



National Climate Change
Adaptation Research Plan

Primary Industries

Update 2013



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Primary Industries

Update Report 2013

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

Disclaimer

The views expressed herein are not necessarily the views of the Commonwealth or NCCARF, and neither the Commonwealth nor NCCARF accept responsibility for information or advice contained herein.

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Primary Industries: National Climate Change Adaptation Research Plan Update 2013

Executive Summary

Purpose of National Climate Change Adaptation Research Plans

Development of National Climate Change Adaptation Research Plans is a key function of the National Climate Change Adaptation Research Facility (NCCARF). These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response is critical in safeguarding against climate change risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to climate change risks. They provide a national blueprint for research investment by research organisations and knowledge user stakeholders. Development of NARPs involves the active participation of both the research community and adaptation stakeholders. Implementation plans are produced for each NARP to identify how the research effort can be directed to the identified priority research questions.

The NARP for Primary Industries (Primary Industries NARP) (Barlow *et al.* 2011) is concerned with identifying priority research questions for primary industries climate change adaptation issues. The knowledge generated by research into these questions should prepare primary industries to take advantage of opportunities for primary industries that result from climate change and to reduce unavoidable detrimental climate change impacts.

For the purposes of the Primary Industries NARP and this Update report, primary industries comprise all forms of agriculture, native and plantation production forestry and freshwater aquaculture. Agriculture occurs throughout Australia, and involves the production and processing of many very different types of products by thousands of independent farmers, pastoralists and graziers for domestic consumption and export. Production forestry occurs mostly in south east Queensland and southern Australia, and is dominated by a limited number of mainly large companies or government agency producers and processors, with some products, such as sawn or finished timber, mostly consumed domestically and some, such as woodchips, exported. Freshwater aquaculture occurs where critical water resources are available, producing a limited number of products mainly for domestic consumption.

Update of the Primary Industries NARP

NARPs and implementation plans are revisited and updated on a regular basis to maintain their currency as a blueprint for national climate change adaptation research and knowledge development. The Primary Industries NARP and Implementation Plan have been revisited in 2012, as part of NCCARF's review processes, and the priority research questions have been updated to ensure currency and to provide guidance for research investment over the next five years.

Updated priority research questions are identified based on:

- Changes to stakeholder needs since the Primary Industries NARP was completed in 2010;
- Relevant research published since the Primary Industries NARP was completed; and
- Areas of current research focus in relation to the Primary Industries NARP.

Changes to stakeholder information needs

Stakeholder information needs have changed significantly in the past 2 years as a result of policy initiatives, research publications and investment and the extreme weather experienced in Australia during that period.

1. The major policy initiatives are concerned with carbon sequestration and greenhouse gas emission reductions; these have affected landholder perceptions of potential opportunities that climate change responses may offer.
2. An extensive body of research publications and investment since 2010 is contributing to the knowledge base available for decisions about climate change adaptation for primary industries, but some topics have received more attention than others.
3. Extreme climate conditions experienced in Australia include the end of a long drought followed by an extreme wet in Eastern Australia and parts of Western Australia.

Major changes to stakeholder needs resulting from these developments include greater demand for:

- communication and education, especially targeted, clear and accessible information exchange about climate change impacts and adaptation at a geographic and time scale relevant to stakeholder needs;
- information about potential sequences and consequences of extreme weather relevant to regions and industry sectors and for all primary industries business activities, including infrastructure on which primary industries depend;
- information, tools and knowledge to support decisions about adaptation in multiple use landscapes (ie primary industries, water production, conservation, tourism, etc);
- knowledge about adaptation in association with land based carbon sequestration initiatives;
- independently verifiable information to support decisions about emissions reduction and carbon sequestration initiatives that can achieve synergies with adaptation outcomes;
- clear definition of the roles and responsibilities of landholders and managers, industry and government at all levels in relation to the opportunities and risks of climate change impacts, adaptation and mitigation.

Research published since 2010

Climate change adaptation for primary industries is a rapidly expanding research area. Rickards et al. (2012) reviewed over 500 research articles and other publications in the last few years since the Primary Industries NARP was completed. Much of this research is about climate change impacts or about adaptation options that adjust current production techniques. More complex research topics, such as adaptive capacity, transformation or landscape-scale adaptation, have received relatively less research attention.

Current research

Since 2010 Australia has invested significantly in research about climate change adaptation in primary industries through a number of programs. This research, when published, will add to the existing knowledge base about climate change adaptation and primary industries.

The Adaptation Research Grants Program (ARGP) managed by NCCARF has invested in four research projects focussed on priority research questions in the Primary Industries NARP, and a further 29 research projects in NCCARF's ARGP or Synthesis and Integrative Research (SIR) programs that are relevant to these priority research questions.

An audit of Australian primary industries research into climate change adaptation, undertaken as part of the Climate Change Research Strategy for Primary Industries (CCRSPI) strategy review, has identified over 500 research projects relevant to climate change adaptation by primary industries, additional to the NCCARF research programs. This research is supported by the Department of Agriculture, Forestry and Fisheries (DAFF), other Commonwealth government agencies, the ARC, industry research and development corporations, cooperative research centres, state government programs, universities, the CSIRO and other organisations.

This breadth of research demonstrates the great commitment by governments and industries across Australia to understanding and addressing the opportunities and risks for primary industries that could arise from climate change.

Stakeholder input to the Update Report

A draft of this Update report was circulated to about 70 key stakeholders nationally, was available for review from the NCCARF website and was reviewed by an international expert. Comments received have contributed to the final Update Report.

Outcomes of this Update Report

This review concludes that all priority research questions in the original Primary Industries NARP remain relevant, but that some changes in emphasis are required to take account of recent policy initiatives and research investment, and generally there needs to be a shift from impacts-focussed research to research that squarely addresses adaptation. This requires minor changes to the wording of five priority research questions and one existing priority research question being split into two questions. Four new priority research question have also been included.

The changes are as follows:

- **One research priority is amended to clarify its focus on ‘adjustment’ level adaptation and to include reference to monitoring and measuring the effectiveness of this type of adaptation:**
 - 3.1 *What ~~types of improvements~~ adjustments to production practices and technologies need to be developed to increase the adaptive capacity of Australia’s primary industries, how can their effectiveness (benefits and costs) be monitored and measured, and what practical issues need to be addressed for implementation?*
- **Four research priorities are restated to extend their scope:**
 - 1.1 *What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels?*
 - 2.2 *What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities?*
 - 3.2 *How might climate change benefit primary industries in Australia, such as through increased atmospheric CO₂ and changes in temperature and water availability?*
 - 6.4 *How can the effectiveness of adaptation by primary industries be monitored and measured across all business activities, including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives?*
- **One research priority is split into two:**

6.2 *How can information about climate change adaptation ~~requirements~~, options, strategies, benefits and costs be integrated with other information critical to primary producers and industries, ~~and communicated to support successful adaptation being determined and implemented?~~*

6.3 *How can information about climate change adaptation ~~requirements~~, options, strategies, benefits and costs be integrated with other information critical to primary producers and industries, ~~and communicated to support effective adaptation being determined and implemented?~~*

- **Four new research priorities are added:**

1.2 *How does industry structure and leadership affect adaptive capacity in the primary industries sector?*

6.5 *How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector?*

6.6 *What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events?*

6.7 *What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries?*

With these changes in emphasis and additions, all eighteen research questions have been assessed to be 'High' priority.

The updated set of priority research questions is listed in the table on the next page.

The updated Primary Industries Implementation Plan is available at <http://www.nccarf.edu.au/content/narp-primary-industries/>

| High priority research questions (2012) |
|--|
| 1. Understanding and expanding adaptive capacity |
| 1.1 What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels? |
| 1.2 How does industry structure and leadership affect adaptive capacity in the primary industries sector? |
| 2. Levels of adaptation |
| 2.1 What factors define the effectiveness of different levels of adaptation response: adjusting practices, changing production systems and transforming enterprises, industries and regions? |
| 2.2 What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities? |
| 3. Adjusting primary production practices and technologies |
| 3.1 What adjustments to production practices and technologies need to be developed to increase the adaptive capacity of Australia's primary industries, how can their effectiveness (benefits and costs) be monitored and measured, and what practical issues need to be addressed for implementation? |
| 3.2 How might climate change benefit primary industries in Australia, such as through increased atmospheric CO ₂ and changes in temperature and water availability? |
| 4. Changing primary production systems |
| 4.1 What characteristics of production system change in primary industries are likely to provide advantage under changed climate conditions? |
| 4.2 What information, knowledge, tools, programs and policies are needed to support effective changes to primary production systems? |
| 5. Transforming primary production enterprises and industries |
| 5.1 What characteristics of transformational change in primary industries are likely to provide advantage under changed climate conditions? |
| 5.2 What information, knowledge, tools, programs and policies are needed to support effective transformative adaptation in primary production systems? |
| 5.3 How can the well-being of individuals and communities unable to undertake transformational changes be maintained? |
| 6. Integrating, implementing and reviewing adaptation |
| 6.1 How can integrated climate change adaptation response plans be developed at the local, landscape and regional scales? |
| 6.2 How can information about climate change adaptation options, strategies, benefits and costs be integrated with other information critical to primary producers and industries? |
| 6.3 How can information about climate change adaptation options, strategies, benefits and costs be communicated to support effective adaptation being identified and implemented. |
| 6.4 How can the effectiveness of adaptation by primary industries be monitored and measured across <u>all business activities</u> , including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives? |
| 6.5 How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector? |
| 6.6 What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events? |
| 6.7 What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries? |

1 Introduction

Development of National Climate Change Adaptation Research Plans is a key function of the National Climate Change Adaptation Research Facility (NCCARF). These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response is critical in safeguarding against climate change risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to climate change risks. They provide a national blueprint for research investment by research organisations and knowledge user stakeholders. Development of NARPs involves the active participation of both the research community and adaptation knowledge users. Implementation plans are produced for each NARP to identify how the research effort can be directed to the identified priority research questions.

The NARP for Primary Industries (Primary Industries NARP) (Barlow *et al.* 2011) is concerned with identifying priority research questions (PRQs) for primary industries climate change adaptation issues. The knowledge generated by research into these questions should prepare primary industries to take advantage of opportunities for primary industries that result from climate change and to reduce unavoidable detrimental climate change impacts.

For the purposes of the Primary Industries NARP and this Update report, primary industries comprise all forms of agriculture, native and plantation production forestry and freshwater aquaculture. Agriculture occurs throughout Australia, and involves the production and processing of many very different types of products by thousands of independent farmers, pastoralists and graziers for domestic consumption and export. Production forestry occurs mostly in south east Queensland and southern Australia, and is dominated by a limited number of mainly large companies or government agency producers and processors, with some products, such as sawn or finished timber, mostly consumed domestically and some, such as woodchips, exported. Freshwater aquaculture occurs where critical water resources are available, producing a limited number of products mainly for domestic consumption.

NARPs and implementation plans are revisited and updated on a regular basis to maintain their currency as a blueprint for national climate change adaptation research and knowledge development. The Primary Industries NARP and Implementation Plan have been revisited in 2012, as part of NCCARF's review processes, and the PRQs have been updated to ensure currency and to provide guidance for research investment over the next five years.

The revisit and update is informed by:

- a comprehensive review of the scientific research literature undertaken since March 2010 (Rickards *et al.* 2012) when the Primary Industries NARP was originally drafted,
- current research addressing research priorities identified in the Primary Industries NARP,
- information about recent policy initiatives,
- information about changes to the priority needs of primary industry stakeholders in Australia, and
- input from the Primary Industries Adaptation Research Network (PIARN), the Climate Change Research Strategy for Primary Industries (CCRSPI) partnership and other key stakeholders.

Other activities and reports have also contributed to this update, especially those by PIARN and the CCRSPI partnership.

A discussion of each research priority and any amendments is set out in section 4 of this report; consideration of new priority research areas is found in section 5. Changes to the original PRQs are summarised in section 6.

An updated table of PRQs resulting from this revisit is provided in section 7.

The draft of this Update report was circulated to about 70 key stakeholders nationally, was available for review from the NCCARF website and was reviewed by an international expert. Comments received have contributed to the final Update Report. The updated Primary Industries Implementation Plan is available at <http://www.nccarf.edu.au/content/narp-primary-industries/>.

2 Major changes to stakeholder information needs since 2010

The information, tool and knowledge needs of Australian primary industry stakeholders have been affected by several events since 2010.

2.1 Drought and drought policy reform

The end of the long drought (1997 to 2010) that affected most of eastern Australia and parts of Western Australia, and its replacement with an extreme wet (see Box 1) has raised awareness that climate variability occurs on a multiple-year basis as well as on a seasonal basis. These recent events also demonstrated that extremes are not necessarily rare events and can exceed historical experience. They have increased stakeholder awareness of the need to manage surface and groundwater resources carefully. Moreover, the current drought in North America, and its effect on global grain prices, has demonstrated the effect of climate on the global and interlinked systems of production, marketing, and consumption of primary produce.

A review of the National Drought Policy (2008 – 2009) comprised an economic assessment of drought support measures, a social impact assessment of drought on farm families and rural communities and a climate assessment of likely future climate patterns. The review informed the development of policies to help farmers better prepare for a changing climate. The resultant drought reform measures were piloted in part of Western Australia during 2010 – 2012, and a reformed national drought policy is being developed on the basis of this experience.

2.2 Short-duration extreme weather events

After the long drought broke in 2010, several regions in Australia were affected by heatwaves, bushfires, floods and storms (see Box 1). These experiences highlighted to primary producers the great variability of climate conditions that could occur in much of Australia and the vulnerability of rural producers and residents to these conditions.

2.3 Clean Energy Future Initiative and carbon farming

Australia's Carbon Farming Initiative legislation was enacted in 2011 and 'Securing a Clean Energy Future' legislation was enacted in 2012. The Clean Energy Future legislation established a price on carbon emissions from July 2012, progressing into a carbon trading scheme in 2015. The agriculture forestry and fisheries industries are not covered in this legislation, and therefore are only liable for indirect carbon taxes through their use of stationary energy. However, the separate Carbon Credits (Carbon Farming Initiative) legislation provides a mechanism for the land based sector to generate carbon price offsets through proactive activities that reduce emissions and/or sequester carbon into the landscape. As part of this legislation the government has established the Carbon Farming

Futures research development and extension (RDE) program to support the development of technologies, management systems and methodologies for land managers to participate in the Carbon Farming Initiative.

The Clean Energy Future legislation has also established programs to improve the adaptive capacity and preparedness of Australian landscapes to future climate change. The Carbon Farming Futures RDE embraces adaptation as well as mitigation, and particularly the interaction between adaptation and mitigation.

Most elements relevant to primary industries are concerned with emission reductions and organic carbon sequestration through changes to production practices or options. The 'Regional Natural Resources Management Planning for Climate Change Fund' will help regional natural resources management (NRM) organisations update plans to consider the impacts of climate change and maximise the benefits of bio-diverse carbon stores and carbon farming projects.

2.4 Summary

In the preparation of this report, stakeholder information needs have been assessed by the Writing Team through discussions with key stakeholders and relevant organisations and processes, such as CCSRPI and PIARN and consultation on a draft of this report. Major changes to stakeholder needs from these developments include greater demand for:

- communication and education especially targeted, clear and accessible information exchange about climate change impacts and adaptation at a geographic and time scale relevant to stakeholder needs;
- information about potential sequences and consequences of extreme weather relevant to regions and industry sectors and for all primary industries business activities, including infrastructure on which primary industries depend;
- information, tools and knowledge to support decisions about adaptation in multiple use landscapes (ie primary industries, water production, conservation, tourism, etc);
- knowledge about adaptation in association with land based carbon sequestration initiatives;
- independently verifiable information to support decisions about emissions reduction and carbon sequestration initiatives that can achieve synergies with adaptation outcomes;
- clear definition of the roles and responsibilities of landholders and managers, industry and government at all levels in relation to the opportunities and risks of climate change impacts, adaptation and mitigation.

Box 1. Some recent examples of extreme climatic events and their impacts

THE BIG DRY: The recent 13-year drought in the southern Murray-Darling Basin (MDB) and Victoria was unprecedented compared with other recorded droughts since 1900. Impacts on primary industries included major crop losses, a significant reduction in livestock numbers and substantial reductions in irrigation production.

Source: <http://www.bom.gov.au/climate/drought/archive/20100408.shtml> - extracted 26 January 2012.

HEATWAVES and BUSHFIRES: Associated with El Niño conditions, a severe heatwave occurred in southern Australia from 26 January to 7 February, 2009. There was a record run of days above 43°C at Adelaide and Melbourne. Estimates of deaths resulting from the hot conditions range from 424 to 500 people. Power outages resulting from bushfires and transport system disruptions to the Melbourne rail network caused financial losses estimated at \$800 million. On 7 February, strong, dry north-westerly winds fanned bushfires which claimed 173 lives, mostly in areas northeast of Melbourne. This heatwave also had a considerable impact on agricultural industries in Southern Australia, such as grape yields (Jones and Webb 2010), in addition to the direct damage of the bushfires.

Sources: Bureau of Meteorology Annual Climate Summary 2009 (2010), http://www.bom.gov.au/climate/annual_sum/2009/index.shtml - extracted 26 January 2012. Reeves (2012), Impacts and adaptation responses of infrastructure and communities to heatwaves (NCCARF). <http://www.nccarf.edu.au/publications/impacts-and-adaptation-responses-infrastructure-and-communities-heatwaves> - extracted 13 November 2012.

Kiem et al. (2010), Learning from experience (NCCARF); <http://www.nccarf.edu.au/publications/learning-experience-historical-case-studies-and-climate-change-adaptation> - extracted 13 November 2012.

FLOODS OF SEPTEMBER 2010: In early September 2010, associated with a switch to La Niña conditions, there was flooding on many rivers in northern Victoria. In September 2010, a tropical depression formed over the Gascoyne area of Western Australia, producing severe floods in the region. Impacts on primary industries included losses of 2000 head of cattle and damages estimated at \$100 million.

Sources: Bureau of Meteorology Annual Climate Summary 2010 (2011), http://www.bom.gov.au/climate/annual_sum/2010/index.shtml - extracted 26 January 2012. http://en.wikipedia.org/wiki/2010_Gascoyne_River_flood.

FLOODS OF DECEMBER 2010 - JANUARY 2011: A series of floods hit Eastern and SE Australia, including river and flash flooding, beginning in December 2010 and early 2011, primarily in the state of Queensland including its capital city, Brisbane. More than 78 per cent of the state (an area bigger than France and Germany combined) was declared a disaster zone. These floods forced the evacuation of thousands of people from towns and cities. At least 70 towns and over 200,000 people were affected. In Emerald, a 16.05 metre peak in the Nogoa River on 31 December set a new record for the town. The Nogoa River peak caused major flooding in Emerald, where between 1,000 and 1,200 houses were flooded to some degree and approximately 95 per cent of businesses were damaged. Two thousand, four hundred and sixty-three residents registered as evacuees, and more than 400 were forced to stay in evacuation centres. In Brisbane, 22,000 homes and businesses were inundated over January 12 and 13. Altogether there were 2.5 million people affected and an estimated 29,000 homes and businesses suffered some form of inundation. Damage across the state was estimated in excess of \$5 billion. Thirty-five people died in the floods; three remain missing. 78% of the state was declared a disaster zone. The flooding in eastern Australia is estimated to have reduced agricultural production by at least \$500–600 million in 2010–11, with significant impacts on the production of fruit and vegetables, cotton, grain sorghum and some winter crops.

Sources: Queensland Floods Commission of Inquiry: Interim Report (August 2011) <http://www.floodcommission.qld.gov.au/publications/interim-report>; <http://www.floodcommission.qld.gov.au/publications/final-report>, ABARES (2011). http://adl.brs.gov.au/data/warehouse/pe_abares99001773/Floods_on_commodities_2011_REPORT.pdf, http://www.bom.gov.au/announcements/media_releases/climate/change/20120104.shtml Bureau of Meteorology Annual Climate Summary 2010 (2011), http://www.bom.gov.au/climate/annual_sum/2010/index.shtml and Bureau of Meteorology Annual Climate Summary 2011 (2012), http://www.bom.gov.au/climate/annual_sum/2011/index.shtml - extracted 26 January 2012

CYCLONE YASI: In February 2011, Cyclone Yasi was one of the most powerful cyclones to have affected Queensland. Tully Sugar Mill recorded sea level pressure of 929 hPa as the eye passed over, suggesting wind gusts of about 285 km/h were possible, leaving behind significant damage. Approximately 75% of the banana crop was wiped out, valued at \$350 million. Sugar producers lost 20% of their crop, with a total estimate of \$500 million in damages to crop and infrastructure.

Sources: <http://www.bom.gov.au/cyclone/history/yasi.shtml> - extracted 26 January 2012. <http://www.news.com.au/business/bananas-sugar-growers-worst-hit-by-tropical-cyclone-yasi/story-e6frfm1i-1226000185348> - extracted 13 November 2012. News: <http://www.news.com.au/business/bananas-sugar-growers-worst-hit-by-tropical-cyclone-yasi/story-e6frfm1i-1226000185348#ixzz2C5DZvwSf>

3 Research findings and activities since 2009

3.1 Published findings

Research published since the Primary Industries NARP was completed has been reviewed by Rickards et al. (2012). They reviewed and summarised over 500 relevant research publications and other documents published between 2010 and 2012. The report was structured around the research priorities of the Primary Industries NARP, allowing some key knowledge gaps to be identified. Key findings have been extracted from that report and included in Section 4, with representative references; other information has also been used and is acknowledged where appropriate. See Rickards et al. (2012) for a full review of publications.

3.2 Current research

Since 2010 Australia has invested significantly in research about climate change adaptation and primary industries through a number of programs. This research, when published, will add to the existing knowledge base about climate change adaptation and primary industries

The Adaptation Research Grants Program (ARGP) managed by NCCARF has invested in four research projects directly relevant to the primary industries theme (see Box 2), involving an ARGP investment of more than \$1,200,000, and a total research value of more than \$2,750,000 (cash and in-kind). Four ARGP research projects in other themes (see Box 3) are also relevant to the PRQs for primary industries; these projects involve an ARGP investment of about \$1,230,000 and a total value of over \$2,500,000. Twenty-five climate change adaptation research projects relevant to primary industries have been commissioned through NCCARF's Synthesis and Integrative Research (SIR) program (see Box 4), involving a total investment of more than \$2,100,000. NCCARF's research investment in 33 research projects relevant to the primary industries theme thus totals more than \$4,500,000, with a total research value of more than \$7,300,000.

An audit of Australian primary industries research into climate change adaptation, undertaken as part of the CCRSPI strategy review, has identified over 500 research projects relevant to climate change adaptation by primary industries, additional to the NCCARF research programs. This research is being supported by the Department of Agriculture, Forestry and Fisheries (DAFF), other Commonwealth government agencies, industry research and development corporations, the ARC, cooperative research centres, state government programs, the CSIRO and other organisations.

DAFF has administered a number of grant programs in which climate change adaptation has been an integral priority. These programs focus on scientific research to develop a better understanding of what adaptation options are available to Australia's primary industries, as well as translating these higher level research findings into realistic and practical land management solutions to climate change. For instance, DAFF's Climate Change Research Program has recently invested more than \$11.5 million to test responses of key crops to increases in temperature and carbon dioxide; monitor ways to manage heat stress in livestock; examine potential new shrub-based forages for livestock; and evaluate the relocation of various crops to northern Australia. The Farm Ready Program aimed to boost training opportunities for primary producers and Indigenous land managers, and enable industry, farming groups and natural resource management groups to develop strategies for adapting and responding to the impacts of climate change. Over \$3.6 million has been invested in research aimed to develop information that would allow the commercial forest sector, forest planners and managers, and forestry dependent communities to better adapt to climate change. This research was aimed at developing diagnostic tools and techniques to determine when (and what) specific management intervention is required to respond to

the threats and opportunities of climate change. A number of projects also focused on examining forestry-relevant tree species and determining which species (and their genotypes) are most likely to thrive under projected climatic changes. In addition, research also examined options to mitigate the projected increase in bush fire risks, and testing and advancing Australia’s biosecurity preparedness with regard to major forest pests.

Most other research investors have a more limited sectoral or geographic focus, while CSIRO’s research focus can address local, regional or national topics.

Sixty -five projects relevant to the Primary Industries NARP PRQs are referenced in Section 4 (see Box 5).

Box 2:

NCCARF (ARGP) research projects directly relevant to priority research questions in the Primary Industries NARP

NCCARF’s investment in research for the Primary Industries theme has been directed to three areas: adaptive capacity, transformation-level adaptation and integrated adaptation at the landscape scale.

(Note: further information about these projects is available in Appendix 3 and at

- <http://www.nccarf.edu.au/research/thematic/393> and
- <http://www.nccarf.edu.au/research/thematic/400>)

| Research Project Title | Principal Investigator | Institution |
|---|-------------------------------|---|
| PI11 01 - Will primary producers continue to adjust practices and technologies, change production systems or transform their industry - an application of real options | Gregory Hertzler | University of Sydney |
| PI11 02 - Adaptive capacity and adaptive strategies of broadacre farms experiencing climate change | Ross Kingwell | Department of Agriculture and Food (WA) |
| PI11 03 - EverFarm® - Design of climate adapted perennial-based farming systems for dryland agriculture in southern Australia | Amir Abadi | CRC FFI |
| TB11 09 - Adapted future landscapes - from aspiration to implementation ¹ | Wayne Meyer | University of Adelaide |

Box 3:

NCCARF-managed (ARGP) research projects relevant to the priority research questions in the Primary Industries NARP, commissioned under other themes

Other NCCARF ARGP research relevant to the primary industries theme is concerned with adaptation issues for multi-objective landscapes.

(Note: further information about these projects is available at <http://www.nccarf.edu.au/research/thematic-research-grants>)

¹ Note that NCCARF/ARGP project TB11 09 [Meyer], concerned with climate change adaptation in multiple use landscapes, was commissioned under three themes (Primary Industries, Terrestrial Biodiversity and Freshwater Biodiversity).

| Research Project Title | Principal Investigator | Institution |
|--|-------------------------------|--|
| <i>TB11 01 - The architecture of resilient landscapes: scenario modelling to reveal best-practice design principles for climate adaptation.</i> | Veronica Doerr | CSIRO |
| <i>TB11 03 - Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species.</i> | Margaret Byrne | Dept Environment and Conservation; Western Australia |
| <i>TB11 05 - Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species.</i> | Lesley Hughes | Macquarie University |
| <i>FW11 09 - Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems.</i> | Michael Dunlop | CSIRO |

Box 4:

NCCARF's Synthesis and Integrative Research (SIR) projects relevant to the priority research questions in the Primary Industries NARP

NCCARF's SIR research program supports projects having a wide scope of relevance to adaptation for primary industries.

(Note: further information about these projects is available at <http://www.nccarf.edu.au/research/s-and-i>)

| SIR Research Project Number and Title | Principal Investigator | Institution |
|--|-------------------------------|-----------------------------------|
| P1ACP1 - An assessment of the nature and utility of adaptive capacity research. | Tim Smith | University of Sunshine Coast |
| P1HCS4 - The 2008 Floods in Queensland. | Armando Apan | University of Southern Queensland |
| P1HCS6 - Drought and the future of small inland towns | Anthony Kiem | University of Newcastle |
| P1HCS7 - Resilience and water security in two outback cities | Glen Albrecht | Murdoch University |
| P1HCS8 - Learning from experience: Historical Case Studies and Climate Change Adaptation | Anthony Kiem | University of Newcastle |
| P1FVA4 - Forest Vulnerability Assessment 4: Climate change adaptation options, tools and vulnerability | Steve Turton | James Cook University |
| P1FVA5 - Forest Vulnerability Assessment 5: Synthesis | Roger Kitching | Griffith University |
| P2LTA1 - Limits to climate change adaptation in the Great Barrier Reef: Scoping ecological, institutional and economic limits | Louisa Evans | James Cook University |
| P2LTA5 - Limits to Climate Change Adaptation for Two Low-Lying Communities in the Torres Strait | Scott Smithers | James Cook University |
| P2LTA6 - Limits to climate change adaptation for small inland communities affected by drought | Anthony Kiem | University of Newcastle |
| P2IMLR - iClimate Project | Elvira Poloczanska | CSIRO |

| | | |
|--|------------------------|--|
| P2CES1 - Coastal Ecosystems Response to Climate Change 1: Climate and Climate Change and its impacts | Wade Hadwen | Griffith University |
| S3ABA1 - Cross-Scale Barriers to Adaptation in Local Government, Australia | Natasha Kuruppu | Macquarie University |
| S3AFL2 - Living with floods: key lessons from Australia and abroad | Karen Hussey | Australian National University |
| S3AUN1 - Bridging the gap between end user needs and science capability: dealing with uncertainty in future scenarios | Danielle Verdon-Kidd | University of Newcastle |
| S3AUN2 - Understanding end-user decisions and the value of climate information under the risks and uncertainties of future climates | Alan Randall | Sydney University |
| S3BST2 - Overcoming challenges for decision making about climate change adaptation | Kambiz Maani | Griffith University |
| S3BIB2 - Climate change adaptation: A framework for best practice in financial risk assessment, governance and disclosure | Jason West | Griffith University |
| S3BAM1 - Climate change adaptation: A framework for best practice in financial risk assessment, governance and disclosure | Max Finlayson | Charles Sturt University |
| S3BCM1 - Enhancing Climate Change Communication: Strategies for Profiling and Targeting Australian Interpretive Communities. | Donald Hine | University of New England |
| S3BEC2 - The economics of government as insurer of last resort for climate change adaptation | Leo Dobs | Australian National University |
| S3BWT1 - Web based tools for adaptation in Australia – an international and Australian review | Bob Webb | Australian National University |
| S3AFS1 - Australian Food Security: Impact of Climate Change for Risk Management: How prepared are food industry leaders? | David Michael | Wondu Business and Technology Services Pty. Ltd. |
| S3AFS2 - Creating a climate for food security: the business, people & landscapes in food production | Angela Wardell-Johnson | University of the Sunshine Coast |
| S3AFS3 - Urban food security, urban resilience and climate change | Paul Burton | Griffith University |

Box 5:

Climate change adaptation (current and recent) research projects relevant to the priority research questions in the Primary Industries NARP, commissioned and managed by other organisations

An audit of current research relevant to climate change issues (both mitigation and adaptation) undertaken as part of the 2012 review of the CCRSPI strategy has identified over 500 of research projects. This box lists a selection of these projects, to which reference is made in Section 4.

| Research Project Title | Principal Investigator | Institution |
|---|---|---------------------------------|
| ARC Grants (For further information: http://arc.gov.au/applicants/fundingoutcomes.htm) | | |
| [FL100100066] New approaches for pest control and maintaining healthy environments under climate change | Ary Hoffmann | University of Melbourne |
| [FL100100195] Tipping points in Records of Extreme Events in Australasia: Using the Past to Understand and Plan for Abrupt Future Climate Change | Chris Turney | University of New South Wales |
| [DP0880933] Extreme weather and population health in Australia: risk assessment, prediction of health impacts and disease burden, and adaptive strategy exploration | Peng Bi | University of Adelaide |
| [DP120101983] Assisting rural communities in South Australia adapt to the health challenges of increasing temperatures and climate change | Peng Bi | University of Adelaide |
| [DP0986041] Making less space for carbon: cultural research for climate change mitigation and adaptation | G Waitt | University of Wollongong |
| [DP120104797] Rethinking climate justice in an age of adaptation: capabilities, local variation, and public deliberation | David Schlosberg | University of Sydney |
| [DE120100786] Slow catastrophes: drought resilience amongst farmers and agricultural communities in south eastern Australia, 1880s-2000s | Caroline Jones | Australian National University |
| [LP120200002] Ecological responses of native fishes to dynamic water flows in northwest arid Australia | Pauline Grierson | University of Western Australia |
| [LP120200380] Providing a genetic framework to enhance the success and benefits from forest restoration and carbon plantings in rural landscapes | Bradley Potts | University of Tasmania |
| Research and Development Corporations | | |
| Forest and Wood Products Australia (For further information: http://www.fwpa.com.au/) | | |
| RDC 1 - Climate Change and Australia's plantation estate: Analysis of vulnerability and preliminary investigation of adaptation options | M. Battaglia, J. Bruce, C. Brack & T. Baker | FWPA & CSIRO |
| Grains Research and Development Corporation (For further information: http://www.grdc.com.au/) | | |
| [BWD00019] Australian farm groups demonstrating adaptive practices to minimise the impact of climate change on farm viability | N/A | GRDC |
| [DAQ00163] Participatory adaptation and mitigation strategies for climate change on the mixed farms of northeastern Australia | N/A | GRDC |
| Grape and Wine Research and Development Corporation (For further information: http://www.gwrdc.com.au/) | | |
| [CSP 0902] Enhanced varieties and clones to meet the challenges of climate change and deliver lower alcohol wines | PR Clingeffer & HP Davis | CSIRO |
| [MU 08/01] Adaptation of the Australian wine industry to climate change - opportunities and vulnerabilities | Snow Barlow | University of Melbourne |

| | | |
|---|----------------------------------|---|
| Horticulture Australia (For further information: http://www.horticulture.com.au/) | | |
| [AH06019] Australian horticulture's response to climate change and climate variability | Peter Deuter | DAFF Queensland |
| [HG08037] Critical thresholds ('tipping points') and climate change impacts/adaptation in horticulture | Peter Deuter | DAFF Queensland |
| Cooperative Research Centres (CRCs) | | |
| Cotton Catchment Communities CRC (For further information: http://www.cottoncrc.com/) | | |
| CCC/CRC-1 Socio Economic Impacts climate change, technology and water policy | Tony Jakeman | CCC CRC |
| CCC/CRC-2 A historical geography of cotton farming in NSW & Qld: adaptation and adoption | Wendy Shaw | University of New South Wales & CCC/CRC |
| Future Farm Industries CRC (For further information: http://www.futurefarmcrc.com/) | | |
| FFI/CRC-1 The economics of technological innovation for adaptation to climate change by broadacre farmers in Western Australia | Donkor Addai | University of Western Australia |
| CSIRO | | |
| Climate Adaptation Flagship (For further information: http://www.csiro.au/) | | |
| CSIRO-1 Developing agribusinesses more resilient to climate change | Steven Crimp | CSIRO |
| CSIRO-2 Assessing the capacity of rural communities to adapt to climate change | Steven Crimp | CSIRO |
| CSIRO-3 Exploring how to adapt dairy enterprises to climate change | Uday Nidumolu & Steven Crimp | CSIRO |
| CSIRO-4 Australian primary industries transforming for a changing climate | Anne-Maree Dowd | CSIRO |
| Commonwealth Department of Agriculture, Fisheries and Forestry (DAFF) (For further information: http://www.daff.gov.au/) | | |
| Australia's Farming Future - Climate Change Research Program (CCRP) | | |
| DAFF/AFF 1 - A national research program for climate-ready cereals | Scott Chapman | CSIRO |
| DAFF/AFF 2 - Developing climate change resilient cropping and mixed cropping/grazing businesses in Australia | Steven Crimp | CSIRO |
| DAFF/AFF 3 - Relocation of intensive crop production systems to northern Australia: Costs and opportunities | N/A | DEEDI Qld |
| DAFF/AFF 4 - Agriculture transforming to adapt to climate change: The peanut industry expansion in the NT as a blueprint | Peter Thorburn | CSIRO |
| DAFF/AFF 5 - Development of effective management strategies to adapt production to mitigate climate change challenges in the wine industry | N/A | GWRDC |
| DAFF/AFF 6 - Mitigation and Adaptation in the Australian Dairy Industry (MAADI) | Joe Jacobs, Graeme Ward & others | Dairy Australia (DA) |

| | | |
|--|--|---|
| DAFF/AFF 7 – Climate change adaptation in the southern livestock industries | <i>Richard Eckard & Andrew Moore</i> | Dairy Australia (DA); Meat and Livestock Australia (MLA); Australia Wool Innovation (AWI) |
| DAFF/AFF 8 - Adaptation of a range of wheat types to elevated atmospheric CO2 concentration | <i>N/A</i> | University of Melbourne |
| DAFF/AFF 9 - Developing improved on-ground practices and industry strategies for adapting to climate change within beef production enterprises across northern Australia | <i>N/A</i> | Meat and Livestock Australia (MLA) |
| DAFF/AFF 10 – Amelioration of thermal stress impacts on animal performance and welfare in southern Australia dairy, beef and sheep industries | <i>N/A</i> | University of Melbourne |
| DAFF/AFF 11 – Adaptation of fishing and aquaculture sectors and fisheries management to climate change in south-eastern Australia | <i>N/A</i> | Department of Primary Industries, Victoria |
| Farm Ready- <i>(For further information see http://www.daff.gov.au/climatechange/australias-farming-future/farmready)</i> | | |
| DAFF/FR 1-16 DAFF's Farm Ready program, which closed on 30 June 2012 aimed to boost training opportunities for primary producers and Indigenous land managers, and enable industry, farming groups and natural resource management groups develop strategies to adapt and respond to the impacts of climate change. | <i>N/A</i> | DAFF |
| Forest Industries Climate Change Research Fund <i>(For further information: http://www.daff.gov.au/forestry/national/climate-change-research/adaptation)</i> | | |
| DAFF/FICCRF 1 - Adapting and mitigating climate change through the sustainable production and use of forest biomass for commercial scale bioenergy production | <i>N/A</i> | Rural Industries Research and Development Corporation |
| DAFF/ FICCRF 2 - Climate adaptation strategies to manage drought risk and mortality in existing and new forest plantations in Australia | <i>Don White</i> | CSIRO |
| Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) <i>(For further information: http://www.climatechange.gov.au/)</i> | | |
| DCCEE 1 - Study of national indicators of climate change adaptive capacity | Rohan Nelson | CSIRO |
| DCCEE 2 - The Economic Case for Adaptation | <i>N/A</i> | Australian National University |
| DCCEE 3 - Climate Extremes Grant | Roger Jones | CSIRO |
| DCCEE 4 - Tradeoffs and Policy Mechanisms in Managing Land Use as an Adaptation Response | <i>N/A</i> | CSIRO |
| Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) <i>(For further information: http://www.environment.gov.au/)</i> | | |
| SEWPaC 1 - Improving landscape connectivity & biodiversity for climate change adaptation | <i>N/A</i> | Hunter-Central Rivers CMA |

| | | |
|---|--|--------------------------------------|
| SEWPaC 2 - Best Management Practice Grazing Strategies for Adapting to Climate Variability in the Maranoa-Balonne | N/A | Queensland Murray-Darling Committee |
| SEWPaC 3 - Planning for multiple use landscapes on farms | N/A | Eyre Peninsula NRM Board |
| SEWPaC 4 - Prerequisites and limits for economic modelling of climate change impacts and adaptation | <i>Frank Jotzo</i> | Australian National University |
| SEWPaC 5 - Rural landholders adapting to climate change: Social research perspectives | <i>Nicole Mazur, Allan Curtis and others</i> | Charles Sturt University |
| SEWPaC 6 - A Future Without Water Entitlements: Effects on a Changing Climate on Farming Communities in the Greater Shepparton Area | N/A | Greater Shepparton City Council |
| Murray Darling Basin Authority (MDBA) (<i>For further information: http://www.mdba.gov.au/</i>) | | |
| MDBA 1 - Indicators of community vulnerability, resilience and adaptive capacity across the Murray-Darling Basin | N/A | DAFF / BRS |
| <u>South Australia (SA)</u> | | |
| SA 1 - Building research capability to identify climate change vulnerability and adaptation options for South Australian Landscapes. | Wayne Meyer | University of Adelaide |
| VCCCAR (<i>For further information: http://www.vcccar.org.au/</i>) | | |
| VCCCAR1 - Framing multi-level and multi-actor adaptation responses in the Victorian context | Darryn McEvoy RMIT University | RMIT University |
| VCCCAR2 - Building common understanding of scenario based strategies to inform climate change adaptation | John Wiseman | University of Melbourne |
| VCCCAR3 - Understanding policies and governance for integrated landscape management in a changing environment | Andy Bennett | Deakin University |
| VCCCAR4 - Enhancing water infrastructure provision with climate change uncertainty | Harry Clarke | La Trobe University |
| VCCCAR5 - Learning from Indigenous natural resources management in the Barmah-Millewa | Dave Griggs | Monash University |
| VCCCAR6 - Design-led decision support for regional climate change | Ralph Horne and John Martin | RMIT University, LA Trobe University |
| VCCCAR7 - Decision Taking in Times of Uncertainty. Towards an efficient strategy to manage risk and uncertainty in climate change adaptation | Jens Zinn | N/A |

4 Updated information for Section 4 of the Primary Industries NARP

This section summarises information that has become available since the Primary Industries NARP was completed and outlines the consequences for PRQs in the NARP. The information in this section is based on Rickards et al. (2012), audits of current research undertaken by NCCARF and CCRSPI, and other information (cited as appropriate).

Section 4 of the original Primary Industries NARP sets out the basis for PRQs for primary industries. The section is structured into five focussed themes (understanding and expanding adaptive capacity, levels of adaptation, adjusting primary production practices and technologies, changing primary production systems, transforming primary production

enterprises and industries) and a sixth cross cutting theme (integrating, implementing and reviewing adaptation. The PRQs themselves are stated in broad terms, recognising the large number of relevant factors and the complex interactions involved in each of the issues they address.

The discussion in this section is organised in relation to each theme and research question in the Primary Industries NARP.

All research questions listed in a NARP merit research support. They are prioritised using 6 criteria:

1. Severity of potential impact to be avoided or degree of potential benefit to be derived (essential);
2. Immediacy of required intervention or response (essential);
3. Need to change current intervention and practicality of alternative intervention (essential);
4. Potential for co-benefit (desirable);
5. Cross-sectoral relevance (desirable);
6. Equity considerations (desirable).

All PRQs in the original Primary Industries NARP were assessed to be 'High' priority. As a result of the information and analysis in this section, the priority of all updated research questions has also been assessed to be 'High'.

However, the relative prioritisation between research questions may differ between regions, stakeholders or research investors, a matter that is not considered here.

4.1 NARP Section 4.1 Understanding and expanding adaptive capacity: Priority research questions

1.1 What is adaptive capacity in the primary industries sector and how can it be measured and increased at individual, industry, regional and national levels?

Research on adaptive capacity is increasingly common, as the emphasis in Australian adaptation research shifts from climate change exposure to other aspects of vulnerability (Smith et al., 2011). However, adaptive capacity in Australia's primary industries sector remains poorly defined because climatic change is just one of a complex set of local, regional and international environmental, social, political and economic drivers affecting rural populations and industries (Brooks and Loevinsohn, 2011; Puig et al., 2011), all of which affect adaptive capacity. For some analyses, adaptive capacity to climate change impacts has not been distinguished from adaptive capacity to other factors (e.g. ABARES 2012).

A recent review of adaptive capacity (Engle 2011) suggests that two broad approaches to investigating and understanding adaptive capacity have emerged, 'top-down' and 'bottom up'. The 'top down' approach seeks to measure the level of adaptive capacity using secondary statistical data about a suite of factors considered to influence or reflect adaptive capacity (Iglesias, 2011; Safi et al., 2012; Aggarwal et al., 2010). Few top-down empirical studies of adaptive capacity exist (Berman et al., 2012), but three recent empirical studies have used a livelihoods analysis approach (Nelson et al., 2010a,b; Crimp et al. 2010). The 'bottom up' approach seeks to understand the complex array of factors that affect the perceived and actual capacity of stakeholders to adapt to the diverse pressures they are under (Marshall, 2010; Head et al., 2011; Leith, 2011; Brown et al. 2010; Hogan et al., 2011; Cobon et al., 2009). Here, the subjective rather than objective nature of adaptive capacity is emphasised (McManus et al., 2012; Greenhill et al., 2009; Edwards et al., 2009).

An index derived from the 'rural livelihoods framework' (Ellis, 2000) has the most credence in recent work about climate change adaptive capacity in primary industries (Nelson et al. 2010a,b; Aggarwal et al., 2010). This framework identifies five forms of 'capital' – human, social, financial, physical and natural, each of which has several constituents. Recent research has been reported about most of these constituents (see Rickards et al., 2012), but determining adaptive capacity remains difficult due to lack of data. While Rickards et al. (2012) found numerous general statements about adaptive capacity, they found very few studies apart from those listed above that explicitly and comprehensively examine the adaptive capacity of Australian primary industries (Pearson et al., 2011) and for some elements of primary industries no research was found.

Considerable research (some overseas, but mainly Australian) was found about factors that constrain adaptive capacity (Robertson et al., 2009; Cotching et al., 2009), and about barriers to adaptation (Chhetri et al., 2012; Lockwood et al., 2009; Allan, 2009).

Participatory or 'client based' (Reilly 2011) research involving a process of open-ended and democratic 'social learning' (Collins and Ison, 2009) enables primary producers and others to contribute more fully to the ongoing creation and evaluation of new knowledge (Cohen, 2011; Helfrich and Prasad, 2011). In addition, systems thinking by farmers (Malcolm, 2011; Hayman et al., 2011; Hayman et al., 2012; Ison, 2010) and greater knowledge of underlying science and especially climate literacy are also advocated (Reilly, 2011; Parks and Bernier, 2010; McCown, 2012). Research on decision-support systems for climate change adaptation has been reported (McCown et al., 2009; Hochman et al., 2009; Dalglish et al., 2009; Carberry et al., 2009).

Tension between time-intensive participatory and real-time adaptation decision making needs has been noted (McCown et al., 2009). The scale, locus of control (e.g. centralised or dispersed) or level of integration of primary production systems may influence the adaptive capacity of individuals or groups (Reilly 2011). Similarly, the capacity of a producer or related entity can be affected by adaptation or other change implemented by other producers or players in related businesses (Park et al., 2012; Nicholas and Durham, 2012).

Current research:

- One NCCARF/ARGP Primary Industries theme research project is relevant to this topic (**PI11 02**) (See Box 2).
- No NCCARF/ARGP research projects in another theme are relevant to this project.
- Thirteen NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1ACP1; P1HCS6; P1HCS7; P1HCS8; P1FVA4; P1FVA5; P2LTA6; S3ABA1; S3BST2; S3AUN1; S2AUN2; S3BWT1; S3BIB2**) (See Box 4).
- One ARC research project (**DP0987099**), two CSIRO research projects (**CSIRO 1, CSIRO 2**), one DAFF research project (**DAFF/AFF 2**), one DCCEE research project (**DCCEE 1**), one MDBA research project (**MDBA 1**) and one VCCCAR project are relevant to this topic to some degree (**VCCCAR5**) (See Box 5).

Summary: Rickards et al. (2012) conclude that while considerable research has been published about components of and contributors to adaptive capacity, very little research has explicitly and comprehensively examined the adaptive capacity of Australia's primary industry sector. Few publications were found that were concerned with adaptive capacity in the forestry (e.g. ABARES 2012) or freshwater aquaculture sectors (e.g. Balcombe et al., 2011; Koehn et al., 2011). Similarly, while the effect on primary producers of non-climate change challenges is well recognised, there is relatively little research into how climate change may alter these challenges, and less about opportunities that could arise. These challenges include factors internal and external to Australia that may affect input or product prices. The role of industry structure has also received virtually no research attention. In addition, there is little empirical research evidence to support assumptions that underlie the

approaches currently used to understand adaptive capacity. Finally, no clear link has been established between adaptive capacity and effective adaptation outcomes. Thus, while adaptive capacity remains an important factor for climate change adaptation policy and other decision-making, there remain fundamental knowledge requirements for the concept to be applied effectively and with confidence to the primary industries sector.

Update outcome: Retain PRQ 1.1 as set out below, and maintain its 'High' priority; introduce a new PRQ 1.2 concerned with the influence of industry structure on adaptive capacity.

PRQ 1.1 as amended:

1.1 What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels?

New PRQ 1.2:

1.2 How does industry structure and leadership affect adaptive capacity in the primary industries sector?

4.2 NARP Section 4.2 Levels of adaptation: Priority research questions

2.1 What factors define the effectiveness of different levels of adaptation response: adjusting practices, changing production systems and transforming enterprises, industries and regions?

This PRQ is concerned with a three level climate change adaptation response framework for primary industries ((a) incremental or adjustment, (b) systems and (c) transformational change) adapted from Howden et al. (2007; 2010). This framework provides the structure for much of the remainder of the NARP. The three levels in the framework are not mutually exclusive (Wilkinson, 2011; van der Veen, 2010).

Rickards et al. (2012) found several alternative conceptual frameworks, including incremental and transformational adaptation forming two ends of a spectrum of adaptation options (Hayman et al., 2012), and adaptation responses being interdependent rather than fitting neatly into slots in a linear spectrum (Park et al., 2012). Other frameworks include using four coping and adaptation strategies (Agrawal and Perrin, 2009), eight classes of adaptation action (Macgregor and Cowan, 2011), five strategies for adaptation under uncertainty (Hallegatte, 2009), and a differentiation based on the scale of climate event or impact (Dovers 2009).

Regarding the effectiveness of adaptation responses, Rickard et al. (2012) note a shift from prescriptive adaptation options to identifying management principles from which locally-specific options can be generated (e.g. Price and Hacker, 2009; Bell and Moore, 2012; Duru and Hubert, 2009, Macgregor and Cowan, 2011). In like vein, resilience principles have been advocated for adaptation planning and outcomes: especially redundancy (Linnenluecke and Griffiths, 2010; flexibility (Rodriguez et al., 2011) and cross-scale awareness (Hallegatte, 2009).

Adaptation currently practiced in primary industries often reflects existing good practice (Macgregor and Cowan 2011; Stokes and Howden 2010), and this is likely to continue under moderate climate change impacts (Dovers 2009). However, extending this approach to the exclusion of other options (i.e., focusing adaptation solely on existing good practice) into the realm of more extreme climate changes could result in several challenging outcomes: (a) it could limit planning for transformational changes (Stafford Smith et al., 2011), (b) it could limit future adaption options (Chappells and Medd 2011) and (c) it could be inadequate to

deal with the complex challenges and opportunities associated with climate change – a more radical approach to climate change adaptation being advocated (Pelling, 2011; O'Brien, 2011; Inderberg and Eikeland, 2009; Norgaard, 2011; Chappells and Medd, 2011; Ison, 2010). For these reasons the three-level adaptation framework developed by Howden et al. (2007; 2010) was adopted for the original NARP and is maintained here.

While the benefits of incremental climate change adaptation in agriculture have been relatively extensively studied, there is relatively less understanding of the benefits and challenges of other levels of adaptation and of the cost of adaptation initiatives (Fankhauser 2010). There is also relatively limited information about other factors affecting the effectiveness of adaptation options, such as lost work time and costs for training (Pannell and Vanclay, 2011), price of products (Fankhauser, 2010) and financial risks (Jackson et al., 2009; Hutchings and Nordblom, 2011). Personal circumstances and the local and regional social setting can also be very influential.

Current research:

- Two NCCARF/ARGP Primary Industries theme research projects are relevant to this topic (**PI11 01, PI11 02**) (See Box 2).
- No NCCARF/ARGP research projects in another theme are relevant to this project.
- Twelve NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1HCS6; P1HCS7; P1HCS8; P1FVA4; P1FVA5; S3ABA1; S3BST2; S3AUN1; S2AUN2; S3BWT1; S3BIB2; S3BAM1**) (See Box 4).
- One CSIRO research project (**CSIRO 4**), three DAFF research projects (**DAFF/AFF 2; DAFF/AFF 3; DAFF/AFF 4**), two DCCEE research projects (**DCCEE 2; DCCEE 4**), and one VCCCAR project are relevant to this topic to some degree (**VCCCAR2**) (See Box 5).

Summary: The framework adopted for this PRQ and for the Primary Industries NARP remains useful and effective. Considerable research has been found about incremental- or adjustment-level adaptation, but less about systems and transformation adaptation, and about how decision-makers could understand the relative costs and benefits of each level or combinations of levels. A more balanced research investment between the three levels would appear to be required. Analysis of the potential benefits, costs and risks of incremental versus systems or transformational changes needs to be integrated into management processes. Timing is also critical - deciding when to change, and what climate signals drive that decision, are critical issues for agriculture, forest and aquaculture managers. This research topic addresses a key element of the information decision-makers need, and it requires much more investigation.

Update outcome: Retain PRQ 2.1 unchanged and maintain its 'High' priority.

2.2 What information, knowledge, tools, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities?

Rickards et al. (2012) summarise research about the information, knowledge, tools, programs and policies relevant to each level of adaptation against the appropriate PRQ; considerable research was found for the adjustment level of adaptation but less for the system and transformational levels.

This PRQ is concerned with the information, knowledge, tools, programs and policies required to enable decision-makers to distinguish between the levels or to determine what combinations of adaptation responses would be most effective for their circumstances. A fundamental factor affecting effectiveness in adaptation relates to threshold climate conditions when adaptation can generate net benefits in comparison with not adaptation, or relatively greater

benefits from one type of adaptation in comparison with other types, but factors other than climate may be equally influential. Only one current research project (CSIRO 4), appears to directly address this complex issue, with other potentially relevant research publications and current research activities concerned with generating more general findings. These include important but less directly relevant research topics such as a fuller understanding of the range of costs of adaptation (Pannell and Vanclay, 2011), embedded financial risks within all adaptation options (Fankhauser, 2010), and calls for a multi-faceted approach to adaptation (Steenberg et al., 2011) and combinations of emerging and future adaptation technologies (Hochman et al., 2012). Management skills capable of handling uncertainty and complexity may also be a critical element of effective decision-making for adaptation in the primary industries sector.

Current research:

- One NCCARF/ARGP Primary Industries theme research project is relevant to this topic (**PI11 01**) (See Box 2).
- No NCCARF/ARGP research projects in another theme are relevant to this project
- Seven NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA4; S3ABA1; S3BST2; S3AUN1; S2AUN2; S3BWT1; S3BIB2**) (See Box 4).
- One ARC research project (**FL100100195**), one RDC project (**MU08/01**), two CRC projects (**CCC/CRC-2; FFI/CRC-1**), three CSIRO projects (**CSIRO-1; CSIRO-2; CSIRO-4**), twenty DAFF projects (**DAFF/AFF 3; DAFF/AFF 4; DAFF/FR-1 to DAFF/FR-16; DAFF/FICCRF 3; DAFF/FICCRF 4**), one DCCEE research project (**DCCEE 3**), one SEWPaC research project (**SEWPaC 4**) and two VCCCAR projects are relevant to this topic (**VCCCAR2; VCCCAR7**) (See Box 5).

Summary: While a large amount of current research is relevant to this topic to some degree, the complex issue with which it is concerned (differentiating between levels of adaptation response) requires considerably more research.

Update outcome: Retain PRQ 2.2 as set out below and maintain its 'High' priority.

PRQ 2.2 as amended:

- *2.2 What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities?*

4.3 NARP Section 4.3 Adjusting primary production practices and technologies: Priority research questions

3.1 What types of improvements to production practices and technologies exist or could be developed to increase the adaptive capacity of Australia's primary industries, and what practical issues need to be addressed for implementation?

A great deal of research has been published that is relevant to this PRQ. Rickards et al., (2012) discuss an extensive, though still not comprehensive, set of publications relevant to both elements in this PRQ (i.e. (a) what improvements exist or could be developed, and (b) what issues need addressing for implementation) for agriculture, but note that relatively

fewer publications were found about forestry and freshwater aquaculture. The discussion covers the following areas:

- Improvements in climate forecasting (Hochman et al., 2009); issues include better understanding producer needs (e.g. Dilling and Lemos, 2011; Challinor, 2009a);
- Risk management tools and processes (e.g. McCown et al., 2009; McCown et al., 2012; McCown, 2012; Carberry et al., 2009; Dalgliesh et al., 2009; Hochman et al., 2009); issues include integration within existing decision-making processes (Coles and Scott, 2009);
- Crop management (e.g. Bindi and Olesen, 2011; O'Leary et al., 2011; Gouache et al., 2012; Kirkegaard and Hunt, 2010; Anderson, 2010); issues include dissemination and uptake of research findings;
- Livestock management (Renaudeau and Gourdiere 2010; Hoffmann, 2010; Henry et al., 2012); issues include dissemination and uptake of research findings;
- Water management including storage and efficiency (Khan et al., 2009); issues include policies and **uncertainty**;
- Energy and emissions management (Khan et al., 2009; Henry et al., 2012; Petrie et al., 2010, Rowntree et al., 2010, Staerfl et al., 2012, Alcock and Hegarty, 2011, Kristensen et al., 2011; Huth et al., 2010) issues include **dissemination and uptake**, in light of the complex interactions involved in this area;
- Soil management publications are mainly focussed on mitigation and the narrow topic of biochar (McHenry, 2009; Downie et al., 2011; Quilliam et al., 2012);
- Natural resource management – (McKeon et al., 2009; Marshall and Smajgi, 2012); issues include identifying useful metrics, links between natural resource management and producer and community wellbeing;
- Forest management (Pinkard et al., 2010, 2011; Pinkard and Bruce, 2011; Mitchell et al., under review; Kolström et al., 2011 in relation to Europe; D'Amato et al., 2011); issues include productivity, drought, fire, water resources and the impacts of pests.

Rickards et al., (2012) write that even with the extensive research evident in the publications surveyed, much more research is required. They nominate several topics, including:

- Understanding the basic science underpinning many adaptation options;
- Assessing current best practice and new options under various climate change scenarios;
- Developing, testing and demonstrating assessment methods for adaptation options, including cost-benefit analysis and pluralistic methods, and financial and other metrics;
- Assessing synergies and perverse interactions between practices and their system effects;
- Conducting empirical studies, including longitudinal studies;
- Understanding how effective extension skills and capacity could be developed;
- Reviewing assumptions in risk management messages;
- Integrating primary industries and social science; and
- Integrating mitigation (especially carbon sequestration) and adaptation research.

While all adaptation incurs costs of some kind, one of the main benefits of incremental or adjustment-level adaptation options is that they are relatively inexpensive and easy to understand and implement, and thus represent a lower risk than system or transformational changes (Nicholas and Durham, 2012). Moreover, the availability of incremental or adjustment options that are similar to adjustments regularly implemented for other reasons, allows adaptation to occur before a primary industries stakeholder might be convinced that adaptation to climate change is necessary (Stokes and Howden 2010). However, three main concerns are identified about incremental or adjustment-level adaptation:

- Adjustment adaptation may be ineffective for larger-scale climate changes and co-existing pressures (Reidsma et al., 2010; Qiu and Prato, 2012; Luo et al., 2009);

- Adjustment adaptation may be ineffective for climate change over a longer time frame (Stafford Smith et al., 2011; Nicholas and Durham, 2012);
- Adjustment adaptation may constrain future adaptation options, especially to change to significantly better alternatives for primary production (Pelling, 2011; O'Brien, 2011; Inderberg and Eikeland, 2009; Norgaard, 2011; Chappells and Medd, 2011; Ison, 2010).

Incremental or adjustment adaptation will require ongoing access to and evaluation of potentially beneficial genetic materials and genotypes, and management of pest species that might benefit from climate change. The current high level of research investment for this topic therefore appears to be justified, and will need to be augmented with efforts to ensure genetic materials that may be needed for future adaptation are available to researchers and producers.

Current research:

- No NCCARF/ARGP Primary Industries theme research project is relevant to this topic.
- One NCCARF/ARGP research project in another theme is relevant to this project (**TB11 03**).
- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**S3AFS1; S3AFS2; S3AFS3**) (See Box 4).
- Three ARC research projects (**FL100100066; LP120200002; LP120200380**), one RDC research projects (**RDC1**), three DAFF research projects (**DAFF/AFF-1; DAFF/AFF-2; DAFF/AFF-5**), one SEWPaC research project (**SEWPaC 2**) and one VCCCAR project are relevant to this topic to some degree (**VCCCAR4**) (See Box 5).

Summary: This PRQ has been and will continue to be a major focus of research activity by government and industry investors. As Rickards et al (2012) note, there are far more publications about what options for incremental- or adjustment-level adaptation exist or could be developed than there are about what options have been applied and how effective they are (noting that this is itself a researchable challenge). Very little research is concerned with supporting critical analysis of the options and their relative cost and benefits in different circumstances. While the topic of monitoring and measuring lies within PRQ 6.3 (see below) it merits attention in conjunction with this PRQ given the need for evidence-based evaluation of outcomes. This PRQ should be altered accordingly.

Update outcome: Retain PRQ 3.1 as set out below and maintain its 'High' priority.

PRQ 3.1 as amended:

- *3.1 ~~What types of improvements~~ adjustments to production practices and technologies ~~exist or could need to be developed to increase the adaptive capacity of Australia's primary industries, how can their effectiveness (benefits and costs) be monitored and measured,~~ and what practical issues need to be addressed for implementation?*

3.2 What adaptations could yield benefits from changing atmospheric and climate conditions, such as increased atmospheric CO₂ and changes in temperature and water availability?

The goal of this PRQ is to generate, assemble and communicate information about beneficial adaptation options relevant to the incremental- or adjustment-level of climate change adaptation. Adaptation of this type will continue to be essential for ongoing primary industries productivity and viability, even if systems or transformational adaptation is also required.

As noted in the discussion of the previous PRQ (3.1), a great deal of research has been published that is relevant to this PRQ. Rickards et al., (2012) note that climate change adaptations that do not result in benefits of some type or which result in costs on other values, interests, individuals or groups would be termed 'maladaptations'. Preferred adaptations would both avoid harm and deliver a positive benefit / cost outcome, however these benefits and costs are measured (Keenan 2012). Adaptation options will need to be carefully considered, as, for instance, increases in temperature and carbon dioxide may have strong but opposing effects (McKeon et al., 2009). Adaptation benefits other than productivity and profitability are being identified, such as to conservation (e.g., Breed et al., 2011), or to human health and well-being (e.g. Abraham et al., 2010; Sherren et al., 2012). These broader benefits should be taken into account as adaptation options are assessed and information generated. Research is also required that takes account of adaptations involving all business activities in primary industries.

Research that focusses on identifying how primary industries might benefit from climate change, including from increasing atmospheric CO₂. would contribute to benefit / cost analyses of adaptation options. The findings of this research topic would also open new concepts of climate change response for primary industries, contributing to planning for food security and rural sustainability.

Current research:

- No NCCARF/ARGP Primary Industries theme research project is relevant to this topic.
- One NCCARF/ARGP research project in another theme is relevant to this project (TB11 03).
- Two NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA4; P2LTA6**) (See Box 4).
- Many research projects supported by CSIRO, RDCs, CRCs and DAFF are relevant to this topic (See Box 5).

Summary: Recent published research and current research are identifying a wide range of potential incremental or adjustment adaptation options for primary industry, and this type of research will continue to be the focus of industry-funded research investment. The emerging challenge for this topic appears to relate to synthesizing and integrating this body of research as it is generated, and identifying potential synergies and conflicts between adaptation options. Identifying potential benefits to primary industries from climate change impacts is a much less researched topic that merits greater attention.

The PRQ should be amended to refocus the research towards the relatively little-researched topic of beneficial climate change impacts on primary industries.

Update outcome: Retain PRQ 3.2 as restated below and maintain its 'High' priority.

PRQ 3.2 as amended:

- *3.2 How might climate change benefit primary industries in Australia, such as through increased atmospheric CO₂ and changes in temperature and water availability?*

4.4 NARP Section 4.4 Changing primary production systems: Priority research questions

4.1 *What characteristics of production system change in primary industries are likely to provide advantage under changed climate conditions?*

Changes in the mix of activities in primary production enterprises have been and continue to be common in much of Australia, in response to changing market opportunities and other drivers. The limited analyses to date of such system changes show that there is 'no universal solution' to the challenges generated by climate change (Hacker et al., 2009; p. 966). For instance, increasing landscape diversity, such as through forming contours, retaining or growing trees or maintaining multiple land uses, can provide benefits to both conservation and production (e.g. Manning et al., 2009; Breed et al., 2011; Witt et al., 2011) but may have positive or negative external impacts depending on many contextual factors.

Mixed farming can provide greater flexibility and resilience in the face of climate variability than a more limited set of activities or a single activity for some farmers (Bell and Moore, 2012, Aggarwal and Singh, 2010; Barbieri and Mahoney, 2009).

The extent to which greater integration of different activities into a mixed farming operation yields benefits or imposes costs for climate change adaptation has had limited analysis (Bell and Moore, 2012), and there is a need to maintain potential reversibility should external conditions change (Kirkegaard et al., 2011).

Rickards et al., (2012) identified several key research issues in relation to this PRQ, including:

- Adaptation principles need to be developed that can deal with the diversity across farming systems, that are sufficiently general to guide analysis but also sufficiently specific to guide decision-making;
- Existing systems-level adaptations, and interactions between them, have not been monitored or analysed (e.g. Witt et al., 2011);
- Barriers and enablers to adopting systems-level adaptations need to be understood, including policy (e.g. Sherren et al., 2012) and attitudes to risk;
- The application and implications of emerging principles of adaptation to system-level adaptation need to be better understood, especially concerning how diverse, integrated enterprises can be developed that remain flexible and resilient to future climate conditions.

Current research:

- One NCCARF/ARGP Primary Industries theme research project is relevant to this topic (**PI11 01**) (See Box 2).
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Four NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA4; P2LTA1; P2LTA6; P2CES1**) (See Box 4).
- One ARC research project (**DE120100786**), one CSIRO research project (**CSIRO-1**) and seventeen DAFF projects (**DAFF/AFF-2; DAFF/FR-1 to DAFF/FR-16**) are relevant to this topic to some degree (See Box 5).

Summary: While relatively few recent publications have been found that are relevant to this research topic, a large amount of current Australian research is relevant to it. Most current research is about individual instances of systems-level adaptation and, once reported, might support integrative analysis that would address the focus of this research topic. This analysis

could then identify characteristics of effective systems-level adaptation options to guide future decision-making.

Update outcome: Retain PRQ 4.1 unchanged and maintain its 'High' priority.

4.2 What information, knowledge, tools, programs and policies are needed to support effective changes to primary production systems?

Current research:

- No NCCARF/ARGP Primary Industries theme research projects are relevant to this topic;
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Seven NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA4; S3ABA1; S3BST2; S3AUN1; S2AUN2; S3BWT1; S3BIB2**) (See Box 4).
- Eighteen DAFF projects (**DAFF/FR-1 to DAFF/FR-16; DAFF/FICCRF 3; DAFF/FICCRF 4**), and one CRC research project (**CCC/CRC-2**) are relevant to this topic to some degree (See Box 5).

Summary: As for PRQ 4.1, (see above) virtually no scientific publications were found that were relevant to this PRQ, but a large amount of current Australian research is relevant to it. This current research, once reported, would likely support research to identify communication, policies and other factors necessary to support decisions about system-level changes.

Update outcome: Retain PRQ 4.2 unchanged and maintain its 'High' priority.

4.5 NARP Section 4.5 Transforming primary production enterprises and industries: Priority research questions

5.1 What characteristics of transformational change in primary industries are likely to provide advantage under changed climate conditions?

Transformational adaptive change has received considerable research attention since 2010, with several definitions being preferred (e.g., Park et al. 2012; Rickards and Howden 2012; Kates et al. 2012), and characteristics set out (e.g., Kates et al. 2012; Rickards and Howden 2012). The potential benefits of transformational change include providing an opportunity to address underlying vulnerabilities and maladaptations that are currently harming primary industries (e.g. Eakin et al., 2009a; O'Brien, 2011) even where these are unrelated to climate change.

The scope of transformational adaptation and its potential benefits and risks have been widely, if not thoroughly, explored. Strategies include moving existing activities to a new location (Rickards and Howden, 2012; Tacoli, 2009; Turner et al., 2011; Keating and Carberry, 2010; Park et al., 2012; Nicholas and Durham 2012). For primary industries sectors that have close links between production, initial processing and value adding, such as the wine industry, careful staging of relocation will be necessary (e.g., Jones and Webb 2010). A change in land use may also be transformational, such as forestry expansion into agricultural land (Lambin and Meyfroidt 2011).

Current research:

- Two NCCARF/ARGP Primary Industries theme research projects are relevant to this topic (**PI11 01, PI11 03**) (See Box 2).

- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Two NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P2LTA1; P2LTA6**) (See Box 2).
- One RDC research project (**HG08037**), one CSIRO project (**CSIRO-4**), two DAFF research projects (**DAFF/AFF-3; DAFF/AFF-4**) are relevant to this topic (See Box 5).

Summary: Transformational adaptation has received considerable research attention as a broad topic. However, further research is warranted given the variety, complexity and risks inherent in this adaptation level.

Update outcome: Retain PRQ 5.1 unchanged and maintain its 'High' priority.

5.2 What information, knowledge, tools, programs and policies are needed to support effective transformative adaptation in primary production systems?

Four key issues for transformational change, and thereby requirements for knowledge, tools, programs and policies, have been identified Rickards and Howden (2012): costs, maladaptation, adaptive capacity and the role of government. Other issues that could be barriers to adaptation are: uncertainty (risks and adaptation benefits), costs and institutional and behavioural barriers (Kates et al., 2012). Information to support decisions about transformational adaptation must be cross-scale, cross-sectoral and integrated with mitigation where appropriate (Nelson et al., 2008; see also Leys and Vanclay (in press)). Several approaches to support decision processes about transformational change have been developed (e.g., Cobon et al., 2009; Park et al., 2012; Linnenluecke and Griffith, 2010).

Current research:

- Two NCCARF/ARGP Primary Industries theme research projects are relevant to this topic (**PI11 01; PI11 03**) (See Box 2);
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Seven NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA4; S3ABA1; S3BST2; S3AUN1; S2AUN2; S3BWT1; S3BIB2**) (See Box 4).
- One CSIRO research project (**CSIRO-4**) and eighteen DAFF projects (**DAFF/FR-1 to DAFF/FR-16; DAFF/FICCRF 3; DAFF/FICCRF 4**) are relevant to this topic to some degree (see Box 5).

Summary: Current research about transformational change for primary industries, once reported, should enable research that identifies the information, knowledge, tools, programs and policies necessary for effective transformational change.

Update outcome: Retain PRQ 5.2 unchanged and maintain its 'High' priority.

5.3 How can the well-being of individuals and communities unable to undertake transformational changes be maintained?

No publications were found that directly examine this PRQ, but several were found that provide some insight about the issues it raises. The uneven nature of climate change impacts, vulnerability and adaptive capacity has been well established, but its redistributive nature is now being explored (Marino and Ribot, 2012). Previously effective adaptations to changing climate conditions may become ineffective or maladaptive as climate change progresses, a situation that may be prolonged because of lack of policy responsiveness (Beilin et al. 2011) or an adaptation path lock-in to past adaptive responses (Beilin et al. 2012).

Current research:

- No NCCARF Primary Industries theme ARGP research projects are relevant to this PRQ;
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Seven NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1HCS4; P1HCS6; P2LTA5; P2LTA6; P2IMLR; S3AFL2; S3BEC2**) (See Box 4).
- One ARC research project (**DP120104797**), two CSIRO research projects (**CSIRO-2; CSIRO-4**) and two SEWPaC research projects (**SEWPaC 5; SEWPaC 6**) are relevant to this topic to some degree (See Box 5).

Summary: Limited published research relevant to this PRQ has been found, and none of this research directly addresses its core issue. Some current research activities are relevant to this PRQ.

Update outcome: Retain PRQ 5.3 unchanged and maintain its 'High' priority.

4.6 NARP Section 4.6 Integrating, implementing and reviewing adaptation: Priority research questions

6.1 How can integrated climate change adaptation response plans be developed at the local, landscape and regional scales?

Integration here refers to managing multiple use, or multiple-objective, landscapes. However, the topic raises other interactions of interest, and thus should also encompass emergency management, the water sector, health sector and potentially others. This broad scope is reflected in the very few recent publications found that are relevant to this PRQ: natural resource management (Bardsley and Sweeney, 2010), biodiversity (Prober and Smith, 2009; Dwyer et al., 2009; de Chazal and Rounsevell, 2009), micro- or local climate (McAlpine et al., 2009) and health (Ziska et al., 2009).

Current research:

- One NCCARF/ARGP Primary Industries theme research project is relevant to this topic (**TB11 09**) (See Box 2).
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Four NCCARF Synthesis and Integrative Research projects are relevant to this topic (**S3BST2; S3BWT1; S3BAM1; P2CES1**) (See Box 4).
- One ARC research project (**DP0880933; DP120101983**), one CRC research project (**CCCCRC-1**), two SEWPaC research projects (**SEWPaC 1; SEWPaC 3**) and four VCCCAR projects are relevant to this topic to some degree (**VCCCAR1; VCCCAR3; VCCCAR5; VCCCAR6**) (See Box 5).

Summary: No publications were found that are directly concerned with integrated climate change adaptation research relevant to primary industries, but one NCCARF / ARGP research project is directly relevant to this topic, and several other research projects have some relevance. This topic is of increasing interest to stakeholders (see Section 2, above).

Update outcome: Retain PRQ 6.1 unchanged and maintain its 'High' priority.

6.2 How can climate change adaptation requirements, options, benefits and costs be integrated with other information critical to primary producers and industries, and communicated to support effective adaptation being determined and implemented?

Adaptation planning needs to shift from projecting impacts to evaluating adaptation options (Henry et al., 2012; Howden et al. 2012) and become part of primary industry and natural resource management research and development (Howden and Crimp, 2011). Information about all types of climate change adaptation is required for effective adaptation (Park et al., 2012).

Integrating and communicating adaptation options will require institutional capacity for long-term strategic planning processes (Boyle and Dowlatabadi, 2011) and capacity among extension officers and agricultural consultants (Henry et al., 2012). Several options for integrating climate change adaptation assessment and planning with primary industry initiatives have been proposed, including:

- A continuous four stage assessment and planning cycle (Moser and Ekstrom, 2010; Park et al., 2012);
- An integrated property planning tool (Reid et al., 2009);
- A three-step methodology for primary industry and producers, (Cobon et al., 2009);
- A framework for analysing adaptation as an investment (Antle and Capalbo 2010); and
- Syntheses of published studies (Challinor et al., 2009a).

Current research:

- No NCCARF Primary Industries theme ARGP research projects are relevant to this PRQ;
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- Seven NCCARF Synthesis and Integrative Research projects are relevant to this topic (**S3AUN1; S3AUN2; S3BCM1; S3BCM1; S3BWT1; S3BIB2; S3BAM1**) (See Box 4).

Summary: This PRQ contains two research topics, both of which appear to have received some attention. The topics would benefit from being separated to highlight the key research issues: (a) integration of information about adaptation with other information and (b) communication of information about adaptation.

Update outcome: Retain PRQ 6.2 as set out below and maintain its 'High' priority, and include new PRQ 6.3 also with a 'High' priority.

PRQ 6.2 as amended:

- *6.2 How can information about climate change adaptation ~~requirements~~, options, strategies, benefits and costs be integrated with other information critical to primary producers and industries, ~~and communicated to support successful adaptation being determined and implemented?~~*

Include new PRQ 6.3:

- *6.3 How can information about climate change adaptation ~~requirements~~, options, strategies, benefits and costs be communicated to support effective adaptation being identified and implemented?*

6.3 How can adaptation by primary industries be monitored and measured, including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives?

Measuring, or even identifying, adaptation in the primary industries sector is complicated by the influence of many non-climate factors and the inter-relations between these factors and climate factors, and the local, regional, national and international scales pertinent to primary industries. Personal factors and social settings also affect individual producer decisions.

Nevertheless, the importance of monitoring and measuring is recognised (e.g. for forestry (Kolström et al., 2011; ABARES 2012) and for Mediterranean ecosystems (Abbott and le Maitre 2010)). Some challenges and opportunities have been explored, such as circumstances where adaptation seems to occur in the absence of adaptation plans (Wei et al., 2012; Lawson et al. 2009; Schlenker and Roberts, 2009), where efficient adaptation options are constrained by other factors (Chhetri et al., 2010; Whittaker et al., 2012), maladaptation (Macgregor and Cowan, 2011; Barnett and O'Neill, 2010), perverse outcomes (Asseng et al., 2010) and the needs for indicators (Rodriguez et al., 2011; Macgregor and Cowan, 2011; Brown, 2011).

Current research:

- No NCCARF Primary Industries theme ARGP research projects are relevant to this PRQ;
- No NCCARF ARGP research projects from other themes are relevant to this PRQ;
- No NCCARF Synthesis and Integrative Research projects are relevant to this topic.

Summary: Progress on this topic is necessary for a structured and defensible approach to adaptation. While some research effort is evident, much more will be required.

Update outcome: Retain PRQ 6.3 as set out below, but renumber it as 6.4, and maintain its 'High' priority.

PRQ 6.4 as amended:

- *6.4 How can the effectiveness of adaptation by primary industries be monitored and measured across all business activities, including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives?*

5 Potential new research areas for the Primary Industries NARP

The research needs to support sound decisions about adaptation in the primary industries sector are vast and varied. Each of the existing PRQs in the original NARP (discussed in Section 4) builds on existing knowledge but identifies areas of large remaining uncertainty and ignorance.

5.1 New research areas identified in the Literature Review

Rickards et al (2012) identified six further areas of research that merited further consideration for research investment at this time.

Primary production adaptation, emissions reductions and carbon sequestration.

The introduction of policies since 2010 that are aimed at increasing land- and land use-based carbon sequestration has raised the importance of understanding the relationships between mitigation and adaptation in Australia. These matters are not well explored and warrant further study (Smith and Olesen, 2010), with potential synergies and conflicts communicated to avoid maladaptation and increase co-benefits (Ravindranath 2007). This will require scientifically defensible indicators and metrics for assessing the condition of the relevant system and how this changes (Smyth et al. 2009). Independently generated and verifiable information will be essential to ensure that landholders and managers can have confidence in the decisions they make to engage in carbon sequestration and other mitigation initiatives. This research will include investigation of tradeoffs between optimal land use and forest and farm compositions under current and future conditions (Keenan, 2012), similar to the research focus of PRQ 6.1.

Current research:

- One ARC research project (**DP0986041**), one RDC project (**DP0986041**) and two DAFF research projects (**DAFF/AFF-6; DAFF/FICCRF 2**) are relevant to this topic to some degree (See Box 5).

Summary: This topic has links to PRQ 6.1 and PRQ 6.4, but refers specifically to a new and important issue for Australia's primary industry sector.

Update outcome: Introduce new PRQ 6.5 as set out below with a 'High' priority.

PRQ 6.5:

6.5 How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector?

Soil health

The role of soil organic carbon in primary production systems needs to be better understood (Cotrufo et al., 2011), including basic aspects of soil health such as short and long term interactions between soil biota, nutrient cycles, water cycles and production regimes, now and under climate change (Eisenhauer et al., 2012).

Summary: This topic is one of many that would provide basic understanding for climate change impacts and would contribute to adaptation planning. However, it is not an adaptation research topic in its own right.

Update outcome: Do not include.

Groundwater and use of surface/groundwater systems Groundwater is an important component of primary industries inputs, and is affected by climate change and adaptation

measures. Significantly less is known about projected impacts of climate change on groundwater systems than is known for surface water resources. The Murray Darling Basin plan (MDBA 2012) seeks to begin addressing this issue in one important river basin in Australia.

Summary: This topic is one of many that would provide basic understanding for climate change impacts and would contribute to adaptation planning. However, it is not an adaptation research topic for primary industries in its own right.

Update outcome: Do not include.

Climate change and rural health.

Climate change is likely to affect the health of individuals and communities engaged in or dependent on primary industries in many ways. This topic is a key interaction between the Human Health NARP and research program and the Primary Industries NARP and research program.

Summary: This topic lies more completely in the Human Health theme, which already has several PRQs that focus on occupational health, mental health, air quality, heat and other relevant risks and impacts.

Update outcome: Do not include.

Consistent terminology and meta-analysis.

Hoffman (2011) advocates the development of a systematic and flexible framework of existing knowledge and experience about climate change adaptation in primary industries, including a classification of adaptation studies. This has been reiterated for crop modelling (White et al., 2011) and forestry (Kolstrom et al., 2011).

Summary: This topic is concerned with information management, rather than research *per se*. Existing PRQs are concerned with generating new knowledge for adaptation through research.

Update outcome: Do not include.

Analytical methodologies

Climate change impacts and adaptation practice include considerable work to develop analytical methodologies, indicating the early stage of the practice and the large areas of uncertainty that remain. This includes modelling approaches, techniques and tools (e.g. Wu et al., 2010, Reidsma et al., 2009) for challenges such as uncertainty in crop models (Challinor et al., 2009b), or forest production and carbon sequestration (Simioni et al., 2009).

Summary: This topic is concerned with technical matters, rather than research *per se*.

Update outcome: Do not include.

5.2 New research areas arising from changes to stakeholder information needs

Two further areas of research were identified as a result of changes to stakeholder information needs.

Extreme events: adaptation and resilience for Primary Industries.

Australia has experienced a series of extreme weather events since 2010 that have affected both rural and urban regions (see Box 1). Some rural regions and communities have been affected by more than a single event (e.g. more than one flood) and by more than one kind of event (e.g. both drought and flood). These events can affect all aspects of primary industries business activities, including production, storage, transport, use and export. Extreme weather in one area may affect the capacity of producers in regions that have not been affected to deliver their produce and gain value from it.

Current research:

- No NCCARF/ARGP Primary Industries theme research project is relevant to this topic (See Box 2);
- No NCCARF ARG P research projects from other themes are relevant to this PRQ;
- Six NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1HCS4**; **P1HCS6**; **P1HCS8**; **P2LTA1**; **P2LTA6**; **S3AFL2**) (See Box 4);
- Two ARC research projects (**DP120104797**; **DEP120100786**), one RDC research project (**DAQ00163**), TWO DCCEE research projects (**DCCEE 1**; **DCCEE 3**), and one VCCCAR project are relevant to this topic to some degree (**VCCCAR7**) (See Box 5).

Summary: This topic has links to many PRQs in the Primary Industries NARP, but provides a key focus on extreme events.

Update outcome: Introduce new PRQ 6.6 as set out below with a ‘High’ priority.

PRQ 6.6:

6.6 What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events?

Roles of key stakeholders for adaptation in Primary Industries.

As noted in Section 4 (above), adaptation in primary industries needs to take account of a vast set of social, economic and environmental factors that operate at the individual, community, regional, state, national and international levels, in addition to changes in climate conditions that may operate at any of those levels. Identifying the roles and responsibilities of the various actors, including landholders and managers, industry and government at all levels in relation to the opportunities and risks of climate change impacts, adaptation and mitigation would help clarify the options available to individual stakeholders and so facilitate the implementation of adaptation initiatives.

Current research:

- No NCCARF/ARGP Primary Industries theme research project is relevant to this topic;
- No NCCARF ARG P research projects from other themes are relevant to this PRQ;
- No NCCARF Synthesis and Integrative Research project is relevant to this topic;

- One ARC research project (**FL10010019; DP0880933**), two RDC research projects (**RDC1; HG08037**), one DCCEE research project (**DCCEE 1**), and two VCCCAR projects are relevant to this topic to some degree (**VCCCAR1; VCCCAR3**) (See Box 5).

Summary: Clarifying the roles, responsibilities and options available to individual stakeholders would facilitate the implementation of adaptation initiatives.

Update outcome: Introduce new PRQ 6.7 as set out below with a 'High' priority.

PRQ 6.7:

6.7 What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries?

6 Changes to the research topics and priorities

This review concludes that all PRQs in the original Primary Industries NARP remain relevant, but that some changes in emphasis are required to take account of recent policy initiatives and research investment, and generally there needs to be a shift from impacts-focussed research to research that squarely addresses adaptation. This requires minor changes to the wording of two PRQs and one existing PRQ being split into two questions. As a result of policy developments in the area of mitigation (Carbon Farming Initiative) one new PRQ has been included. All PRQs have been assessed as 'High' priority.

- **One research priority is amended to clarify its focus on 'adjustment' level adaptation and to include reference to monitoring and measuring the effectiveness of this type of adaptation:**

3.1 *What ~~types of improvements~~ adjustments to production practices and technologies ~~exist or could need to be developed to increase the adaptive capacity of Australia's primary industries, how can their effectiveness (benefits and costs) be monitored and measured, and what practical issues need to be addressed for implementation?~~*

- **Four research priorities are restated to extend their scope:**

1.1 *What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels?*

2.2 *What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities?*

3.2 *How might climate change benefit primary industries in Australia, such as through increased atmospheric CO₂ and changes in temperature and water availability?*

6.4 *How can the effectiveness of adaptation by primary industries be monitored and measured across all business activities, including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives?*

- **One research priority is split into two:**

6.2 *How can information about climate change adaptation ~~requirements, options, strategies, benefits and costs~~ be integrated with other information critical to primary producers and industries, ~~and communicated to support successful adaptation being determined and implemented?~~*

6.3 *How can information about climate change adaptation options, strategies, benefits and costs be ~~integrated with other information critical to primary producers and industries, and communicated to support effective adaptation being identified and implemented?~~*

- **Four new research priorities are added:**

1.2 *How does industry structure and leadership affect adaptive capacity in the primary industries sector?*

6.5 *How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector?*

6.6 *What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events?*

6.7 *What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries?*

An updated table of PRQs is provided in Section 7 of this report.

7 High priority research questions (2012)

| High priority research questions (2012) |
|--|
| 1. Understanding and expanding adaptive capacity |
| 1.1 What is adaptive capacity in the primary industries sector, what are the key factors that affect it and how can it be measured and increased at individual, industry, regional and national levels? |
| 1.2 How does industry structure and leadership affect adaptive capacity in the primary industries sector? |
| 2. Levels of adaptation |
| 2.1 What factors define the effectiveness of different levels of adaptation response: adjusting practices, changing production systems and transforming enterprises, industries and regions? |
| 2.2 What information, knowledge, tools, management skills, programs and policies are necessary for primary producers and industries to identify the range of potential climate change adaptation responses and understand their benefits, costs, risks and opportunities? |
| 3. Adjusting primary production practices and technologies |
| 3.1 What adjustments to production practices and technologies need to be developed to increase the adaptive capacity of Australia's primary industries, how can their effectiveness (benefits and costs) be monitored and measured, and what practical issues need to be addressed for implementation? |
| 3.2 How might climate change benefit primary industries in Australia, such as through increased atmospheric CO ₂ and changes in temperature and water availability? |
| 4. Changing primary production systems |
| 4.1 What characteristics of production system change in primary industries are likely to provide advantage under changed climate conditions? |
| 4.2 What information, knowledge, tools, programs and policies are needed to support effective changes to primary production systems? |
| 5. Transforming primary production enterprises and industries |
| 5.1 What characteristics of transformational change in primary industries are likely to provide advantage under changed climate conditions? |
| 5.2 What information, knowledge, tools, programs and policies are needed to support effective transformative adaptation in primary production systems? |
| 5.3 How can the well-being of individuals and communities unable to undertake transformational changes be maintained? |
| 6. Integrating, implementing and reviewing adaptation |
| 6.1 How can integrated climate change adaptation response plans be developed at the local, landscape and regional scales? |
| 6.2 How can information about climate change adaptation options, strategies, benefits and costs be integrated with other information critical to primary producers and industries? |
| 6.3 How can information about climate change adaptation options, strategies, benefits and costs be communicated to support effective adaptation being identified and implemented. |
| 6.4 How can the effectiveness of adaptation by primary industries be monitored and measured across <u>all business activities</u> , including assessing synergies, maladaptation and interactions with other sectors, to support ongoing improvements to adaptation approaches and initiatives? |
| 6.5 How can potential synergies between climate change adaptation and mitigation be identified and achieved and potential perverse outcomes avoided in Australia's primary industries sector? |
| 6.6 What strategies and management approaches can support effective climate change adaptation for primary industries in the face of changed incidence and intensity of extreme weather events? |
| 6.7 What are the roles and responsibilities of key stakeholders and decision-makers involved in climate change adaptation for primary industries? |

8 Acronyms

| | |
|--------|---|
| ARC | Australian Research Council |
| ARGP | Adaptation Research Grant Program (Commonwealth Funding to support adaptation research commissioned against priorities identified in NARPs, supporting research managed by NCCARF). |
| CCRSPI | Climate Change Response Strategy for Primary Industries |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DCC | Department of Climate Change |
| DCCEE | Department of Climate Change and Energy Efficiency |
| NARP | National Climate Change Adaptation Research Plan |
| NCCARF | National Climate Change Adaptation Research Facility |
| NRM | Natural resource management |
| PIARN | Primary Industries Adaptation Research Network |
| PRQ | Priority research question |
| RDE | research development and extension |
| SIR | Synthesis and Integrative Research (NCCARF funded and managed research program). |

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Appendix 1: Criteria for setting research priorities

The criteria listed below will guide the research planning process to set research priorities.

1. Severity of potential impact or degree of potential benefit

What is the severity of the potential impact to be addressed or benefit to be gained by the research? Potentially irreversible impacts and those that have a greater severity (in social, economic or environmental terms) will be awarded higher priority.

2. Immediacy of required intervention or response

Research will be prioritised according to the timeliness of the response needed. How immediate is the intervention or response needed to address the potential impact or create the benefit? Research that must begin now in order to inform timely responses will receive a higher priority than research that could be conducted at a later date and still enable a timely response.

3. Need to change current intervention and practicality of intervention

Is there a need to change the intervention used currently to address the potential impact being considered. If yes, what are the alternatives and how practical are these alternative interventions? Research that will contribute to practicable interventions or responses will be prioritised. Does research into the potential impact of the intervention being considered contribute to the knowledge base required to support decisions about these interventions?

Desirable

4. Potential for co-benefits

Will the research being considered produce any benefits beyond informing climate adaptation strategies?

5. Potential to address multiple, including cross-sectoral, issues

Will the research being considered address more than one issue, including cross-sectoral issues?

6. Equity considerations

Will the research being considered address more than one issue, including cross-sectoral issues?

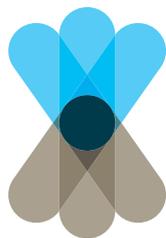
Appendix 2: Current NCCARF (ARGP) research projects directly relevant to the Primary Industries NARP

NCCARF is supporting four research projects commissioned to that focus on the priority research questions in the original Primary Industries NARP.

| Project Title | Lead Organisation | Lead Investigator |
|--|--|-------------------------|
| PI11 01 - Will primary producers continue to adjust practices and technologies, change production systems or transform their industry - an application of real options | University of Sydney | Gregory Hertzler |
| <p>This project directly addresses Priority Research Area 2: Transformational change in Australia's primary industries as an adaptation response to climate change. It less directly addresses but has implications for Priority Research Area 1: Adaptive capacity and options for adaptation response in Australia's primary industries. Crop-livestock farms have evolved to have a mix of cropping and grazing and within the cropping enterprise to have a suite of higher return higher risk crops and lower return lower risk crops. Given projections of a warmer drier future, decisions are made at the level of 1) adjusting practices and technologies, 2) changing production systems, or 3) transforming to new areas or industries. Adjustment changes are relatively easy to make but system and transformation changes may be irreversible, or partially irreversible, leaving stranded assets. Making the switch will require investments and infrastructure. This is the so-called hysteresis effect which makes switching difficult and mistakes costly. Real Options offers a framework to structure thinking and analysis for these difficult choices. This project will determine the thresholds, with climate change, where growers will choose to switch from intensive wheat dominant systems to mixed farming or switch to livestock dominant systems with opportunity cropping or switch to extensive grazing. A decrease in rainfall and increase in temperature, on average, will hasten a switch to less intensive agriculture. A high degree of year to year and decade to decade variability may delay a switch as it becomes difficult to ascertain how the climate is actually changing and growers will 'wait and see' to keep their options open. We will use data and modelling results from previous research projects (especially DAFF Australia's Farming Future), ABARE survey data and individual farm records to model transformation of wheat dominant cropping in NSW, SA and WA. This will help primary producers understand the relative benefits and costs of switching between production regimes. We will quantify the option value that producers will be willing to pay to keep their options open and avoid costly mistakes, the transactions costs of reversing a mistake and the expected times it will take before producers switch from wheat to mixed farming to livestock to extensive grazing. The results will help policy-makers to forecast the future structure of agriculture in Australia, understand the benefits of drought policies such as Farm Management Deposit Bonds and learn the time frame in which new technologies must be developed before it is too late and farmers will have already switched and transformed into a different industry.</p> | | |
| PI1102 - Adaptive capacity and adaptive strategies of broadacre farms experiencing climate change | Department of Agriculture and Food (WA) | Ross Kingwell |
| <p>This project addresses aspects of the priority research area 1 "Adaptive capacity and options for adaptation response in Australia's primary industries" by focusing on the adaptive capacity and adaptation responses of broadacre farmers in a key agricultural region of Australia, acknowledged as very probably already experiencing climate change over recent decades. The study will focus on individual businesses, their region and industry. Farms in three sub-regions (north, east and south) of the WA agricultural region will be investigated. The more livestock dominant farming systems of the southern region will be contrasted against the crop dominant businesses of the east and north. By following the nature and performance of the same farm businesses over several</p> | | |

| Project Title | Lead Organisation | Lead Investigator |
|---|---------------------------------------|--------------------|
| years it should be possible to discern what farm characteristics and adaptation strategies have led these farms to be resilient (or vulnerable). | | |
| PI1103 - EverFarm® - Design of climate adapted perennial-based farming systems for dryland agriculture in southern Australia | CRC for Future Farm Industries | Amir Abadi |
| <p>This project tentatively titled EverFarm will use best-practice research outcomes from the FFI CRC farming systems (New Woody Crops, EverGraze, Enrich and EverCrop) to test a whole farm approach to climate change adaptation for dryland agriculture in southern Australia. Combining the knowledge of farming systems with economic analysis skills will provide the opportunity to test the role of new perennial plant technologies to provide the transformational change required for Australian agriculture to adapt to climate change. The delivery of this information will also be enhanced by utilising the extensive existing communication and training capacity within the FFI CRC.</p> <p>The specific aim of the EverFarm project is to evaluate whether and the extent to which dryland agriculture incorporating novel perennial plant technologies and farming systems can adapt to climate change. This will be achieved by modelling the performance of the new perennial systems developed by the Future Farm Industries CRC (FFI CRC) under predicted future climate scenarios for the dryland agricultural zone of southern Australia. The project will assess the economic feasibility for large scale adoption of perennial plants in dryland agricultural systems thus providing farmers and regional industries with the tools to assess the role of perennials in adapting to climate change. In doing this the project will address NCCARF Priority Research Area 2 'Transformational change in Australia's primary industries' as an adaptation response to climate change and specifically addresses research questions 5.1 and 5.3 (Transforming primary production) of the NARP.</p> <p>Integration of woody crops into dryland farming systems is a transformational change, introducing industries and markets that are entirely new in the relevant rural regions. The woody crop production systems that form the basis of this research use native tree species such as mallees that have evolved in a variable semi-arid climate and are highly productive in dispersed plantings that occupy only around 10% of the land. The trees can be arranged in narrow belts so that they cause minimal interruption to conventional cropping systems which will continue in the wide alleys between the belts.</p> <p>These trees live for over 50 years and regrow, or coppice, after periodic harvests that remove their above ground biomass. The harvested biomass can be locally processed thus supporting regional economic development through new employment opportunities and investments in capital and infrastructure. The biomass provides feedstocks for producers of bioenergy, biofuels and renewable industrial materials. The trees utilise the water and nutrients that move beyond the roots of annual crops and pastures, provide shelter benefits for livestock, and confer protection against erosion. These new crops can provide fundamental biological and economic change for agricultural regions with mixed crop and livestock enterprises and improve the resilience of conventional farming systems in the face of climate change.</p> <p>Additionally the project addresses the high priority research question of 'Changing production systems' (4.1-4.2) identified by NCCARF in the Primary Industries NARP. The selection, development and utilisation of perennial plants for grazing and cropping systems increases the proportion of rainfall used by the system which may provide higher productivity and greater capacity to withstand dry periods. Outputs of the FFI CRC research to date on the performance of perennial plants in farming systems provide the opportunity to test the effectiveness of these systems against existing annual systems. The relative performance of these systems will be modelled under current and predicted future climate conditions.</p> | | |
| TB1109 - Adapted future landscapes - from aspiration to implementation | University of Adelaide | Wayne Meyer |

| Project Title | Lead Organisation | Lead Investigator |
|---|-------------------|-------------------|
| <p>Helping regions in Australia plan for and implement changes in the way we use our land for food and conservation in the face of changing climate, markets and social requirements is important. Researchers have developed ways of bringing all the information about a region together and then making projections about how we might change what we do where on the land that will help us adapt into the future. It is possible to show that we can adapt well but this will require changes and hence policy incentives and guidance to guide what we plan to do. This new project will work with two natural resource management regions to develop an experimental implementation process that uses future land use projections and allows assessment of possible policy and guidance incentives. If the experimental process is successful then other regions in Australia can be expected to take up the process and use it in their planning for a better future. This will help regional areas and communities become more “climate change ready”.</p> | | |



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