Mean "winter" (April to October) temperature (°C)	11.3	10.8 - 12	12.3	*>BL*	11.8 - 13	78 , >BL	13.3	*>BL*	12.8 - 14	>BL , >BL
Mean "summer" (October to April) temperature (°C)	16.9	16.3 - 17.4	17.9	*>BL*	17.3 - 18.4	85 , >BL	18.9	*>BL*	18.3 - 19.4	>BL , >BL
Mean January temperature (°C)	19.2	17.1 - 21.1	20.2	*75*	18.1 - 22.1	32 , >BL	21.2	*91*	19.1 - 23.1	43 , >BL
GDD (October to April) (°C days)	1465	1364 - 1563	1672	*>BL*	1570 - 1771	96 , >BL	1882	*>BL*	1780 - 1983	>BL , >BL
BEDD (October to April) (°C days)	1243	1196 - 1288	1388	*>BL*	1342 - 1436	>BL , >BL	1521	*>BL*	1476 - 1566	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	64	60 - 67	58	*<BL*	55 - 60	<BL , 19	50	*<BL*	44 - 54	<BL , <BL
Utah model (chill units)	1356	1233 - 1509	1092	*<BL*	966 - 1270	<BL , 20	795	*<BL*	646 - 949	<BL , <BL
Positive Utah model (positive chill units)	1431	1316 - 1544	1205	*<BL*	1086 - 1342	<BL , 13	961	*<BL*	834 - 1088	<BL , <BL
Chill Hours (0 to 7.2 °C)	535	384 - 730	318	*4*	208 - 486	<BL , 38	164	*<BL*	80 - 306	<BL , 3
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	7	3 - 13	11	*76*	5 - 19	42 , >BL	14	*95*	8 - 22	68 , >BL
Days when maximum temperature warmer than 40 °C	0.2	0 - 1	0.5	*87*	0 - 1.1	0 , >BL	1.5	*>BL*	0 - 3.1	0 , >BL
Excess heat temperature (°C)	24.7									
Severe heat threshold (°C)	30.3									
Excess heat factor (annual total) (°C^2)	180	37 - 356	277	*79*	109 - 489	26 , >BL	406	*96*	178 - 688	69 , >BL
Maximum daily value of Excess heat factor (°C^2)	42	14 - 69	52	*71*	21 - 86	18 , >BL	62	*84*	28 - 101	25 , >BL
Number of days with positive Excess heat factor	11	7 - 17	16	*85*	10 - 25	52 , >BL	22	*>BL*	15 - 31	76 , >BL
Number of days with positive Severe heat factor	0.2	0 - 0	0.2	*95*	0 - 0	0 , 0	0.6	*96*	0 - 1.3	0 , 97
Comfort and productivity of animals										
Days THI greater than 68 units	89	79 - 103	106	*96*	95 - 121	73 , >BL	125	*>BL*	113 - 142	>BL , >BL
Days THI greater than 72 units	52	41 - 63	63	*91*	52 - 76	46 , >BL	76	*>BL*	66 - 90	97 , >BL
Days THI greater than 78 units	15	9 - 25	21	*84*	14 - 32	52 , >BL	29	*>BL*	21 - 40	84 , >BL
Days THI greater than 82 units	4	0 - 7	6	*75*	2 - 11	26 , >BL	10	*>BL*	6 - 18	67 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	0.7	0 - 2	0.2	*69*	0 - 1	0 , 74	0.1	*69*	0 - 0.1	0 , 69
First day of year when minimum temperature colder than 1°C	61	0 - 208	30	*69*	0 - 186	0 , 78	20	*69*	0 - 19	0 , 69
Last day of year when minimum temperature colder than 1°C	64	0 - 214	30	*69*	0 - 187	0 , 73	20	*69*	0 - 19	0 , 69
Frost risk duration (days)	3	0 - 13	1	*73*	0 - 1	0 , 74	0	*69*	0 - 0	0 , 69
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	834	568 - 1044	750	*24*	512 - 940	3 , 78	667	*18*	455 - 835	0 , 44
Mean "winter" (April to October) evapotranspiration (mm)	407	380 - 434	419	*69*	392 - 447	30 , >BL	427	*80*	399 - 455	37 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	29	20 - 38	32	*64*	22 - 40	13 , 93	35	*74*	25 - 44	28 , 99
Days when evapotranspiration greater than 8 mm	2.2	0 - 4.1	3.2	*75*	0 - 7.1	0 , 98	3.6	*77*	0.9 - 7.2	21 , 99
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	8	7 - 9	8	*46*	7 - 9	5 , 81	8	*24*	7 - 8	<BL , 79
RAW = 25mm, Kc = 0.6, in January	8	7 - 8	7	*34*	6 - 8	<BL , 74	7	*31*	6 - 8	<BL , 57
RAW = 25mm, Kc = 0.6, in December	8	7 - 10	8	*49*	7 - 9	<BL , 83	8	*35*	7 - 9	<BL , 82
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	11.3	3.9 - 20.4	10.6	*57*	2.9 - 18.3	5 , 88	9.7	*57*	2.9 - 16.4	5 , 87
Moisture positive days in December and January	9.3	3.8 - 15.5	8.6	*72*	2 - 14.4	0 , 88	7.9	*72*	2 - 12.6	0 , 82
Moisture positive days in February and March	8	1.8 - 15	7	*55*	1.8 - 14	10 , 82	6.4	*55*	0.9 - 12.1	8 , 74

Location	MOUNT BARKER				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	14.2									
Mean Annual Rainfall (mm)	706									
Mean Annual Evapotranspiration (mm)	1115									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	14.2	13.8 - 14.7	15.2	*>BL*	14.8 - 15.7	>BL , >BL	16.2	*>BL*	15.8 - 16.7	>BL , >BL
Mean "winter" (April to October) temperature (°C)	11.5	11 - 12	12.5	*>BL*	12 - 13	84 , >BL	13.5	*>BL*	13 - 14	>BL , >BL
Mean "summer" (October to April) temperature (°C)	17	16.6 - 17.3	18	*>BL*	17.6 - 18.3	>BL , >BL	19	*>BL*	18.6 - 19.3	>BL , >BL
Mean January temperature (°C)	19.5	17.6 - 21.5	20.5	*77*	18.6 - 22.5	26 , >BL	21.5	*90*	19.6 - 23.5	47 , >BL
GDD (October to April) (°C days)	1490	1404 - 1557	1700	*>BL*	1614 - 1768	>BL , >BL	1911	*>BL*	1826 - 1980	>BL , >BL
BEDD (October to April) (°C days)	1265	1203 - 1312	1411	*>BL*	1355 - 1459	>BL , >BL	1542	*>BL*	1491 - 1583	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	59	54 - 62	53	*<BL*	49 - 56	<BL , 19	46	*<BL*	40 - 51	<BL , <BL
Utah model (chill units)	1152	1021 - 1252	949	*<BL*	788 - 1056	<BL , 18	711	*<BL*	549 - 828	<BL , <BL
Positive Utah model (positive chill units)	1259	1145 - 1322	1108	*<BL*	989 - 1181	<BL , 15	941	*<BL*	834 - 1016	<BL , <BL
Chill Hours (0 to 7.2 °C)	631	534 - 732	486	*6*	385 - 593	<BL , 36	359	*<BL*	278 - 472	<BL , 5
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	11	6 - 18	16	*83*	9 - 21	34 , 94	20	*92*	16 - 25	84 , >BL
Days when maximum temperature warmer than 40 °C	0.8	0 - 2.1	1.7	*83*	0 - 5	0 , >BL	3.3	*>BL*	1 - 7	53 , >BL
Excess heat temperature (°C)	23.9									
Severe heat threshold (°C)	29									
Excess heat factor (annual total) (°C^2)	137	38 - 236	219	*88*	91 - 372	38 , 98	331	*94*	162 - 535	65 , >BL
Maximum daily value of Excess heat factor (°C^2)	34	13 - 52	43	*72*	20 - 62	23 , >BL	52	*96*	27 - 71	28 , >BL
Number of days with positive Excess heat factor	10	5 - 18	17	*82*	9 - 25	47 , >BL	24	*>BL*	16 - 34	78 , >BL
Number of days with positive Severe heat factor	0	0 - 0	0.3	*>BL*	0 - 1.1	0 , >BL	0.6	*>BL*	0 - 2.1	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	108	97 - 116	128	*>BL*	116 - 139	92 , >BL	149	*>BL*	135 - 162	>BL , >BL
Days THI greater than 72 units	65	56 - 71	78	*97*	69 - 87	73 , >BL	92	*>BL*	83 - 100	100 , >BL
Days THI greater than 78 units	23	17 - 29	32	*96*	26 - 39	73 , >BL	40	*>BL*	34 - 46	98 , >BL
Days THI greater than 82 units	7	2 - 14	11	*78*	6 - 17	47 , >BL	16	*>BL*	11 - 24	79 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	15.5	8.7 - 27.4	7.4	*8*	2 - 14.1	BL , 63	3	*BL*	0.9 - 5.1	BL , 3
First day of year when minimum temperature colder than 1°C	138	111 - 152	162	*95*	134 - 207	31 , 99	173	*96*	127 - 218	24 , 100
Last day of year when minimum temperature colder than 1°C	267	232 - 294	238	*13*	211 - 269	BL , 43	196	*BL*	149 - 258	BL , 32
Frost risk duration (days)	130	94 - 173	77	*7*	23 - 131	BL , 45	24	*BL*	1 - 78	BL , 7
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	568	429 - 683	511	*21*	386 - 615	4 , 68	454	*16*	343 - 547	2 , 39
Mean "winter" (April to October) evapotranspiration (mm)	412	386 - 443	424	*75*	398 - 456	22 , >BL	432	*78*	405 - 465	36 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	30	24 - 38	33	*83*	26 - 39	14 , 92	36	*88*	28 - 43	20 , >BL
Days when evapotranspiration greater than 8 mm	2.5	0 - 6	3	*63*	0 - 6.1	0 , 95	4	*73*	0 - 7.1	0 , >BL
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	8	7 - 9	8	*54*	7 - 9	<BL , 86	7	*16*	7 - 8	<BL , 77
RAW = 25mm, Kc = 0.6, in January	7	7 - 8	7	*35*	7 - 8	6 , 63	7	*22*	6 - 8	0 , 55
RAW = 25mm, Kc = 0.6, in December	8	7 - 9	8	*49*	7 - 9	<BL , 79	8	*41*	7 - 9	<BL , 73
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	10	4.9 - 13.4	8.8	*55*	3.8 - 12.5	5 , 76	7.8	*55*	2.9 - 11.3	4 , 70
Moisture positive days in December and January	8.1	4 - 13.3	7.3	*66*	3.8 - 12.4	5 , 88	6.3	*66*	2 - 11.2	3 , 85
Moisture positive days in February and March	6.4	0 - 13	5.9	*56*	0 - 12	0 , 87	5.4	*56*	0 - 12	0 , 87

Climate analysis for Willunga Basin Subregion: McLaren Vale

Location	MCLAREN VALE				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	16.1									
Mean Annual Rainfall (mm)	540									
Mean Annual Evapotranspiration (mm)	1170									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	16.1	15.7 - 16.5	17.1	*>BL*	16.7 - 17.5	>BL , >BL	18.1	*>BL*	17.7 - 18.5	>BL , >BL
Mean "winter" (April to October) temperature (°C)	13.5	13.1 - 13.9	14.5	*>BL*	14.1 - 14.9	93 , >BL	15.5	*>BL*	15.1 - 15.9	>BL , >BL
Mean "summer" (October to April) temperature (°C)	18.6	18.1 - 19.2	19.6	*>BL*	19.1 - 20.2	88 , >BL	20.6	*>BL*	20.1 - 21.2	>BL , >BL
Mean January temperature (°C)	20.8	19.2 - 22.3	21.8	*82*	20.2 - 23.3	35 , 97	22.8	*93*	21.2 - 24.3	61 , >BL
GDD (October to April) (°C days)	1835	1728 - 1951	2047	*>BL*	1940 - 2163	88 , >BL	2259	*>BL*	2152 - 2375	>BL , >BL
BEDD (October to April) (°C days)	1574	1520 - 1626	1688	*>BL*	1635 - 1726	>BL , >BL	1776	*>BL*	1735 - 1803	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	47	42 - 51	37	*<BL*	31 - 43	<BL , 13	26	*<BL*	18 - 33	<BL , <BL
Utah model (chill units)	721	575 - 868	416	*<BL*	260 - 572	<BL , 10	93	*<BL*	-104 - 273	<BL , <BL
Positive Utah model (positive chill units)	914	797 - 1018	709	*<BL*	605 - 814	<BL , 12	523	*<BL*	418 - 635	<BL , <BL
Chill Hours (0 to 7.2 °C)	226	135 - 354	128	*9*	64 - 220	<BL , 56	64	*<BL*	19 - 131	<BL , 9
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	11	6 - 16	13	*77*	8 - 21	21 , >BL	18	*100*	10 - 24	47 , >BL
Days when maximum temperature warmer than 40 °C	1.5	0 - 4.1	2.1	*74*	0 - 5.1	0 , >BL	3.9	*83*	1 - 7	42 , >BL
Excess heat temperature (°C)	25.3									
Severe heat threshold (°C)	30.7									
Excess heat factor (annual total) (°C^2)	156	29 - 305	242	*78*	78 - 448	24 , >BL	357	*99*	154 - 613	52 , >BL
Maximum daily value of Excess heat factor (°C^2)	38	11 - 59	48	*65*	19 - 71	27 , >BL	57	*88*	26 - 83	29 , >BL
Number of days with positive Excess heat factor	10	4 - 19	16	*78*	9 - 25	37 , >BL	24	*>BL*	17 - 33	79 , >BL
Number of days with positive Severe heat factor	0.1	0 - 0	0.2	*95*	0 - 0.2	0 , 95	0.5	*96*	0 - 1.1	0 , 98
Comfort and productivity of animals										
Days THI greater than 68 units	109	99 - 122	137	*>BL*	123 - 153	96 , >BL	164	*>BL*	149 - 178	>BL , >BL
Days THI greater than 72 units	62	51 - 69	76	*95*	64 - 86	57 , >BL	94	*>BL*	84 - 106	>BL , >BL
Days THI greater than 78 units	21	13 - 27	27	*89*	18 - 34	31 , >BL	35	*>BL*	27 - 43	89 , >BL
Days THI greater than 82 units	7	3 - 11	11	*88*	6 - 16	57 , >BL	15	*100*	9 - 21	68 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	0.3	0 - 0.1	0.2	*90*	0 - 0	0 , 0	0.1	*90*	0 - 0	0 , 0
First day of year when minimum temperature colder than 1°C	16	0 - 15	8	*90*	0 - 0	0 , 0	8	*90*	0 - 0	0 , 0
Last day of year when minimum temperature colder than 1°C	18	0 - 15	10	*90*	0 - 0	0 , 0	8	*90*	0 - 0	0 , 0
Frost risk duration (days)	2	0 - 0	2	*95*	0 - 0	0 , 0	0	*90*	0 - 0	0 , 0
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	442	361 - 519	398	*27*	325 - 467	8 , 65	354	*10*	289 - 415	6 , 37
Mean "winter" (April to October) evapotranspiration (mm)	456	432 - 479	469	*70*	445 - 494	31 , >BL	479	*81*	454 - 503	45 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	28	23 - 34	30	*80*	24 - 37	21 , 93	33	*90*	29 - 41	57 , 96
Days when evapotranspiration greater than 8 mm	2.8	0 - 6	3.8	*67*	0.9 - 6.2	15 , >BL	4.2	*80*	0.9 - 7.2	15 , >BL
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	8	7 - 8	8	*41*	7 - 8	<BL , 82	7	*21*	7 - 8	<BL , 71
RAW = 25mm, Kc = 0.6, in January	7	7 - 8	7	*24*	7 - 8	6 , 79	7	*15*	6 - 8	<BL , 63
RAW = 25mm, Kc = 0.6, in December	8	7 - 9	8	*50*	7 - 9	2 , 86	7	*36*	7 - 8	<BL , 69
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	7.1	2.9 - 12.1	6.4	*57*	1.9 - 11	5 , 84	5.5	*57*	0.9 - 10	BL , 79
Moisture positive days in December and January	5.8	1.9 - 9.4	5.3	*61*	1 - 9.2	0 , 90	4.6	*61*	0.9 - 9.1	BL , 90
Moisture positive days in February and March	5.1	0 - 10.2	4.6	*50*	0 - 9.1	0 , 85	4	*50*	0 - 8.2	0 , 80

Location	MOUNT COMPASS				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	14.7									
Mean Annual Rainfall (mm)	799									
Mean Annual Evapotranspiration (mm)	1067									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	14.7	14.3 - 15	15.7	*>BL*	15.3 - 16	>BL , >BL	16.7	*>BL*	16.3 - 17	>BL , >BL
Mean "winter" (April to October) temperature (°C)	12.2	11.8 - 12.7	13.2	*>BL*	12.8 - 13.7	94 , >BL	14.2	*>BL*	13.8 - 14.7	>BL , >BL
Mean "summer" (October to April) temperature (°C)	17.1	16.6 - 17.7	18.1	*>BL*	17.6 - 18.7	88 , >BL	19.1	*>BL*	18.6 - 19.7	>BL , >BL
Mean January temperature (°C)	19.2	17.7 - 20.4	20.2	*84*	18.7 - 21.4	35 , 96	21.2	*94*	19.7 - 22.4	56 , >BL
GDD (October to April) (°C days)	1515	1408 - 1630	1727	*>BL*	1619 - 1840	88 , >BL	1939	*>BL*	1830 - 2052	>BL , >BL
BEDD (October to April) (°C days)	1374	1299 - 1439	1519	*>BL*	1454 - 1576	>BL , >BL	1644	*>BL*	1589 - 1687	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	57	55 - 61	50	*<BL*	46 - 54	<BL , 8	39	*<BL*	32 - 46	<BL , <BL
Utah model (chill units)	1073	942 - 1210	787	*<BL*	643 - 931	<BL , 9	480	*<BL*	329 - 623	<BL , <BL
Positive Utah model (positive chill units)	1173	1049 - 1277	943	*<BL*	814 - 1042	<BL , 9	722	*<BL*	618 - 823	<BL , <BL
Chill Hours (0 to 7.2 °C)	350	238 - 476	210	*3*	125 - 316	<BL , 41	111	*<BL*	55 - 180	<BL , <BL
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	7	3 - 13	9	*76*	6 - 14	26 , >BL	12	*88*	8 - 19	67 , >BL
Days when maximum temperature warmer than 40 °C	0.7	0 - 2.1	1.2	*85*	0 - 4	0 , >BL	2	*89*	0 - 5	0 , >BL
Excess heat temperature (°C)	23.8									
Severe heat threshold (°C)	29.2									
Excess heat factor (annual total) (°C^2)	158	28 - 313	243	*75*	79 - 457	27 , >BL	356	*97*	147 - 640	51 , >BL
Maximum daily value of Excess heat factor (°C^2)	40	15 - 71	49	*64*	22 - 84	27 , >BL	59	*85*	29 - 96	29 , >BL
Number of days with positive Excess heat factor	10	5 - 18	16	*80*	9 - 24	42 , >BL	23	*>BL*	15 - 31	79 , >BL
Number of days with positive Severe heat factor	0.1	0 - 0	0.3	*95*	0 - 0.2	0 , 95	0.6	*96*	0 - 2	0 , 100
Comfort and productivity of animals										
Days THI greater than 68 units	168	157 - 183	193	*>BL*	181 - 207	88 , >BL	219	*>BL*	209 - 235	>BL , >BL
Days THI greater than 72 units	109	96 - 123	130	*>BL*	117 - 147	80 , >BL	148	*>BL*	140 - 165	>BL , >BL
Days THI greater than 78 units	42	32 - 52	54	*>BL*	46 - 64	75 , >BL	68	*>BL*	60 - 78	>BL , >BL
Days THI greater than 82 units	14	9 - 18	21	*96*	15 - 28	53 , >BL	31	*>BL*	22 - 39	97 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	0.5	0 - 0.2	0.4	*90*	0 - 0.1	0 , 90	0.2	*90*	0 - 0	0 , 0
First day of year when minimum temperature colder than 1°C	16	0 - 15	16	*90*	0 - 15	0 , 90	8	*90*	0 - 0	0 , 0
Last day of year when minimum temperature colder than 1°C	20	0 - 20	18	*90*	0 - 15	0 , 90	10	*90*	0 - 0	0 , 0
Frost risk duration (days)	5	0 - 5	2	*90*	0 - 0	0 , 89	2	*90*	0 - 0	0 , 0
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	663	482 - 831	597	*27*	434 - 748	7 , 72	530	*17*	386 - 665	<BL , 52
Mean "winter" (April to October) evapotranspiration (mm)	409	388 - 434	421	*71*	400 - 447	30 , >BL	429	*79*	408 - 456	53 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	20	15 - 25	22	*57*	16 - 26	16 , 95	24	*82*	19 - 29	26 , 98
Days when evapotranspiration greater than 8 mm	1.7	0 - 4.1	2.5	*76*	0 - 5.1	0 , 95	2.8	*78*	0 - 5.1	0 , 95
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	8	8 - 9	8	*31*	8 - 9	<BL , 86	8	*24*	8 - 9	<BL , 78
RAW = 25mm, Kc = 0.6, in January	8	7 - 9	8	*29*	7 - 8	7 , 73	8	*19*	7 - 8	3 , 66
RAW = 25mm, Kc = 0.6, in December	9	8 - 10	8	*49*	7 - 9	3 , 68	8	*45*	7 - 9	1 , 66
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	10.2	2 - 16.6	8.9	*52*	1 - 16.2	3 , 90	8.1	*52*	0.9 - 15.2	2 , 77
Moisture positive days in December and January	7.9	1.9 - 12.8	6.9	*58*	1 - 11.5	5 , 82	6.2	*58*	0.9 - 11.5	5 , 82
Moisture positive days in February and March	7.4	0 - 14	6.6	*52*	0 - 14	0 , 84	6.2	*52*	0 - 14	0 , 84

Location	PARAWA (SHARON)				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	13.6									
Mean Annual Rainfall (mm)	927									
Mean Annual Evapotranspiration (mm)	966									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	13.6	13.1 - 14	14.6	*>BL*	14.1 - 15	94 , >BL	15.6	*>BL*	15.1 - 16	>BL , >BL
Mean "winter" (April to October) temperature (°C)	11.3	10.9 - 11.8	12.3	*>BL*	11.9 - 12.8	92 , >BL	13.3	*>BL*	12.9 - 13.8	>BL , >BL
Mean "summer" (October to April) temperature (°C)	15.9	15.3 - 16.4	16.9	*>BL*	16.3 - 17.4	86 , >BL	17.9	*>BL*	17.3 - 18.4	>BL , >BL
Mean January temperature (°C)	17.7	16 - 19	18.7	*84*	17 - 20	30 , >BL	19.7	*96*	18 - 21	49 , >BL
GDD (October to April) (°C days)	1251	1141 - 1360	1459	*>BL*	1344 - 1569	86 , >BL	1671	*>BL*	1553 - 1779	>BL , >BL
BEDD (October to April) (°C days)	1206	1090 - 1281	1370	*>BL*	1257 - 1439	67 , >BL	1518	*>BL*	1410 - 1580	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	63	60 - 68	56	*<BL*	51 - 60	<BL , 11	46	*<BL*	40 - 51	<BL , <BL
Utah model (chill units)	1281	1143 - 1426	990	*<BL*	822 - 1168	<BL , 16	683	*<BL*	516 - 858	<BL , <BL
Positive Utah model (positive chill units)	1331	1186 - 1451	1074	*<BL*	904 - 1219	<BL , 14	822	*<BL*	676 - 964	<BL , <BL
Chill Hours (0 to 7.2 °C)	374	245 - 549	197	*<BL*	91 - 339	<BL , 44	88	*<BL*	37 - 157	<BL , <BL
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	3	1 - 6	5	*77*	2 - 10	36 , >BL	7	*98*	3 - 11	47 , >BL
Days when maximum temperature warmer than 40 °C	0.1	0 - 0	0.1	*95*	0 - 0	0 , 0	0.5	*97*	0 - 2	0 , >BL
Excess heat temperature (°C)	22									
Severe heat threshold (°C)	27.3									
Excess heat factor (annual total) (°C^2)	187	50 - 332	278	*78*	100 - 445	21 , 96	399	*94*	184 - 612	57 , >BL
Maximum daily value of Excess heat factor (°C^2)	43	20 - 83	53	*77*	27 - 94	32 , >BL	63	*82*	34 - 105	39 , >BL
Number of days with positive Excess heat factor	12	7 - 19	17	*82*	11 - 26	57 , >BL	25	*>BL*	19 - 34	84 , >BL
Number of days with positive Severe heat factor	0.2	0 - 0.1	0.4	*91*	0 - 1.1	0 , 95	0.8	*93*	0 - 2.1	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	57	48 - 66	74	*>BL*	63 - 84	78 , >BL	92	*>BL*	82 - 105	>BL , >BL
Days THI greater than 72 units	31	22 - 38	39	*96*	31 - 48	52 , >BL	49	*>BL*	39 - 57	96 , >BL
Days THI greater than 78 units	7	3 - 12	11	*81*	5 - 17	26 , >BL	15	*100*	10 - 21	73 , >BL
Days THI greater than 82 units	1	0 - 4	3	*86*	0 - 5	0 , >BL	4	*>BL*	1 - 9	52 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	0.4	0 - 0.1	0.3	*91*	0 - 0.1	0 , 90	0.1	*90*	0 - 0	0 , 0
First day of year when minimum temperature colder than 1°C	16	0 - 15	16	*90*	0 - 15	0 , 90	8	*90*	0 - 0	0 , 0
Last day of year when minimum temperature colder than 1°C	18	0 - 15	18	*90*	0 - 15	0 , 90	8	*90*	0 - 0	0 , 0
Frost risk duration (days)	2	0 - 0	2	*95*	0 - 0	0 , 90	0	*90*	0 - 0	0 , 0
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	758	597 - 931	682	*30*	537 - 838	5 , 78	606	*14*	477 - 745	<BL , 36
Mean "winter" (April to October) evapotranspiration (mm)	363	337 - 393	374	*74*	347 - 404	27 , >BL	382	*79*	354 - 412	35 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	14	9 - 20	15	*70*	10 - 20	15 , 95	16	*73*	11 - 22	21 , 97
Days when evapotranspiration greater than 8 mm	0.8	0 - 2	1.3	*75*	0 - 3.1	0 , >BL	1.3	*75*	0 - 3.1	0 , >BL
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	9	9 - 10	9	*38*	8 - 10	<BL , 84	9	*27*	8 - 10	<BL , 72
RAW = 25mm, Kc = 0.6, in January	9	8 - 10	9	*36*	8 - 9	8 , 82	8	*26*	8 - 9	6 , 66
RAW = 25mm, Kc = 0.6, in December	9	8 - 11	9	*52*	8 - 11	7 , 83	9	*46*	8 - 10	5 , 73
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	13.9	5.8 - 19.6	12.4	*55*	4.8 - 17.7	7 , 77	10.7	*55*	2 - 16.4	BL , 65
Moisture positive days in December and January	10	3.9 - 15.9	9	*56*	2.8 - 14	5 , 84	7.8	*56*	1.9 - 12.8	3 , 81
Moisture positive days in February and March	11.5	1 - 18.1	10.3	*47*	0.9 - 17	5 , 79	9.4	*47*	0 - 17	0 , 79

Location	VICTOR HARBOR COMPARISON				*Station 23083*					
Subregion	Northern coast and plains									
Main Industries	Annual horticulture, Viticulture, Perennial Horticulture									
Mean Annual Temperature (°C)	15.9									
Mean Annual Rainfall (mm)	521									
Mean Annual Evapotranspiration (mm)	1086									
	Baseline		**1°C warmer, 10% less rainfall, 3% more ETo**				**2°C warmer, 20% less rainfall, 5% more ETo**			
	Mean	**D1 to D9**	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***	**Mean**	***Frequency(%)***	**D1 to D9**	***Frequency(%)***
1. Warmer mean temperature										
Growth temperature										
Mean Annual Temperature (°C)	15.9	15.6 - 16.3	16.9	>BL	16.6 - 17.3	>BL , >BL	17.9	>BL	17.6 - 18.3	>BL , >BL
Mean "winter" (April to October) temperature (°C)	13.9	13.5 - 14.3	14.9	>BL	14.5 - 15.3	96 , >BL	15.9	>BL	15.5 - 16.3	>BL , >BL
Mean "summer" (October to April) temperature (°C)	18	17.7 - 18.5	19	>BL	18.7 - 19.5	93 , >BL	20	>BL	19.7 - 20.5	>BL , >BL
Mean January temperature (°C)	19.8	18.4 - 21	20.8	81	19.4 - 22	43 , >BL	21.8	>BL	20.4 - 23	71 , >BL
GDD (October to April) (°C days)	1708	1630 - 1812	1920	>BL	1843 - 2024	94 , >BL	2132	>BL	2056 - 2236	>BL , >BL
BEDD (October to April) (°C days)	1585	1533 - 1626	1706	>BL	1666 - 1739	>BL , >BL	1794	>BL	1758 - 1822	>BL , >BL
Chill accumulation										
Dynamic model (chill portions)	41	37 - 46	30	<BL	25 - 37	<BL , 11	19	<BL	14 - 26	<BL , <BL
Utah model (chill units)	551	431 - 717	231	<BL	117 - 412	<BL , 9	-100	<BL	-219 - 75	<BL , <BL
Positive Utah model (positive chill units)	780	710 - 894	582	<BL	498 - 714	<BL , 10	411	<BL	316 - 530	<BL , <BL
Chill Hours (0 to 7.2 °C)	163	80 - 279	90	13	26 - 174	<BL , 57	47	<BL	11 - 103	<BL , 19
2. Extreme hot weather										
Hot days and heatwaves										
Days when maximum temperature warmer than 35 °C	8	5 - 12	10	69	6 - 14	26 , >BL	12	96	7 - 17	31 , >BL
Days when maximum temperature warmer than 40 °C	1.5	0 - 4	2.2	74	0 - 4	0 , 84	3.6	82	1 - 6.1	32 , >BL
Excess heat temperature (°C)	23.7									
Severe heat threshold (°C)	29									
Excess heat factor (annual total) (°C^2)	145	25 - 320	217	75	58 - 420	25 , >BL	318	89	114 - 577	55 , >BL
Maximum daily value of Excess heat factor (°C^2)	40	8 - 64	49	70	17 - 76	21 , 92	58	82	25 - 87	30 , 94
Number of days with positive Excess heat factor	9	4 - 18	15	86	7 - 23	41 , >BL	24	>BL	16 - 32	87 , >BL
Number of days with positive Severe heat factor	0.1	0 - 0	0.3	96	0 - 1	0 , 100	0.5	97	0 - 2	0 , >BL
Comfort and productivity of animals										
Days THI greater than 68 units	90	77 - 106	121	>BL	105 - 137	88 , >BL	156	>BL	143 - 172	>BL , >BL
Days THI greater than 72 units	41	31 - 48	52	>BL	44 - 60	51 , >BL	70	>BL	59 - 81	>BL , >BL
Days THI greater than 78 units	15	9 - 20	19	86	13 - 24	29 , >BL	24	>BL	17 - 33	62 , >BL
Days THI greater than 82 units	7	3 - 10	9	68	5 - 12	26 , 97	12	96	7 - 16	42 , >BL
3. Extreme cold weather										
Days when minimum temperature colder than 1 °C	0.3	0 - 0.1	0.1	90	0 - 0	0 , 0	0	0	0 - 0	0 , 0
First day of year when minimum temperature colder than 1°C	16	0 - 16	8	90	0 - 0	0 , 0	0	0	0 - 0	0 , 0
Last day of year when minimum temperature colder than 1°C	18	0 - 17	8	90	0 - 0	0 , 0	0	0	0 - 0	0 , 0
Frost risk duration (days)	2	0 - 0	0	90	0 - 0	0 , 0	0	0	0 - 0	0 , 0
4. 'Winter' (April to October) rainfall										
Mean "winter" (April to October) rainfall (mm)	521	459 - 607	469	23	413 - 547	5 , 73	416	5	367 - 486	2 , 38
Mean "winter" (April to October) evapotranspiration (mm)	450	428 - 476	463	75	441 - 491	35 , >BL	472	80	450 - 500	61 , >BL
5. Demand for Irrigation										
Extremely dry days										
Days when evapotranspiration greater than 6 mm	14	10 - 20	15	51	11 - 20	14 , 95	16	71	13 - 21	35 , >BL
Days when evapotranspiration greater than 8 mm	1.9	0 - 4.1	2.1	79	0 - 5	0 , 95	2.5	80	0 - 5.1	0 , 95
Days of moisture in the soil profile										
RAW = 25mm, Kc = 0.6, in Summer (December to February)	9	8 - 9	9	35	8 - 9	<BL , 76	8	21	8 - 9	<BL , 54
RAW = 25mm, Kc = 0.6, in January	8	8 - 9	8	35	8 - 9	6 , 81	8	23	7 - 9	<BL , 66
RAW = 25mm, Kc = 0.6, in December	9	8 - 10	9	47	8 - 10	4 , 85	8	38	8 - 9	3 , 76
			10% more rainfall, 3% more ETo, 1°C warmer				**20% more rainfall, 5% more ETo, 2°C warmer**			
6. Summer rainfall increases										
Moisture positive days in Summer (December to February)	7.4	2 - 11.1	6.6	41	2 - 10.1	5 , 79	5.6	41	1 - 10	3 , 68
Moisture positive days in December and January	5.8	0.9 - 10.1	5.1	58	0.9 - 9	10 , 79	4.4	58	0.9 - 8	10 , 74
Moisture positive days in February and March	6.2	0 - 13.1	5.6	60	0 - 12.1	0 , 87	4.9	60	0 - 10.2	0 , 77

Climate analysis for the Homologue locations

Location	LOXTON		MURRAY BRIDGE		MILDURA		GRIFFITH		PEARCE		DONNYBROOK		TATURA		CAMDEN		ROCKHAMPTON	
Main Industries																		
Mean Annual Temperature (°C)	16.3		16.3		17.0		16.7		18.7		16.6		14.8		16.9		22.7	
Mean Annual Rainfall (mm)	259		359		280		436		692		934		468		774		747	
Mean Annual Evapotranspiration (mm)	1347		1251		1436		1371		1460		1257		1168		1200		1583	
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
	Mean	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**	**Mean**	**D1 to D9**
1. Warmer mean temperature																		
Growth temperature																		
Mean Annual Temperature (°C)	16.3	15.7 - 17	16.3	15.8 - 16.7	17	16.5 - 17.5	16.7	16.2 - 17.2	18.7	18.2 - 19.1	16.6	16.1 - 17.1	14.8	14.1 - 15.3	16.9	16.2 - 17.4	22.7	22.3 - 23.1
Mean "winter" (April to October) temperature (°C)	12.8	12.4 - 13.6	13.4	13 - 13.9	13.2	12.7 - 13.6	12.6	12.1 - 12.9	15.5	14.8 - 16.1	13.6	13 - 14.2	11.2	10.7 - 11.6	13.7	13.1 - 14.3	20.1	19.5 - 20.8
Mean "summer" (October to April) temperature (°C)	19.7	18.9 - 20.5	19.1	18.6 - 19.7	20.8	20 - 21.3	20.9	20.2 - 21.5	21.7	21 - 22.3	19.5	18.9 - 20.1	18.3	17.5 - 18.9	20.2	19.5 - 21.2	25.7	25.1 - 26
Mean January temperature (°C)	22.7	20.7 - 25.2	21.5	19.9 - 23.3	24.1	22.2 - 26.1	24.6	22.5 - 26.7	25	23.2 - 26.8	22.6	21.3 - 23.9	21.6	19.4 - 23.6	22.8	21.4 - 24.3	27.4	26.5 - 28.6
GDD (October to April) (°C days)	2057	1898 - 2230	1941	1828 - 2052	2296	2130 - 2404	2311	2163 - 2443	2487	2325 - 2613	2025	1891 - 2143	1768	1602 - 1885	2165	2021 - 2365	3329	3210 - 3409
BEDD (October to April) (°C days)	1535	1446 - 1596	1560	1507 - 1605	1627	1572 - 1679	1618	1563 - 1679	1736	1686 - 1774	1562	1507 - 1614	1410	1306 - 1485	1708	1658 - 1754	1908	1903 - 1917
Chill accumulation																		
Dynamic model (chill portions)	50	48 - 53	46	42 - 50	51	48 - 54	51	48 - 55	23	17 - 30	39	34 - 45	59	57 - 61	41	36 - 45	3	0 - 6
Utah model (chill units)	856	754 - 953	739	626 - 856	912	834 - 995	940	809 - 1021	44	-173 - 242	548	373 - 718	1164	1063 - 1238	603	486 - 698	-963	-1075 - -765
Positive Utah model (positive chill units)	1088	1036 - 1137	1014	951 - 1102	1138	1083 - 1189	1149	1073 - 1189	588	479 - 684	907	800 - 993	1267	1202 - 1326	951	896 - 1006	289	212 - 373
Chill Hours (0 to 7.2 °C)	621	487 - 729	459	352 - 598	618	505 - 739	710	617 - 823	151	76 - 225	412	325 - 552	816	721 - 911	563	415 - 691	88	34 - 136
2. Extreme hot weather																		
Hot days and heatwaves																		
Days when maximum temperature warmer than 35 °C	28	20 - 36	22	13 - 28	32	20 - 41	30	18 - 44	33	24 - 43	16	11 - 21	12	2 - 21	12	4 - 22	18	10 - 26
Days when maximum temperature warmer than 40 °C	5.8	1 - 12.3	4.2	1 - 8.1	6.2	1 - 10.2	3.6	0.9 - 6.1	6.5	2 - 10.1	1.1	0 - 3	0.9	0 - 2.1	1.7	0 - 4.1	0.6	0 - 1.1
Excess heat temperature (°C)	27		26.2		28.1		27.9		28.5		25.9		25.1		25.4		28.8	
Severe heat threshold (°C)	31.9		30.9		33		32.3		32.8		30.1		29.4		28.8		31.3	
Excess heat factor (annual total) (°C^2)	120	6 - 250	103	12 - 229	157	15 - 349	145	36 - 232	118	18 - 225	112	32 - 180	118	11 - 221	61	2 - 119	52	11 - 94
Maximum daily value of Excess heat factor (°C^2)	28	3 - 55	28	5 - 49	34	6 - 55	33	12 - 53	27	6 - 39	28	14 - 44	26	5 - 45	14	1 - 24	12	5 - 20
Number of days with positive Excess heat factor	10	3 - 22	9	3 - 17	13	4 - 23	14	4 - 26	12	4 - 16	11	6 - 17	12	3 - 22	12	1 - 23	17	7 - 28
Number of days with positive Severe heat factor	0.3	0 - 0.2	0.1	0 - 0	0.2	0 - 0.1	0.1	0 - 0	0.1	0 - 0	0.2	0 - 0.1	0.1	0 - 0	0	0 - 0	0.3	0 - 1
Comfort and productivity of animals																		
Days THI greater than 68 units	170	158 - 185	150	136 - 167	172	162 - 184	175	163 - 188	197	181 - 208	168	157 - 183	137	126 - 150	197	181 - 208	327	317 - 335
Days THI greater than 72 units	111	97 - 126	90	81 - 100	116	105 - 129	124	112 - 137	139	124 - 151	109	96 - 123	87	72 - 101	139	124 - 151	270	255 - 286
Days THI greater than 78 units	46	39 - 60	37	31 - 44	49	39 - 60	58	42 - 70	61	49 - 74	42	32 - 52	31	19 - 42	61	49 - 74	145	130 - 156
Days THI greater than 82 units	20	11 - 29	17	12 - 23	21	11 - 30	25	13 - 36	25	17 - 35	14	9 - 18	11	2 - 18	25	17 - 35	52	41 - 65
3. Extreme cold weather																		
Days when minimum temperature colder than 1 °C	22.3	13.3 - 28.4	8.7	2 - 15.5	9.7	3 - 19.3	22.8	13.9 - 38.1	0.9	0 - 2.3	6.1	1.8 - 9.6	30	15.9 - 38.6	23.3	3.9 - 38.3	0.1	0 - 0
First day of year when minimum temperature colder than 1°C	141	124 - 155	161	123 - 208	165	137 - 206	145	121 - 172	59	0 - 191	154	114 - 201	134	113 - 147	153	128 - 194	9	0 - 0
Last day of year when minimum temperature colder than 1°C	258	234 - 282	241	210 - 276	229	205 - 251	256	236 - 271	63	0 - 216	237	192 - 295	265	246 - 293	241	213 - 261	9	0 - 0
Frost risk duration (days)	117	93 - 140	80	23 - 136	65	24 - 104	111	81 - 144	5	0 - 22	83	12 - 141	131	104 - 166	89	44 - 125	0	0 - 0
4. 'Winter' (April to October) rainfall																		
Mean "winter" (April to October) rainfall (mm)	182	138 - 242	260	195 - 319	180	96 - 231	269	187 - 342	613	499 - 726	824	675 - 1020	314	246 - 388	397	196 - 560	306	135 - 520
Mean "winter" (April to October) evapotranspiration (mm)	506	472 - 547	488	451 - 520	539	499 - 561	498	455 - 532	561	531 - 596	458	437 - 484	404	368 - 426	518	470 - 566	773	728 - 807
5. Demand for Irrigation																		
Extremely dry days																		
Days when evapotranspiration greater than 6 mm	62	50 - 74	41	32 - 49	82	63 - 93	76	57 - 93	80	67 - 95	52	43 - 63	40	24 - 57	27	13 - 40	58	41 - 71
Days when evapotranspiration greater than 8 mm	6.7	1 - 13.1	4.3	0.9 - 8	11.2	2.9 - 21.1	7.4	2.9 - 13	11.5	7.8 - 16.1	3.1	0.9 - 5	1.3	0 - 3.1	0.7	0 - 2.1	0.7	0 - 3.1
Days of moisture in the soil profile																		
RAW = 25mm, Kc = 0.6, in Summer (December to February)	6	6 - 7	7	7 - 8	6	6 - 7	6	6 - 7	6	6 - 6	7	6 - 7	7	7 - 8	8	8 - 9	7	7 - 8
RAW = 25mm, Kc = 0.6, in January	6	6 - 7	7	7 - 7	6	5 - 6	6	6 - 7	6	5 - 6	6	6 - 7	7	6 - 7	8	7 - 9	7	6 - 8
RAW = 25mm, Kc = 0.6, in December	6	6 - 7	7	7 - 8	6	5 - 7	6	5 - 7	6	5 - 7	7	6 - 7	7	6 - 8	8	7 - 9	7	6 - 8
6. Summer rainfall increases																		
Moisture positive days in Summer (December to February)	5.6	0 - 10	7	1.9 - 10	6.7	0 - 13.2	10.2	2.9 - 19.2	3.4	0 - 6.3	5.3	0.9 - 12.1	10.6	2.9 - 18.2	25.2	9.8 - 41.5	20.8	14.6 - 30.3
Moisture positive days in December and January	3.9	0 - 8.2	5.4	0.9 - 8.1	5	0 - 8.5	7	1 - 12.6	1.6	0 - 3.3	2.6	0 - 7	7.3	1.9 - 12.1	17	5 - 24.5	13.8	9.7 - 19.1
Moisture positive days in February and March	3.5	0 - 8.1	4.2	0.9 - 10.1	3.4	0 - 7	6.5	1.9 - 12.1	4	0.9 - 9.1	6	1.9 - 11	7.4	2 - 16.1	18.1	10.7 - 25.1	12.8	7.4 - 19.3

Appendix 3. Summary of Stakeholder Comments.

Viticulture comments

Increased irrigation demand and decreased water availability

- Water availability was often mentioned as the chief climate-related concern for the AMLR NRM region's wine grape growers.
- Barossa and McLaren Vale growers are increasingly concerned that winter and spring drying will mean insufficient salt leaching and a potentially harmful build-up of soil salinity levels.
- Improving soil health makes for good preparation for a water-constrained future, as better soils require less irrigation inputs.
- Under-vine mulching is an effective moisture retention method, and also helps in keeping the soil cooler, which is particularly important for vine heat wave recovery at night time. The transportation and spreading of mulch can get fairly expensive, and some growers are therefore trying to use locally available alternatives (such as winery waste).
- Maintaining mid row grasses improves water infiltration into the soil, benefiting the vines (although in a dry winter those grasses have to be carefully controlled so that they don't compete with the vines for available moisture).
- Soil moisture monitoring has been strongly promoted by experts and industry bodies in the Barossa, and is gaining popularity within the region's growers as a more effective and economic method to time irrigation events.
- One Barossa grower estimated the potential yield losses of a dry spring at up to 30%.
- Applying irrigation to supplement rainfall in spring is very important, as a full soil profile at bud burst is considered a crucial factor for a good yield. Barossa growers are therefore shifting towards irrigating earlier in the season (even through winter periods in which traditionally they would rely solely on rainfall, as they would only commence irrigation around December).
- Growers are realising the potential economic benefits of using floating dam covers, considering the likely increase in summertime evaporation losses and the increasing value of water in a more drought-prone future.
- To adapt to a water-constrained future, some growers are considering or actively pursuing the use of small scale reverse osmosis plants to desalinate their saline bore water, and this may become a more prevalent trend.
- Falling water tables in the Adelaide Hills was mentioned as a serious issue for some of that region's growers.

Increased mean temperatures and increased frequency/duration of extreme heat events

- Heat waves tend to affect Adelaide Hills growers more severely, because working in a generally cool region they are less prepared for them (e.g. they utilise an open canopy structure, designed to maximise sunlight penetration rather than protect fruit from heat)
- An improved ability to apply high irrigation inputs throughout the vineyard within a short space of time is a key adaptation to increasing heat waves, and currently many growers have inadequate irrigation infrastructure to meet this challenge.
- Some growers (for example in the Barossa) are therefore expanding their retention dams, as well as considering expanding the capacity of their pumping infrastructure. Obviously with higher pumping capacities come higher overall electricity costs, exacerbated by the rising unit cost of electricity, which is seen by some growers as a serious profitability-limiting factor.
- The use of fruit sun screens (calcium carbonate based products applied prior to a heatwave to reflect heat away from fruit) is expanding.

Increased summer rainfall

- In the Adelaide Hills region a 20 percent wetter summer would pose a more significant risk than in drier areas (e.g. the Barossa), because baseline rainfall amounts are much higher there.
- The precise impacts of higher summer rainfall (in terms of the risk of diseases, such as Botrytis) will depend on its duration and timing. If additional summer rain falls in one large event and then the vines

have a chance to dry, that can normally be managed, but several consecutive wet days at a time when the fruit is almost ready to harvest give the disease the opportunity to really develop, and then losses can be significant.

Systemic adaptation measures (potential or already practiced)

- Some Barossa growers have replaced high water using varieties like Semillon with red varieties which use less water.
- A north-east to south-west row orientation is a good adaptation to increased heatwave conditions, however that's only applicable where new vineyard developments are taking place.
- Barossa growers are familiar with alternative varieties such as Tempranillo, Aglianico, Sangiovese, Nero d'Avola, Montepulciano and Nebbiolo, and some growers are experimenting with some of these varieties, but not on a large scale. In McLaren Vale there's also some experimentation with new varieties, but more so in the smaller wineries.
- Drought tolerant root stocks are probably a good adaptation option into the future, but the transition costs for current growers could be prohibitive, as it requires the vineyard be replanted.
- Grafting of more drought and heat resilient varieties onto existing vines is also an option, although it comes with some risks and costs, including the loss of at least one years' crop during the grafting and retraining process, and potentially the loss of 2-10% of the vines (and the associated ongoing yield).
- Barossa Infrastructure Limited is in the process of expanding its capacity in order to provide higher volumes of water to Barossa vignerons, partly to address their climate change related water availability concerns.

General industry vulnerability and resilience comments

- Overall the viticulture sector in the AMLR NRM region is not currently under existential threat.
- If the AMLR NRM region's viticulture sector was to diminish in size in coming years, that would probably be driven more by market forces than by climate change.
- Growers at the lower end of the price range suffer from oversupply issues and are more vulnerable than those able to sell at higher unit prices. In this regard Barossa growers are overall in a relatively privileged position, due to the strength of the region's brand.
- There is a movement in the Riverland towards collaborative farming, a trend which we may see increasing in the Barossa as well, and which could increase the sector's overall efficiency and economic resilience (but may also see the demise of some family-run farms).

Dairy Comments

Increased irrigation demand and decreased water availability

- An overall climatic trend for drier springs is definitely a challenge for the dairy industry in terms of managing the costs of the summer 'feed gap'.
- With increasing power costs, dairy farmers in the Fleurieu and in the Adelaide Hills have increasingly moved to buy feed in, instead of irrigating their pastures during summer.

Increased mean temperatures and increased frequency/duration of extreme heat events

- While the construction of shade shelters is preferable to tree planting as a short term shading strategy, there seems to be increasing farmer interest in tree planting as a long term strategy.
- Ability to feed near shaded areas is an important heatwave mitigation strategy, and some dairy farmers in the Mount Lofty Ranges are now using feed pad systems.
- Ability to deliver water to various locations within the farm is an important heatwave mitigation strategy.
- High upfront costs restrict many farmers from converting their traditional outdoors dairy systems to the more heatwave-resilient intensive systems featuring sheds, sprinklers, feed pads and other such infrastructure.
- Heatwaves with very high minimum (night time) temperatures seem to have the most adverse impact on dairy cows.

Increased summer rainfall

- Increased summer rainfall would be overall beneficial to farmers running a perennial pasture system, but could also encourage more weed growth.

Systemic adaptation measures (potential or already practiced)

- To deal with rainfall variability, Queensland dairy farmers are increasingly undertaking forage cropping, which enable them to take advantage of large rainfall events to grow and then store additional feed. This is a practice Fleurieu farmers might consider adopting into the future.

General industry vulnerability and resilience comments

- The expansion of urban development into rural areas and the resulting increase in land values is a major vulnerability factor for the dairy industry.
- Milk price variability impacts farmers' income much more than climate variability.
- The AMLR region is more resilient to drier summers than a region such as Gippsland (Victoria), because AMLR dairy farmers have already adapted to drier summers by using relatively low stocking rates.
- With its relatively cool climate, the Fleurieu region is one of the best in South Australia in terms of its ability to cope with climate change pressures into the next 30-40 years. However expansion of the dairy industry in this region is now unlikely, due to very high land prices.

Perennial horticulture comments

Increased irrigation demand and decreased water availability

- Many growers cannot access their full water allocation because they do not have the infrastructure capacity required to do so.

Increased mean temperatures and increased frequency/duration of extreme heat events

- Receiving sufficient chill units is a key issue for cherry growers.
- In cherries, pollinators and target varieties need to flower at the same time for pollination to occur. As the timing of flowering could be affected by future warming, this may be an additional climate change related concern for cherry growers.
- In the apple industry pulse irrigation is used during a heatwave to protect the fruit from heat damage, which is a more important risk factor than summer rainfall.

Increased summer rainfall

- Summer rainfall (from around mid-November) is a key vulnerability for Adelaide Hills cherries, as it can cause fruit 'cracking'. Keeping moisture levels up in the soils is known to reduce this problem[40].
- In the apple industry, 'drizzly' summer rain over a long period can lead to increased disease, but shorter bursts of rain can be positive as they help in replenishing soil moisture and the trees have a chance to dry off in the event's aftermath before disease can take hold.

Systemic adaptation measures (potential or already practiced)

- Orchard netting is now practised widely in the Adelaide Hills apple industry, with the associated benefits being both climatic (e.g. hail damage prevention and protection from extreme heat) and non-climatic (e.g. protection from birds and flying foxes).
- Installing a cool room to enable fruit (such as cherries) to be picked and stored in advance of a forecast (potentially damaging) summer rain event can be considered a systemic climate change adaptation measure.

General industry vulnerability and resilience comments

- In general the region's primary producers are of an older age cohort, with not enough young farmers in the mix, an issue which presents growth and succession questions for the industry as a whole.

[40] Research has indicated that cracking in cherries can occur because when the trees experience dry conditions the fruit shrinks in the day and swells at night, affecting the skin. It is therefore prone to cracking due to the rush of water experienced by the tree during high rainfall events. For more information about the link between summer rainfall and cracks in cherries refer to http://www.cherrygrowers.org.au/assets/climate_risk_management_for_cherry_production.pdf

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