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Preparing for a changing and variable climate

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Department of Agriculture and Food

GOVERNMENT OF WESTERN AUSTRALIA

Australian Government

Grape and Wine Research and Development Corporation

PREPARING FOR A CHANGING AND VARIABLE CLIMATE

FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Principal Investigator: **Glynn Ward**

Research Organisation: **Department of Agriculture and Food, Western Australia**

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Cover photograph: Sunrise over a wine grape vineyard in the Margaret River region of Western Australia.

Contents

Abstract

Climate change has the potential to reshape the Australian wine industry. Regions will be differentially impacted and will respond according to their unique viticultural, environmental, economic and social characteristics.

An industry forum and regional workshop series was held in Western Australia focusing on three wine regions: Margaret River, Pemberton and Mount Barker. Fine scale climate information (mesoscale maps) and overviews of current and emerging technologies and resources that can be used by the wine industry to plan for and manage the risks and opportunities resulting from a changing and variable climate were presented. The information indicated that the wine regions in South West Western Australia (SWWA) will remain ideally suited to further viticulture development for the production of high quality grapes and wine in the future. Grape and wine producers identified seven key strategic areas where they will need support in order to manage the impacts of climate change. Producers developed detailed plans for actions they would like to see happen in their regions on climate information and projections, variety suitability and choices, vineyard water resources and water use, and vineyard management.

The information outlined in this report has been compiled in collaboration with the specialist speakers at the forum and regional workshops: Prof. Tom Lyons, Murdoch University; Prof. Snow Barlow, Melbourne University; Dr Tony Proffitt, AHA Viticulture; Dr Erika Winter, GrapeLinks; Dr Leanne Webb, CSIRO/Melbourne University; Dr Victor Sadras, South Australian Research and Development Institute; Paul Petrie, Fosters Group; Dr Ian Foster, Department of Agriculture and Food, Western Australia; and Nyamdorj Namjildorj, Curtin University of Technology.

Executive summary

Recent research indicates that climate change has the potential to fundamentally reshape the Australian wine industry. The wine industry's special dependence on unique regions is strongly climate related. Western Australia's eight wine producing regions and five subregions in the south west span cool and warm climate viticulture and high and low rainfall areas. Their focus is on regional variety character, wine styles and blends from premium quality grapes.

Climate and climate variability is region specific and each region will respond differently to changes in climate depending on their diverse viticultural, environmental, economic and social characteristics. Region specific information is needed to better understand the potential impacts and assist the industry to prepare for a changing climate. To date, little information has been available for individual wine regions in the detail needed for industry decision makers.

This report details the region specific information presented in an industry seminar and regional workshop series in order to understand the potential impacts of a changing climate, identify the challenges and opportunities, and assist grape and wine producers to better plan and manage their regions, vineyards and businesses.

The project utilised innovative fine scale (mesoscale) climate models focusing on three Western Australian wine regions: Margaret River, Pemberton and Mount Barker. The models were used to predict past, current and future climates. The climatic differences within and between regions and seasons highlighted the importance of providing climate information on a region, catchment and vineyard scale in order to best support grape and wine producers in their decision making.

A major outcome from the information presented was the indication that the wine regions in South West Western Australia (SWWA) will remain ideally suited to further viticulture development for the production of high quality grapes and wine in the future.

The changing and variable climate will present challenges and opportunities for each region. Producers identified four key areas where they need ongoing support to manage the challenges: identifying the key climatic factors impacting on grape and wine quality, the future suitability of some existing varieties and choice of new ones, vineyard water resources and use in some lower rainfall regions, vineyard management practices to moderate bunch zone temperatures and maximise grape and wine quality. The opportunities include: more quality vintages particularly for later maturing red wine grape varieties, and increase in the diversity of wine varieties, styles and blends to better match consumer preferences and market demand. Grape and wine producers participating in the workshops said they want to be kept informed, involved and engaged with researchers on these climate change and variability issues.

Specialist speakers presented the most up to date information on available tools, technologies and options in four key strategic areas: climate information and projections, variety suitability and choice, water resources and water use, and vineyard management.

Fine scale climate maps (1 km^2 grids) produced for Margaret River, Pemberton and Mount Barker (50 km^2 area) will assist grape and wine producers in these regions to better match existing and potential new varieties to their micro-climates and adapt their vineyard management practices. We now have the capability to produce detailed regional climate maps for a range of climatic variables.

A key climatic variable determining variety suitability to a region is the average growing season temperature. The average growing season temperature is projected to increase about 0.25^oC in Margaret River and up to 1.5^oC in Pemberton and Mount Barker by 2050, indicating that existing key varieties in these regions will remain suitable in the future. In all the regions more quality vintages for later maturing red wine varieties (e.g. Cabernet Sauvignon) and improved vintages for some new varieties (e.g. Tempranillo) are expected. Changes in vine canopy and vineyard management practices may be needed to adapt the more temperature sensitive varieties such as Riesling to the future climate. The diversity of climates within and between the regions provides opportunities to select sites for existing key varieties and increase the diversity in wine varieties, styles and blends. Grape and wine producers are keen to form groups to share their viticulture and wine quality information from past and future vintages with researchers in order to identify the key variables and enhance our understanding of existing varieties in our regional climates.

Water supply is expected to be the main challenge for lower rainfall areas in south west Western Australia (SWWA). Climate change is expected to reduce water supply from surface run-off by 2-20% and increase evaporative demand by up to 30%. These projections need to be taken into account in water policy and planning for the future. Currently available technologies tools and strategies for improving rainfall catchment, alternative water sources, water storage, and vineyard water use if adopted have the potential to meet present and future demand in limited rainfall areas. Further research, development and demonstration of new technologies are needed to explore their potential. In particular new surface treatments for roaded catchments, harvesting rainfall from vineyard inter-rows, improved design of vineyards and drought tolerant rootstocks, varieties and clones need further investigation.

The information presented in the project highlighted the importance of bunch zone temperature in determining wine quality, aroma and flavour characters. The project identified tools and strategies to adapt vineyard design and management practices to optimise bunch zone temperatures and moderate adverse temperatures in the vine canopy. The use of simple, inexpensive datalogger technology to monitor canopy temperatures was highlighted. Further work needs to be done to determine optimum bunch zone temperatures and heat stress and cold stress temperature threshold of key varieties. Grape and wine producers are keen to form groups to monitor bunch zone temperatures and develop climate adapted canopy management systems for key varieties in their region.

The outcomes of this project were considerably enhanced by the contributions of the specialist speakers: Tom Lyons, Murdoch University; Snow Barlow, Melbourne University; Tony Proffitt, AHA Viticulture; Erika Winter, GrapeLinks; Leanne Webb, CSIRO/Melbourne University; Victor Sadras, South Australian Research and Development Institute; Paul Petrie, Foster's Group; Ian Foster, Department of Agriculture and Food, Western Australia, and Nyamdorj Namjildorj, Curtin University of Technology.

Background

The Western Australian wine industry is based on the production of premium quality grape varieties for the high quality wine market. The focus is on regional variety character, wine styles and blends. The eight wine producing regions and five subregions in Western Australia (Figure 1) span cool and warm climate viticulture and high and low rainfall areas. The suitability of the regions for premium quality grape and wine production is defined principally on the basis of climatic and soil criteria (Olmo 1956; Gladstones 1965a, 1965b, 1999). The wine industry's special dependence on unique regions (terroirs) is strongly climate related (Seguin & Cortazar 2005).

The world's climate has changed, largely as a result of increased concentrations of green house gases, and it will continue to change for decades even if the concentrations were immediately reduced to 1990 levels (Whetton 2007). Viticulture zones are predicted to shift southward in the southern hemisphere as the growing season average temperatures rise (Jones 2006). Western Australia's geographical location means that the state's south-west corner will be one of the most vulnerable regions in the world. By 2030 its climate will most likely be typified by lower rainfall (10-20% less), higher average temperatures (0.2-2.1˚C), more severe weather events such as heat waves and frosts, and greater seasonal variability (IOCI 2005). The potential impact of projected changes in temperature on wine grape yield, phenology, quality and variety suitability varies between growing regions (Webb 2006). Greater impacts are expected in the hotter inland regions than cooler regions closer to the coast. Changes in climate will be region-specific and each region will respond differently depending on their diverse technical, environmental, economic and social characteristics (Schultz 2007).

Figure 1 **Western Australia's wine producing GI regions and subregions (Wine Industry Association of Western Australia)**

Region-specific information and knowledge is needed to better understand potential impacts, provide solutions and assist industry's decision making. A range of climate modelling and viticulture research addressing these issues is being carried out around Australia. In Western Australia climate modellers are able to produce credible, high resolution climate projection scenarios which can be specifically tailored to regional conditions (Lyons & Considine 2007). In-vineyard research on the impact of higher and variable temperatures on vine growth, berry quality and composition is being conducted in South Australia (Soar & Sadras 2007). The climatic adaptation of varieties grown in Australia and identification of new varieties and clones suited to our projected warmer and drier future climate need further research and investigation.

Many wine growing regions in the world are already dealing with climate change, particularly in the northern hemisphere where increases in temperature have been more marked. It is evident that because of the complexity of the factors and relationships influencing climate, that changes will vary considerably between regions. Continuing advances in climate modelling is allowing us to make projections at much higher resolution that can be tailored to specific regions. We are fortunate to have several leading researchers in this field in Australia and Western Australia.

To date little information has been available for individual wine regions in the detail needed for industry decision makers. The current project was therefore developed to bring together the most up to date information on fine scale climate projections, and current and emerging technologies and resources that industry can use to plan for and manage the risks and opportunities resulting from a changing and variable climate. Information on the effects of climate on grape and wine production and quality was presented in a series of industry seminars and workshops leading to a better understanding of the future potential impacts, opportunities and management strategies needed. Further more, industry participants identified key 'strategic areas of need' and developed detailed plans for research, development and communication actions they want to see happen in their region.

This study was funded by GWRDC as a Regional Innovation and Technology Adoption project in response to interest from regional Western Australia.

Project aims and performance targets

The main aim of this project was to bring key industry representatives and researchers together to develop region specific information on changes and variability in future climate, assess opportunities and challenges for the Western Australian wine industry and develop collaboration in future research and development. The workshops and seminar program was of major relevance and interest to the Western Australian wine industry. Given the significance of the changing and variable climate to other Australian wine regions the outcomes of the project will benefit the whole of the Australia wine industry. Although the project application was submitted as a regional project it has national linkages and benefits. The benefits of the seminar and workshop series for the Western Australian regional wine industry include:

- sharing of information that will help shape wine industry response and decision making
- developing high resolution, region-specific climate scenarios for wine regions which meet the information needs of industry and decision makers
- encouraging collaborative links between and within the industry and research community
- providing a forum for economic, environmental and social considerations in addition to technical aspects
- being better prepared to assess future challenges and capture opportunities
- providing direction for future research, development, extension and communication for the industry, regional communities and government.

The key objectives of the workshops were to:

1. provide vignerons, wine makers and viticulturists with the most up-to-date information on climate change projections for Western Australia's wine regions
2. focus on how these regional climate change projections could impact on the wine industry
3. enable industry participants to identify key areas in which they will need support in order to capture the opportunities and manage the impacts of a changing and variable climate.

The objectives were achieved in a series of seminars and workshops delivered in two phases. The initial industry forum pooled existing information for WA wine regions, determine vulnerability and provide direction for industry response and future research and development. The industry participants were expected to identify key 'strategic areas of need' in order for them to manage the impacts of climate change in their vineyards. The subsequent regional workshops further developed the key strategic areas of identified need, communicated latest international, national and region specific information to industry and provided an overview of technologies and resources that can be used to tackle climate change. The outputs and performance targets are shown below.

Outputs and Performance Targets 2007-09	
Outputs	**Performance targets**
1. Hold forum (Seminar and Workshop) for Industry and Researchers in Manjimup	November 2007
2. Produce proceedings of forum	January 2008
3. Hold regional workshops focusing on high resolution climate scenarios for specifically tailored for three regions: Margaret River, Pemberton and Mount Barker	September 2008
4. Submit final report to GWRDC	July 2009

The industry forum was held in Manjimup and the regional workshops focused on the Margaret River, Pemberton (held in Manjimup) and Mount Barker (held in Albany) wine regions. Handouts of presentations were made available to participants. Articles on the findings were published in appropriate industry journals and the general media.

Method

The seminar and workshop series was delivered in two phases. An initial industry forum was held in Manjimup on 5 November 2007 followed by three regional workshops in September 2008 to address the outcomes of the forum.

1. Forum

The initial seminar and workshop was held with the wine industry and researchers in Manjimup on 5 November 2007.

The objective of the workshop was to provide vignerons, wine makers and viticulturists with the most up-to-date information on climate change projections for Western Australia's wine regions and focus on how these could impact on the wine industry. The industry participants would then identify the key areas in which they will need support in order to manage the impacts of a changing and variable climate.

At the workshop six expert speakers delivered presentations that examined the global and local projections for climate change and their potential impacts on the WA wine industry. The speakers and topics covered were:

- Advancement in grape maturity in Australia—Potential causes and impacts
  Paul Petrie (Foster's Group Ltd)
- Climate change projections for southern Western Australia
  Dr Ian Foster (Department of Agriculture and Food, Western Australia)
- Mesoscale climate of the Margaret River region
  Professor Tom Lyons (Murdoch University)
- Projected climate change impact on the Australian wine industry
  Dr Leanne Webb (CSIRO Marine and Atmospheric Research, University of Melbourne)
- Determining climate change impacts on viticulture in the Great Southern region of Western Australia
  Nyamdorj Namjildorj (Curtin University of Technology)
- Quantifying the improvement in Australian wine quality in the last two decades: Can technology counteract warming trends?
  A/Professor Victor Sadras (South Australian Research and Development Institute)

Industry representatives then identified seven key topic areas:

- Effects of climate change on vines
- Varietal choices and suitability
- Water use and management
- Information provision and ongoing engagement
- Vineyard management
- Social impacts
- Business strategies.

The workshop content and structure were developed by the Department of Agriculture and Food (Kristen Kennison and Diana Fisher) and Curtin University of Technology (Mark Gibberd) in consultation with Andrew Huffer who facilitated the industry discussion session in which key topic areas were identified.

2. Regional workshops

Three half-day regional workshops were held in Margaret River, Manjimup and Albany in September 2008 (see attachments). The workshops focused on region-specific information for Margaret River, Pemberton (presented at the Manjimup workshop) and Mount Barker (presented in Albany). These regions were selected because they represented a range of climates: maritime (Margaret River); cool wet (Pemberton); and cool dry (Mount Barker). Fine-scale climate projections and maps had also been produced for these regions.

The objectives of the workshops were to provide producers with access to better information, options and tools to capture opportunities and manage risks associated with climate change and seasonal variability. The workshops focused on four of the main topics identified at the wine industry forum: regional climate information and projections; variety suitability and choices; water use management and vineyard management.

At the workshops producers provided feedback and ideas, and developed plans for actions they want to see happen in their regions. Specialist speakers delivered presentations on the four topic areas. The topics and speakers (Figure 2) were:

- Climate information and projections—what key climatic information do you need?
  Professor Tom Lyons (Murdoch University)
- Variety suitability and future choices—what options could suit your region?
  Professor Snow Barlow (University of Melbourne)
- Water use management—how can we address future issues?
  Dr Tony Proffitt (AHA Viticulture)
- Vineyard management—how can we adapt our practices?
  Dr Erika Winter (GrapeLinks)

Workshop structure

The participants were asked to write down their thoughts and ideas in relation to each presentation for use in the following workshop session. A specific question was shown at the beginning of each presentation to assist the participant to focus their thoughts. The focus questions for each of the topic presentations were:

Topic	Focus question
Climate information and projections	What key climatic information do you need?
Variety suitability and future choices	What options could suit your region?
Water use management	How can we address future issues?
Vineyard management	How can we adapt our practices?

In the workshop session each participant sat in one of four topic groups in which they had the most interest. The specialist speakers joined the groups to interact on their topic areas.

Participants grouped similar individual ideas and worked on them in more detail. The topic groups developed action plans for as many of the ideas as they could by considering the following:

- What needs to be done? (detail actions/tasks/activities)
- Why should it be done? (why is it a priority?)
- Who should do it? (who should be responsible for it?)
- How long should it take? (timeline)
- Any other comments or suggestions?

The regional workshop content was developed by the specialist speakers (Tom Lyons, Snow Barlow, Tony Proffitt and Erika Winter) and DAFWA (Glynn Ward and Colin McDonald). The facilitated workshop structure was developed by DAFWA (Kerry Hill, Colin McDonald and Glynn Ward). The workshops were chaired in Margaret River by Mark Gibberd (Curtin University of Technology), in Manjimup by Diana Fisher (DAFWA) and in Albany by Colin McDonald (DAFWA). Glynn Ward (DAFWA) facilitated the action planning sessions. David Beard (DAFWA) developed the workshop evaluation questionnaire.

Figure 2 **Presenters at the Manjimup workshop (left to right): Tom Lyons, Tony Proffitt, Snow Barlow, Diana Fisher (Chairman), Erika Winter and Glynn Ward (Facilitator)**

Results and discussion

1. Forum

The forum was attended by 47 people including 24 wine industry representatives (vignerons, viticulturists and winemakers); 17 research and development staff from universities and government agencies; and the six expert speakers. All presentations were printed in the proceedings and were able to be viewed in lecture video format, PowerPoint or pdf file by accessing http://muresk.curtin.edu.au/conference/climate/

1.1 Summary of information presented

Future climate in South West Western Australia

- Higher average temperatures:
  - increased 0.8^{o}C since 1950s; and
  - projected to increase by 0.2-1.8^{o}C by 2030.
- Lower rainfall:
  - has declined by 15% since 1976;
  - projected decline 9-20% by 2030;
  - less winter and spring rainfall;
  - more summer showers;
  - later break to the season; and
  - fewer run-off events.
- Higher evaporation:
  - projected to increase by 0-10% by 2030.
- Higher saturation deficit and lower relative humidity.
- Warmer and colder extremes:
  - number of hot days (> 35°C) to increase by 2 to 16 by 2030; and
  - increased spring frost risk in some regions (Pemberton, Manjimup, inland Great Southern).
- Higher carbon dioxide.
- Moderating influence of the coast on temperatures:
  - Margaret River, Denmark.
- Sunshine and cloudiness?
- Sea breeze?

Implications for grapes and wine

- Higher temperatures:
  - higher growing season temperatures (heat summations);
  - less winter chilling, more heat units;
  - phenology changes (early/delayed budburst, earlier harvest, compressed growing season);
  - ripening changes: sugar ahead of aroma and flavour development;
  - changes in varietal characters and wine styles; and
  - suit later maturing varieties, particularly high quality red wines (e.g. Cabernet Sauvignon).

- Lower rainfall in winter-spring:
  - lower run-off for water supply;
  - less risk of rain when harvesting late varieties; and
  - more effective disease control.

- Higher CO_2:
  - may offset effect of high temperature; and
  - may retain quality and yields.

1.2 Workshop results and mind maps

The industry participants identified 59 individual ideas (Appendix 5.1) which were then grouped into seven key topic areas of need to enable the wine industry to better manage the impacts of climate change (Table 1).

Table 1 **Key topic areas identified by industry representatives at the Manjimup Forum where they will need further support to manage the impacts of climate change**

Topic no.	Key topic area	No. of individual ideas
1	Effects of climate change on vines	6
2	Variety choices and suitability	15
3	Water use and management	11
4	Information provision and ongoing engagement	10
5	Vineyard management	10
6	Social impacts	2
7	Business strategies	4
Total	**7 key topic areas**	**59**

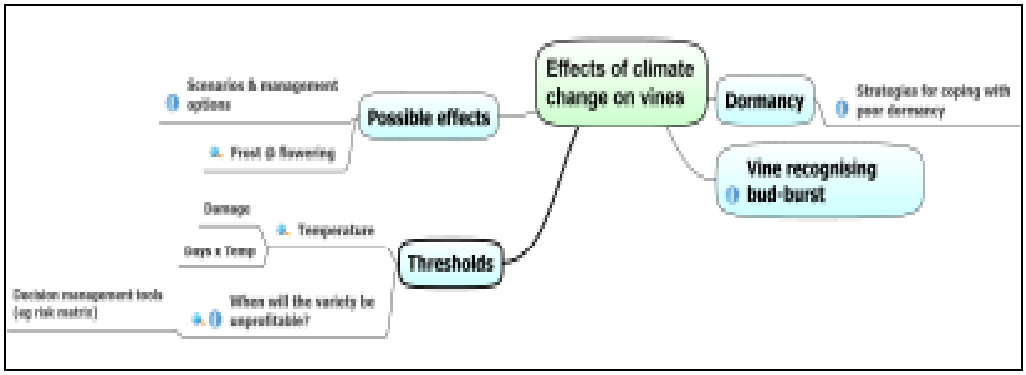
The four priority key topic areas based on the number of individual ideas captured were: varietal choices and suitability, water use and management, vineyard management and information provision and ongoing engagement.

Strategic areas of need

The industry participants further grouped the individual ideas into 'Strategic areas of need' for each topic to assist prioritisation of areas for further development and actions at future regional workshops. Mind maps (Table 2) were constructed to show the linkages between the 'Strategic areas of need' and individual ideas of participants. The mind maps also identify the resource requirements to address these strategic areas including: information sharing, research, grower investment, collaboration, time limited, internet tools, and regulation.

Table 2 **Mind maps for the seven key 'strategic areas of need' identified by industry in Manjimup**

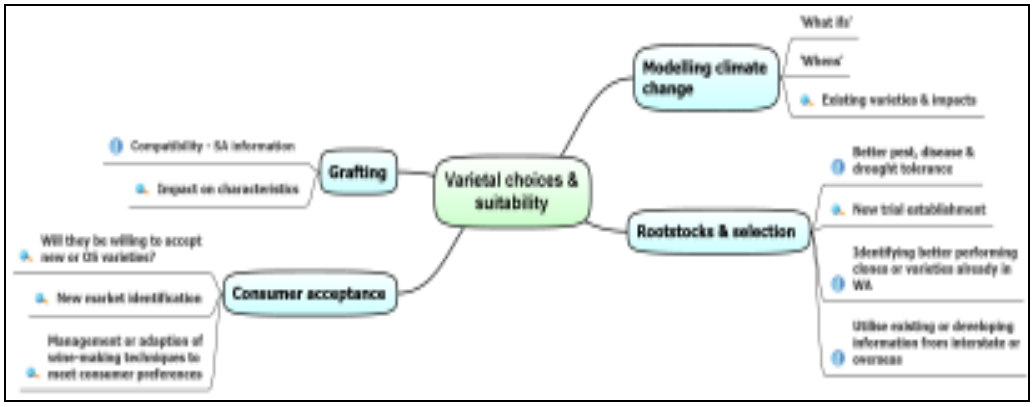
Key to symbols:



(i) ***Effects of climate change on vines***

Need to know how climate change will impact on vine phenology and production, performance of existing varieties, grape berry and wine quality.
Develop specific strategies and actions:

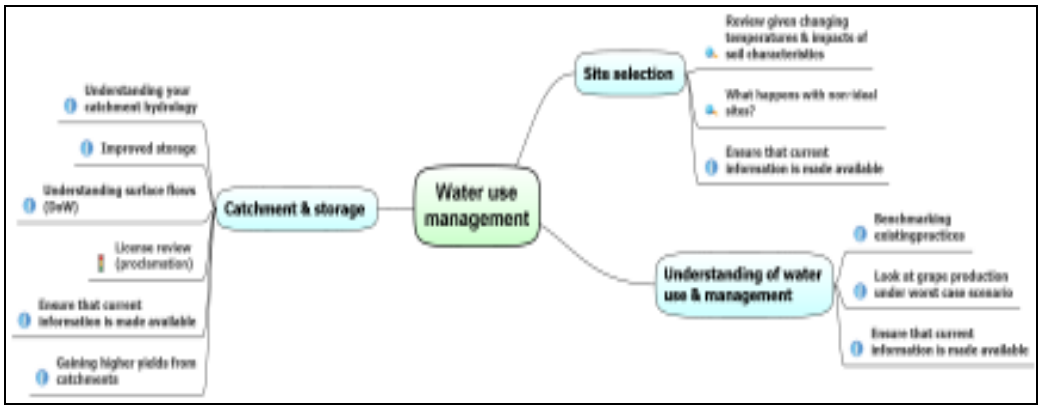
- to manage lack of dormancy leading to poor bud burst;
- to develop management options for different climate scenarios and frost risks;
- develop decision making tools for management of risks associated with temperature damage and profitability of existing varieties.



(ii) Varietal choices and suitability

Need to know how existing varieties will perform under different climate scenarios, when will they become unprofitable, and suitable alternative varieties, clones and rootstocks.
Develop specific strategies and actions:

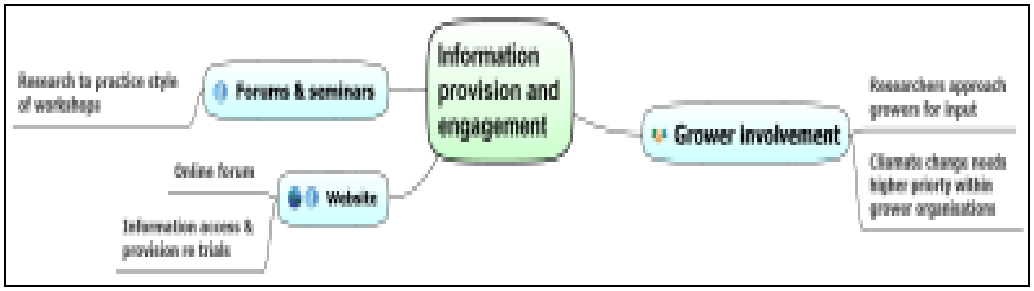
- to determine impact of climate change on future suitability, sustainability and profitability of current varieties in each region;
- to determine suitable varieties, clones and rootstocks to minimise negative impacts and capture opportunities of climate change in each region;
- to determine consumer acceptance to changes in wine quality and styles, different varieties and identify new markets.



(iii) Water use management

Need to know how climate change will impact on water availability and management.
Develop specific strategies and actions:

- to increase security of water supply through improved catchment management and water storage;
- to improve future site selection and management of suboptimum sites;
- to improve water use management to preserve grape berry quality characteristics.

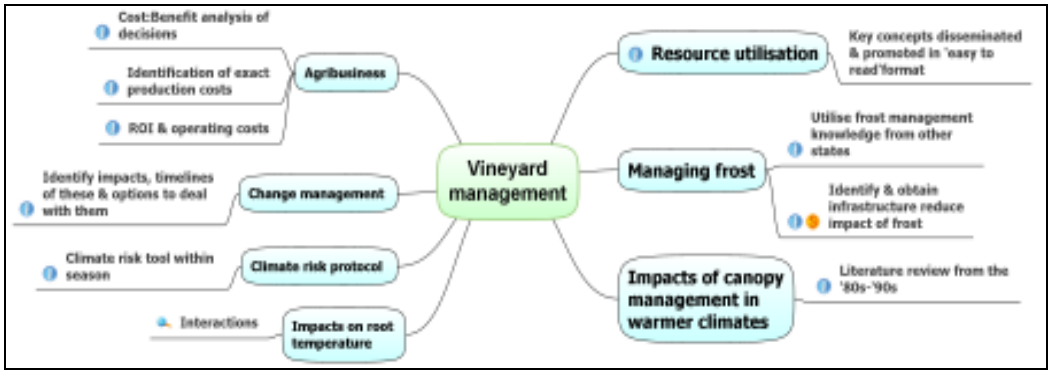


(iv) Information provision and engagement

Need to improve information transfer and ongoing engagement between industry and researchers.

Develop specific strategies and actions:

- to engage state and regional organisations and encourage grower involvement in research;
- to disseminate information through a range of mediums including development of a website;
- to provide region specific information in Research to Practice® style workshops and seminars.

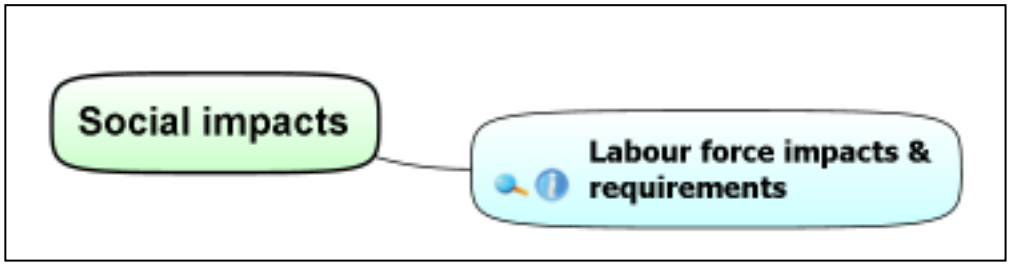


(v) Vineyard management

Need to develop vineyard management options and risk management strategies to benefit from opportunities and minimise any negative impacts of climate change on grape and wine quality and production.

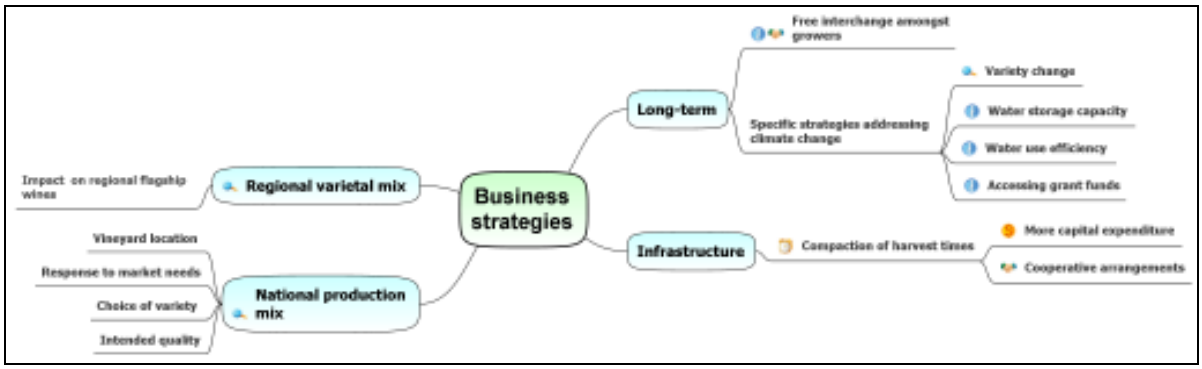
Develop specific strategies and actions to:

- identify and disseminate information on canopy, vineyard floor and root zone management in warmer climates to reduce impact of climate change on yield and quality and increase drought tolerance;
- identify and disseminate knowledge on managing frost risk;
- provide analysis of the impacts of changes in vineyard management systems and practices on business parameters, costs and outcomes;
- develop a decision making tool for within season climate risk protocols;
- develop options to deal with impacts of changes in vineyard management systems in a timely way.



(vi) Social impacts

Need to better understand and plan for the social, environmental and economic impacts of climate change on the Australian wine industry.
This key area of need was not developed by the group to the same extent as others and requires further investigation.



(vii) Business strategies

Need to understand and plan the long-term development of the Australian wine industry, its businesses and competitiveness of its wine regions in response to climate change.
Develop specific strategies and actions:

- to develop specific strategies addressing varieties, water, infrastructure and accessing funding.

2. Regional workshops

The regional workshops were attended by 44 people in Margaret River, 19 in Manjimup and 26 in Albany. All presentations were printed as handouts for the workshops and placed as PowerPoint pdf files on the DAFWA website: www.agric.wa.gov.au.

2.1 Summary of information presented

Speakers presented up to date information of four key topic areas (climate projections, variety suitability and choices, water use and management and vineyard management). The information focused on three regions: Margaret River, Pemberton and Mount Barker.

Climate information and projections—what climatic information is important to you? (Tom Lyons)

A broad overview of the climate projections for South West Western Australia (SWWA) from global modelling was presented. The scale of the global models (about 500 km^2) is too coarse to provide practical information to plan and manage for climate change at the region, catchment and vineyard level.

The mesoscale climate model takes account of the influence of topography, soils, vegetation and ocean temperatures on the local climate. The model generates hourly temperatures on a 1 km^2 grid. The temperature data was then used to calculate the following range of climate variables:

- Average growing season temperature (October to April)
- Average hours in the optimum temperature range for vine growth (18-28°C) during the growing season (October to April)
- Saturation deficit—measure the evapotranspiration demand on vines; as saturation deficit increases growth and yield are reduced and potassium content in juice, must and wine tends to increase.
- Days to maturity from budburst for Chardonnay (1150 day degrees)
- Days to maturity from budburst for Cabernet Sauvignon
- Accumulated winter chilling hours (temperature < 10^oC).

Regional climate maps showed the variation of each climatic variable over time and over a 50 km^2 area for each of the three regions, Margaret River, Pemberton and Mount Barker. Climate maps were produced for the past four vintages (2005-2008) and forward to 2046-2054. Climate projections are based on 1.5 times CO_2 concentrations in 2000 which will be reached in about 2050 in this model.

The mesoscale climate model and maps provide information on scale (catchment, locality, vineyard) needed for decision makers. The accuracy and reliability of the mesoscale model has been tested against observed hourly temperature data (2000–2005).

The climate maps show how the climatic indicators vary within and between regions and from year to year, both historically and prospectively. Climate maps and information can be produced for a multitude of climate variable. For example, the occurrence of heat waves and frosts, winter chill accumulation, average temperature in the weeks leading up to harvest. The key question is what climate information is most important to producers in their region.

The mesoscale climate model is also able to generate real time information and forecast within season climate which will be important for short-term response.

Average growing season temperature

Figure 2 shows the average season growing temperatures for 2008 and projected for 2050 in the Margaret River, Pemberton and Mount Barker regions. The average growing season temperature varies considerably within and between regions and seasons (Table 2).

In 2008 Margaret River (16.25–17.0°C) was the warmer of the three regions followed by Pemberton (15.5–15.75°C) and the coolest is Mount Barker (14.25–15.5°C) in 2008.

The projected increase in average growing season temperatures by 2050 is about 0.25^oC for Margaret River and 1.5°C for Pemberton and Mount Barker. The average growing season temperatures for the three regions are projected to be very similar by 2005 and similar to the current climate in Bordeaux.

Proximity to the coast has a highly moderating effect on climate across the Margaret River region with several micro-climates within the region.

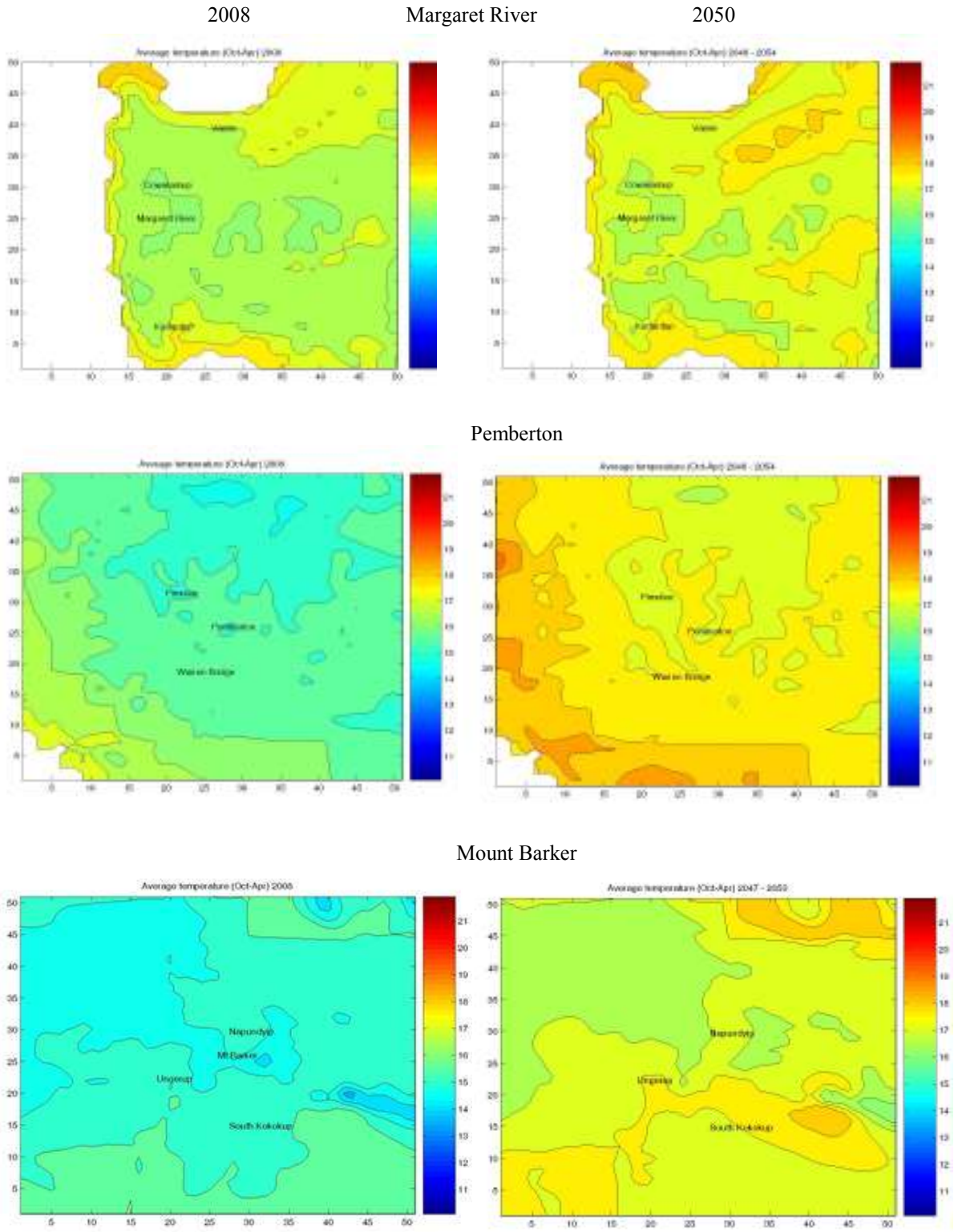


Figure 3 **Mesoscale climate maps of average growing season temperature (October to April) for Margaret River, Pemberton and Mount Barker regions in 2008 and 2050 (Lyons 2008)**

Table 3 **Average growing season temperature (October to April) predicted by the mesoscale climate model for Margaret River, Pemberton and Mount Barker regions: 2006 (atypically cool), 2008 (most recent) and 2050 (projected) vintages**

Region	Average October to April temperature (°C)		
	Cool vintage 2006	Normal vintage 2008	Projected vintage 2050
Margaret River	14.25–15.75	16.25–17.0	16.5–17.5
Pemberton	13.0–15.5	15.5–15.75	16.75–17.5
Mount Barker	12.5– 14.0	14.25–15.5	16.25–17.5

Other climatic variables

Average growing season temperature is just one climatic variable.

Information presented on the following:

- Average hours in the optimum temperature range (18-28°C) for vine growth during the growing season (October to April)
- Saturation deficit—moisture in the atmosphere
- Days to maturity from budburst for Chardonnay and Cabernet Sauvignon.

Table 4 **Days to maturity from budburst (1 October) for Chardonnay and Cabernet Sauvignon in Margaret River, Pemberton and Mount Barker regions: 2008 and 2050 vintages**

Region	Days to maturity	
	2008	2050
Chardonnay		
Margaret River	135–145	120–130
Pemberton	150–160	125
Mount Barker	160–165	135–140
Cabernet Sauvignon		
Margaret River	150–165	135–145
Pemberton	165–175	145
Mount Barker	175–185	150–160

- Chill accumulations. Grapevines require between 100 and 500 hours at less than 8^{o}C during dormancy depending on variety. Budburst and flowering in higher chill varieties which receive insufficient chill in warmer winters may be delayed and prolonged. For example, this may be a potential issue for Chardonnay in Margaret River where accumulated chill (May to August) is predicted to decline by 100 to 200 hours by 2050.

- Rainfall projections vary much more than temperature and projection are not as reliable. The trend is for lower rainfall in the SWWA. Projections reductions vary from 2% to 20%. Potential impact of reduced rainfall will vary considerably between regions depending on the current rainfall. The high rainfall regions Pemberton (1145 mm annually) and Margaret River (1045 mm) will be less affected than the lower rainfall areas of the Great Southern Region such as Mount Barker (660 mm).

Other climatic factors

Participants raised the following climatic information for consideration:

1. Growing day degrees (GDD)
2. Temperature variability during maturation/ripening—January, February and March
3. Relative humidity
4. Influence of sea breezes
5. Duration of extremes in conditions——warning systems needed
6. Review what our great red and white vintages are and relate to climatic data
7. Models for GDD (± other quality KPI) for main varieties: Chardonnay, Sauvignon Blanc, Semillon and Cabernet Sauvignon
8. Ocean temperatures since 1970s (i.e. via satellite data) to determine the influence of the Leeuwin Current
9. Ability to interpret changes in season as the season progresses (i.e. budget vs. actuals)
10. Expression of projections with probabilities
11. Within season forecasts in order to better manage for climate and weather extremes: heat stress / heat waves, frost, cooler or warmer seasons, etc.

Climate variability

The mesoscale model predicts greater fluctuations in temperatures resulting in greater seasonal variation in climatic factors. Greater diurnal temperature variation with higher daily maximum and lower daily minimum temperatures throughout the year are expected. In Margaret River, for example, a slight increase in the number of hours above 25°C in summer and below 10°C in winter is projected for 2050 (Figure 4). Similar projections with higher maximum and lower minimum temperatures were made for Pemberton and Mount Barker. The impact of greater variability in temperature will depend on a particular variety's sensitivity to temperature.

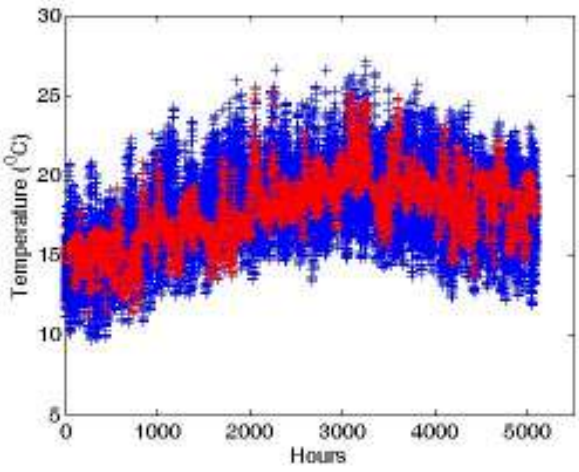


Figure 4 **Comparison of hourly temperatures predicted for Margaret River, showing 2007-08 in red and 2047-2053 in blue**

Variety suitability and future choices—growing quality grapes in a changing and variable climate (Snow Barlow)

Topics covered wine grape varieties, wine and climate, temperature influences on vine phenology, future changes in climate and potential adaptation strategies.

Grape and wine production is really about producing quality grapes by matching variety with the climate and soil in a region, the 'terroir', to produce the quality and style of wine desired. Western Australia has established its reputation on high quality, fine wines styles. The future challenge is to maintain and enhance the WA brand in a changing climate.

Sweet spot for varieties

Finding the 'right' variety for the climate and region is based on the climate parameters driving grape and wine production and quality. The 'optimum' climate zone for a variety produces consistent yields, balanced fruit composition, ripe flavours typical of the variety and acceptable vintage variation (Figure 5). If the climate is too cool for a particular variety sugar levels will be lower, flavours unripe and the wine unbalanced. If the climate is too warm the acid retention will be lower, sugar accumulation may be higher producing higher alcohol wines, flavours overripe and wine unbalanced.

Cool early season harvest temperatures may favour good wine quality in early maturing varieties. Excessively hot temperatures later in the season detract from the quality of late maturing varieties. For example, the 2008 Barossa Valley vintage was in two parts. Early season harvest temperatures were around 17.0-18.0°C producing good quality wine. The valley experienced 17–18 days above 38°C later in the season which produced grapes with high sugars and high alcohol wines.

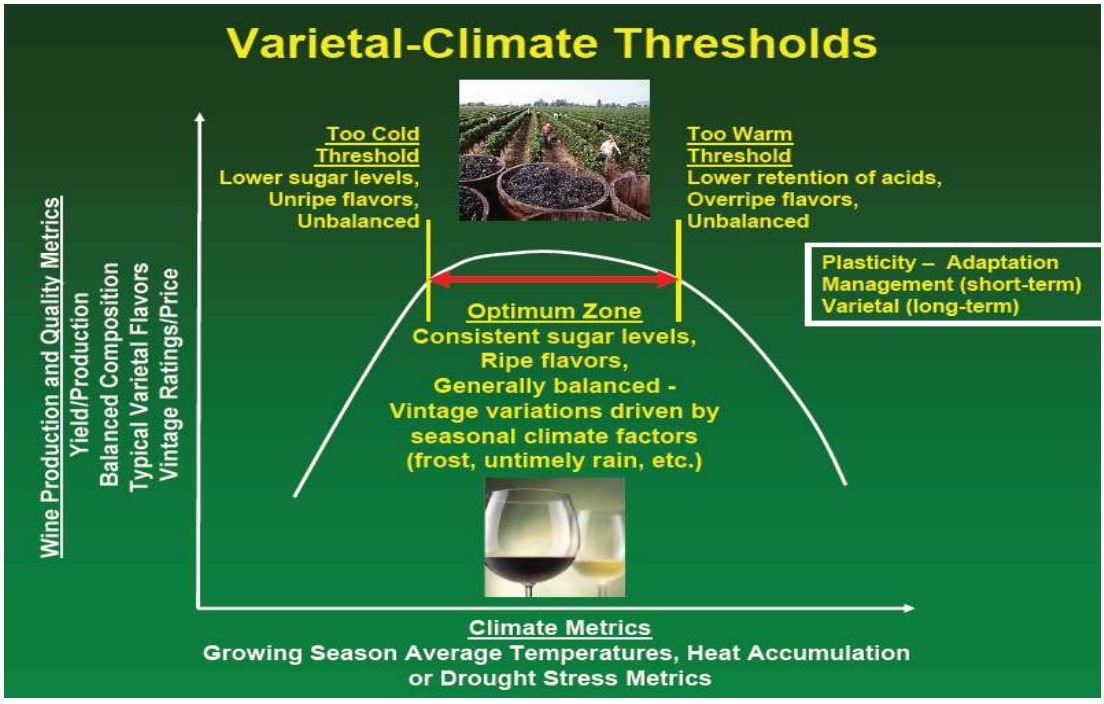


Figure 5 **Influence of climate on variety performance in grape and wine production (Jones 2008)**

The regions of SWWA have unique climate cycles. For example, Margaret River's maritime climate does not get as hot in summer or as cold in winter as other wine regions in Australia (Figure 6). Climate projections will also be region-specific resulting in different potential impacts and adaptation strategies.

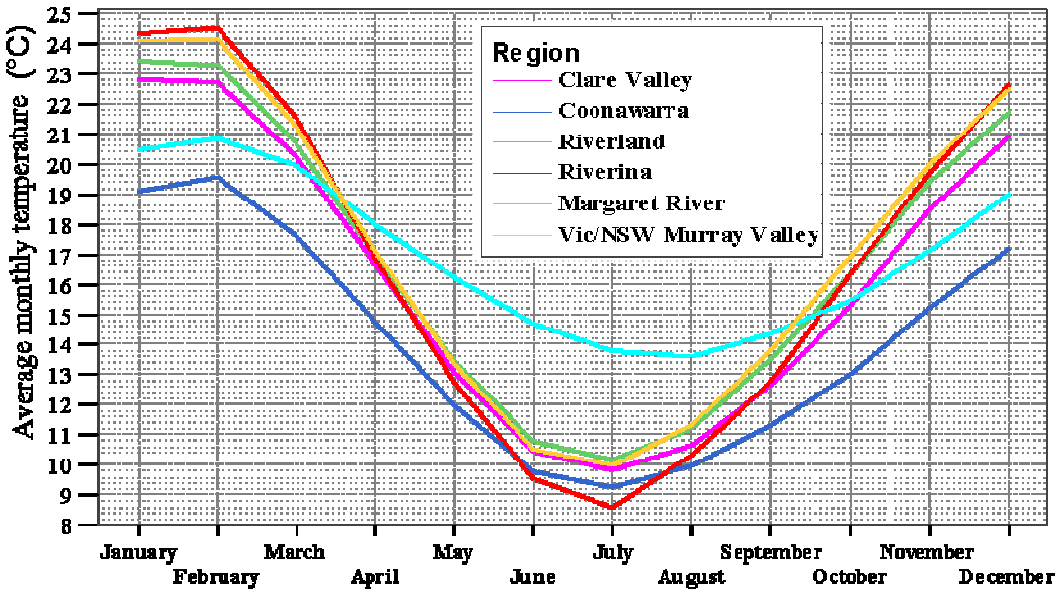


Figure 6. **Average monthly temperature for Australian wine production regions (Barlow 2008)**

The ability to produce fine scale climate information for individual regions will be very helpful in developing adaptation strategies for WA regions and subregions.

Grapevines and wine grapes follow a two-year growth cycle. Yield potential, fruitfulness is determined by temperature the previous season. The timing of phonological stages (e.g. flowering, veraison, maturation and harvest) is also very sensitive to temperature in the current season. Climate can influence grapevine performance in a number of ways:

- Warmer winter temperatures will reduce chill accumulation and may result in delayed and prolonged budburst of some varieties.
- Higher temperatures will advance and compress the timing of phenological stages.
- Higher temperatures can also alter the balance of maturity and flavour ripening.
- Extreme events (high temperatures) can influence grape quality through heat stress and sunburn.
- Elevated CO_2 may also alter vine balance.
- Water use can be an issue.

Variety suitability to climate and region

Wine grape varieties fit into particular climates. One relationship between variety and climate is the average growing season temperature and wine grape maturity groupings (Figure 7). This relationship may be used as a guide for the suitability of existing varieties and future variety choices. The variety/climate grouping has been developed for the northern hemisphere and needs to be tested for Australian climate conditions and wine styles. The relationship between variety and climate may be different for the southern hemisphere. In Australia grapes are grown at lower latitudes and higher average growing season temperatures than the equivalent varieties and wine styles in Europe. Gladstones noted that *climatic x variety* comparisons between European and

Australian vineyards are influenced by length of daylight in summer and other factors. He observed that varieties in the northern vineyards of European at higher latitudes (46-50°N) ripen with lower average growing season temperature summations than in the southern vineyards of Australia at lower latitudes (34-38°S). The average growing season temperature is just one indicator of variety performance and other climatic indicators may be more critical in different regions

Variety sensitivity

Wine grape varieties will grow and produce fruit in a wide range of climates. However, the quality, style and varietal wine characters are sensitive to temperature within their growing range. This was illustrated using grape price as a surrogate for quality and relating price to the mean January temperatures in a range of Australian grape growing regions (Figure 8). Temperature sensitive varieties include Chardonnay, Sauvignon Blanc, Pinot Noir and Pinot Gris. Varieties which seem to exhibit high resilience to temperature include Cabernet Sauvignon, Cabernet Franc and Semillon. Those with intermediate resilience include Shiraz.

Regional variety impact

The potential regional variety impact to will depend on the projected shift in temperatures and the current variety mix. In Margaret River the main red varieties are Cabernet Sauvignon, Shiraz and Merlot and white varieties are Chardonnay, Semillon and Sauvignon Blanc. These varieties are expected to remain ideally suited to Margaret River given the projected very slight shift in average growing season temperature. The projected future climate should result in more good vintages for later maturing red varieties such as Cabernet Sauvignon. In the Great Southern, including the Mount Barker subregion, the main red varieties are Shiraz, Cabernet Sauvignon and Merlot and white varieties Chardonnay, Sauvignon Blanc and Riesling. The average growing season temperatures for Mount Barker and Pemberton are projected to move close to that of Margaret River. Later maturing red varieties such as Cabernet Sauvignon and Shiraz are expected to perform even better in these regions in future. Adaptive management strategies may be needed for some of the more sensitive varieties such as Riesling and Sauvignon Blanc to maintain the same wine styles and flavour characters. The projected average growing season temperatures in all three regions indicated the future climate will result in more favourable seasons for later maturing red varieties such as Cabernet Sauvignon and increased the suitability of some of the newer varieties being grown such as Tempranillo.

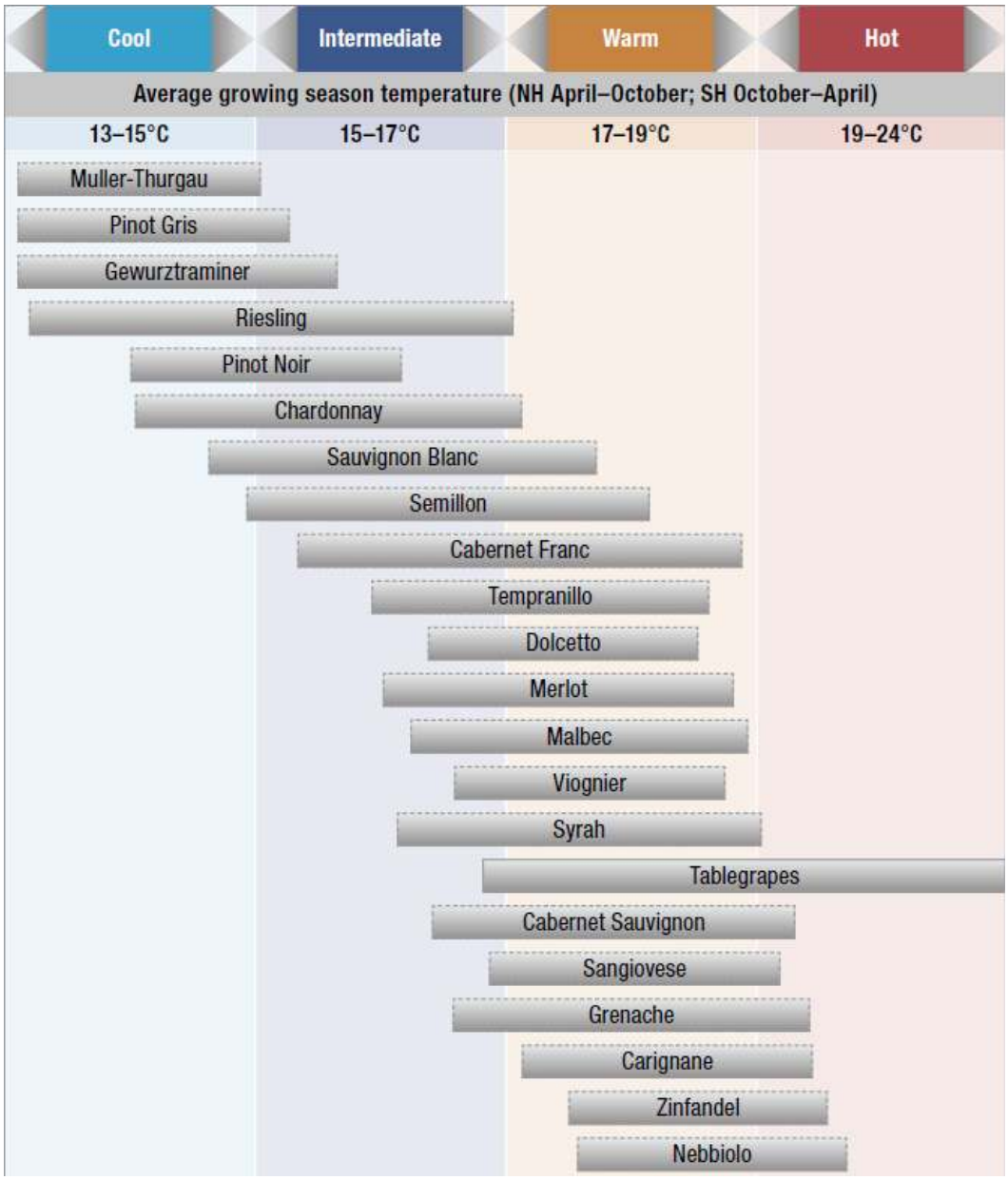


Figure 7 **Grapevine climate—maturity groupings based on relationship between phenological requirements and climate for high quality wine production in world benchmark regions for each variety. Length of bar indicates estimated span of ripening (Jones 2006)**

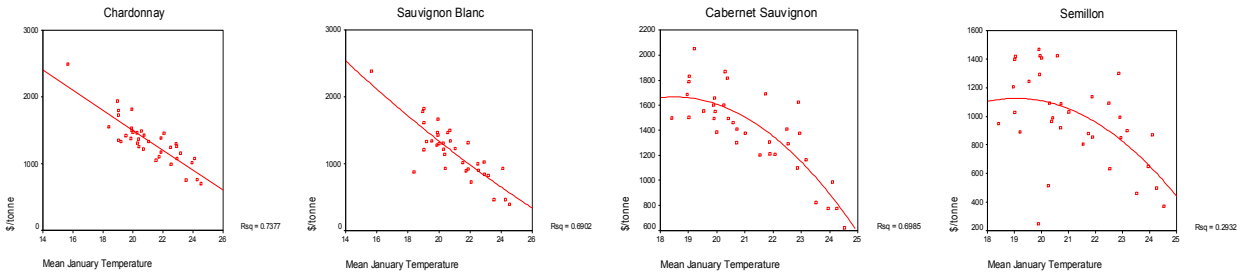


Figure 8 **Indicative variety temperature sensitivities. Influence of mean January temperatures (Australia's wine growing regions) on grape price, a surrogate for quality (Webb 2006)**

Main challenges

What is needed to make more informed decisions about the suitability of current varieties, choice of future varieties and adaptive management strategies:

- Better understanding of how varieties perform in our region and climate
- Information, knowledge and data to respond to climate change and variability
- Recognition of the sensitivity or resilience of each variety to temperature, and what the milestone/indicators are to know when to think about managing them differently and to consider changing varieties.

What can be done to answer these needs:

- The ability to get fine scale climate maps of our region will be very helpful.
- Regional relationships between climate and grape phenology and grape and wine quality are very important. The data we need are available from the climate, phenology and wine records of previous vintages.
- Active groups in each region providing and sharing information on phenology, grape and wine quality from previous and current seasons.
- Overlaying vineyard areas with Tom Lyons' fine scale climate maps (mesoscale) for your region.
- The above information and activities will help us identify what are the best varieties in which location and site. For example, Margaret River has many micro-climates because of maritime influence. Charts can be constructed for each region based on micro-sites.
- Determine how hot is too hot for current varieties.
- Investigate how budburst can be manipulated.
- Determine if the region has the data to respond to regional climate scenarios.
- Identify the milestones in terms of dangerous climate change.

Vineyard water resources and water use in a changing climate (Tony Proffitt)

Presented information on a range of strategies and technologies available to grape and wine producers to manage their water resources and plan for the future.

Key messages:

- Vine water use is likely to increase due to higher temperatures.
- Greater reliance on irrigation but with reduced availability of water due to more variable rainfall and reduced run-off.
- Increased need to harvest and store a greater proportion of our rainfall than we currently do.
- Increased need to use water more efficiently and to reduce losses.
- Plan for the future and evaluate individual situations: there are options and management tools available.

Climate change has the potential to reduce available water supply and increase water requirement in SWWA.

The main source of water for irrigated viticulture in the SWWA comes from the catchment and storage of surface run-off from rainfall.

Rainfall has declined 10-15% since the 1970s and is projected to decline another 2–22% by 2030 (IOCI 2005). Rainfall varies considerably between regions in SWWA. Potential impact of reduced rainfall will vary considerably between regions depending on current rainfall. The high rainfall regions of Pemberton (1145 mm annually) and Margaret River (1045 mm) will be less affected than the lower rainfall areas in the Great Southern such as Mount Barker (660 mm).

The rainfall is projected to become more variable in volume, timing and intensity. It will become increasingly important to capture sufficient run-off when it occurs.

Potential evaporation is projected to increase by 0–30% by 2030.

Strategies to manage water resources

The following strategies were considered:

1. Improving the security of water supply
2. Reducing water loss from the source
3. Maximising water use efficiency
4. Adjusting vineyard management practices
5. Improving site, variety and rootstock selection.

Improving the security of water supply

Maximise dam storage capacity to capture sufficient run-off when it occurs.

New water policy and licensing regulations are being developed. Accurate and up to date information on vine water use will be needed for the approval of vineyard dams and bores and to plan for future climate change.

(i) Roaded catchments

In low rainfall areas of the Great Southern roaded catchments are used to improve the efficiency of water catchments (Figure 9). Roaded catchments are a cost effective technique for increasing the volume of run-off several fold (Stanton 2005). About 1 ha of well designed and maintained roaded catchment will catch sufficient rainfall to irrigate 2.5 ha of wine grapes. The ‘run-off threshold’ is a critical factor determining the efficiency of roaded catchments. The efficiency of roaded catchments has been found to vary considerably between vineyards with run-off thresholds ranging from 2 mm to over 14 mm (Lantzke 2005; Lang 2009). Compaction of the soil surface, application of soil sealants and removal of weeds will make surfaces more impervious to water, reducing run-off thresholds and increase run-off volumes.

Figure 8 **Roaded catchment to improve collection of rainfall run-off in Great Southern, Western Australia (Stanton 2005)**

(ii) New technologies to harvest more rainfall

Harvesting water from vineyard mid-rows can increase run-off volumes considerably. At a vineyard in Frankland black plastic sheeting covering alternate inter-rows (Figure 10) collected 0.74 ML water/treated ha of vineyard during a low rainfall year (600 mm). This volume is sufficient to irrigate 1 ha of vineyard in this region (Rob Hetherington, DAFWA, pers. comm). Harvesting water from vineyard inter-rows can reduce the reliance on roaded catchments.

New techniques and surface treatment for roaded catchments are being tested and further developed and have the potential to improve catchment efficiency and longevity significantly (David Stanton, DAFWA, pers. comm. 2009).

Figure 10**. Harvesting rainfall from the mid-row of vineyards using black plastic sheeting in Frankland, Western Australia (McDonald 2008)**

(iii) Alternative water sources

Use of recycled water from the winery and vineyard; recycled waste water.

Desalination and reverse osmosis to recover otherwise unusable and saline water.

Reducing water loss from the source

Water loss from dams occurs through evaporation and leakage.

Evaporation is a major contributor to water loss from vineyard dams. Average annual evaporation losses in the south west: Mount Barker 1051 mm; Manjimup 1296 mm; Pemberton 1210 mm; Margaret River 1566 mm. Up to 70% of the annual evaporation loss in the south west occurs from October to March.

Several products are available to reduce evaporation loss from dams. These include suspended and floating covers and mono-layer films applied to the water surface.

Food-safe monolayers have been reported to reduce evaporation by up to 30%. This equates to saving 6 ML for a 150 ML capacity dam.

Windbreaks reduce wind speed and improve the microclimate around dams reducing evaporation by 20–30% (Hipsey 2002).

Reduce leakage from dams. The maximum tolerable leakage is approximately 2 mm/day but many dams have higher leakage rates. Leakage of water from earth dams can be significant. Repairing leaking dams can be expensive. Treating the soil directly is usually more successful than adding sealants to the dam water. Walls are best repaired by placing clay around the leakage area when dry to form a compacted soil cover.

A well designed and constructed dam in the right site is a cheaper option to expensive repairs. Design dams to reduce evaporation by reducing the surface area to volume ration. Smaller surface area and deeper dams are better than shallow dams. Rounder shaped dams have less surface area than square or rectangular ones. Pump water into a single dam to increase depth and reduce the surface area to volume ratio.

Maximising water use efficiency

(i) Irrigation efficiency

The irrigation system should be checked to ensure that pressures and flow variations are within acceptable limits, and maintained to prevent losses during delivery to and use within the vineyard.

With above ground drip irrigation watering at night can reduce evaporation loses by about 10%.

Optimise vineyard irrigation requirement using irrigation scheduling plans based on soil type, crop factors and evaporation timing and volume of irrigation (Lantzke 2005).

Regulated deficit irrigation (RDI) and partial root zone drying (PRD) are techniques developed to control vine vigour, improve grape quality and maximise water use efficiency. PRD has had limited success in SWWA because spring rainfall limits the opportunity to impose soil moisture stress early in the season. Under a drying climate with less spring rainfall PRD may become an option.

Subsurface drip irrigation reduces water loss to soil evaporation and run-off.

Monitor soil moisture content using sensors to schedule irrigation and minimise leaching loss. A range of sensors is commercially available.

(ii) Resource utilisation

A range of technologies are available to assist in better positioning of moisture sensors in representative sites in the vineyard. High resolution imagery and yield maps in conjunction with soil and elevation maps are highly beneficial in managing variability in the vineyard.

Adjusting vineyard management practices

Strategies to conserve soil moisture and increase the amount of soil moisture available to the vine will reduce reliance on irrigation when water supply is limiting.

(i) Conserving soil moisture

Mulching under vines can reduce evaporation losses by up to 10–30% (Buckerfield & Webster 2001). In the Great Southern mulch applied 75 mm deep by 0.5 m wide under vines significantly increased water content in the soil profile (Bob Paulin, DAFWA pers. comm.).

Controlling under-vine weeds will reduce competition for soil moisture. The selection of cover crop type and width will influence the competition for water.

(ii) Increasing soil moisture availability

Increase the root volume available to the vine by deep ripping to loosen impermeable clay subsoils prior to planting. Compacted subsoils caused by continuous use of machinery in vine inter-rows can be deep-ripped while vines are dormant.

(iii) Crop regulation and canopy management

Canopy management and crop regulation practices are critical in seasons when soil water and irrigation supplies are limited. Reducing canopy size and crop load can reduce the vine demand for water. A number of strategies can be adopted to achieve this: severe winter pruning; removing unproductive shoots before flowering; removing bunches to reduce crop load after fruit set; slowing shoot growth by removing shoot tips at bunch closure; removing bunches at veraison if necessary to maintain vine condition and balance between canopy and crop if water is limiting. When water supply is insufficient for the whole vineyard it may be necessary to ration water to ensure the most valuable blocks receive sufficient water at critical times at the expense of less economic varieties.

(iv) Improving site, variety and rootstock selection

Managing vineyard site variability by matching grapevine varieties and rootstocks with soil types and their water-holding capacity and microclimates will be a key area in future vineyard developments. Rootstocks are important in managing vine vigour and their influence on yield and fruit quality of the scion variety. 'Drought-tolerant' rootstocks have been identified but require further testing in dry conditions, with different scion varieties and in different sites before recommendations can be made.

Managing vineyards in a changing climate—providing optimum bunch zone temperatures (Erika Winter)

Information on tools and vineyard management options for moderating bunch zone temperatures under warm conditions was presented.

Results and data from three projects with grape and wine producers in Victoria were presented**:** *Bunch zone temperature monitoring and grape and wine quality assessment of Shiraz in North-East Victoria and Pinot Noir in the Mornington Peninsula, and Sustainable management of water and other natural resources for improved wine quality for Shiraz and other varieties in NE Victoria*.

Regional climate data and growing degree days (e.g. Winkler Growing Degree Days) have limited use at the individual vineyard level. The monthly and daily averages do not tell us when and how long grapes are exposed to particular temperature ranges or thresholds.

Importance of bunch zone temperatures

Bunch zone temperature has an important effect on grape quality criteria through its influence on sugar accumulation, acid depletion, colour development, maturation of phenolics and aroma characters. Under hot, dry conditions sugars become concentrated, acid (malic) is depleted, red colour is lost, phenolics may not mature and aromas become 'jammy'.

Bunch zone temperatures were measured hourly during the ripening phase from veraison to harvest.

Bunch zone temperature summations are expressed as the cumulative degree hours above $0^{o}C$ or above a heat stress or below a cold stress threshold temperature. Average degree hours allow comparisons between regions and vineyards and show site, season and management specific effects.

Bunch zone temperature parameters

The optimum bunch zone temperature range and threshold temperature may be variety-specific. Work with Shiraz in NE Victoria and Pinot Noir in the Mornington Peninsula provide an indication of the bunch zone temperature optimum ranges for these varieties (Table 4).

Table 4. **Indicative bunch zone temperature optimum ranges for Shiraz and Pinot Noir from literature**

Variety	Optimum bunch zone temperature	Reference
Shiraz	15–35°C	Bergquist *et al*. 2001 Spayd *et al*. 2002
Pinot Noir	15–26°C	Pirie & Mullins 1980

The optimum bunch zone temperature summation (degree hours > 0°C) varied between warm and cold years.

For example Shiraz in NE Victorian (Winter *et al*. 2007):

Cooler year 2005: Best wines from bunch zone with 23,000 to 28,000 deg h > 0°C

Warm year 2006: Best wines from bunch zone with 20,000 to 26,000 deg h > 0°C.

Bunch zone temperatures were measured using simple, inexpensive temperature datalogger technology. Tiny tag® dataloggers were placed in the bunch zone of the vine canopy (Figure 11).

For Pinot Noir in all years the berry sensory assessment scores and young wine scores were higher where grapes came from a higher percentage of hang time in the beneficial temperature range of 15-26°C (Winter *et al*. 2009).

Bunch zone temperatures are different to those measures in a weather station which tends to moderate the temperatures and heat peaks. Bunch zone temperatures differ from those measured in weather stations which moderate the temperatures and heat peaks.

Canopy management strategies include:

- Growing more leaves in hot years to shade fruit
- Leaf removal on SE or E side of canopy to capture the morning sun
- Shoot positioning on NW or W side of canopy to shade fruit in the hot afternoon
- Managing water to retain differential leaf cover and avoid heat stress.

Berry sensory assessment, berry chemistry (e.g. anthocyanins, Brix, TA and pH), wine chemical and sensory assessment data for each vineyard were related to bunch zone temperature summations (veraison to harvest) to determine optimum average degree hours for the variety and climate. This enables optimum canopy manipulation to be determined to achieve better bunch zone climates for the variety, season and site.

Many single vineyards in the Yarra Valley and the Mornington Peninsula now use dataloggers to monitor the bunch zone temperature of their key varieties.

Bunch zone temperature monitoring enables variety specific, regionally and seasonally adapted differential canopy management (leaf area, leaf health, shoot positioning, fruit load, and fruit exposure) and informed harvest decisions, even in the worst climate scenarios.

Figure 11 **Tiny tag® temperature datalogger measuring and recording bunch zone temperature in the grapevine canopy (Winter. *et al.* 2007)**

Options for the future

Develop the use of temperature dataloggers to optimise bunch zone temperatures in the vineyard. To mange bunch zone temperature we need to be able to measure it. Dataloggers placed in the canopy are an excellent tool. Tiny tag® dataloggers are inexpensive, easy to download and have sufficient capacity to run hourly readings over 70 days, or for the full growing season either 2-hourly readings with two downloads needed.

Investigate the effect of pre-veraison exposure on grape quality (norisoprenoids).

Develop a decision making tool that uses datalogger generated cumulative degree hours (base 0°C) or heat load accumulations (base 35°C) as warning systems.

Develop flexible wire lifting procedures that allow morning sun side wire lifting in cold years and overhanging shoot positioning on the afternoon sun hot side.

Clarify what other factors besides bunch zone temperatures could influence colour, mouth feel and aroma in your wines.

Develop regional variety-specific recommendations through producer group activities to define and ensure regional quality.

2.2 Workshop results and action plans

The wine industry participants identified 217 individual ideas across the four topic areas and three regions (Table 5). Over all regions the topic areas ranked in decreasing order of the number of individual ideas captured were: climate information and projections, water use and management, variety suitability and choice and vineyard management.

Table 5 **Individual ideas in four key strategic areas generated by industry participants at regional workshops**

Topic area/region	Margaret River	Pemberton	Mount Barker	Total	%
Climate information and projections	37	17	18	72	33
Variety suitability and choice	23	7	18	48	22
Water use and management	33	10	22	65	30
Vineyard management	17	7	8	32	15
Total	**110**	**41**	**66**	**217**	**100**

The participants were highly interested in climate information and projections for their region because this information is not easy to come by and is perceived to be highly relevant to their decision making. Vineyard water resources and water use management were also topics of high interest particularly in areas of the Great Southern region due to recent changes in the rainfall pattern. Variety suitability and choice did not show up as highly but were regarded as inextricably linked to climate and included in many of the climate projection ideas. Climate change adapted vineyard management practices did not show up as highly as producers considered much of the information needed is available in industry journals and taught in industry education and workshop programs.

The participants grouped similar individual ideas in each topic and developed action plans for as many of these as possible. A total of 26 action plans were developed across the three regions. Where regions had similar ideas these were combined in the same plan resulting in the following 15 action plans including three for climate information and projections, three for variety suitability and future choices, seven for water resources and use, and two for vineyard management.

Action plans

The industry participants developed plans for actions they would like to see happen in their region. Where regions had similar ideas these were combined in the following plans:

Climate information and projections		
1	**Idea**	**Determine key climate indicators and relate phenology and vintage performance for individual locations** Examples: 1. Growing day degrees (GDD)—defining parameters relevant to Margaret River, Pemberton 2. Temperature variability, mainly during January, February and March ripening period 3. Relative humidity (sea breezes) 4. Duration of extremes in conditions—warning systems needed 5. High resolution 1 km^2 6. Review what our great red and white vintages are and relate to climatic data 7. Models for GDD (± other quality KPI) for main varieties: Chardonnay, Sauvignon Blanc, Semillon and Cabernet Sauvignon 8. Ocean temperatures since 1970s (i.e. via satellite data) to determine the influence of the Leeuwin Current 9. Ability to interpret changes in season as the season progresses (i.e. budget vs. actuals) 10. Expression of projections with probabilities 11. Look at Gladstones' regional map and what makes Willyabrup the best Cabernet Sauvignon area
	What	**Research:** Regional **Information:** Greater information is needed for the region
	Why	Needed for future planning to increase safety, security and profitability
	Who	Growers, Regional Associations, Researchers, local consultants and interests
	When	Start in next 12 months
	Region	Margaret River, Pemberton
2	**Idea**	**Map areas for temperature and other key climate parameters to indicate appropriate planting areas by variety—current and future**
	What	**Research**
	Why	Information needed for planning for future plantings as these regions become more attractive
	Who	Researchers
	When	Start in next 12 months
	Region	Pemberton
3	**Idea**	**Seasonal forecasts and real time information**
	What	Research
	Why	Within season forecasts need in order to better manage for climate and weather extremes: e.g. heat stress and heat waves, frost, cooler or warmer seasons (crop regulation and canopy manipulation)
	Who	Researchers, BOM
	When	Start in next 12 months
	Region	Pemberton, Margaret River, Mount Barker

Variety suitability and choices		
1	**Idea**	**Inventory of variety, climate, soil, clones and rootstocks.**
	What	**Regional research:** Information provision, collation and analysis. Information sharing.
	Why	Determine the most suitable variety/clone for the location and site in each region.
	Who	1. Growers provide information. 2. DAFWA and universities to collate and interpret information and provide recommendations. 3. Funding from GWRDC.
	When	In the next 6–12 months gather basic information Long-term data collection and evaluation—depending on funds
	Region	Margaret River, Pemberton
2	**Idea**	**Variety and climate modelling projections** Snow Barlow and Tom Lyons to collaborate
	What	
	Why	1. Identify varieties suited to specific regions (Pemberton and Manjimup) with climate change in mind 2. Model a wide range of varieties—refer to DAFWA Alternative Varieties Block at MHRI 3. Advising marketing people what will grow best in specific regions and thus what they will need to market ⇨ and which variety for the vineyard to grow from those that are marketable
	Who	1. Growers—provide phenology and variety information for data base and modelling 2. Researchers—Snow, Tom and others in this field 3. DAFWA in cooperation with growers and associations to co-ordinate this information gathering 4. WAVIA—other varieties of interest into WA 5. Winemakers—evaluate wines: Standardise (i.e. provide fruit for micro processing) and/or individual (i.e. own bottled wine)
	When	In the next 6–12 months gather basic information Long-term data collection and evaluation—depending on funds
	Region	Pemberton
3	**Idea**	**Investigate new and current varieties more suited to expected future climate**
	What	**Research:** Prior data on phenology; Management practices of existing local varieties. **Information:** New and locally untested varieties; Saline and drought resistant rootstocks. **Information sharing:** Define grower data collection as ongoing; Website for ongoing data collection and information dissemination.
	Why	1. Industry sustainability in face of climate change 2. Consider cost of changing varieties (grafting vs. rootlings, etc.) 3. Varietal marketability to farm regional advantage.
	Who	All: 1. Growers—initiate and provide data, cooperation and support 2. Wine companies—marketing and funding 3. Researchers and universities—research and analysis 4. DAFWA—facilitate process, include grant applications and many other.
	When	Within 12 months—data collection and collation Within 2 years—industry plan and extension Longer than 5 years—part of an ongoing project.
	Region	Mount Barker, Pemberton

Water use and management		
1	**Idea**	**Extension of information on water policy and legislation**
	What	**Research:** Current evaporation water use figures and prediction tool for the future should be based on climate change information so 30 to 40 years it is still relevant. **Information:** Current policy. **Training:** Training required.
	Why	• Lack of information within the industry • Clarify water rights, user obligations, licensing and issues surrounding water trading (DOW) • Clearing for infrastructure—roaded catchments and dams (DEC) • To keep producers updated and aware of opportunities and responsibilities (legal) • Empower growers in water rights knowledge.
	Who	• Researchers: Update or generate data in uniform format • DAFWA: Facilitate process • DAFWA and Universities: Provide recommendations on policy • Department of Water (DOW): Deliver • Department of Environment and Conservation (DEC): Deliver • WIAWA.
	When	Immediate need within 6 months Long-term, more than 5 years, ongoing.
	Other considerations	• Improve information on vineyard water use, evaporation, etc. within climate change • Industry to be consulted in ongoing development of policy • Should be delivered regionally with relevant, specific information • Much licensing is based on old data so water use/evaporation information needs to be updated to ensure legislation is going to be effective/correct and based on best available information.
	Region	Margaret River, Pemberton, Mount Barker
2	**Idea**	**Update information on water use and management in vineyards for planning and policy decisions**
	What	**Research:** Research and collation of up-to-date vineyard water use and evaporation data
	Why	Need up-to-date accurate information
	Who	• Growers • Researchers, universities and DAFWA
	When	Start within 6 months Ongoing longer than 5 years
	Other considerations	To guide policy makers in decisions using relevant data.
3	**Idea**	**Maintaining/maximizing the water source—water collection and security**
	What	**Research:** Research new products and technologies including waste water management **Information:** Extend information
	Why	• Development of new products and technologies • Collation of current information • Maintaining the current research to sustain the industry and environment
	Who	• Researchers, universities • DAFWA, DEC • Growers, Wine companies.
	When	Within 12 months: Current information extended Within 3 years and ongoing: New research and development.
	Other considerations	Extend information on: • Mulches • Weed control • Run-off techniques • New products for run-off • Reduce dam leakage (e.g. bentonite) • Recycling waste water • Magnet technology for salinity • Desalination.
	Region	Mount Barker, Pemberton

Water use and management continued		
4	**Idea**	**Managing water in vineyards**
	What	**Research** **Demonstrations:** Demonstration sites in vineyards **Information:** Collation and extension of information
	Why	• Increase water use efficiency ⇨ efficient application and monitoring of efficiency of irrigation systems⇨soil structure (organic mater) and soil management (cover crops) and mulch • Maintaining the resource to sustain industry and the environment
	Who	• Growers • Wine companies • Researchers • DAFWA
	When	Seasonal every 12 months Within 3–5 years
	Other considerations	Application of information from other production systems Show benefits of systems used through demonstrations and field trips
	Region	Mount Barker, Margaret River
5	**Idea**	**Information on rootstocks and variety selection for drought tolerance**
	What	**Research:** Rootstocks for drought tolerance **Demonstration:** Demonstration of rootstocks and alternative varieties in the regions **Information:** Information needed
	Why	• Lack of information/knowledge on drought tolerant rootstocks • Lack of demonstration of alternative varieties • Water use efficiencies and maintain production and quality in future • To verify current claims/studies on better/drought tolerant rootstocks
	Who	• Growers • Wine companies • Researchers • Universities • DAFWA • In association with grower/producer groups: WIAWA • International wine growing regions
	When	Within 6 months—update on current research Ongoing, longer than 5 years
	Region	Margaret River, Pemberton
6	**Idea**	**Case study/information on composting and mulching**
	What	**Research:** Research has already been done **Demonstrations:** Demonstrations of 'how to', products, etc. benefits, uses, disease prevention **Information:** Collation of information
	Why	• Improving production (yield and quality) • Environmental management improvements • Collating and distributing current information that is valuable to the industry
	Who	• Growers • Wine companies • Researchers and universities—collate information • DAFWA • WIAWA, WFA, GWRDC, etc.
	When	In the next 12 months Updated in 2 years
	Other considerations	• Also cover topics of soil health, nutritional value, chemical use, water efficiencies, disease, IPM prevention/management • Publication of case study document would be great
	Region	Pemberton

Water use and management continued		
7	**Idea**	Extension project on Best Management Practices for water use/storage grape and wine producer.
	What	**Demonstrations:** Innovation demonstrations on grower properties ⇨ farm visits. **Information:** BMPs, tools.
	Why	• To distribute current information and recommended practices. • Raise awareness and action, especially in areas where water is scarce.
	Who	• Growers • Wine companies • Researchers/universities/DAFWA collation of information • Industry groups, regional associations, state association • WIAWA.
	When	In next 12 months in each region Update annually/biannually.
	Other considerations	• Two-part program—'Pre & post-pump'. • Can be split into grape production & wine production.
	Region	Pemberton

Vineyard management		
1	**Idea**	**Manage climate change and seasonal variability by collecting bunch zone temperature data and relate to wine quality and make recommendations for vineyard management.**
	What	**Research:** What is optimum for wine style and how hot is too hot per variety (temperature x duration). Collect data from number of demonstration plots on commercial vineyards in the SW regions. **Demonstrations:** Producer groups and group events for learning. **Information:** Conduct literature review. Share temperature and quality data. **Training:** How to interpret data for decision making and Berry Sensory Assessment. **Information sharing:** Data base shared via website. **Wine quality:** Small lot winemaking at DAFWA or Curtin Uni. **Variety:** Sauvignon Blanc could be used as model. Develop management tools to prevent greenness or loss of passionfruit character according to intended wine style. SB is an important variety across the SW regions. Riesling also suggested.
	Why	• Manage impact of increase in temperature and extreme temperatures and on wine quality using canopy management to moderate bunch zone temperature. • Develop database and link with weather predictions to develop a warning system with real time data.
	Who	• Growers • Wine companies • Researchers including Universities (grape chemistry) and DAFWA (group coordinator) • Consultants • Regional Wine Industry Association: Margaret River, Pemberton, Great Southern, Blackwood Valley, WIAWA • Field coordinator, data manager, group coordination DAFWA
	When	Within next 12 months: Initial results Second year and ongoing: Use information to change canopy management and other vineyard management practices
	Other considerations	• How much does it cost and who pays (DAFWA, GWRDC, SW Development Corporation)? • Who keeps the project on track? • 'End point' of data produced from initial trial: - How to roll it out - How to make it available - Training on how to interpret/apply in own vineyard - Cost to the buyer
	Region	Margaret River, Pemberton, Mount Barker
2	**Idea**	**Influence of vineyard management practices and vine planting design on bunch zone temperatures and wine quality**
	What	**Short-term research:** • Mulch, weeds, plastic, bare soil, cultivation • Cutting sward, irrigation, training, leaf plucking, canopy management, trellis management, kaolin clays, surround nets and their colour, fans **Long-term research:** • Trellis structure • Row orientation
	Who	• Growers • Wine companies • Researchers • Universities • DAFWA
	When	Start in next 12 months, then ongoing longer than 5 years.
	Region	

Workshop evaluation

The results, summary and conclusions of an evaluation questionnaire distributed to the regional workshop participants and collected at the end of each workshop have been compiled by David Beard (Attachments). The following summarises the response of participants to questions on: the relevance of the workshop to their work and business; whether they would recommend the workshops to others; did the workshops meet their expectations; and would they like to learn more and what should be included in future workshops.

Relevance of the workshop to everyday management

Participants were asked "Will this workshop help you in your everyday management and planning for the future? How?"

A total of 36 participants responded to the question, 30 in the affirmative, four qualified their reasons in some way and for two participants the question was not considered applicable to their circumstances.

Improved canopy management was the most predominant issue mentioned by participants, typified by the comments*: "I have certainly taken some ideas I can use especially in terms of canopy management", "Buy a little datalogger for bunch zone temperature monitoring"* and *"Yes, canopy temperature management"*.

Participants also found value for their day to day management in other key topic areas: *"Yes, choice in varieties plus areas to plant", "Yes, vine physiology meshed with climate projections", "Yes, new plantings", "Irrigation and vineyard design"* and *"Water management"*.

Several participants saw the value in increased awareness in turn impacting on day to day management*: "Awareness of climate and microclimate on grape quality"* and *"Mainly by increasing awareness to pick up on readings and information"*.

Some participants also saw value for the longer, as well as shorter term management planning: *"Maintaining water and canopies in short-term and varietal selections in the long-term", "Definitely, gives motivation to increase day to day monitoring and information vital to future planning and viability"*.

Finally two of the few people qualifying their response in some way responded: *"Not really, the key is managing what you have as best for the conditions faced in the season"* and *"Not particularly, just emphasises current decisions to improve catchments, water storage, etc."*. Two others presumably needed more reflection/exploratory time: *"Not yet, need to access more info"* and *"Not yet, need more conclusions"*.

Participant recommendations to others

Participants were asked if they would recommend the workshop to others.

A total of 38 participants responded to the question, and all said "Yes".

Many people added comments which often included adjectives such as "very good", "definitely", "very informative", "good relevant information". Several reinforced the importance of the workshops for planning for the future: *"Yes, gaining of knowledge and future planning"* and *"Made me realise more of how it is a global problem"* and *"Gives us many planning strategies to handle the challenge of climate change".*

Several participants emphasised the value of the workshops in galvanizing local action: *"Yes, it sparks areas/opportunities for improvement within own business",* and *"Yes, good brain pooling and encourages local actions".*

Participant expectations

Participants were asked "Did this workshop cover the subjects you thought it would?"

A total of 38 participants responded to the question, and of these 36 responded positively. Three people added the comment "and more". One person commented that the workshop was *"More practical than I thought (it would be)"* and several commented on the workshop presentation/organisation, e.g. *"Yes, they have explained it very well"* and *"Yes, very well organised and pre-workshop info was great - kept to time too!"* One person clearly wanted more with the comment *"Yes, a full day for greater detail would have been good".*

Only one participant responded negatively with the comment: *"I would have liked the scientists to agree on some KPIs for climate/quality."*

Participant learning aspirations

Participants were asked "Would you like to learn more? If so what would you like to see included in any future workshop series?"

A total of 30 participants responded positively, and many e made suggestions on possible content.

The large majority of suggestions related to more management content orientated around the subjects addressed in the workshop series: *"More information on vineyard management in warmer climate, more information on variety/clone suitability for climate", "Varieties (not French) that may be more suitable taking climate change into account", "Awareness of climate and microclimate on grape quality", "More on rootstocks and drought tolerance", "Water use/varieties", "Yes, more detail re water harvesting and efficient (water) use", "Pest and disease control"* and *"Production with limited water".*

One participant wanted to learn more about use of new technologies: *"Magnetism/desalination technologies for irrigation water".* Several participants saw a need to maintain a practical approach: *"More on practical management"* and *"Practical training in datalogger use".* One participant emphasised the need to provide locally-orientated content: *"Yes, more local data so it's more applicable locally".*

Several participants reinforced the need for the maintenance of continuity in information provision*: "Yes, ongoing reports"* and *"Keep the climate change information coming, along with case studies/talks from producers who are adapting and how".*

Outcomes and conclusions

This project achieved the main objectives and performance targets using the seminar and workshop program outlined in the project proposal. Key researchers came together to share their knowledge and provide grape and wine producers with the most up-to-date information on climate projections and variability for WA's wine regions and to focus on how these could impact on the wine industry. The grape and wine producers identified seven key 'strategic areas of need' in which they would require support to capture the opportunities and better plan for and manage the potential risks from climate change and variability in their regions.

Producers in three key regions (Margaret River, Pemberton and Mount Barker) developed plans on four key strategic areas (climate, varieties, water and vineyard management) for actions they want to see happen in order for them to make more informed management and planning decisions. It is recommended that the ideas and actions developed by the producers at the regional workshops be supported through ongoing provision of information and engagement with grape and wine producers in practical on-the-ground projects in their regions.

A major outcome of this project is the information presented indicates that the wine regions in South West Western Australia (SWWA) will remain ideally suited to further viticulture development for the production of high quality grapes and wine in the future. The project highlighted the importance of producing regional climate scenarios to provide practical support to grape and wine producers.

Grape and wine producers want to be kept informed, involved and engaged with researchers in their region in order to capture the opportunities and better manage the potential risks from a changing and variability climate.

Over all regions the top strategic areas were: climate information and projections, variety suitability and future choices, vineyard water resources and water use, and vineyard management. The seminar and workshop series highlighted the currently available information, tools, technologies and management options which can be adopted or trialled by producers to adapt to climate change and variability and assist in future planning and management decisions.

Climate information and projections

Fine scale regional climate maps (mesoscale, 1 km^2 grids) can now be produced for specific regions (50 km^2 areas). This powerful tool enables regional climate scenarios to be developed and identification of micro climates within regions.

Regional climate maps can be produced for a range of climate variables. The choice of climate variable will depend on region and what climate information is important to grape and wine producers in their region. Average growing season temperature (October-April), which is a guide to the suitably of a variety to a region, currently differs markedly between Margaret River (intermediate), Pemberton (cool) and Mount Barker (cold). Climate projection for 2050 show a small increase in the average growing season temperature for Margaret River (0.25°C) and larger changes for Pemberton (1.5°C) and Mount Barker (1.5°C).

Greater seasonal variability, increase in the number of warmer years, greater diurnal temperature fluctuations, and higher maximum and lower minimum daily temperature are projected to be features of the future climate.

Variety suitability and choices

The project highlighted the ability to produce fine scale climate information for individual regions and localities will be very helpful in determining the suitability of existing varieties, choice of new varieties and development of adaptation strategies.

The existing key varieties in the three focus regions in this project (Margaret River, Pemberton and Mount Barker) are expected to remain suitable under the current climate projections to 2050. In all regions the vintages for later maturing red varieties (e.g. Cabernet Sauvignon), Semillon and some new varieties (e.g. Tempranillo) are expected to improve. Adaptive vineyard management strategies may be needed for some of the more temperature sensitive aromatic white varieties (e.g. Sauvignon Blanc, Riesling) and Chardonnay for regions to maintain their current wine characters and styles. Climate maps indicate there are ranges of microclimates in each region which can be selected to suit a full range of varieties.

The project highlighted the need to better understand our varieties in our regions. Producers in each region were very interested in forming a group to collect and share their viticulture and wine quality information with researchers to develop a better understanding of varieties in their region and vineyards and identify key climatic indicators. The current variety-climate groupings are based on European benchmarks. The relationship between variety and climate will be quite different in Australia where vineyards are located in lower latitudes. There is a major opportunity to evaluate alternative varieties in our regions for suitability to current and projected climates and to enhance the diversity and quality of the WA wine brand. The choice of varieties and suitability of different wine styles will need to be matched with consumer preference.

Vineyard water resources and water use

The wine industry in SWWA is based on irrigated viticulture from surface water run-off. Climate change is projected to reduce water supply from reduced rainfall and surface run-off and increase water use by vines through increased evaporative demand. The average rainfall in SWWA is expected to decline by 2–22% and evaporative demand to increase up to 30%. High rainfall regions such as Margaret River (1045 mm annually) and Pemberton (1145 mm) will be less challenged by these changes than lower rainfall areas such as Mount Barker (660 mm annually).

The project presented information on a range of strategies and available and emerging technologies that producers can adopt to significantly increase run-off efficiencies and storage volumes, and reduce water use in the vineyard. Improving the efficiency of existing catchments has the potential to increase water catchment volumes 2 to 5 times. New technologies allow significant rainfall volumes to be captured from vineyard inter-rows reducing the reliance on roaded catchments. New surface treatments for roaded catchments can significantly increase their efficiency and longevity. Reverse osmosis and desalination technologies enable the use of alternative sources of water, such as winery water and saline water are available. The project highlights the need for these new technologies to be demonstrated and further developed on vineyards.

Water losses from evaporation and dam leakage can be reduced by 30–60%. Water use in vineyards can be reduced by 10–50% by increasing irrigation efficiency and adjusting vineyard practices to conserve soil moisture and increase soil moisture availability. Drought tolerate rootstocks, clone and variety selection have the potential to further reduce the water requirements of vineyards. Drought tolerant rootstocks in particular need to be tested in vineyard demonstration blocks in different regions.

The vision of vineyards self-sufficient in water is a possibility using current strategies and technologies.

Vineyard management in changing climate

The project highlighted the importance of bunch zone temperature in determining grape and wine quality, sensory attributes, aroma and flavour characters. Bunch zone temperature measurement is an important tool in the production of grape and wine quality in order to ensure regional and varietal expression of sensory attributes and flavour characters.

Canopy positioning and other vineyard management practices such as use of mulch, ground covers and protective sprays can be used to modify bunch zone temperatures in response to season, region and site or short-term weather events.

High interest was shown in the use of simple, inexpensive datalogger tools to measure and monitor hourly temperature within the canopy. It was wondered wether information from the datalogger could eventually be used in quality assurance programs by grape producers and suppliers. It was considered important to determine the optimum temperature bracket for each wine style and how hot is too hot through research. A decision making tool based on bunch zone temperatures and updated with real time data and weather prediction should be developed as a heat load warning system.

High interest was shown in grower group activities to develop specific recommendations for key varieties by region underpinned by research. Sauvignon Blanc was suggested as a pilot model because of its sensitivity to climate in preventing greenness or loss of passionfruit character according to intended wine style.

Bunch zone temperature monitoring would generate the data base needed to develop specific variety, regional and seasonal recommendations for canopy management (leaf area, leaf health, shoot positioning, fruit load, and fruit exposure) and harvest decisions.

Recommendations

The key recommendation is that the ideas and actions developed by grape and wine producers at the regional workshops are supported by ongoing provision of information and engagement with researchers in practical on-the-ground projects in their region.

An understanding of the climatic factors driving grape production and wine quality and how the climate is projected to change in their region provides information to be used by grape and wine producers to capture opportunities, and as a risk assessment tool for planning and managing their vineyards and businesses now and in the future. It is recommended that the variety sensitivity to climate factors outlined in the workshop information be taken into consideration when managing existing varieties and choice of varieties for future plantings. It is recommended that grape and wine producers continue to monitor and record phenology, yield, and grape and wine quality data and provide data from past vintages to researchers in order to develop a better understanding of their varieties in their regions, vineyards and climates. It is recommended that producers identify the key climate factors and information that are most important to them.

The knowledge on vineyard water resources and water use provides vignerons with improved tools and options to plan and manage their water resources to minimise the risks from declining and variable rainfall and increased vine water use demand projected under a changing and variable climate. It is recommended that the new and improved strategies and technologies outlined in the workshops are adopted by producers when managing their existing water resources and irrigation systems, and planning future water requirements. These include, where appropriate: increasing catchment efficiencies, harvesting rainfall for vineyard inter-rows, developing alternative water sources, reducing water loss from dam evaporation and leakage, increasing irrigation efficiency, and adopting vineyard practices that conserve soil moisture and increase soil moisture availability. It is recommended that vignerons collaborate with researchers to identify potential drought tolerant rootstocks, clones and varieties and establish evaluation or demonstration blocks in their region.

The knowledge on the effect of bunch zone temperature on grape and wine quality provides grape and wine producers with improved decision making tools to adjust vineyard design and management practices to optimise bunch zone temperature and moderate adverse canopy temperatures. It is recommended that vignerons monitor bunch zone temperatures of their key varieties to provide an indication of optimum bunch zone temperature, bunch zone heat and cold thresholds temperatures and as an early warning system for adverse temperatures. Simple to use, inexpensive dataloggers can be used.

The nature of climate and its interaction with grapevine varieties is complex. This project recommends grape and wine producers to be cautious when basing their planning and management decision on just one climatic factor. The key climatic factors for each region need to be identified. Furthermore, the regional mesoscale climate models need to be tested against the climate and vintage data for previous seasons to build confidence in their predictions. It is recommended that the climate and wine researchers collaborate with grape and wine producers to collect and analyse these data to determine the key climatic indicators.

The project improved awareness of climate change and seasonal variability issues and identified the possible impacts and opportunities for the wine industry. Producers identified key areas of strategic need and developed action plans for further information, research, development and extension needed in their regions. To increase our understanding and provide practical outcomes for grape and wine producers to tackle climate change and variability recommendations for further research, development and extension include:

Climate information and varieties

- The development of better understanding of the sensitivity/resilience of existing varieties to climate in WA wine regions. This can be achieved by producers collecting and sharing their viticulture and wine quality information from the past with researchers to correlate with climate and identify the key climatic factors in each region.
- Develop a database of variety performance (e.g. phenology, harvest date, fruit and wine quality) for each region and correlate with climate for past and future vintages. This would establish the key climatic factors/indicators and strengthen the climate models.
- Model key viticulture performance indicators (e.g. timing of phenology stages, harvest dates) and wine performance indicators (e.g. quality) with climate projections to assist in planning and managing vineyards in the future.
- Produce mesoscale climate maps for each region. This would provide grape and wine producers and potential investors with the information needed for planning future plantings.
- Develop accurate and timely within-season climate projections and weather forecasts in order to better manage extremes events such as heat waves, heat stress, water stress, frost and warmer or cooler seasons. This would provide a warning system to enable producers to adjust their management strategies such as crop regulation, canopy manipulation and irrigation.
- Utilise the climate-variety models to identify potential new varieties suited to the current and projected climate in each region.
- Identify, introduce and develop new and existing varieties better suited to the current and future climate. For example, seek potentially more suitable alternative varieties from warmer and drier regions in Italy, Spain, Portugal, southern France and Greece. Early knowledge of viticulture, wine quality and style, marketability and consumer preferences of potential new varieties will assist future sustainability of industry.
- Market development and consumer preference research is needed to match potential new wine styles and varieties with consumer and markets.

Water use and supply

- Develop an extension program to deliver most the up to date information including: water policy and legislation; Best Management Practices in rainfall catchment; alternative water sources; water storage and water use in vineyards. Program should include demonstration sites on vineyards and field visits in each region.
- Establish demonstration sites on commercial vineyards to monitor and demonstrate water use efficiency technologies, tools and strategies.
- Further develop and extend technologies which maximise rainfall catchment run-off, collection and storage. Establish a demonstration site on current or new vineyard utilising all available technologies to maximise water source in a sustainable self sufficient way.
- Update information on evaporation and water use in vineyards. Accurate information will benefit planning and policy decisions for future water supply in a changing climate.
- Identify and demonstrate drought tolerant rootstocks, varieties and clones. Information on drought tolerance will assist industry to plan and manage for a sustainable future in a drier climate.

Vineyard management

- Develop a greater understanding of the role on bunch zone temperature in development of wine quality, aroma and flavour characters of key varieties in SWWA wine regions. Determine optimum bunch zone temperatures, duration and timing, and heat stress and cold stress thresholds to provide grape and wine producers with useful information to for their vineyard and winery decisions and for risk analysis in the future.
- Establish a model in-canopy temperature monitoring and warning system to measure bunch zone temperatures in vineyards. It is recommended that the system is based on simple-to-use, inexpensive dataloggers placed in the vine canopy. Furthermore, the system could be developed as a decision making tool which is updated with real time weather data.
- Investigate and develop options for vine growing practices and canopy management systems to moderate bunch zone temperature to enhance grape and wine quality in SWWA. This includes the adaptation of canopy assessment and vineyard management tools (vine balance, leaf health, shoot positioning, fruit load, and fruit exposure) to key varieties and regions.

Appendix 1. Communication

Communication of the most up-to-date information and research on climate change and variability and the potential impacts in Wester Australian wine regions has been a focus of this project. Outcomes have been delivered to industry and research colleagues during presentations at:

- Industry Forum: 'Preparing for climate change in the wine industry' in Manjimup, 5 November 2007
- Regional Workshops: 'Preparing for a variable and changing clime in the wine industry' in Margaret River 16 September, Manjimup 17 September and Albany 18 September 2008
- Climate 21 Conference: 'Planning and managing vineyards in a variable and changing climate' in Perth 5 March 2009.

Presented a summary of the findings and outcomes of this project at the DAFWA-sponsored Climate 21 Conference in Perth on 5 March 2009.

Written communication has been conveyed to industry and a larger audience on a number of occasions. Reports have been included in the *WA Wine Industry Newsletter* and *Australian Viticulture*:

- Proffitt, T. and Ward, G. (2009). South-west Western Australian vineyard Water Resources in a changing climate. *Australian Viticulture* 13 (2): 15-20.

A number of newspaper articles on the regional workshops were published including:

- Climate issues for wineries. *Manjimup Bridgetown Times*, 24 September 2008
- Wine and climate change. *Augusta-Margaret River Mail*, 17 September 2008
- Climate change for local winemakers. *The Extra* (Albany), 26 September 2008
- Climate ushers in changing times. *Countryman* (Horticulture Supplement), 2 October 2008.

Appendix 2. Intellectual property

No intellectual property has been generated as part of this research and extension project. This research has focused on the development of knowledge for industry which is contained herein.

Appendix 3. References

Barlow, S. Webb, L. & Dunn, G. (2008). Growing Quality Grapes in a Changing Climate – are your varieties right for the future? Presentation at Western Australian Regional Workshop series 'Preparing for a variable and changing climate in the wine industry', September 2008. www.agric.wa.gov.au

Bergquist, J., Dokoozlian, N. & Ebisuda, N. (2001). Sunlight exposure and temperature effects on berry growth and composition of Cabernet Sauvignon and Grenache in the Central San Joaquin Valley of California. Am. J. Enol. Vitic. 52 (1), 1-7.

Gladstones, J.S. (1965a). The climate and soils of south-western Australia in relation to vine growing. *Journal of the Australian Institute of Agricultural Science* 31, 275-88.

Gladstones, J.S. (1965b). Soils and climate of the Margaret River-Busselton area: their suitability for wine grape production. Department of Agronomy, The University of Western Australia, mimeo, p. 11.

Gladstones, J.S. (1999). Inaugural Wine Baron Lecture: Western Australian Viticulture—then and now. Department of Agriculture Western Australia, Miscellaneous Publication 25/91.

Hipsey, M. (2002). Using windbreaks to reduce evaporation from farm dams. Farmnote 72/2002. Department of Agriculture and Food, WA.

IOCI (2005). Bulletin 6. Indian Ocean Climate Initiative panel, Perth, August.

Jones, G. (2006). Climate change and wines: observations, impacts and future implications. *Wine Industry Journal* 21 (4): 21-26.

Jones, G.V. (2008). Climate change impacts on terroir: how have viticulture terroirs changed and what does the future hold? Presentation as part of Miegunyah Distinguished Visiting Fellow, Melbourne University, 7 May.

Lantzke, N. (2005). Increasing runoff to on-farm irrigation dams. *Australian Viticulture* September/October: 70-71.

Lang, M. (2009). Every drop counts in water harvesting. *Australian Viticulture*13 (4) 37-43.

Lyons, T.J. & Considine, J.A. (2007). Modelling meso-climate in Margaret River. *Australian and New Zealand Grapegrower and Winemaker* 524: 65-9.

McDonald, C. (2008). Increasing irrigation water and controlling vigour by collecting runoff from the mid rows in vineyards. GWRDC project 04/01-1, Final report.

Olmo, H.P. (1956). A survey of the grape industry of Western Australia. Vine Fruits Research Trust, Perth.

Proffitt, T. & Ward, G. (2009). South-west Western Australian vineyard water resources in a changing climate. *Australian Viticulture* 13 (2): 15-20.

Schultz, H.R. (2007). European challenges: proceedings 13th Australian Wine Industry Technical Conference, Adelaide SA, 28 July to 2 August 2007.

Seguin, B. & Cortazar, I.G. (2005). Climate warming: consequences for viticulture and the notion of 'terroirs' in Europe. *Acta Horticulturae* 689: 61-71.

Soar, C. & Sadras, V. (2007). Impacts of temperature on yield and berries are investigated. GWRDC, R&D at Work, August 2007.

Spayd, S.E., Tarara, J.M., Mee, D.L. & Ferguson, J.C. (2002). Separation of sunlight and temperature effects on the composition of Vitis Vinifera cv. Merlot berries. *Am. J. Enol. Vitic.* 53 (3), 171-182.

Stanton, D. (2005) *Roaded catchments to improve reliability of farm dams,* Bulletin 4660, Department of Agriculture, Western Australia.

Webb, L.B. (2006). The impact of green house gas-induced climate change on the Australian wine industry. PhD thesis, School of Agriculture and Food Systems, The University of Melbourne. http://eprints.infodiv.unimelb.edu.au/archive/00003030/

Whetton, P.H. (2007). 'Global climate change—the underlying causes and predictions for the future,' Proceedings 13th Australian Wine Industry Technical Conference, Adelaide SA, 28 July to 2 August 2007.

Winter, E., Lowe, S. & Bullied, N (2007). Bunch zone temperature monitoring throughout ripening and grape and wine quality of Shiraz in North-East Victoria. *Australian Viticulture*, January 2007.

Winter, E., Braybrook, D. & Aldridge, M. (2009). ' From vine to wine—benchmarking Pinot Noir in the Mornington Peninsula.' *The Australian and NZ Grapegrower and Winemaker*, January 2009, pp. 40-46.

Appendix 4. Staff

Staff engaged on this project included:

- Mr Glynn Ward, Project Manager for the Development of Premium Winegrapes, Department of Agriculture and Food, Western Australia (0.25 FTE)
- Ms Kristen Kennison, Viticulture Research and Development Officer, Department of Agriculture and Food, Western Australia (0.1 FTE)
- A/Prof Mark Gibberd, Curtin University of Technology, School of Agriculture and Environment (0.1 FTE)
- Ms Diana Fisher, Viticulture Development Officer, Department of Agriculture and Food, Western Australia (0.1 FTE)
- Mr Colin McDonald, Viticulture Research Officer, Department of Agriculture and Food, Western Australia (0.1 FTE)
- Mr David Beard, Development Officer, Industry and Rural Services, Department of Agriculture and Food, Western Australia (0.05 FTE)
- Ms Kerry Hill, Development Officer, Natural Resource Management, Department of Agriculture and Food, Western Australia (0.05 FTE)

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Appendix 5

5.1 Individual ideas underpinning topics identified at the industry forum.

This section groups all the ideas identified by the individual industry participants at the forum workshop into seven key topic areas.

Effects of climate change on vines

- Climate modelling for local response—emphasis on phenology for Mount Barker Region
- Research impact on quality
- Research into possible ways to moderate responses to increasing temperature (e.g. hormones)
- Effects on dormancy, e.g. shorten dormancy period; storage of carbohydrates, etc.
- What areas in WA will benefit or suffer relative to others
- Better knowledge of the effects on temperature of the Southern Ocean sea breeze in summer.

Varietal choices and suitability

- Quality implications of earlier harvest and shorter growing seasons from a varietal perspective. (Balance of grape composition when high baumé is reached earlier.)
- Effect of change on quality/variety due to heat-load.
- Research on different clones in area on a collaborative basis.
- Identify specific clones that can adapt to a warming climate rather than changing grape varieties per se.
- Will it be better financially to continue with the grapes we have or to change varieties?
- Varietal and rootstock development research.
- Variety/clonal selection research.
- Varietal suitability—clonal variation.
- Vineyard development—suitability of varieties to regions.
- Identify if/when slow-ripening varieties (e.g. Riesling) will become unsustainable in southern regions (Mount Barker, etc.).
- Suitability of existing or new varieties/clones to specific sites and subregions.
- Variety types for regions in the future.
- Local research on climate and grape variety performance (Mount Barker). Researchers need to approach growers to assist in studies (most of us are very willing).
- Variety choices and recommendations.
- Need to know at a regional level, what are the varieties and what are the comparative advantages of different regions when it comes to grape quality.

Water use and management

- Application of water to prolong rapid sugar levels rising—to preserve berry and flavour characteristics.
- What are the impacts for non-irrigated organic vineyards?
- Define water use impacts and quality parameters.
- Improved quality of water—available water is of poor quality (saline). How can this be achieved?
- Water collection—less evaporation.
- Water storage, management and use guidelines.
- The best ways to manage our water supplies.
- Water management—maximising efficiency of irrigation.
- Water requirements (irrigation) to counter reduced rainfall.
- Methods for improving water-use efficiency in the Great Southern.
- Methods for increasing security of water supply in the Great Southern. Increasing catchment yields and reducing evaporative loss.

Information provision and ongoing engagement

- Aid to producers on developing relevant data banks (e.g. for Leanne Webb's research).
- Tiered approach—research; operational; region and variety specific.
- Must first involve regional associations before state or national bodies.
- On the ground regional information sets as a first step in information provision (region x variety specific).
- Better regional information on daily maximum and minimum temperature during the growing season over the last 20 years.
- Practical advice on where (at regional levels) vineyard development is most at risk.
- Website information that shows general climatic trends (simple for farmers to read).
- Website to provide industry networking opportunities to see how other viticulturists are dealing with climate change.
- More information on the climate change as it occurs.
- Newsletters on local effects of climatic change and varieties being trialled.

Vineyard management

- What specific technology can be used to combat climate change? i.e. sprays onto fruit/canopy to repel radiation?
- Practical measures to manipulate phenology in warmer climate scenario.
- Adoption of management practices to cope with climate change.
- Managing effects of higher sugar levels (alcohol) due to greater sugar ripening ahead of flavour and colour ripening.
- Support in more organic soil management principles which enables natural processes to help vines cope with higher temperatures by increasing water-holding capacity and biological activity within the soil profile.
- Management options to deal with frosts in Margaret River (from warmer springs and less cloud cover).

- Managing effects of storm events, i.e. damaged vines and botrytis.
- How to maximise yield and quality in a warmer climate.
- Canopy protection during periods of high temperatures—research into products to reduce transpiration, etc. or environmental management (mulches, watering, etc.).
- Information on making vines more drought tolerant.

Social impacts

- Social study on the impact of climate change on the wine industry.
- Relocation of the Australian wine industry out of the heartland of South Australia—what is the cost and where will it reside—environment, economic and social impacts.

Business strategies

- How will climate change affect Australia's quality and competitiveness as a whole?
- Business strategies for coping with costs of modifications and changes.
- Long-term SWOT analysis on the regional, state and Australian wine industries (marketing and economics).
- Effects of lower yields on prices and effects of these on production efficiencies.

5.2 Individual ideas underpinning the action plans developed at the regional workshops

5.2.1 Climate information and projections

Margaret River

Idea for action	Individual ideas covered
Key climate indicators and climate projection maps for specific regions and areas	We need very localised data collection—microclimate data in 1 to 2 km^2 areas.
	Regional models run in predictive mode with prediction of temperature January to March.
	Would smaller scale actually give more information?
	Set up more automated weather stations (meteorolgical services) between the capes for extra data.
	What are the specific factors that contribute to patterns of modelling (e.g. altitude)? There is an area around Forest Grove that seems to be less affected, why?
	Is there a significant impact of sward/colour of land mass (i.e. not just vegetation) compared to bare earth? Are there implications for vineyard management (including water use)?
	What are the impacts of dams and evaporation for the climate predictions and if we increase dams or change our dam management will this impact or is it insignificant?
	Does dry = less cloud more sunburn?
	Temperature variability—Gladstones' concept, how can we use meteorological data to predict this.
	Influence of creek system cf sea breeze conducted up creeks.
	Can projected mapping be used to redefine the boundaries of the subregions in the Margaret River area?
	Regional mapping and interpretation/explanation/variety sweet spots
	Publication of models in A4 format or larger (digital)
	Extension and interpretation KPIs—^oC, rain, distribution
	What will change in the ripening periods (e.g. GDD) across the region?
	We need rainfall projections.
	Is there an effect on light quality/intensity through climate change?
	How will warming affect the watertable?
	Can we have larger pictures to better see resolution?
	Will the SW (Margaret River) be less affected by change due the ocean orientation around the cape (i.e. three oceans to the cape compared to inland regions.
	Predicted increase in average temperature 0.2-1.8°C is pretty big range (x 9). How do we know importance?
	Can we affect local CO_2 levels and would it make a local difference?
	Changes in water run-off events?
	Changes in soil water retention during winter?
	Leeuwin Naturaliste Current / melting Antarctica
Within season climate forecasts	Projected temperatures over the growing season and rainfall.
	What is the effect on wind velocities (average) during the growing season?
	What are the likely events of hail or 10/10/20 increases?
	As a vineyard manager the variability of individual seasons plays a greater role in quality management than the overall warming trend. Monitor and adapt vineyard practices to the current season.
	Information on within season risks (e.g. > 35^oC).
	Predictions of variations for the season ahead (i.e. accurate long-range changes).
Accuracy and confidence in climate projections	How accurate is the modelling in predicting small areas of the SWWA for the next 30 years (i.e. the productive age of grapevines)?
	Are there emerging technologies that will aid in the modelling 5 years from now to help with projected plantings going forward.
	End of 'little ice age' effect temperature data for this season.
	When is the next ice age due?
	Are the local weather conditions going to change (i.e. wind speed and strength, RH, sea breeze direction, rainfall intensity/period/timing).

Manjimup

Idea for action	Individual ideas covered
Key climate indicators and climate projection maps for specific regions and areas	Can we get data and projections for our local (vineyard level) area
	Have to be able to give people/industry positive actions and practices to move forward with, otherwise potential to get overwhelmed and feel useless
	What data do we want from the model: - potential for frost/storm warning or high risk times for powdery mildew - get variety predictions, etc. for other regions (e.g. Blackwood Valley)
	Projected season length for each variety is data that I think is essential and should be made available with an expert summary ⇨ in a time frame that is of use to change management practices
	Growing season for grapes for Chardonnay re wine quality for 120 vs. 140 days.
	Could we look at this data to project vine stages more exactly from budburst date?
	Mean temperature variability across a region and interpretation would be data I would like access to.
	2006 was a globally warm year but cooler for the SWWA, why?
Accuracy and confidence in climate projections	Do the projected outcomes allow for government changes on global warming after 20 years.
	Where did the temperature data come from for the projections.
	Where did the rainfall data come from for the projections.
	Is there a difference in global warming from the northern and southern hemispheres?
Within season climate forecasts	Could we look at this data to foresee problems, e.g. cold year may need more bunch plucking, sunlight penetration tactics?
	Forecast to predict seasonal variability, e.g. knowing when it is going to be hotter or cooler season ⇨ manage pruning, crop load, etc.
	Forecast model for extreme weather events in a growing season, i.e. hail forecast that Margaret River had last season.

Albany

Idea for action	Individual ideas covered
Key climate indicators and climate projection maps for specific regions and areas	Broader analysis by geographic area, i.e. Frankland, Denmark
	Projected growing season days by variety—maybe over 5 year periods
	Short growing season
	Extreme spikes within season have potential to cause more problems than small general increase
	Need data for Albany and Denmark
	Need individual vineyard microclimate data, record growing degree days
	How do you adjust heat loads during ripening if bunch zone temperature indicates such needs; at what trigger points? How many trigger points?
	Forward looking climate maps for specific areas, where to get information.
Within season climate forecasts	Accurate weather predictions will become more important than warming trends.
	Satellite climate warnings.
	To be forewarned of change, therefore adjust management.
	Two to 5 day forward outlooks for heat spikes during growing season particularly leading into vintage (veraison onward).
	Local temperature/weather monitoring, not only for growth but spray windows.
	With predicted climate changes can you also predict changes in wind?
Accuracy and confidence in projected climate information	How accurate is the information (vineyards data—how good?).
	Nothing seems new from 1960/70 predictions of Indigo Jones and Lennox Walker on the SW corner of WA becoming hotter and dryer with greater accuracy. Yet today's weather forecasters can't seem to get tomorrow's weather predictions right.

5.2.2 Variety suitability and future choices

Margaret River

Idea for action	Individual ideas covered
Variety x climate suitability of current varieties in the Margaret River regions	Can you get access to climate maps (current and projected) to overlay vineyard/variety locations? Will keep to …?… future plantings and fruit sourcing.
	Is there clonal data for the grapevine climate/maturity groupings.
	Climate zone where a particular variety can perform well for a given place.
	Research on climate if climate change will pass the threshold zone.
	Internet data base needed for the phenological information for the whole region.
	Climate/maturity groupings for the Margaret River region.
	Database for current varieties—amount under vines, prices, market projections.
	What varieties for ultra premium wines by micro climate local data.
	Do we need to rethink/alter our viticultural practices (i.e. irrigation, canopy management) to accommodate the change in climate with particular reference to those varieties that are marginal (e.g. Riesling) versus suiting the variety to the change in climate?
	Temperature x variety mapping of Margaret River.
	Carbon dioxide levels x variety mapping of Margaret River.
	Why does CO_2 decrease water use when temperature increases?
Variety choice and management for specific locations and sites	Site selection and management practices can overcome effects of climate change to some degree
	Will irrigating at the end of winter especially during dry years delay budburst by decreasing soil temperature? Also the effect of cover crops on soil temperature and budburst.
	Is there any data or trials completed on partial dormancy of grapevines and longevity of health/viability? Does lack of dormancy affect life of vines?
	Rootstock trials in northern versus southern WA (e.g. Dandaragan vs. Pemberton) by variety to compare—phenological parameters, canopy adaptation to low RH and high CO_2 flavour development at high temperatures.
	Variety and rootstock behaviour and selection under drier and warmer climates.
	Rootstocks versus own rooted
	Grafting and genetic health/compatibility
	Aromatic versus textural selections
	Temperature ripening for maturity groups versus RH in the models
	Rootstocks
	Can GM play a part in temperature tolerance/variability?

Manjimup

Idea for action	Individual ideas covered
Variety x climate suitability of current varieties in the Margaret River regions	Harold Olmo recommendations for the South West in 1950s
	Grapevine/maturity groupings needed for all Western Australian regions
	Growing only the varieties that are best expressed in GI climate
	Can we have this data tied together with Tom Lyons' climate work to give us information for varieties for our vineyards
	Possibility of wine companies purchasing Sauvignon Blanc from Pemberton only: Margaret River north growing Cabernet Sauvignon, Merlot, Chardonnay, etc.
Variety choice and management for specific locations and sites	Varieties are market-driven not climatic at the moment.
	We need varieties that are suited to more variability. For example, can handle hotter but more variable temperatures.

Albany

Idea for action	Individual ideas covered
Variety choice and management for specific locations and sites	More suitable varieties other than the classic French varieties
	What new varieties developed are allowing for climate change. For example is climate change being taken into consideration so that whites can be successfully grown in climates 1-2°C warmer?
	Better information for variety selection to suit climate change
	Grape varieties to handle a dry climate in the next 10 years.
	Testing grape varieties for a dry climate.
	Need for new white varieties to the region
	Winemaker to pay attention to the style of wine produced
	Optimum climate range for particular varieties. How flavour characteristics affected by warming
	Do we have local evidence of phenological shifts over the region based on producer data and what does it show up?
	Have we mapped the two-year cycle of phenology of our various varieties to determine differences
	Great Southern has advantage of starting cooler than other areas ⇨ $$$$!!
	Balance will be a bigger issue (acid level ±)
	Managing sugar levels for optimal result
	What happens with flavours?
	Earlier ripening with higher alcohol levels.
	Rootstocks: What effect will changing them have?
	Reds for the Mount Barker region should improve
	What microclimate change can minimise the impact of increase in temperature, e.g. decreasing the density of canopy to increase the cooling early sea breeze.

5.2.3 Vineyard water resources and water use

Margaret River

Idea for action	Individual ideas covered
Current and new technologies for water catchment and storage	Leaking dams
	Windbreaks
	What are the predicted changes in watertables?
	More information on treating winery waste water for vineyard use and/or reusing in the winery—recycle water
	If reduce the amount of water evaporating from dams is there a climatic implication or is it insignificant?
	Water harvesting from plastic sheeting does it have an impact on canopy temperature? Amount of water deep in the root zone? Colour probably has a significant impact, e.g. RMI research on black asphalt and green … trees in urban areas changed local temperatures by 2^{o}C.
	Water harvest and storage versus the environment
	If we catch more run-off what are the implications for surrounding vegetation and for the aquifers? Should there be a limit? Are there public policy implications?
	Better use of available moisture in soils and dams
	Aquitaine, is it environmentally friendly? Any research.
Current and new technologies to reduce water use and improve irrigation efficiency	Cover crop management—significance of slashing (i.e. keeping crop low on water use)
	Water use by young vines higher than mature cropping vines
	Look at changing irrigation blocks
	Water to soil type
	Require simple to use moisture monitoring system better than gypsum blocks
	Require techniques to manage vines to produce quality grapes with minimum or no irrigation.
	Will there be an effect to established unirrigated vines/vineyards?
	Effect of fewer deeper watering during hot weather
	How do you store water in the profile?
	Plastic strip under vine (e.g. strawberry).
	Cultivate surface mid-row to reduce capillary action evaporation vs temperature from bare soil?
	Does raised CO_2 lower water use?
	Use of native grasses as cover crops
	Precision viticulture techniques to use water more efficiently
	Increase root zone
	Canopy management
	Mulching
	Establish young vines under sprinklers to increase root zone size
.	Water availability is already becoming limited (i.e. Willyabrup). Lobbying is required to ensure continued access to develop the industry. Relate $ value of end product to each megalitre used in the wine industry.
	Augusta-Margaret River requires 'justification' for dam sizes. Political change required for easier approval of water safeguarding requirements.
	Better information on current and predicted vineyard water use.
Drought tolerance—rootstock, variety and clone selection for dry climates	Rootstock research needed.
	Information needed on suitability of rootstocks in Margaret River.

Manjimup

Idea for action	Individual ideas covered
Current and new technologies for water catchment and storage	More awareness/education on water use and storage efficiencies as accepted. Best management practice.
	Not only water use/storage but quality.
	Plenty of water.
	Aquitaine x windbreak interaction to reduce evaporation from water storage
	Water storage in aquifer recharge.
Current and new technologies to reduce water use and improve irrigation efficiency	Use of systems such as environmental management systems, Freshcare and other quality assurance programs to provide tools for better monitoring and management of issues such as water use efficiency.
	Compost and mulches ⇨ best ones to use, disease potential.
	Improve soil water-holding capacity
Drought tolerance—rootstock, variety and clone selection for dry climates	Rootstock trials with regards to wine quality and drought tolerance.
	Follow up research on drought-tolerant rootstocks.

Albany

Idea for action	Individual ideas covered
Develop and extend current and new technologies for water catchment and storage	The effects of dams/water catchments on water table levels: - best suggestions (e.g. location, size, depth) for low impact vs. worst types with high impacts.
	Effects of more dams and catchments on the environment, e.g. groundwater decrease, land clearing effect on microclimate, increase of decreased groundwater on salinity—trees, vegetation.
	Utilisation of technology and desalination.
	Technology for poor quality water.
	Reducing water loss after capture (evaporation/leakage).
	Accurate localised evaporation figures.
	Better water management techniques: - run-off - mulching, what are the different types and $$$$ - dams.
	More dams?
	Recycle waste water from winery.
	Deep dams are better.
	Find alternatives to roaded catchments which may become environmentally inappropriate in the future.
Develop and extend current and new technologies to reduce water use and improve irrigation efficiency	Increased evaporation is - constant or improved with CO_2 change; - crop needs ⇨water storage and irrigation efficiency.
	Better water management techniques: - run-off - mulching, what are the different types and $$$$ - dams
	Weed control!
	Value of increasing organic content of soil to increase water-holding capacity of soil.
	Techniques to compost grass between rows and pruning and place under the vine row.
	Efficiency of water application versus capital costs.
	Less water how to use better.
Extend information and provide input into water policy and legislation for future	Water policies, regulations
	Identify water supply needs for the future: - impact of climate change on water storage and matching to water requirements.

5.2.4 Vineyard management in a changing climate

Margaret River

Idea for action	Individual ideas covered
Monitor bunch zone climate to determine optimum conditions and heat load thresholds for specific existing varieties	Measure and adapt in individual vineyards Use dataloggers to measure bunch zone temperatures Heat loads and cold nights have more influence than optimum growth temperature range 18 to 28^{o}C Corresponding bunch zone temperature data for Margaret River would be good Where do you buy the Tiny tag dataloggers? Need canopy data sets, interpretation of data, decision-making and training Hot temperatures—duration at high temperature and how long does it have to be very hot to be significant (e.g. 30 min, 1 hour, 6 hrs) How to obtain good quality weather predictions/real time information to make changes to vineyard management practices
Options for training and canopy management systems to optimise grape and wine quality	Variety x style x row orientation ⇨ exposure, balance What will be the different trellis practices suited for the future? What is the effect of shading on fruitfulness?
Other vineyard practices influencing canopy climate	Use of sprinklers/fans to reduce temperature Clay screen prevent heat accumulation Bare ground under vine raises canopy temperatures What is the interaction of water management practices with canopy temperatures? How much can canopy temperatures be manipulated by irrigation? Do clay sunscreens prevent heat accumulation?

Region: Manjimup

Idea for action	Individual ideas covered
Monitor bunch zone climate to determine optimum conditions and heat load thresholds for specific existing varieties	How to bring this information and methods down to our region/vineyard Groups checking grapes and wine and feedback of colour/flavour to find out problems RITA funding for benchmarking survey as undertaken in Mornington Peninsula, King Valley Potential for a group looking into these factors across the wine areas. Better comparison of fruit quality x vine management x temperature x water irrigation, etc. to gauge where we can improve practices and quality. Integrate datalogger monitoring with disease prediction.
Other vineyard practices influencing canopy climate	What would be the key stages/times to measure and determine what, if any, canopy management procedure needs to be done.

Albany

Idea for action	Individual ideas covered
Monitor bunch zone climate to determine optimum conditions and heat load thresholds for specific existing varieties	Monitoring canopy climate. Awakened appreciation of vineyard evaluation. Market price dependent on datalogger proving that optimal temperature range was achieved for a given variety. Manage canopy in higher vigour environment, e.g. disease management. Canopy management through temperature monitoring in order to offset temperature shifts through climate change leads to better management of sugar levels and flavour.
Options for training and canopy management systems to optimise grape and wine quality	Impact of different trellising systems on bunch zone temperature: - Smart-Dyson and either east or west side training foliage down.
Other vineyard practices influencing canopy climate	Microclimate assistance i.e. mulch? Soil conditioners? Already not 1 October, now 3 years in very early September coupled with harvest finish in march (5 weeks earlier). Rootstock selection. Forced feeding vines?

Appendix 6. Budget reconciliation

Budget reconciliation is supplied by the Wine Industry Association of Western Australia (WIAWA) in a separate document.

Preparing for a Variable and Changing Climate in the Wine Industry

Half day Regional Workshops in Margaret River, Manjimup and Albany

Planning and managing vineyards under a changing climate
What are the challenges and what are the opportunities for your region?

Workshops held in:

Margaret River
Tuesday 16 September 2009
8.20 am to 12.30 pm
Centre for Wine Excellence, Curtin University

Manjimup
Wednesday 17 September 2009
8.20 am to 12.30 pm
Manjimup Horticulture Research Institute
Department of Agriculture and Food

Albany
Thursday 18 September 2009
8.20 am to 12.30 pm
Albany Senior Citizens Hall
Grey Street, Albany

Free half day workshop. Refreshments provided.

RSVP by 12 September to:

Department of Agriculture and Food's Manjimup Horticulture Research Institute
Telephone: 9777 0000
Email: dfisher@agric.wa.gov.au

Grape and wine producers are invited to attend one of three regional workshops to hear specialists' presentations which will assist you in making more informed decisions in managing and planning vineyards under a variable and changing climate and have your say on the important factors for your vineyard, business and region. ***These workshops will focus on climate projections for the Margaret River, Pemberton and Mount Barker regions.***

Climate change has the potential to fundamentally reshape the Australian wine industry. Western Australia's south west will become more important relative to other warmer growing wine regions of the nation. Climate change and seasonal variability will present the state's wine industry with challenges and opportunities. At last year's seminar and workshop grape and wine producers identified key topic areas where they wanted to be kept informed, involved and engaged with researchers in order to better plan and manage their vineyards and businesses under future climates.

The regional workshops will focus on four key topic areas

1. ***High resolution climate change projections for your region.***
2. ***Suitability of existing varieties and variety choices for the future.***
3. ***Managing water more efficiently and addressing future water availability.***
4. ***Managing vineyards to ensure quality in hotter seasons and warmer***

Specialist Presenters are:

Professor Snow Barlow (University of Melbourne)
Snow Barlow is at the forefront of thinking and planning on climate change in the Australian wine industry. He will report the impact of a warmer climate on grape ripening patterns and wine styles in existing varieties and present options for future choices in varieties and locations of vineyards in Western Australia's wine regions.

Professor Tom Lyons (Murdoch University)
Tom Lyons is a leading climate modeller whose work attracts interest and support from national and international organisations. Tom has produced detailed, high resolution (mesoscale) climate models for the Margaret River, Pemberton and Mount Barker regions and will discuss how these projections will impact on viticulture parameters in your region.

Dr Erika Winter (GrapeLinks)
Erika Winter will present information on how vineyard management practices can be adapted to hotter seasons and warming climates and demonstrate monitoring tools which can assist grape producers and viticulturists. Erika is well known to many Western Australian vignerons who have attended her training workshops on 'wine grape quality management' and 'wine grape berry sensory assessment'.

Dr Tony Proffitt (AHA Viticulture)
Managing water more efficiently and future water availability for irrigation is one of the most critical issues facing the wine industry. Tony Proffitt has extensive experience in planning and developing vineyards in Western Australia's wine regions and will present information on how we can address future water availability and management issues in a drying climate.

Have your say:

In addition to hearing about the latest practical information, options and tools, grape and wine producers will be asked to share ideas and identify the important factors for their region, say what needs to be done, when and by whom.

Your input is needed to ensure that we can work with you to meet the challenges of a changing climate.

For further information on the workshops please contact Glynn Ward, Department of Agriculture and Food, Western Australia
Telephone: 9368 3568 Mobile: 0439 523 024 Email gward@agric.wa.gov.au.

Preparing for a Variable and Changing Climate

Regional Workshops for Grape and Wine Producers

Margaret River

Tuesday 16 September 2008

Venue: Winery W10, Centre for Wine Excellence, Margaret River Education Campus, Bussell Highway, Margaret River

Time	Topic	Speaker
8.15 am	Open—tea and coffee	
8.30 am	Welcome	Mark Gibberd, Chairman *Curtin University of Technology*
8.35 am	Background and Overview *What actions do you want to happen in your region?*	Glynn Ward *DAFWA*
8.45 am	Climate change projections for the Margaret River region *What key climate information do you need?*	Tom Lyons *Murdoch University*
9.15 am	Variety choices and suitability *What options could suit your region?*	Snow Barlow *University of Melbourne*
9.45 am	Water use management *How can we address future issues?*	Tony Proffitt *AHA Viticulture*
10.15 am	Vineyard management *How can we adapt our practices?*	Erika Winter *GrapeLinks*
10.45 am	Morning tea	
11.00 am	Workshop session *Ideas for action*	
12.00 am	Summary and Remaining Issues	
12.20 pm	Closing remarks, Evaluation sheets and Farewell	Mark Gibberd, Chairman *Curtin University of Technology*
12.30 pm	Lunch and Close *Lunch provided*	

Preparing for a Variable and Changing Climate

Regional Workshops for Grape and Wine Producers

Manjimup

Wednesday 17 September 2008

Venue: Manjimup Horticulture Research Institute, Department of Agriculture and Food, Western Australia, South West Highway, Manjimup

Time	Topic	Speaker
8.15 am	Open—tea and coffee	
8.30 am	Welcome	Diana Fisher, Chairman *DAFWA*
8.35 am	Background and Overview *What actions do you want to happen in your region?*	Glynn Ward *DAFWA*
8.45 am	Climate change projections for the Pemberton region *What key climate information do you need?*	Tom Lyons *Murdoch University*
9.15 am	Variety choices and suitability *What options could suit your region?*	Snow Barlow *University of Melbourne*
9.45 am	Water use management *How can we address future issues?*	Tony Proffitt *AHA Viticulture*
10.15 am	Vineyard management *How can we adapt our practices?*	Erika Winter *GrapeLinks*
10.45 am	Morning tea	
11.00 am	Workshop session *Ideas for action*	
12.00 am	Summary and Remaining Issues	
12.20 pm	Closing remarks, Evaluation sheets and Farewell	Diana Fisher, Chairman *DAFWA*
12.30 pm	Lunch and Close *Lunch provided*	

Preparing for a Variable and Changing Climate

Regional Workshops for Grape and Wine Producers

Albany

Thursday 18 September 2008

Venue: Albany Senior Citizens Hall, Grey Street, Albany

Time	Topic	Speaker
8.15 am	Open – tea and coffee	
8.30 am	Welcome	Colin McDonald, Chairman *DAFWA*
8.35 am	Background and Overview *What actions do you want to happen in your region?*	Glynn Ward *DAFWA*
8.45 am	Climate change projections for the Mount Barker region *What key climate information do you need?*	Tom Lyons *Murdoch University*
9.15 am	Variety choices and suitability *What options could suit your region?*	Snow Barlow *University of Melbourne*
9.45 am	Water use management *How can we address future issues?*	Tony Proffitt *AHA Viticulture*
10.15 am	Vineyard management *How can we adapt our practices?*	Erika Winter *GrapeLinks*
10.45 am	Morning tea	
11.00 am	Workshop session *Ideas for action*	
12.00 am	Summary and Remaining Issues	
12.20 pm	Closing remarks, Evaluation sheets and Farewell	Colin McDonald, Chairman *DAFWA*
12.30 pm	Lunch and Close *Lunch provided*	

Preparing for a Variable and Changing Climate

Regional Workshops for Grape and Wine Producers

Margaret River

Tuesday 16th September 2008

Venue: Winery W10, Centre for Wine Excellence, Margaret River Education Campus, Bussell Highway, Margaret River

Time	Topic	Speaker
8.15am	Open – tea and coffee	
8.30am	Welcome	Mark Gibberd, Chairman *Curtin University of Technology*
8.35am	Background and Overview *What actions do you want to happen in your region?*	Glynn Ward *DAFWA*
8.45am	Climate change projections for the Margaret River region *What key climate information do you need?*	Tom Lyons *Murdoch University*
9.15am	Variety choices and suitability *What options could suit your region?*	Snow Barlow *University of Melbourne*
9.45am	Water use management *How can we address future issues?*	Tony Proffitt *AHA Viticulture*
10.15am	Vineyard management *How can we adapt our practices?*	Erika Winter *GrapeLinks*
10.45am	Morning tea	
11.00am	Workshop session *Ideas for action*	
12.00am	Summary and Remaining Issues	
12.20pm	Closing remarks, Evaluation sheets and Farewell	Mark Gibberd, Chairman *Curtin University of Technology*
12.30pm	Lunch and Close *Lunch provided*	

PREPARING FOR A VARIABLE AND CHANGING CLIMATE IN THE WINE INDUSTRY

What are the challenges and what are the opportunities?

Please help us improve future workshops by giving us your feedback

1. Which category best describes your enterprise (circle)?

grape producer wine producer consultancy other (please specify)_____

2. How did you hear about the workshop (circle) ?

radio newspaper word-of-mouth other (specify)_____

3. On a scale of 1 to 5, how did you rate your understanding of climate change and the three key management topics before the workshop (circle)?

	basic		*conversational*		*very good*
Climate change projections in your region	*1*	*2*	*3*	*4*	*5*
Varietal suitability/choice for the future	*1*	*2*	*3*	*4*	*5*
Water use efficiency/future water availability	*1*	*2*	*3*	*4*	*5*
Vineyard management in hotter seasons/warmer climates	*1*	*2*	*3*	*4*	*5*

4. On a scale of 1 to 5, which sections were of most and least benefit for you? (circle) Which sections were most interesting, or which sections were least interesting? – please give us your comments

Climate change projections for your region	*1(least)*	*2*	*3*	*4*	*5(most)*
	Comments----------				
Varietal suitability/choice for the future	*1(least)*	*2*	*3*	*4*	*5(most)*
	Comments----------				
Water use efficiency/future water availability	*1(least)*	*2*	*3*	*4*	*5(most)*
	Comments----------				
Vineyard management in hotter seasons/warmer climates	*1(least)*	*2*	*3*	*4*	*5(most)*
	Comments----------				

5. On a scale of 1 to 5, how did you rate your understanding of climate change and the three key management topics after the workshop (circle)?

	basic		*conversational*		*very good*
Climate change projections for your region	*1*	*2*	*3*	*4*	*5*
Varietal suitability/choice for the future	*1*	*2*	*3*	*4*	*5*
Water use efficiency/future water availability	*1*	*2*	*3*	*4*	*5*
Vineyard management in hotter seasons/warmer climates	*1*	*2*	*3*	*4*	*5*

Please Turn Over

6. What did you think of the length of each section?

	too short		*spot on*		*too long*
Climate change projections for your region	*1*	*2*	*3*	*4*	*5*
Varietal suitability/choice for the future	*1*	*2*	*3*	*4*	*5*
Water use efficiency/future water availability	*1*	*2*	*3*	*4*	*5*
Vineyard management in hotter seasons/warmer climates	*1*	*2*	*3*	*4*	*5*

7. Can you suggest any improvements to any of the sections? What?

_____

_____

8. Will this workshop help you in your everyday management and planning for the future? How?

_____

_____

9. Would you recommend this workshop to other people? – please comment

_____

_____

10. Did this workshop cover the subjects you thought it would?

_____

_____

11. Would you like to learn more? If so what would you like to see included in any future workshop series?

_____

_____

Thank you

Australian Government

Grape and Wine Research and Development Corporation