Milestone Report 5.7

Barriers to Climate Change Adaptation in the Australian Tree Fruit Industry

Michael Santhanam-Martin & Rebecca Darbyshire

October 2015
Summary

This document reports the results of a small exploratory study of the barriers to climate change adaptation by Australian temperate perennial fruit growers. It was carried out as part of the Primary Industries Climate Challenges Centre (PICCC) Project 440: Crossing the threshold: adaptation tipping points for Australian fruit trees. While there is now a growing body of scientific knowledge of potential climate change impacts on temperate fruit production, and of possible management responses to these, research on climate change adaptation as a broadly social process of management decision-making by growers is extremely limited, and it is this gap that provides the context for this study.

This report addresses two research questions:

1. What factors and processes influence climate change adaptation decision-making by fruit growers?
2. Based on the answers to Question 1, what features should be considered for inclusion in a future research agenda that aims to support effective adaptation by growers?

In order to address these questions, semi-structured interviews were carried out with six researchers who are involved in the two research projects focused on climate change impacts in temperate perennial horticulture, as well as with one fruit grower who is active in industry research. This is a small dataset, but sufficient to generate insight into the research questions, and to provide signposts to further, more extensive, research.

This report makes the following key findings on the factors and processes that influence adaptation decision-making within the Australian fruit tree industry, and the implications for research that flow from these:

- Growers’ existing practices of adaptive management can result in climate change adaptation over time, whether or not growers position climate change response as a primary decision driver;
- Orchard block development and redevelopement is a critical decision point that needs specific support, so that it can include climate adaptive features;
- Major enterprise change can occur when climate-related productivity thresholds are crossed;
- The decision-making context in which growers operate is at present not strongly co-ordinated or strategically aligned toward achieving climate change adaptation;
- Both scientists and growers benefit when there are strong connections between these two groups;

The following recommendations arise from this study, and can be used to inform development of a future research agenda:

1. Basic research on fruit tree physiology and phenology, and their relationship with climate variables, must continue.
2. The decisions made when orchard blocks are developed or redeveloped should be recognised as a strategic point of intervention for improving the uptake of climate adaptation by fruit growers. Work should begin on understanding what types of interventions are needed (targeting various actors) to respond to this strategic opportunity.
Understanding the diversity of fruit growers’ decision-making styles, management objectives and information sources at this critical stage is key.

3. A high priority should be placed on improving the information and decision support available to growers to inform the selection of planting material (both rootstocks and varieties). This is a complex task that requires collaboration between plant breeders and suppliers, growers, researchers, advisors (public and private) and potentially also supply chain actors (i.e. fruit buyers). Careful consideration is required of what form of decision support products and services can feasibly be developed in a context of (a) incomplete information and (b) the complex and potentially competing decision-making criteria that growers must balance.

4. Researchers should continue to use and expand research methods that promote two-way learning with fruit growers. Research funders should emphasise this as a requirement or assessment criterion in funding schemes.

5. Stakeholders (both industry and government organisations) should give consideration to funding a thorough exploratory investigation of the tree fruit industry from an innovation systems or RD&E system perspective. The objective of such an investigation would be to better understand the actors and relationships that constitute fruit growers’ decision-making context for change management, including adapting to climate change.
# Table of Contents

Summary ................................................................................................................................................. 2  

1. Introduction .................................................................................................................................... 5  
   Research approach ............................................................................................................................. 6  

2. Climate change adaptation in primary industries and in temperate perennial horticulture:  
   literature review ..................................................................................................................................... 7  
   What is adaptation? ............................................................................................................................ 7  
   Factors that influence adaptation ....................................................................................................... 8  
   Adaptive capacity ................................................................................................................................ 9  
   Adaptation for the fruit tree industry ............................................................................................... 11  
   Research, development and extension (RD&E) approaches to build adaptive capacity .......... 14  

3. Results: Adaptation decision-making by fruit growers ................................................................. 16  
   Growers' adaptive management can produce climate change adaptation over time ............... 16  
   Orchard development/redevelopment is a critical decision point that needs support .......... 17  
   Major enterprise change can occur when thresholds are crossed ................................................... 18  
   The decision-making context in which growers operate is not strongly co-ordinated or strategically  
   aligned toward achieving climate change adaptation ...................................................................... 19  

4. Results: Research to support effective climate change adaptation by fruit growers ............ 20  
   Fundamental scientific research must continue ............................................................................... 20  
   Both scientists and growers benefit when there are strong connections between scientists and  
   growers ............................................................................................................................................. 20  
   Engagement with growers needs to be woven into the design of research projects ................... 21  
   Project designs can also create collaboration across industries and organisations ................. 22  

5. Discussion & Conclusions .............................................................................................................. 23  
   Elements of adaptive capacity for the tree fruit industry ............................................................. 23  
   Supporting climate-adaptive orchard redevelopment decisions is a key strategic opportunity ..... 23  
   There are benefits for both growers and researchers in seeking greater engagement ............. 24  
   Engaged research methods on their own do not comprise a functional RD&E or innovation system  
   .......................................................................................................................................................... 24  

6. Recommendations ........................................................................................................................ 25  

7. References .................................................................................................................................... 26
1. Introduction

Fruit production from temperate perennial fruit trees is a significant agricultural industry in Australia. In 2013/14 there were some 6,500 agricultural enterprises in Australia producing fruits and nuts (ABS 2015a), and they produced product worth some Aus$2.2 billion (ABS 2015b). The fruit and nut industries thus comprise 5% of Australian agricultural enterprises, and create 8% of the gross value of crop production.

The temperate perennial fruit tree industry, like all Australian agricultural industries, is expected to experience increasing impacts resulting from anthropogenic climate change over coming decades (Webb and Whetton 2010). The Primary Industries Climate Challenges Centre (PICCC) Project 440, entitled Crossing the threshold: adaptation tipping points for Australian fruit trees, aims to "increase the Australian fruit tree industry's preparedness for climate change, providing region-specific information on the lead times available to implement adaptive management strategies that moderate anticipated climate change impacts" (PICCC 2015). The project involves collaboration between horticultural scientists in Victoria, Tasmania, Queensland and Western Australia, and is focusing in particular on three fruit crops: apples, pears and cherries¹. The project is undertaking a range of field and laboratory experiments designed to investigate key questions concerning the nature of likely climate change impacts on these three crops, and the effectiveness of particular management strategies, or adaptation options, that could be implemented to manage or reduce these impacts.

While it needs to be informed by scientific understanding of the climate and plant production processes involved, the process of climate change adaptation by fruit growers needs to be understood also as a social process. It will involve growers making management decisions. They will make these decisions in the context of their existing life and enterprise circumstances, their knowledge, beliefs and attitudes, the social, professional and industry networks in which they participate, and the wider policy, institutional and market contexts of their industries. Milestone 5.7 within the project was designed to begin exploring these social and economic dimensions of adaptation, by identifying the likely barriers to effective adaptation by fruit growers. Specifically, Milestone 5.7 requires the preparation of a “Summary report of the adaptation barriers identified by industry”.

This report addresses this Milestone requirement. It relies on the expert knowledge and industry networks of the project research team, and on existing research literature on barriers to climate change adaptation in the primary industries. That is, it is a report on adaptation barriers identified by the project research team, on the basis of their extensive experience working with fruit growers and the tree fruits industries, and in the context of existing research literature. One fruit grower, who is also active within the research community, was also interviewed. This report is thus based on a limited dataset, and should be viewed as an initial exploration of the subject matter. It aims to address two particular research questions:

1. What factors and processes influence climate change adaptation decision-making by fruit growers?

¹ Project 440 also involves formal collaboration with Apple and Pear Australia Limited project AN12029: Understanding apple and pear production systems in a changing climate.
2. Based on the answers to Question 1, what features should be considered for inclusion in a future research agenda that aims to support effective adaptation by growers?

Section 2 presents key insights from the existing primary industries climate change adaptation literature, focusing on literature that addresses adaptation as a management process. Sections 3 and 4 synthesise findings from our interviews, in relation to the two research questions above. The final sections of the report presents conclusions concerning the identified barriers to adaptation, and make recommendations for how these might be addressed through future research.

**Research approach**

The research for this report proceeded as follows:

1. A targeted literature review exercise was undertaken to identify existing scientific knowledge on climate change adaptation in primary industries, and social, economic and institutional barriers to agricultural adaptation. The review also identified the key concepts and theoretical frameworks used in this literature. It focused on identifying existing summary, synthesis and review publications, on Australian publications and on publications specifically addressing adaptation in temperate perennial horticulture.

2. In depth semi-structured interviews were conducted with the six lead researchers in the project, and with one fruit grower. The interviewees were asked to read the draft literature review prior to the interview, so that their responses could be informed by, and expressed in the context of, the existing literature. The interview questions aimed to elicit the researchers’ experiential knowledge of, and informed opinions concerning (a) likely barriers to effective adaptation decision-making by fruit growers and (b) possible opportunities to address these barriers through the design and conduct of further research. The schedule of questions used to structure the interviews is shown in Appendix A. The interviews were first analysed thematically to identify points of agreement and divergence between the interviewees. The single grower interviewee was interviewed last, and was asked to comment on key themes emerging from the interviews with researchers. In the second stage of analysis, logical relationships were identified between the salient themes from the interviews, with this step being informed by the concepts identified in the literature. The synthesis presented in Sections 3 and 4 of this report is the result of this analysis.

The interview component of the research was carried out in accordance with human research ethics protocols approved by the Human Ethics Advisory Group of the Faculty of Veterinary and Agricultural Sciences at the University of Melbourne. The information statement for research participants, and the consent form they were asked to sign, are shown in Appendix B. In accordance with these ethics protocols, all the interviewees are referred to in this report using pseudonyms (Researcher 1, Researcher 2 *etc.*).
2. Climate change adaptation in primary industries and in temperate perennial horticulture: literature review

**What is adaptation?**

In climate change research, adaptation refers to responses to the effects, or impacts, of climate change. Adaptation can be *anticipatory* – that is, action taken in advance of climate change occurring, with the intention of avoiding or reducing the impacts, or with the intention of taking advantage of perceived benefits. Or adaptation can be *reactive* – that is, responding to change once it is occurring, in order to avoid or reduce the impacts of, or take advantage of, the change. The construction of sea walls to protect coastal land and infrastructure from the higher sea levels that are expected to result from climate change is an example of an adaptation action. The concept of adaptation is relevant at a range of scales, and to a range of different types of entities. Individual people can undertake adaptation, as can businesses, communities, societies, industries, regions and nations.

A key element is that adaptation concerns a *response*: “Adaptation is essentially a pragmatic response to a perceived present or future imbalance between climate and the societies and environments [or other human activities] that it affects” (Palutikof *et al.* 2015: 10). Applied to primary producers, this concern with responses becomes a concern with producers’ management decision-making (Hertzler *et al.* 2015).

While some authors refer to climate change adaptation as itself a science (Meinke *et al.* 2009), others have argued that it is inherently more multidisciplinary than this suggests: “Adaptation cannot be said to be a ‘science’; rather, it is a complex interdisciplinary field of inquiry whose ultimate rationale must include delivering policy-relevant information to decision-makers” (Palutikof *et al.* 2015: 6-7).

The field of adaptation research has been criticised for creating confusion and obfuscation through the proliferation of classification schemes and theoretical characterisations of different categories of adaptation (Palutikof *et al.* 2015). However in the case of adaptation in the primary industries specifically, the typology of Howden *et al.* (2010) (illustrated in Figure 1) is widely accepted and used (Rickards 2013). It characterises adaptation according to the degree of change to a particular production system that it involves. It divides adaptations into three major categories: those of (1) “incremental adaptation” (least change), (2) “systems adaptation” and (3) “transformational adaptation” (most change), although it is important to note that some of the examples of adaptation options given in Figure 1 are not directly applicable to perennial horticulture, as discussed further on page 11. Generally, the higher the degree of change involved, the higher the degree of complexity, cost and risk involved in implementing the change (Howden *et al.* 2010: 109). The utility of this typology is that it helps to characterise the nature of the decisions faced by producers in implementing different adaptations.
As noted above, the concept of adaptation is applicable at different scales, and to different types of entities, and again understanding adaptation in this way can assist with understanding adaptation in the case of the primary industries. Howden et al. (2007: 19693-19694) establish a distinction between the scale of the “management unit” (such as an individual enterprise or farm) and the scale of the “decision environment” which includes a range of factors external to an individual farm or enterprise (such as markets, policies and available knowledge, discussed further below) that can either assist or impede effective adaptation responses at the management unit scale. That is, while ultimately climate change adaptation must be implemented through management decisions made at the scale of the management unit, these decisions take place in the context of a decision environment that involves policies and politics, markets, growers’ networks and relationships, the services, advice and suppliers that growers interact with, physical infrastructure, scientific knowledge and its communication, and so on. Adaptation in all these elements, and at a variety of scales, may be needed to create an enabling decision environment for adaptation at the scale of the management unit. What science is done, and how it is done, are part of the decision context, and science itself may need to adapt (Howden et al. 2007).

**Factors that influence adaptation**

The discussion above highlights the diversity and complexity of the factors that influence adaptation decision-making by farmers. The literature review chapter of Dang (2014: 27) synthesises the findings of 40 research studies published between 1990 and 2014 on the subject of “factors influencing farmers’ adaptation”. It identifies a total of twenty-nine factors, across five major categories, shown in Table 1 below.
### Table 1: Summary of factors influencing farmers’ adaptation decisions (from Dang 2014: 27)

<table>
<thead>
<tr>
<th>Category</th>
<th>Influencing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic and socio-economic factors</td>
<td>Age, Gender, Education, Income, Assets, Household size, Farm size, Farming experience</td>
</tr>
<tr>
<td>Resources, services and technologies</td>
<td>Availability and access to credit/capital/funds, Availability and access to subsidy, Availability and access to information (climate change, adaptation methods), Availability and access to agricultural extension, Access to land/labour, Access to irrigation, Access to market (input/output), Infrastructure, Technologies</td>
</tr>
<tr>
<td>Institutional factors</td>
<td>Organisation, Structure of interactions, Government policies/directives, Institutional arrangements on land</td>
</tr>
<tr>
<td>Social and cultural factors</td>
<td>Cultural/social norms, Shared values and understandings, Social capital</td>
</tr>
<tr>
<td>Cognitive and psychological factors</td>
<td>Belief in the reality or impacts of climate change, Trust, Denial, Perceived successfulness, Risk perception</td>
</tr>
</tbody>
</table>

The factor “belief in the reality or impacts of climate change” has been the subject of particular research in Australia (Hogan et al. 2011; Buys et al. 2012; Wheeler et al. 2013; Kuehne 2014). On the one hand there is evidence of widespread scepticism concerning the reality of anthropogenic climate change, and hence some difficulty in initiating conversations with farmers about the need for adaptation. Australian research has also found that climate change is only one amongst many challenges or stressors influencing farmers’ management decision-making (Beilin et al. 2012; Askew et al. 2014). Conversely, research has found that Australian primary producers have always had to make management decisions in the context of Australia’s high climate variability, and hence the ability to adapt to seasonal variations in climate is already part of Australian farming systems and management practices (Hertzler et al. 2015). Building on these existing strategies and practices is seen as a suitable initial focus for equipping primary industries to respond to anthropogenic climate change (Stokes and Howden 2010).

**Adaptive capacity**

The concept of adaptive capacity is widely used in the climate change adaptation literature as a way of acknowledging that there are multiple factors, including those listed above, that all interact to influence the ability of an entity to adapt (Marshall et al. 2010; Rickards 2013). This concept is
strongly grounded in the socio-ecological systems and resilience literatures, which conceptualise the entities that might need to adapt as systems made up of interacting components (both social and bio-physical), which can exhibit complex behaviours, such as self-organisation and transformation.

Much research has attempted to identify system properties that contribute to adaptive capacity, and to assess or measure these in empirical studies. The most commonly-used approach draws on the Rural Livelihoods Framework of Ellis (2000), and characterises adaptive capacity as being determined by the available stocks of five different “capitals”: human, social, financial, physical and natural (Rickards 2013). Deficiency in one or more capitals reduces the capacity of a system to adapt, and again the system in question can be conceived at a number of scales such as an individual farm, an agricultural industry, a local community or region. Empirical research has identified many causes of and instances of capital insufficiency that limits adaptive capacity (Rickards 2013). Rickards’ (2013: 58) review also identifies a number of “cross-capital issues” – that is factors that affect adaptive capacity but that are to do with the relationships between the capitals, rather than stocks of individual capitals per se. Rickard’s (2013) summary of adaptive capacity constraints identified in the literature on Australian primary industries is reproduced in Table 2.

The “capitals” approach to assessing adaptive capacity has also been criticised on the basis that it embodies a particular set of assumptions concerning who has the power and the responsibility to adapt (Rickards 2013). Critics argue that this approach is infused with a neoliberal political ideology that frames adaptation as a responsibility to be exercised from the “bottom up” by individual farmers, rural communities or regions, for example, and that this detracts attention from the power relations that may be constraining adaptive capacity at these lower scales and that may need to be addressed through higher-level political or policy reform.

Adaptive capacity for primary industries also includes the ability to respond to climate change even as substantial scientific uncertainty remains concerning both climate processes and their impacts on farming systems (Stokes and Howden 2010).

**Table 2: Main adaptive capacity constraints in Australian primary industries suggested to date (from Rickards 2013: 8-9)**

<table>
<thead>
<tr>
<th>Type of capital</th>
<th>Adaptive capacity constraints in some populations or areas of primary industry suggested by research to date</th>
</tr>
</thead>
</table>
| Human capital    | Poor physical and mental health  
|                  | Unhelpful coping strategies  
|                  | Low levels of understanding and acceptance of climate change  
|                  | Distorted perceptions of climate change and risks of different response options  
|                  | Time scarcity  |
| Social capital    | Poor social networks and support  
|                  | Lack of government support  
|                  | Labour constraints and lack of alternative employment  
|                  | Eroding or constraining intergenerational bonds  
|                  | Unhelpful cultural norms  
|                  | Threats to consumer support  
|                  | Constraining industry characteristics  
|                  | Inadequate research and professional capacity  |
| Financial capital | Limited on-farm investments  
|                  | Excessive or limited access to credit  |
| Physical capital  | Limits to current productive biodiversity, including genetic diversity  |
Adaptation for the fruit tree industry

The discussion above summarises current knowledge concerning climate change adaptation in general, with a focus on primary industries. There are particular features of tree fruits as a farming system that are relevant to understanding adaptation for this industry (Webb and Whetton 2010; Webb et al. 2014). Webb et al. (2014) note that both positive and negative effects can be expected. The discussion below focuses on the possible negative effects, and on management options available for responding to them.

Temperate fruit trees are perennial plants, and this makes fruit production more vulnerable to climate change impacts than annual crops such as grains. Perennial plants go through an annual sequence of development stages across all four seasons, all of which are susceptible to climatic influences, and all of which can affect the quality and quantity of fruit produced. The climate variables that can affect fruit trees, and the range of possible effects, are summarised in Table 3.

Table 3: Summary of possible climate change impacts on the production of temperate perennial fruits (from Webb and Whetton 2010: 121-124)

<table>
<thead>
<tr>
<th>Climate impacts</th>
<th>Implications for temperate perennial tree fruit production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased temperatures</td>
<td>Changed timing of phenological stages (bud break, flowering), although considerable uncertainty remains concerning the precise nature of these effects. Pollination problems if flowering of cross-pollinating varieties become asynchronous. Problems with pollination if flowering becomes asynchronous with the life cycle of pollinator (e.g. insect) species. Inadequate winter chill can result in prolonged and/or uneven flower break, which complicates the timing and management of other orchard operations and can result in reduced yield. Inhibition of colour development in apples. Heat/sunburn damage to fruit. Changes in pest patterns (range, emergence timing, number of generations).</td>
</tr>
<tr>
<td>Reduced rainfall</td>
<td>Greater requirement for irrigation, and reduced availability of irrigation water. Perennial crops are particularly susceptible as they must receive a minimum water requirement every year for survival.</td>
</tr>
</tbody>
</table>
Climate impacts | Implications for temperate perennial tree fruit production
--- | ---
More frequent extreme events (extreme rainfall, hail, frost, extreme heat, drought) | Direct hail damage of fruit.
Increased risk of frost damage to flowers, if earlier flowering occurs due to increased temperatures.
Heat/sunburn damage to fruit.
Increased drought frequency will exacerbate the impacts of reduced rainfall.
Increase likelihood of cherry split or cracking with extreme rainfall events (affects some varieties of apples too).

Changes to pest, weed and disease interactions | Changes to pest, disease and weed occurrence, timing and lifecycle, requiring changes in management responses.

Carbon dioxide enrichment effects | Possible increase in tree water use efficiency; a range of possible effects on: canopy development, plant nutrient balance and pest interactions.

Fruit trees are long-lived, with trees often remaining in production for several decades. Some crops, for example pears, also have an extended juvenile phase of several years, before they begin to produce crops. This means that fruit trees are likely to experience a changing climate during their lifetime (Webb et al. 2014). It also means that orchardists’ decisions concerning crops and varieties to plant are necessarily long-term, irreversible and high-risk. Unlike growers of annual crops, fruit growers do not have the option of changing to a new crop or variety each year in response to changing seasonal or market conditions.

Conversely, tree fruits are high-value crops that are grown on much smaller areas of land than those used for broad acre production. Some management interventions are feasible on these small areas that are not feasible in larger-scale production systems, for example physical crop protection through netting. Fruit production also involves intensive management and frequent interaction with the trees. This provides frequent opportunities for observation and management intervention.

Some of the known management options that are available to fruit growers for climate change adaptation are summarised in Table 4, arranged approximately in ascending order of the scope of change to the production system that each management option involves. The purpose of this table is to give an indication of the types of management decisions available to growers. It is not an authoritative or comprehensive summary of scientific understanding of the very complex, variable (across species and varieties) and imperfectly understood interactions that occur between management options and crop responses².

---
² Many management options also have second-order effects, for example the increase in relative humidity that occurs under netting.
**Table 4: Summary of some available management options to respond to the impacts of climate change on temperate perennial fruit production (based on Webb and Whetton 2010; Webb et al. 2014)**

<table>
<thead>
<tr>
<th>Least change (incremental)</th>
<th>Possible management options</th>
<th>Impacts addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of dormancy-breaking chemicals to promote bud burst</td>
<td>Chill requirement, delayed flowering, uneven flowering, asynchrony of cross-pollinating varieties.</td>
<td></td>
</tr>
<tr>
<td>Orchard netting</td>
<td>Hail damage, Extreme heat, Pest damage (birds, fruit bats)</td>
<td></td>
</tr>
<tr>
<td>Evaporative cooling via overhead sprinklers</td>
<td>Extreme heat, Low winter chill</td>
<td></td>
</tr>
<tr>
<td>Increased irrigation efficiency (through irrigation management and/or infrastructure, including netting)</td>
<td>Reduced average rainfall, Drought</td>
<td></td>
</tr>
<tr>
<td>Changed pruning/canopy management (e.g. to provide self-shading of fruit)</td>
<td>Extreme heat, Colour development</td>
<td></td>
</tr>
<tr>
<td>Changed trellising and training system (resulting in changed tree physical form and canopy structure)</td>
<td>Extreme heat, Colour development</td>
<td></td>
</tr>
<tr>
<td>Use of different rootstocks or varieties that are better suited to altered climate</td>
<td>Changed timing of phenological stages, Chill requirement, Increased temperatures, Pollination problems, Changed pest, weed and disease interactions, Colour development, Extreme heat</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Most change (transformational)</th>
<th>Possible management options</th>
<th>Impacts addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing crops</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>Relocating current crop to a more suitable location</td>
<td>Various</td>
<td></td>
</tr>
</tbody>
</table>

Fruit growers are typically highly engaged with the markets into which they sell. That is, they pay attention to what markets are demanding, and seek to manage their orchards to produce products that the market wants, in order to maximise profits. This also involves managing the timing of harvest (for example to achieve fruit of an acceptable quality, but not at a time of market glut and hence depressed prices) (Webb and Whetton 2010). This means that growers are used to making adaptive management decisions to try to get the best return from their crop. Some growers are highly protective of their management strategies and averse to sharing openly with their peers, as a result of the highly competitive nature of the fruit industry, and the relatively lower prevalence historically of industry collective institutions (such as the statutory marketing authorities that were

---

3 The commonly used existing rootstocks have not been tested in relation to climate adaptation benefits, and there are as yet to specifically-developed climate-adapted rootstocks.
common in other agricultural industries until recently, and the farmer co-operatives that are still prevalent in the dairy industry⁴). Fruit growers are often in direct competition with their neighbours.

Despite the existing knowledge of potential climate change impacts and possible management responses summarised above, specific research on climate change adaptation decision-making by growers in the Australian temperate perennial fruit industry is very limited. Rickard’s (2013) review of nearly 1,000 publications published between 2009 and 2012 did not include a single paper focused specifically on horticulture or on the fruit industry, and nor does this review make any findings specifically in relation to these industries. What is required is to develop understanding of growers’ decision-making processes in response to the potential impacts and management options discussed in Table 4. The first objective of this exploratory study is to contribute to this understanding.

**Research, development and extension (RD&E) approaches to build adaptive capacity**

The second objective of this study is to provide recommendations to inform future research programs to support effective climate change adaptation by fruit growers. General literature on how research can best contribute to improved decision-making by farmers is relevant here, as is specialist literature on research approaches to enhance climate change adaptive capacity, noting that research is only one of a range of related functions (often referred to as the research, development and extension (RD&E) system) that are required to support agricultural innovation.

In terms of the general literature on agricultural and rural change, a general finding that has emerged from research over many decades is that practice change is more likely to occur when the interests and decision-making context of farmers are given priority, rather than the scientific interests of researchers (Chambers et al. 1989). This principle is reflected in the development of agricultural innovation and extension practice in Australia, from the era of “transfer of technology” in the 1960s, to a focus on “capacity building and community engagement” in the 21st century (Vanclay and Leach 2011: 10). This is not to deny the importance of the base scientific research that is needed to inform the development of new technology and practices. The point is rather that practice change occurs most readily when different knowledges – for example farmers’ practice-based knowledge and researchers’ scientific knowledge – are brought together as part of work on a particular problem or challenge. This process has been described as “co-innovation” or “innovation co-production” (Klerkx and Nettle 2013), and is a form of participatory research.

Effective “co-innovation” requires well-functioning relationships between different parties including farmers and researchers, educators, farm advisors (in both the public and private sectors), commercial developers and suppliers of technology and sometimes policy-makers and regulators. Social scientific examination of recent research on cherry growing, for example, has identified the enhanced potential for learning and change that arises when there are long-term and trusting relationships between researchers and growers (Fleming et al. 2015). The larger set of organisations and relationships that come into play in agricultural innovation, and the practices that support them, can be described as an “innovation system” (Klerkx et al. 2012), and innovation researchers have developed approaches for assessing the properties and effectiveness of different innovation systems (Lamprinopoulou et al. 2014).

¹⁴ However processing co-operatives did exist until recently in the fruit industry, and grower and packing co-operatives still exist.
The importance of creating linkages between scientific research and farmers’ practice has also been recognised in the climate change adaptation literature, as have challenges to achieving this in practice:

There is also broad literature on the need for and benefits and challenges of participatory research, learning and planning for adaptation in combination with more traditional knowledge transfer. Challenges to conducting participatory approaches include the very issues they are being used to address, such as disengaged, stressed and distressed producers. Some Australian researchers are nevertheless leaders in participatory methods, including the use of participatory workshops on climate change risks, responses and decision making tools (Rickards 2013: 9).

Through analysis of three case studies of innovation programs in the Australian and New Zealand dairy industries, Nettle et al. (2015) identify 11 specific question to be considered in determining whether a particular approach to research, development and extension supports farmers adaptability, and hence the resilience of farming systems. This research was not focused on adaptation to climate change specifically, but the principles identified are relevant:

Does RD&E support adaptability of farmers and hence resilience by:

1. Supporting the management of risk and uncertainty by building skills and providing opportunities for learning?
2. Engaging with groups outside the RD&E system to support financial and personal flexibility?
3. Supporting motivational strategies to increase interest in adapting?
4. Encouraging the formation of groups and self-organisation?
5. Supporting and being available to the self-organising efforts of farmers?
6. Facilitating and supporting the sense of confidence to act and continual review of progress on-farm?
7. Seeking out and providing new networks and engaging with alternative views/work?
8. Supporting innovative funding models for self-organising and active participation of local actors in testing and adapting new options?
9. Embodying ethics and representing those that cannot speak for themselves?
10. Conducting analysis across scales (farm, community, region, value chain, catchment) to support resilience and learning?
11. Applying adaptive governance models to enable responses to emerging issues?

(Nettle et al. 2015: 853)

In summary, both the specific climate change adaptation literature and general farm innovation literature highlight the range of factors beyond scientific knowledge that will contribute to the adaptive capacity of the Australian temperate tree fruits industry, and also identify pointers for research practice that enhance the contribution of research to an overall innovation or RD&E system.
3. Results: Adaptation decision-making by fruit growers

The key themes that emerged from our interviews concerning climate change adaptation decision-making by fruit growers are summarised below.

Growers' adaptive management can produce climate change adaptation over time

Interviewees agreed that most Australian fruit growers have always had to be adaptive managers, in response to the high variability of the Australian climate and in response to the highly competitive and volatile markets into which they sell. As a result many, but not all, growers are open to considering new information, and are willing to try new ideas and management techniques. In fact, many new management techniques are founded upon growers' observations, ideas and trials.

Since growers have always had to make adaptive management decisions in response to seasonal conditions and longer-term investment strategies, their management may result in adapting to climate change, even if they themselves do not categorise it as such. For example, their management practices can adjust over time in response to their observations of reduced winter chill, or increased risk of hail, frost or extreme heat damage, or reduced irrigation water availability. Several interviewees noted that it is experiences of individual instances of extreme weather events that cause major crop loss, rather than observation of slow incremental change, that often precipitate significant change to routine management practices. Extended drought, severe hail, and extreme temperature events are examples.

The types of management changes that growers can and do make, and which are relevant to climate change adaptation, include changes to tree training, canopy management and thinning practices, the use of new forms of physical crop protection such as orchard netting or evaporative cooling and changed irrigation equipment and practices. Most of these involve substantial change to long-lasting elements of orchard infrastructure and require substantial investment, and so are not at the "incremental" end of the Howden et al. (2010) typology. Nevertheless they are incremental in some ways: they can and are implemented by growers progressively on individual block as these are redeveloped. This is discussed further under the next sub-heading concerning orchard development.

There are also climate change impacts that may be less amenable to gradual adaptive management responses over time. An example provided by one interviewee was the impact of reduced water availability in fruit growing regions that are dependent on irrigation (noting that this is a case where government policy to rebalance water allocation between agriculture and the environment is interacting strongly with climate influences) This interviewee noted...
that fruit growers in the Goulburn Valley kept their trees alive through the Millennium Drought by purchasing temporary water allocations from dairy farmers. As a result of the further development of water markets, such temporary water may not be available the next time drought strikes. Growers need to be thinking now about how to adapt their orchards so that they can be managed as well as possible under conditions of prolonger water shortage.

**Orchard development/redevelopment is a critical decision point that needs support**

All interviewees agreed that decisions made when a new orchard block is developed, or an old block redeveloped, are absolutely critical for climate change adaptation. These decisions include the selection of planting material (both crop varieties and root stocks), the choice of training system, and the selection of orchard infrastructure such as trellising systems, irrigation systems and netting. Orchard redevelopment is expensive, and many of the decisions made cannot be readily reversed. Once developed, an orchard block is expected to be in production for anything from 15 to 30+ years, and so ideally these decisions should be made with an understanding of the potential implications of climate change over these timescales. Growers redevelop individual blocks within their orchards on an on-going and rotational basis, and so by incorporating climate adaptation criteria in decision-making at this point, orchards can become incrementally better adapted to climate impacts over time.

Some interviewees noted instances of climate change adaptation in orchard development practice. For example orchard netting and overhead watering systems for evaporative cooling, both used to protect fruit from extreme heat events, appear to be becoming standard practice for new and redeveloped orchard blocks in the Goulburn Valley. (Orchard netting has the additional benefits of protecting fruit from hail damage, and from birds).

In the case of planting material selection, most interviewees observed that growers are much more focused on prices and market demands than on future climate suitability. They will typically plant the variety that they judge as most likely to achieve a good price in the context of current market trends, whether or not that variety is the best adapted to what scientists foresee as the likely future seasonal conditions over the projected life of that orchard block. Some orchardists’ profit margins are small, and so this focus on responding to markets is necessary and understandable.

Additionally, there is a great deal of uncertainty both about the specifics of future weather conditions in fruit growing regions under climate change, and about the behaviour and performance of different fruit tree planting material under different weather conditions. The winter chilling requirements of different crops and varieties, and the effects of differing chill levels on tree development and yield, are a good example. Basic scientific understanding of
the mechanisms linking chill to tree development and yield is lacking, as is specific guidance on the requirements and performance of different varieties under different chill regimes. Where such information is available, it often comes from research conducted in other countries, and so its applicability to Australian conditions is uncertain. In the context of this lack of clear information for growers to support climate-adaptive planting material selection it is hardly surprising that other criteria, such as market demand, will carry greater weight. There is also an overall constraint on the types and quantities of planting material available for orchards to select from, and this further limits the ability of growers to incorporate climate change adaptation criteria in their selection decisions.

Our single grower interviewee observed that at least some orchardists do think about the productivity and profitability of an orchard block over its whole expected life when they are selecting varieties for planting, and that their observations concerning the recent performance of their current varieties will inform these decisions. Thus there is a mechanism whereby these decisions can be climate-adaptive; if a variety currently being grown is performing poorly, and if the grower links this poor performance to what they see as a pattern of recent seasonal conditions (or a climate change trend), then they may opt for a different variety that they judge to be better suited to the seasonal conditions they expect in the future. However, the deficiencies in available information and planting material noted above still apply.

**Major enterprise change can occur when thresholds are crossed**

Beyond changing management practices, changing infrastructure or changing varieties, potential enterprise change decisions of a more transformational nature include changing to a different tree crop, exiting fruit growing entirely, or moving an enterprise to a new location where the climate is more suitable.

Our interviewees consider it unlikely that many fruit growers will move their enterprises to new locations. Particular industries are tied to particular locations by a whole range of factors including infrastructure, supply chains, skills, labour markets, and identity or tradition. The spatial distribution of particular industries may shift very gradually over time however, as a result of the accumulation of decisions by individual land owners to change out of a production system that is no longer feasible, or to develop a new enterprise that they have assessed to be potentially profitable or otherwise more attractive. Some apple growers in Western Australia, for example, are deciding that avocados are an easier crop to produce profitably than apples, in their environment.

Our grower interviewee framed the decision to stop growing a particular crop as the end point of an adaptive management process; if seasonal conditions over several years render it no longer possible...
to produce a crop that returns a profit, despite the deployment of whatever adaptive management responses a grower may have tried, then exit is the only option. This description of the context in which ‘transformative’ adaptation might occur is concerning, since it suggests that a grower would arrive at this decision with severely depleted resources with which to embark on a new enterprise or livelihood. This is a situation that an industry climate change adaptation strategy or research agenda should seek to avoid.

The decision-making context in which growers operate is not strongly co-ordinated or strategically aligned toward achieving climate change adaptation

Some aspects of the context in which fruit growers make management decisions, including decision related to climate change adaptation, have already been noted above, including the need to be highly responsive to market demands, and the dearth of information concerning the relationship between weather and fruit tree physiology, to inform the selection of planting material. Other aspects of decision-making context noted by interviewees were:

- The small size of the fruit industry overall (in terms of number of growers and total value of production, resulting in limited resources for research, development and extension (RD&E));
- Lack of connection and information flow between different commodity groups (e.g. apples and cherries) within the tree fruits industry;
- Steady decline in government-provided extension resources, leading to an increasing use by growers of private sector advisors such as agronomists. (These trends are the desired result of current policy, and can be expected to continue);
- Lower-priority strategic focus on the part of industry organisations on climate change adaptation (as compared to other issues and challenges the industry faces).

Interviewees gave quite varying impressions of the extent and effectiveness of grower peer networks (both place-based and commodity-based) as aspects of growers’ decision-making context. Growers of some crops, and in some locations, apparently share information and learn from each other readily, whereas such networks are absent or less effective in the case of other crops and locations.

In general terms, this decision-making context is aligned more around market-responsive and profitability in the short to medium term, and is not currently providing strong or consistent messaging on the need for climate change adaptation.
4. Results: Research to support effective climate change adaptation by fruit growers

The key themes that emerged from our interviews concerning the role of research for supporting climate change adaptation decision-making by fruit growers are summarised below.

**Fundamental scientific research must continue**

There was strong agreement from our interviewees that the fundamental scientific knowledge that is needed to underpin climate change adaptation in the tree fruits industry is still severely lacking. As noted above, this includes scientific understanding of basic plant processes such as the influence of weather conditions on tree phenology (flowering and maturity), and the different responses of different crops and varieties to climatic conditions. This fundamental scientific understanding underpins tree physiology modelling, and hence the outputs produced from these models, such as predictions of climate change impacts on yield or estimates of the benefits of adaptive management responses, are only as reliable as the fundamental scientific knowledge upon which the models are based.

Research within Project 440 has begun, and is continuing to, progress knowledge on interactions between climate and tree flowering phenology, and on susceptibility to extreme heat. There are other areas of basic orchard science that have yet to begin, including the impacts of climate change on orchard pests and diseases. Basic knowledge of the life cycle of many pest and disease organisms is lacking, especially under Australian conditions necessarily limiting understanding of changes as a result of climate change.

Researchers understand that there will continue to be a lack of definitive scientific knowledge to inform adaptation decision-making for the foreseeable future, especially given the great diversity of crops, varieties, soils, climates and management systems within the Australian tree fruits industry. This highlights the importance of findings ways to support adaptation decision-making by growers in the context of continuing uncertainty. Nevertheless they see it as essential that basic scientific research should continue. Given the small size of the Australian tree fruits industry and research community, it is also essential that Australian researchers continue to network and collaborate effectively with each other (that is, across different industries/fruit species) as well as within the international research community. On this, there was strong agreement from our interviewees that the collaboration between researchers within Project 440, and between Project 440 and AP12029, has been highly productive and valuable (as noted also by Barlow (2014)).

**Both scientists and growers benefit when there are strong connections between scientists and growers**

The researchers interviewed universally agreed that there are substantial benefits for both parties when research is carried out in close collaboration with fruit growers, and our grower interviewee strongly endorsed this view. This is especially important given the need noted above for growers to be able to undertake effective adaptation in the context of on-going deficiency in scientific knowledge. The benefits of such collaboration include:

- Growers’ observations, interpretations and ideas can provide insights that inform scientists understanding of the phenomena they are investigating;
- Emerging scientific understanding of phenomena can help growers make sense of, and think freshly about, their own observations, deductions and management decisions;
- Growers are often the source of new management ideas and practices;
- Scientific research can be used to test, refine and document growers' management innovations;
- When growers are engaged in research projects there is also the possibility for researchers to access and make use of growers' data, noting however that this data may not be of the quality required for some scientific purposes.

Examples provided of these processes in action included mutual learning between growers and researchers on the relationship between seasonal conditions and tree flowering response, and scientific work in the Goulburn Valley on evaporative cooling of fruit using overhead sprinklers, which began as a grower innovation.

Engagement with growers needs to be woven into the design of research projects
To achieve the benefits noted above, interaction between growers and researchers needs to be regular and on-going. Knowledge-sharing by researchers, through for example media articles and field days, is useful but not sufficient. Opportunities for two-way exchange of information and ideas are also needed, and often occur best through regular, informal interactions. This interaction between growers and researchers needs to be built into the design of research projects. Locating research trials on commercial orchards is one way of achieving this, as it provides the opportunity for regular informal interaction between researchers and the participating grower. However, this interaction also needs to extend beyond the typical one- to three- year timeframe of contemporary research projects. That is, it needs to be embraced by research funders and deliverers as an on-going, long-term strategic objective, to which each individual fixed-term project is designed to contribute.

The importance of weaving grower interaction into the design of research projects is even greater in the context of the decline of public extension services. Since there is very limited availability of extension personnel to provide this link between research and practice, researchers themselves must play this role. However, there are good reasons why this often doesn’t occur. While all the researchers interviewed commented on the benefits to be gained from engagement with growers, they also noted the constraints they operate under. The organisations they work for are often more interested in scientific output in the form of publications, rather than in high-quality interaction with growers. Overall funding for research is very limited, and there are strong incentives to prioritise scientific research over grower engagement and extension.

I think there are some physiologically-based processes that we can be clear about, and I think we could probably present them in a way such that growers can use the information and apply it to their own situation. And I think that’s all that research can do (Researcher 1).

Because in the end you are not just talking about research, but research that leads to a change in practice. That’s what adaptation is. I don’t want to do something that’s going to be a waste of time and not help anyone. I’ve always seen it like that. [But] you’re absolutely restricted by budgets, and milestones and outputs... (Researcher 1).

[Some researchers] can talk to growers. They’ve got empathy, and they are passionate about what they do, and that excites me [...]. It’s nice to see growers respond to those people in a positive way, slurping up the messages. I think we are seeing a little bit of a change there. The [researchers] who are coming through seem to be a lot more engaged (Researcher 2).
Where grower engagement is written into research projects, it often takes the form of a limited and one-way communication activity, such as a fact sheet or one-off workshop or field day. There is therefore an opportunity for research funders to specify the type of grower engagement that they expect in research projects.

Our grower interviewee noted that in his experience many scientific researchers are narrowly focused on their area of scientific interest, and are resistant to engaging in two-way interaction with growers. Our researcher interviewees recognised this problem, but observed that this may be changing in the current cohort of horticultural scientists, who attach more value to the practical usefulness of the work they do.

Building in the capacity for grower engagement also requires a degree of flexibility in research project designs, so that researchers have the scope to respond to new questions and areas of interest that emerge through the course of the project.

Even where researchers are able to engage closely with growers in carrying out research, a gap remains in the area of development: that is, turning new scientific knowledge into advice or products for growers to use. This is a separate task, requiring a different skill set from that needed for carrying out research. Development activity, like grower interaction, needs to be written in to project designs in order for it to occur. One particular development opportunity that was identified by several interviewees was to develop a product to provide locally-specific meteorological data such as weather warnings and seasonal climate forecasts.

*Project designs can also create collaboration across industries and organisations*

In addition to creating opportunities for productive interactions between researchers and fruit growers, purposeful project design can also create opportunities for enhancing collaboration between different tree fruit sectors and between different organisations. That has been the experience in PICCC Project 440. The design of this project has facilitated collaboration between University and government agency researchers across four states, and has also created connections between pome fruit and cherry researchers. The researchers we interviewed judged this collaboration to be successful and productive.

This project has not created strong collaboration with private sector agronomists and farm management consultants. This is a further set of relationships that will become increasingly important to attend to in the future, as growers come to rely more and more on advice from private sources.
5. Discussion & Conclusions

Elements of adaptive capacity for the tree fruit industry

Table 5 below relates the findings discussed above to the five "capitals" that have been proposed as contributing to adaptive capacity (as per Rickards 2013). In summary, this exploratory study suggests that there are reasons to be confident about the adaptive capacities of fruit growers themselves, and reasons to be concerned about the decision-making context in which growers operate.

Table 5: Comments on adaptive capacity and the five 'capitals' for the tree fruits industry

<table>
<thead>
<tr>
<th>Type of capital</th>
<th>Adaptive capacity constraints in some populations or areas of primary industry suggested by research to date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human capital</td>
<td>Many (but not all) growers are highly skilled and adaptive managers, with good networks and a willingness to engage with new ideas. (This results in part from the highly market-responsive nature of the industry). There is also a cohort of older growers who are thinking about retirement, and therefore less open to change and new ideas. Limited human capital in the research sector, as a result of the small pool of research funding.</td>
</tr>
<tr>
<td>Social capital</td>
<td>Varying degree of connectedness between growers, and limited connections across different fruit industries. Limited government advisory support. Absence of a well-orchestrated RD&amp;E system. Relatively low priority on climate change adaptation from industry organisations and private sector agronomists. Social capital in the research sector is under pressure due to the small pool of research funds, and the resulting situation of short-term appointments.</td>
</tr>
<tr>
<td>Financial capital</td>
<td>Some enterprises struggle to generate enough profit to reinvest in on-farm change, including climate change adaptation.</td>
</tr>
<tr>
<td>Physical capital</td>
<td>Orchard plantings and infrastructure are long-lived and expensive assets and therefore change to physical infrastructure occurs slowly. Lack of specific knowledge upon which to base investment decisions. Limited genetic diversity of planting material. Constrained availability of planting material through nurseries.</td>
</tr>
<tr>
<td>Natural capital</td>
<td>No specific findings (not the focus of this research).</td>
</tr>
</tbody>
</table>

Supporting climate-adaptive orchard redevelopment decisions is a key strategic opportunity

The timeframes that apply to orchard development and redevelopment decisions are the same timeframes over which change in key climate variables is expected to occur. Improving the opportunity for growers to consider adapting to climate change when they are developing and redeveloping orchard blocks thus appears to be a strategic point of intervention for improving the overall ability of the tree fruit industry to adapt to climate change. Intervention here would require...
firstly a better understanding of the way that different fruit growers approach their decision-making in orchard redevelopment, including understanding their sources of information and their mix of decision-making criteria. Intervention would secondly require a program of work to engage the variety of people and organisations who comprise the decision-making context for these decisions. This includes researchers, advisors (both public sector and private), developers and suppliers of infrastructure and plant material and supply chain organisations including buyers.

The current deficit of scientific understanding and specific information on the chill requirements and other climate-related properties of plant material appears to be a key constraint on the ability of growers to make climate-adaptive decisions.

**There are benefits for both growers and researchers in seeking greater engagement**

This study supports the findings of others (as discussed in Rickards 2013), that both farmers and researchers see the need for and benefits of the two-way exchange of knowledge and learning that can be facilitated through participatory research designs. This study also confirmed the findings of others on the practical barriers that exist to the implementation of participatory research designs. On the growers’ side, these include limited time and resources to take on extra activities beyond running their orchards. On the researchers’ side, the barriers include the very limited total pool of research funds, and the strong organisational incentives to focus on scientific outputs over engagement. Nevertheless, the strong desire for high-quality engagement with growers that was expressed by our researcher interviewees suggests that at least some horticulture researchers will aim to build as much grower engagement into their project designs as they can.

**Engaged research methods on their own do not comprise a functional RD&E or innovation system**

However, while participatory and engaged research approaches are needed, they cannot on their own fulfil all the requirements of a functional RD&E system. Given the reservations expressed by our interviewees concerning the RD&E system for tree fruits, this exploratory study suggests a need for more focused and in-depth research to understand the structure and functionality of the system that connects new knowledge to practice change. Such research would need to look at the roles and relationships between researchers (in the private sector, in government agencies and in universities), technology developers and suppliers (including plant breeders and nurseries, and also the traditional development work of turning scientific knowledge into useful products) and the various kinds of service providers and advisors that fruit growers engage with. This whole system of actors and relationships needs to be appropriately tuned to the task of climate change adaptation (as one objective amongst the many that it serves), in order to support adaptation by growers.
6. Recommendations

This report communicates the results of a small exploratory study, drawing on a very small group of interviewees: six researchers who are involved in PICCC Project 440, and one fruit grower who is active in tree fruit research. As such, the findings reported here must be viewed as initial signposts toward further work that is needed to help the Australian tree fruits industry adapt to climate change over coming decades. With this caveat in mind, we make the following recommendations:

1. Basic research on fruit tree physiology and phenology, and their relationship with climate variables, must continue.

2. The decisions made when orchard blocks are developed or redeveloped should be recognised as a strategic point of intervention for improving the uptake of climate adaptation by fruit growers. Work should begin on understanding what types of interventions are needed (targeting various actors) to respond to this strategic opportunity. Understanding the diversity of fruit growers’ decision-making styles, management objectives and information sources at this critical stage is key.

3. A high priority should be placed on improving the information and decision support available to growers to inform the selection of planting material (both rootstocks and varieties). This is a complex task that requires collaboration between plant breeders and suppliers, growers, researchers, advisors (public and private) and potentially also supply chain actors (i.e. fruit buyers). Careful consideration is required of what form of decision support products and services can feasibly be developed in a context of (a) incomplete information and (b) the complex and potentially competing decision-making criteria that growers must balance.

4. Researchers should continue to use and expand research methods that promote two-way learning with fruit growers. Research funders should emphasise this as a requirement or assessment criterion in funding schemes.

5. Stakeholders (both industry and government organisations) should give consideration to undertaking or funding an exploratory investigation of the tree fruit industry from an innovation systems or RD&E system perspective. The objective of such an investigation would be to better understand the actors and relationships that constitute fruit growers’ decision-making context.
7. References


innovation policies: Comparing the Dutch and Scottish agrifood sectors." Agricultural Systems 129: 40-54.


Appendix A: Interview Schedule

Interviews were semi-structured and covered the following 6 themes. (Possible prompting questions are listed, but the actual questions used depended on the flow of the conversation). The flow of questions informed by the ORID framework: Stanfield (2008)\(^5\).

(a) Introductions:
- Can you tell me a bit about your career and professional background, and how you came to be doing research on fruit trees?
- What is your role in Project 440/Tipping Points?
- How is climate change research the same as, or different to, other topics you have worked on through your career?

(b) Adaptation in the tree fruit industries:
- What do you think will be some of the major changes that fruit growers will need to make to their production systems over the next 10 to 20 years in order to adapt to a changing climate?
- What do you think the current evidence says about which of these changes might occur relatively easily, and which are likely to pose major challenges or barriers for growers?

(c) Experiences with grower decision-making on adaptation:
- What do you find particularly interesting or exciting about the climate change adaptation in the tree fruit industries?
- Is there anything that worries you particularly concerning climate change adaptation in the tree fruit industries?
- Is there anything you find particularly interesting or exciting about the role of research in climate change adaptation in the tree fruit industries?
- Is there anything that worries you about the role of research in climate change adaptation in the tree fruit industries?

(d) Identifying barriers to adaptation:
- What do you think are the major social and institutional barriers to effective adaptation?

(e) Identifying research responses:
- What features do you think a future research agenda needs to incorporate, in order to support effective adaptation by growers?

(f) Is there anything else you’d like to say about “barriers to adaptation” in the tree fruit industries, and how research should proceed so as to facilitate effective adaptation?

Appendix B: Information Statement for Research Participants and Consent Form

Adaptation barriers for the Australian tree fruit industry
Plain Language Statement

Thank you for agreeing to be interviewed as part of this research. My name is Michael Santhanam-Martin and I am a Research Fellow in the Faculty of Veterinary and Agricultural Sciences at the University of Melbourne.

This research is part of Primary Industries Climate Challenges Centre Project 440: Crossing the threshold: adaptation tipping points for Australian fruit trees. The purpose of the research is to learn from your experience as a researcher within this project about the likely social and institutional barriers to effective climate change adaptation by fruit growers. This research has been approved by the University of Melbourne’s Human Research Ethics Committee.

In the interview, you will be asked about:
- the nature of the changes to their production systems that growers may have to make in response to climate change;
- your experiences and opinions about the particular challenges or barriers that may face growers in making these changes;
- your experiences and suggestions about how a future research agenda can be designed to address these challenges and barriers.

The interview will last approximately 1 hour. I will contact you by telephone or email to arrange a time and place for the interview that suit you. If you are located outside Victoria we will need to do the interview by telephone. With your consent, the interview will be audio recorded, so that I have an accurate record of what you say.

I will use the information from the interview to prepare a milestone report for the Federal Government Department of Agriculture. I may also use the information in academic journal articles and conference papers. This may include publishing short quotations from the interview, in order to illustrate important research findings.

I will protect your privacy and the confidentiality of your responses as much as I can, within the limits set by the law. Your name and contact details will be kept in a password-protected computer file separately from the interview recording. Your real name will not be used in any reports or publications. If I do publish quotations from the interview, I will not include personal information that reveals your identity. However, because of the small number of participants in this research, it is possible that someone who reads the report may still be able to guess your identity. The interview recordings will be destroyed after 5 years.

Your participation in this research is voluntary and you may withdraw consent at any time, including by asking for unprocessed data to be withdrawn.

To confirm your agreement to participate in this research, please sign and return the attached consent form.

Contact details
If you require further information, or if you have any concerns, please do not hesitate to contact me:
Michael Santhanam-Martin: Phone 03 8344 9692 or 0447 130 505, email mpmartin@unimelb.edu.au

If you have any concerns about the conduct of this research project please contact the Executive Officer, Human Research Ethics, The University of Melbourne, ph: (03) 8344 2073; fax (03) 9347 6739.

PLS V2, 12/8/2015
HREC #1545217
Faculty of Veterinary and Agricultural Sciences
Consent Form
Adaptation barriers for Australian tree fruit industries

Name of Researcher: Michael Santanam-Martín

Name of Participant: _______________________________________

1. I consent to being interviewed for this research project. The particulars of the research and the interview process have been explained to me, and I have been given written information about the project to keep.

2. I understand that after I sign and return this consent form it will be retained by the researcher.

3. I acknowledge that:
   (a) the project is for the purpose of research;
   (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data provided;
   (c) I have been informed that the confidentiality of the information I provide will be safeguarded, subject to any legal requirements;
   (d) I have been informed that with my consent the interview will be audio recorded and I understand that the recordings will be stored at the University of Melbourne and will be destroyed after five years;
   (f) my name will be referred to by a pseudonym in any publications arising from the research, but that due to the small number of people involved, it is possible that I may be able to be identified;
   (g) I have been informed that a copy of the research findings will be forwarded to me, should I agree to this.

I consent to this interview being audio recorded □ yes □ no (please tick)

I wish to receive a copy of the summary report of research findings □ yes □ no (please tick)

Participant signature(s): ____________________________ Date: ____________________________

Please return to:
Michael Santanam-Martín, Faculty of Veterinary and Agricultural Sciences
Building 142, University of Melbourne, Parkville 3010
mpmartin@unimelb.edu.au

Consent form V1, 27/7/3015 HREC #1545217
Santhanam-Martin, M; Darbyshire, R

Milestone Report 5.7 Barriers to Climate Change Adaptation in the Australian Tree Fruit Industry

2015

Santhanam-Martin, M; Darbyshire, R, Milestone Report 5.7 Barriers to Climate Change Adaptation in the Australian Tree Fruit Industry, PICC Project 440: Crossing the threshold: adaptation tipping points for Australian fruit trees, 2015, pp. 1 - 30

http://hdl.handle.net/11343/194669

Accepted version