Understanding Apple and Pear Growers’ Climate Change Adaptation Decision-making

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Summary
Temperate tree fruits are an important agricultural industry for Australia and are particularly susceptible to a range of potential climate change impacts. This is a report on a study carried out in 2015 and 2016 with Australian apple and pear growers, which sought to understand their thinking and decision-making on climate change adaptation. We interviewed eighteen commercial apple and pear growers across five major fruit growing regions in southern Australia: Tasmania, southern Victoria, the Goulburn Valley (in northern Victoria), the Adelaide Hills and south-west Western Australia. Staff from Apple and Pear Australia Limited assisted with identifying growers to participate in this study, and focused on growers who are actively involved in apple and pear industry affairs and/or research and development programs. Thus, the participants in this study are not representative of the views and experiences of the broader community of apple and pear growers. They are a purposive sample of growers known within the industry to be interested in, and informed about, climate change issues.

The major conclusions and recommendations of this study are as follows:

- There is widespread acceptance that climate change is affecting orchard production and will do so more in the future.
- Growers are aware of and are utilising a range of technologies and management practices to respond to the production challenges posed by climate change, and most are confident that the range of technologies that are already available will be sufficient to enable them to keep producing apples and pears for the foreseeable future. (The exception to this is in Western Australia, where some growers have begun transitioning to other products).
- Climate change adaptation is already occurring as part of growers’ routine management decision-making. Most growers do not separate climate adaptation decisions from other business management decisions aimed at meeting market demands and making profit.
- Most of the adaptation actions growers are currently undertaking are tactical decisions. They involve an adjustment to management practices to respond to changes in conditions that are being experienced now. This contrasts with strategic adaptation, which would see growers making decisions now to adapt their production systems to conditions they expect to experience in the future. This is to be expected since there is so much uncertainty about the timing and precise nature of future climate change.
- Installation of orchard netting is the most prominent current example of a strategic adaptation response. This is a major investment decision that many growers are making now, because they see it is a response to current conditions that they expect to become more pressing in the future. Adoption of more efficient irrigation methods (discussed below) is similar.
- Many growers are already facing very tight profit margins, and climate change adds to this financial pressure on orchard businesses, since most adaptation actions involve additional costs. (Orchard netting is a clear example).
- In some locations, growers have already, or are considering, moving into different perennial fruit products that they think will be more suited to future climates. This allows them to keep using skills and infrastructure that are suited broadly to growing tree crops, and is a helpful adaptation option.
- The security and availability of water resources is the main “game changer” in relation to climate change, and was identified as such by most participants in this research. Most growers have already made significant investments in technology and practices to improve...
irrigation efficiency. If in the future water supplies become unavailable, or unaffordable, then current products and production systems will not be able to continue.

- There is some tension between the highly market-responsive characteristic of orchard businesses and the need to build in climate change adaptation. This is seen most clearly in the case of variety selection. Growers perceive strong economic incentives to plant new varieties that promise higher margins, including proprietary (“club”) varieties, that may not be the most well adapted to current and future climate conditions. This tension is also evident in that some of the fruit characteristics that the market demands (e.g. uniform size, colouration and absence of blemishes) will become increasingly difficult and expensive to achieve as climate conditions become harsher. This raises the question as to whether there is a role of industry to educate or advocate to buyers and consumers on what varieties of fruit, and what characteristics of fruit, are going to be possible and profitable to produce under future climate conditions.

- Discussions of climate change adaptation in Australian agriculture have tended to focus on adaptation by growers. The findings of this study point to the need for adaptation along the value chain. Businesses supplying planting material should provide information about the susceptibility of new varieties to climate risks such as reduced winter chill and heat damage. Buyers and marketers should seek to shape market expectations towards varieties that are going to be possible and profitable to produce into the future.

- Growers are interested in having more, and more accurate, information products and decision support tools to assist them in making good tactical and strategic management decisions. However, much of this information, such as chill requirements and heat sensitivity of varieties and pest and disease physiological information to allow modelling of pest and disease processes is not available. This points to the need for ongoing scientific research to fill information gaps. Further discussion with growers is needed to prioritise information needs, and to understand the types of decision support tools they will find most useful.
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Introduction
Temperate tree fruits are an important agricultural industry for Australia and are particularly susceptible to a range of potential climate change impacts (Webb, Darbyshire, and Goodwin 2014; Webb and Whetton 2010). Horticultural science research aimed at understanding these impacts and the management options available to mitigate them is at an early stage, but is continuing (Thomson et al. 2014; Webb, Darbyshire, and Goodwin 2014; Darbyshire 2016). However, research on climate change adaptation as a broadly social process of management decision-making by growers is extremely limited. In 2015, a small study was conducted with the research team involved in Primary Industries Climate Challenges Centre Project 440: Crossing the threshold: Adaptation tipping points for Australian fruit trees, to identify barriers to adaptation (Santhanam-Martin and Darbyshire 2015). A key recommendation of this study was to carry out further research with fruit growers themselves. Developing a better understanding of climate change adaptation decision-making, based on a variety of Australian fruit grower’s experiences, may assist researchers and the fruit industry to understand what resources, information and decision support tools will be useful for growers in the future. This is a report on a study carried out with Australian apple and pear growers, which sought to understand their thinking and decision-making on climate change adaptation.

In October and November 2016, we interviewed seventeen commercial apple and pear growers across five major fruit growing regions in southern Australia: Tasmania, southern Victoria, the Goulburn Valley (in northern Victoria), the Adelaide Hills and south-west Western Australia. We also had one grower interview available from the 2015 study (Santhanam-Martin and Darbyshire 2015), providing a total sample of eighteen growers from the five regions. The distribution of growers interviewed across these growing regions is shown in Figure 1. We did not recruit participants from New South Wales or Queensland growing regions due to limitations in the resources available to the study, and in response to guidance from researchers and industry contacts, which suggested that the five regions we selected would provide adequate representation of the range of climate change experiences and grower responses.

Figure 1: The locations of the apple and pear growing regions from where participants were recruited for this study.
Staff from Apple and Pear Australia Limited assisted with identifying growers to participate in this study, and focused on growers who are actively involved in apple and pear industry affairs and/or research and development programs. Many of these growers have had previous involvement with research on climate change impacts and adaptation options. Thus, the participants in this study are not representative of the views and experiences of the broader community of apple and pear growers. They are a purposive sample of growers known within the industry to be interested in, and informed about, climate change issues.

The interviews were semi-structured, based on a schedule of questions shown in Appendix A. Their duration varied from twenty-seven to seventy minutes. The interviews aimed to elicit growers’ perceptions of what types of climate changes they are noticing (if any), what impacts of these changes they are seeing in their orchards, and what management decisions and practice changes (if any) they have made or are planning to make in response to climate change. We also asked growers about the sources of information and advice they currently draw on to guide their decision-making, and about additional information or decision support tools they would like to have available.

The interviews were transcribed, and analysed thematically to identify similarities and differences between individual growers and between the different growing regions. From this thematic analysis, and informed also by previous scientific studies of climate change adaptation processes in agriculture (summarised in Santhanam-Martin and Darbyshire 2015), we identified the following major themes in the interview data:

- Climate and weather changes;
- Impacts of climate and weather changes on orchards and fruit;
- Adaptation actions;
- Decision-making processes concerning adaptation actions;
- Wider context for decision-making;
- Decision support tools and information (what is currently used and what is needed).

Figure 1 below shows how these themes can be related to each other to provide a conceptual framework for understanding climate change adaptation decision-making. The interview findings under each of these themes are discussed in the following sections of this report. (Some of the quotes from growers have been edited slightly for clarity).

![Figure 2: A conceptual framework for understanding climate change adaptation decision-making by Australian apple and pear growers (after Howden et al. (2007))](image-url)
Observations about climate and weather changes and their impacts on orchards and fruit growing: what is happening?

The view of most of the growers we interviewed is that climate change is occurring and is impacting their orchard in some way. However, they are uncertain about the specific ways that climate change is going to affect their region in the long-term and how quickly these changes will occur. While noting that there has always been year-to-year variation in weather patterns, most growers across all the growing regions observed that on average the climate is getting warmer and dryer, while extreme weather events such as heat waves, frost events, heavy unseasonal rain and hail storms seem to be becoming more severe and/or frequent.

I've been assessing the risks now [for] 10 years. It's been drying and hotter.
WA Interview 3

Climate change has been something which we are very aware of. You notice that you get more frosts. You notice you have longer droughts. You notice you get longer rain periods, like this year. We've had to adapt our farming techniques because of that.
VIC Interview 4 (Goulburn Valley)

We've seen dramatic changes in rainfall and heat events and that sort of thing that really outweigh the averages.
SA Interview 3

Growers are individually affected by these changes and events in different ways, but the most commonly cited risks included severe crop damage during extreme weather events, decreased quality and quantity of fruit, increased management costs, negative impacts on fruit tree health and limited production capacity due to water constraints. Table 1 summarises the different types of impacts on orchards that were linked to climate change by the growers we interviewed.

Table 1: Summary of climate change impacts mentioned by growers across the five growing regions

<table>
<thead>
<tr>
<th>Climate change impacts</th>
<th>TAS</th>
<th>VIC (S)</th>
<th>VIC (GV)</th>
<th>SA</th>
<th>WA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced water availability for irrigation (due to declining rainfall, but also water resource policy).</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Summer heat damaging fruit</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Other weather-related changes to time and duration of flowering (e.g. reduced winter chill)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unusual/unseasonal rainfall affecting flowering and/or tree health and/or fruit quality</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More and/or changed timing of frost events</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More or more severe hail events</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New or more intense pests and/or diseases issues (birds, fungal diseases, fruit fly, other invertebrates)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing salinity of irrigation water due to declining rainfall</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
When we asked growers which climate change impacts they were most concerned about, the answer in all regions was (1) the effect that climate change is having on water availability; and (2) managing the risks of extreme weather events.

*We might see temperatures increase a little, but it’s been the abnormal events that’s really been the highlight of it. I think we had a series of a fortnight above 35 degrees or something like that in November one year. Totally weird. So far above average it wasn’t funny.*

SA Interview 3

*We’re very conscious of the change in climate, because the climate changing has dramatically affected our water supply.*

WA Interview 4

*Yeah, it’s definitely like climate change is real. There’s no doubt about that from my point of view. What differences? Just that we have more abnormal weather patterns. It’s just not consistent anymore. I mean this year for instance we’ve just had record amount of rain. We’ve just broken records every year it seems. Particularly the last three summers have been so hot. Like really burning hot. That has an effect on the skin of the apples too. They get sunburn and that sort of thing.*

TAS Interview 1 (North)

Only one grower, in the Goulburn Valley, argued that climate change was not impacting their orchard in any significant way that required a specific management response. However, this grower discussed the possibility of shifting over time the balance of fruit types grown in their orchards (away from apples and towards pears and stone fruits), which can be viewed as an adaptation action.

*I think in terms of climate change and orcharding in the Goulburn Valley specifically, what we are, we are such an all-round area. I think the worst predictions I’ve seen is that we may resemble the climate of Griffith. I’m not too concerned about that, if that’s what they’re saying. If that’s a bad scenario, well in terms of growing a lot of stone fruit and pears, I think that may be okay.*

VIC Interview 7 (Goulburn Valley)

Western Australia was the only region where some growers were questioning the feasibility of apple and pear growing for the future due to concerns about water availability, warmer winters impacting chill accumulation and extreme heat in summer. Specifically, those with pre-existing orchards were relatively optimistic about their ability to use adaption methods, but understood that the practical and financial implications of this were not ideal. One grower had begun to diversify their business into avocados because they are less affected by the heat, while other growers mentioned that they had considered doing the same and that many growers in the region were doing so too.
Growers in southern Victoria and southern Tasmania were less concerned than those in other regions about the impacts of climate change, provided that adequate water is available, as discussed further below.

parse_error

Climate change is just-- it doesn't kill us, but it's causing us problems.
VIC Interview 1 (South)

The Huon Valley will always be a good area to grow apples for a long time to come.
TAS Interview 3 (South)
Adaptation Actions: what are we doing about it?
Climate change adaptation refers to the actions that growers can take to reduce the negative impacts of climate change in their orchards (or to take advantage of opportunities created by climate change) (Santhanam-Martin and Darbyshire 2015). Most growers were confident that they have a range of cultural practices available to them that will allow them to adapt their orchard systems to weather patterns as they change. Grower referred to hail netting, use of dormancy breakers, sunscreen application, evaporative cooling with overhead sprinklers, increased irrigation efficiency, increased water storage, changes in herbicide and pesticide application and improved drainage systems.

Many of these practices provided multiple benefits for growers, and have been used previously to cope with the year-to-year variation in weather patterns that has always been part of Australia’s climate. This demonstrates that there is already capacity for adaptive management within Australian growers’ management approach.

Over half (eleven) of the growers we interviewed had already begun setting up hail netting in parts of their orchard, and four more planned to implement netting in the future. In fact, only three of the eighteen growers did not plan to use netting at all. Two of these three were planning to retire in the near future and therefore made this decision because they were not looking at the long-term sustainability of their orchard.

Growers provided estimates for the cost of installing orchard netting that ranged from $20,000 to $100,000 per hectare. The figure most commonly cited was $40,000 to $50,000 per hectare. This is a significant expense, approximately doubling the cost of orchard establishment1. Nevertheless, many growers considered netting to be a worthwhile or even essential investment, because it mitigates multiple risks including hail damage, sunburn, frost, birds and strong winds. Growers also commented that netted orchards use less water, due to reduced evapotranspiration by trees in the more humid microclimate that the nets create. Many growers commented that increasing severity and regularity of extreme weather events has increased the need to manage these production risks. None of the growers mentioned any drawbacks from the use of netting, other than cost.

The hail nets, as they’re always called. But in reality they are also bird and fruit bat protectors and managers of insects, and even the environment is modified under the nets. So if you want to put a climate change word on it, nets are adapting to climate change, there’s no doubt about that.

VIC Interview 3 (South)

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1 Several growers commented that the installation of netting can be staged, to spread the timing of expenditure. For example, poles and wires can be installed at planting and the nets themselves some years later when the first harvest is expected.
Two growers commented that they are interested in soil health and building soil organic carbon, as a climate change adaptation.

“We were always using about five megalitres per hectare, but we have been monitoring our irrigation system, and with the netting we have been able to get down to about three megalitres per hectare, which makes an enormous difference. We can grow another two hectares of fruit with the same resource.”

WA Interview 3

“That sunburn is really due to that intense heat [which] has just become a problem in the last 10 to 15 years. 20 to 30 per cent sunburn is eliminated under the net. So there’s already a 20 per cent pack-out improvement.”

SA Interview 4

“We put certain varieties under net and the quality has improved dramatically, so that’s an incentive for us to continue in putting that permanent net over the top of those varieties.”

SA Interview 4

“All of the structures that we’re putting up are designed for hail netting in the future.”

TAS Interview 1 (North)

Another way that growers have begun to adapt to climate change is through their selection or elimination of particular apple and pear varieties, based on their performance as the climate has changed, or on their predicted performance.

“We have concentrated heavily on soil management, and soil health so that we can use less water, because if you get high organic carbon levels you can retain water and nutrient and that sort of thing. So I guess we’ve gone full out to work better with our environment. The old farming was against it, really.”

VIC Interview 5 (Goulburn Valley)

“I used to grow Royal Gala and I would struggle one year and I’d get them the next. As a result, it’s given me grey hairs. So I pulled them out and I will not put another Royal Gala back in the ground, just due to the fact that we seem to be getting warmer in this area.”

VIC Interview 6 (Goulburn Valley)

“Pink Ladies are a variety which was bred in Australia, for Australian conditions, and it’s a hardy variety. We have a lot less problems growing that particular variety. You’re trying to grow varieties which are not bred for these conditions, and the conditions are becoming harsher so you need to change the climate to suit that piece of fruit.”

SA Interview 4

However, growers commented consistently that market and price factors influence their variety selection decisions more strongly than climate suitability. One grower identified Sundowner as an
example of a variety he considered well suited climate conditions in his location, and yet which is being phased out by many growers due to a lack of market demand.

**Sundowner has come and gone, or is going. Because it's not wanted in the marketplace. It's great for growers, has good yield, high pack-out, works well in hot areas. It grows wonderfully well in the Goulburn Valley [as well as here in southern Victoria]. But you can't make any money.**  
VIC Interview 3 (South)

Several of the growers we interviewed are increasing their plantings of privately-owned apple varieties (“club varieties”), and this is another example of market factors outweighing climate adaptation factors in variety choice decisions. Club varieties are chosen and planted primarily because they offer growers the opportunity to defend their profit margins. Nevertheless, suitability to the growing environment does play a part in both growers’ decisions on which varieties to plant and variety owners’ decisions on where they will allow varieties to be grown.

**A lot of these new proprietary varieties, there’s a significant competition between groups and entities to have access to them. A lot [variety choice decisions] will be intuition and being able to assess how that variety is performing in some other region and make the comparisons and I guess educated observations and guesses and expectations about how it’s going to perform. There’s no doubt, I’ve said it many times, with these new varieties and the new way that they are brought to market, for every success there’ll be a dozen failures.**  
SA Interview 1

**We’d research pretty hard with our apples. If Nelson [in New Zealand] is doing it well - yes, like with “Jazz”. We brought “Jazz” in here and we knew that Nelson could grow the “Jazz”. “Smitten” we’re only just starting into but we’re reasonable confident with that one. As confident as we can be because we can’t afford to make a mistake as most perennial fruit businesses can’t. We can’t afford to put in the wrong variety. It needs to be a winner.**  
TAS Interview 2 (North)

While growers are optimistic about their ability to adapt, they did identify that there are limits beyond which adaptation may not be possible. We refer to conditions that go beyond growers’ ability to adapt as ‘game changers’. A variety of ‘game changing’ scenarios were discussed including reduced winter chill and severe frosts.
The climate change impact that was identified by every participant in this study as a ‘game changer’ was water availability. Growers cannot produce profitable yields of high-quality fruit without access to a minimum amount of water resources needed to keep trees productive. Physical water resource availability is influenced by climatic conditions (rainfall), but water resource availability for growers is also strongly mediated by regulatory and policy regimes. In different growing regions there are regulatory provisions which govern how much groundwater can be extracted (e.g. in South Australia), how much water can be extracted from streams, and whether additional dams to harvest runoff may be constructed (e.g. in southern Victoria), and the availability and price of water in managed irrigation schemes (e.g. in the Goulburn Valley). Therefore, some growers considered engaging in advocacy efforts to secure improved water security to be an adaptation action.
Perhaps the ultimate adaptation option is to move into a protected cropping system where all aspects of the plants’ growing environment can be controlled, and one Tasmanian grower did suggest this as a future option. (However, protected cropping systems still require adequate water supplies).

We invest $100,000, $150,000 per hectare in a crop just to get a planting started and just because we can’t afford a bit of water to keep it alive we stand a chance of losing it. So it’s a bit of a worry.
SA Interview 3

When this farm was bought there’s a big - there’s a valley on one part of the farm. It was discussed with Southern Rural Water you’ll be able to put a wall in there and have a 30 megalitre dam. So that was all good. So you’d have more than a year’s supply of water. So when you have your bad years you’ve got water and you can top it up and you’ll make it through the hard times hopefully. Then there was a government white paper came out three days before the application went it, and it [said] no more farm dams and we’ve struggled since on the water.
VIC Interview 2 (South)

If something does happen such as if we do get a long dry spell and a lot of the water goes to the environment and I can’t actually afford to pay for the water that is available, then that’s a limitation for me. I can’t do anything about that.
VIC Interview 6 (Goulburn Valley)

To feed the world’s population we will be growing our produce in controlled environments...even [now] we’re growing cherries and berries in tunnels. I think we’ll be doing the same [with other fruit]. You’ll have continuity of supply into your market, so we’ll be able to control chill units, no wind, no frost, no harsh sun. Yes. Has a big impact.
TAS Interview 2 (North)
Decision-making: what is guiding decisions?
All growers agreed that management decision-making on their orchards is driven primarily by market considerations: by the necessity of producing fruit that will get a good return in the market and maintain orchard profitability. Growers choose fruit varieties, tree training and canopy design systems and decide on the use of orchard netting and other management measures in order to produce high yields of high quality fruit according to buyers’ specifications (variety; size; colour; absence of blemishes). Several growers commented that they are unable to separate decisions driven by climate change from decisions driven by market demands.

Things that are probably being described as climate change adaptations are actually in fact adaptations to market requirements that are related directly to what the climate does to the product.
VIC Interview 3 (South)

Everything that helps improve yields and improve pack-out from a grower perspective, we try and adapt. If a weather event, i.e. hail or extreme sunburn becomes the problems then we try to mitigate those risks by using either technology or whatever’s available.
WA Interview 1

The demand for growers to keep up with a competitive and constantly changing market has seen the industry become increasingly capital intensive as growers find new and more efficient ways to set-up and run their orchards. In the context of climate change, this trend demonstrates that orchardists are well skilled at adapting and by necessity will continue to adapt as they endeavour to remain profitable. However, as growers have invested such a large amount of capital into their enterprise, the pressure to manage risks and guarantee a return on crops is greater than it has ever been before. This makes growers particularly vulnerable to the risks associated with climate change, because the stakes are high.

I think farming has gone from a way of life and a lifestyle to a business, so as a business you can’t really afford to have - we couldn’t go a year without a crop. That would send us to the wall or everyone would have to be put off and there would be pretty major financial difficulties associated with that.
WA Interview 2

I’ve been thinking about [installing hail netting] for 10 years, but the cost is so prohibitive. It is just incredibly prohibitive. Unfortunately, people don’t want to pay more money for fruit and vegetables. They want to pay less money for it. The supermarkets are encouraging them that they should, that it’s right to pay less for their food.
WA Interview 3

The main thing that would get in the way of growers [adapting] is probably the cost of doing it all. It needs to be able to pay for itself. If we’re not getting high enough prices for our apples, then that’s going to stop people from doing it.
TAS Interview 1 (North)
While growers are used to adapting their orchards to meet market demands, the market does not necessarily consider what will be best for growers as the climate changes. In particular, certain varieties that perform well in an environment, or have been bred to deal with the climatic challenges that growers are facing, may not perform well in the market, making it difficult for growers to use strategic variety selection as an adaption method. In some instances, growers are finding it increasingly difficult to cater to the buyers' specifications as the climate changes (e.g. achieving particular colorations of a variety), forcing growers to go to great lengths and expenditure to meet these demands. So in some circumstances the strongly market-responsive nature of orchard management is working against strategic climate change adaption decision-making.

*The market drives your decisions because the market's telling you what varieties to grow. Those varieties might not be conducive to your area, but you have to make them conducive to the area. Like “Kanzi”® - probably not the perfect climate, but we change the climate. We put the netting on. We put the irrigation on at certain times, a certain amount of time during the week so that that soil's always moist. I know it's done. You can put a microclimate under the net by putting irrigation at the top of the net and cooling the air down.*

SA Interview 4

*I think what the consumer wants has nothing to do with climate change really. The consumer is totally fickle.*

VIC Interview 4 (Goulburn Valley)
Information and decision support tools: What we need

While there are many management practices available to growers, decision-making can be difficult, especially when justifying large capital expenditure such as with hail netting. Thus, there was strong interest from growers in having access to better information, and to decision-support tools. On this topic, one grower noted recent major improvements in the information available on the Bureau of Meteorology website.

Specific information requests included:

- More specific information about climate trends (e.g. likely increase in average winter temperatures, or likely change in average winter chill conditions, looking 10-20 years ahead);
- Better medium-term (seasonal) forecasting;
- Improved warnings for specific weather events such as hailstorms;
- More information about specific climate requirements of varieties (e.g. winter chill);
- Earlier advice on water allocations in managed irrigation schemes;
- Advice and predictions on how pest and disease processes are likely to change;

In the context of the growing interest in planting proprietary (“club”) varieties, several growers commented that this makes it potentially more difficult for growers to understand the environmental and climate requirements of varieties.
In terms of long-term forecasting, several growers commented that it is useful to look at other locations that give an idea of the conditions that their own location is moving towards. This allows them to observe current growing conditions in that region and determine how their own production system might need to change.

I suppose as a producer here right now I probably would look and say well okay, whereabouts in Australia do I look now at an area that is in that temperature range [that my area is heading towards]. What [climate] am I going to move to? I would be looking at those areas that are that amount warmer now and looking at how they are functioning or operating now.

SA Interview 1

If someone said to me, do you want to plant an orchard in Griffith, I'd say yeah, that's not a bad place to plant an orchard. So even in that extreme - they're telling me that's the extreme - it could get like Griffith... But if they said [my climate will come like] Bundaberg then yeah, I'd probably have a problem with that. If they’ve got science that backs it up, then I’m pretty sure I couldn't grow what I’m growing now in Bundaberg, I’d have to grow some bananas or something.

VIC Interview 7 (Goulburn Valley)
Conclusions & Recommendations
The major conclusions and recommendations of this study are as follows:

- There is widespread acceptance that climate change is affecting orchard production and will do so more in the future.
- Growers are aware of and are utilising a range of technologies and management practices to respond to the production challenges posed by climate change, and most are confident that the range of technologies that are already available will be sufficient to enable them to keep producing apples and pears for the foreseeable future. (The exception to this is in Western Australia, where some growers have begun transitioning to other products).
- Climate change adaptation is already occurring as part of growers’ routine management decision-making. Most growers do not separate climate adaptation decisions from other business management decisions aimed at meeting market demands and making profit.
- Most of the adaptation actions growers are currently undertaking are tactical decisions. They involve an adjustment to management practices to respond to changes in conditions that are being experienced now. This contrasts with strategic adaptation, which would see growers making decisions now to adapt their production systems to conditions they expect to experience in the future. This is to be expected since there is so much uncertainty about the timing and nature of future climate change.
- Installation of orchard netting is the most prominent example of a strategic adaptation response. This is a major investment decision that many growers are making now, because they see it is a response to current conditions that they expect to become more pressing in the future. Adoption of more efficient irrigation methods (discussed below) is also a strategic response.
- Many growers are already facing very tight profit margins, and climate change adds to this financial pressure on orchard businesses, since most adaptation actions involve additional costs. (Orchard netting is a clear example).
- In some locations, growers have already, or are considering, moving into different perennial fruit products that they think will be more suited to future climates. This allows them to keep using skills and infrastructure that are suited broadly to growing tree crops, and is a helpful adaptation option.
- The security and availability of water resources is the main “game changer” in relation to climate change, and was identified as such by most participants in this research. Most growers have already made significant investments in technology and practices to improve irrigation efficiency. If in the future water supplies become unavailable, or unaffordable, then current products and production systems will not be able to continue.
- There is some tension between the highly market-responsive characteristic of orchard businesses and the need for climate change adaptation. This is seen most clearly in the case of variety selection. Growers perceive strong economic incentives to plant new varieties that promise higher margins, including proprietary (“club”) varieties, that may not be the most well adapted to current and future climate conditions. This tension is also evident in that some of the fruit characteristics that the market demands (e.g. uniform size, colouration and absence of blemishes) will become increasingly difficult and expensive to achieve as climate conditions become harsher. This raises the question of whether there is a role of industry to educate or advocate to buyers and consumers on what varieties of fruit, and what characteristics of fruit, are going to be possible and profitable to produce under future climate conditions.
• Discussions of climate change adaptation in Australian agriculture have tended to focus on adaptation by growers. The findings of this study point to the need for adaptation along the value chain. Businesses supplying planting material should provide information about the susceptibility of new varieties to climate risks such as reduced winter chill and heat damage. Buyers and marketers should seek to shape market expectations towards varieties that are going to be possible and profitable to produce into the future.

• Growers are interested in having more, and more accurate, information products and decision support tools to assist them in making good tactical and strategic management decisions. However, much of this information, such as chill requirements and heat sensitivity of varieties and pest and disease physiological information to allow modelling of pest and disease processes is not available. Ongoing scientific research is needed to fill information gaps. Further discussion with growers is needed to prioritise information needs, and to understand the types of decision support tools they will find most useful.
References


Appendix A: Interview schedule

Understanding Fruit Grower’s Climate Change Adaptation Decision-making

Interview Schedule

Researcher: Michael Santhanam-Martin

Interviews will be semi-structured and cover the following 6 themes. Possible prompting questions are listed, but the actual questions used will depend on the flow of the conversation. (Flow of questions informed by the ORID framework: Stanfield (2008)).

(a) Introductions:

- Can you tell me a bit about your orchard, and about your own background in the fruit industry?
- Have you given much thought to the issue of climate change and what it might mean for the future of your orchard and your industry?

(b) Adaptation in the apple and pear industry:

- What do you think will be some of the major changes that apple and pear growers will need to make to their production systems over the next 10 to 20 years in order to adapt to a changing climate?
- Which of these changes do you think might occur relatively easily, and which are likely to pose major challenges or barriers for growers?
- Would you say that you have already been making some management decision in your orchard in response to climate change?
- Do you think you will need to take climate change into account in future decision-making?
- Who do you go to for information on how to adopt your orchard to climate change?
- Is the information and advice you need available?

(c) Experiences with decision-making on adaptation:

- Is there anything you find particularly interesting or exciting about the task of climate change adaptation for the apple and pear industry?
- Is there anything that really worries you about climate change adaptation in the apple and pear industry?

(d) Identifying barriers to adaptation:

- What do you think are the major things that could get in the way of apple and pear growers adapting successfully to climate change?

(e) Identifying research responses:

- What features do you think a future industry research and development agenda needs to incorporate, in order to support effective adaptation by growers?
- Are there any specific decision support tools or information that you need to help you adapt?

(f) Is there anything else you’d like to say about climate change adaptation for the apple and pear industry?
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