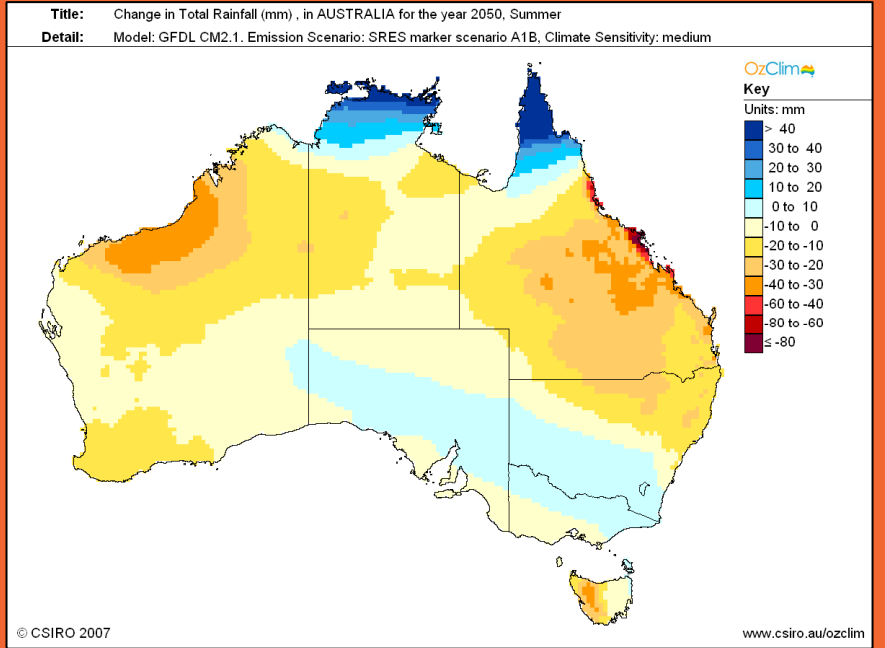


Responding to Climate Change in the Fitzroy Basin



Richard Routley, QPI&F, Toowoomba
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Executive Summary

This project involved a review and synthesis of published literature, a stakeholder workshop and a survey of RD&E providers to help develop recommendations as to how the Fitzroy Basin Association could contribute towards a response to the impacts and implications of projected climate change in the Fitzroy basin.

A modification of the DPSIR framework is described and proposed as a useful conceptual framework for considering climate change, its impacts and appropriate adaptation and mitigation responses.

Six principles are identified that should underpin the development and implementation of future responses to climate change in the region:

- A focus on community engagement
- A Risk management approach
- Ensure local relevance
- An outcomes based focus
- A systems approach
- Integrate action with other programmes

Suggested priorities for responding to climate change in the Fitzroy basin as identified through the stakeholder workshop are presented in a programme logic framework. Priority knowledge and skill outputs required for successful adaptation and mitigation include:

Adaptation:

- Knowledge of the likely nature of future climate scenarios (at a daily timestep) for a range of locations in the Fitzroy basin
- Knowledge of the potential impacts of likely future climate scenarios on natural resource condition and the profitability and productivity of key agricultural enterprises (beef, grains, cotton, horticulture) in central Qld
- Identification and evaluation of the effectiveness of a range of management practices and strategies in minimising the impacts of climate change on natural resource condition and the profitability and productivity of key agricultural enterprises (beef, grains, cotton, horticulture) in central Qld
- Understanding of the potential for novel and innovative or new land use options to achieve natural resource, profitability and productivity outcomes under new climatic conditions
- Understanding of the potential benefits of and barriers to redesigning land use at a landscape scale to achieve natural resource and productivity outcomes under new climatic conditions
- Tools and processes that enable land managers to assess the vulnerability of their enterprises to climate change and climate variability, and help them select and implement appropriate adaptation strategies

Mitigation:

- Improved knowledge of the GHG footprint of a range of existing and potential land use options in the Fitzroy basin.
- Improved knowledge of the impact of management practices on net GHG emissions and interactions between GHG emissions, profitability and natural resource condition, in particular for practices which
 - Improve soil C storage
 - Reduce reliance on fossil fuels as an energy source
 - Reduce methane emissions from grazing animals (per unit of production)
 - Reduce nitrous oxide emissions resulting from inefficient use of N fertilisers
- Improved understanding of the potential opportunities, costs and risks associated with voluntary or legislated emission trading schemes.
- Rigorous and user friendly tools and processes that allow land managers to assess the GHG footprint of their enterprises and the effect of changes to land use and management practices on GHG emissions, natural resource condition and profitability

Previous and current climate change related RD&E of relevance to the Fitzroy Basin is summarised and a Gap Analysis comparing this activity with the desired outcomes listed above suggested the following high priority areas for additional investment:

- Assessing the potential for novel and innovative or new land use options
- Assessing of the potential benefits of and barriers to redesigning land use at a landscape scale
- Tools and processes that enable land managers to assess vulnerability and implement adaptation strategies
- Improved knowledge of the GHG footprint of a range of existing and potential land use options in the Fitzroy basin.
- Improved understanding of the potential opportunities, costs and risks associated with voluntary or legislated emission trading schemes.
- Rigorous and user friendly tools and processes that allow land managers to assess the GHG footprint of their enterprises and the effect of changes to land use and management practices on GHG emissions, natural resource condition and profitability

Suggestions for modification to the Climate Change component of CQSS2 are advanced that focus on explicitly including targets, indicators and actions to address climate change adaptation options, in addition to those directed towards mitigation that currently exist.

Introduction

Background

While the potential impact of human induced changes in the atmospheric concentration of greenhouse gases on the world's climate has been recognised for 3 decades or more, in late 2007 and early 2008, the issue of Climate Change emerged as a major topic of public policy debate throughout Australia and internationally. This rapid escalation of climate change as a topic of community concern and discussion is due, in part, to:

- an increasing consensus within the scientific community that climate change is inevitable and will have significant global impacts
- a recognition by policy makers that action is necessary to minimise potential negative impacts, and
- a recognition by the general public that both climate change *per se* and proposed mitigation measures will impact on their well being

As a community based natural resource management organisation with the Vision of “*Empowered communities for a sustainable CQ*”, the Fitzroy Basin Association (FBA) has recognised that climate change has the potential to impact on the sustainable utilisation of natural resources in the Fitzroy basin.

The current FBA natural resource management plan *Central Qld Strategy for Sustainability – 2004 and beyond* (CQSS2) identifies climate change, and the related pressures of climatic variability, episodic events and extremes in seasonal conditions as having a ‘very high’ potential impact on natural resources in Central Qld. CQSS2 identifies resource condition targets (RCT), management action targets (MAT) and actions in relation to the Climate Change ‘pressure’. The section of CQSS2 dealing with Climate Change is reproduced at **Appendix A**

An informal review of progress against these targets in 2008 identified that:

- the targets are largely focussed on *mitigation* through reduction of greenhouse gas emissions and do not address the important issue of *adaptation* to climate change.
- little work, apart from a recent SKM co-ordinated project, has specifically addressed the issue of adaptation to climate change in central Qld.

It was also recognised that there were a plethora of activities, tools and knowledge being generated in relation to climate change (impacts, mitigation and adaptation) by a range of agencies, organisations and individuals and that the relevance of these to the land managers of the Fitzroy basin was unknown.

A small project was commissioned and funded under the 2008 FBA Innovation Fund to develop a strategic response to climate change for the Fitzroy basin. This document reports the outcomes of that project.

Project Purpose and Objectives

The overall purpose of the project was to develop a strategic response to climate change for the Fitzroy basin. In this context, the term *response* refers to any and all activities that could be undertaken or fostered by the FBA, partner organisations in both the public and private sector, and

the community in general that would help the community of the Fitzroy basin minimise the negative impacts and capitalise on the opportunities arising as a result of climate change.

Specific objectives of the project were:

- To develop a strategic framework for use by FBA (and other investors) to guide future investment in climate change related activities relevant to the Fitzroy Basin
- To develop and prioritise a suite of project concepts in the area of climate change impact, adaptation and mitigation, including identification of providers with the capability and capacity to deliver these projects.
- To review and propose modification to RCT's, MAT's and actions in CQSS2 that relate to the Climate Change pressure.

Project Scope

Climate change has the potential to affect almost every aspect of society and human endeavour. Some examples of how climate change is likely to impact on the central Qld communities include:

- productivity and profitability of land based agricultural production systems
- productivity and profitability of marine and freshwater fisheries
- condition of the regions natural resources including soils, surface, groundwater and marine water quality
- terrestrial and marine biodiversity
- urban water supplies
- the viability of tourism based enterprises through deterioration of the tourism vales of the Great Barrier Reef
- urban infrastructure, especially in low lying areas at risk from rising sea levels

The FBA has arguably a role to play in facilitating a response to all of these potential impacts, however following discussions with FBA staff, it was determined that this project and this report be limited to consideration of responses applicable to land based agricultural production systems. The rationale for this limitation to the project focus includes:

- agricultural production systems are the predominant land use in the Fitzroy basin (~80 % grazing, 6% cropping)
- the extent of human management decisions in of agricultural production systems offers the greatest opportunity to influence environmental, social and economic outcomes by influencing land management practices

Methodology

The major activities undertaken to achieve the project objectives are outlined below.

Desktop Review.

A review of approaches to dealing with climate change proposed in the literature and previous and current research, development and extension relating to climate change (with applicability to the Fitzroy basin) was conducted and findings from this review are summarised here. A selected bibliography of relevant publications relating to climate change is included at Appendix B

Stakeholder Workshop

A workshop with a wide range of stakeholders was conducted in Rockhampton on 25 November, 2008. The objective of the workshop was to identify and prioritise future actions that could be implemented by FBA and other organisations to minimise the impact of climate change on regional assets. Detailed outputs of this workshop are included at Appendix C and form the basis for recommendations included in this report.

Survey of RD&E providers

An email survey of RD&E providers was conducted, supported by an analysis of publically available information (websites etc), to determine current and proposed activities related to climate change, and the interest, capability and capacity of a range of potential partner organisations to engage in future Climate Change related projects relevant to the Fitzroy basin. Findings are summarised in this report and the survey questionnaire, participants and a compilation of responses is included at Appendix D.

A framework for climate change impact and response.

This section proposes a conceptual framework for considering climate change, its impacts and responses. A detailed analysis of the nature of climate change, potential impacts in the Fitzroy basin, and suitable adaptation and mitigation responses is beyond the scope of this report, however these topics are discussed in brief to provide context for the recommendations developed in the following chapters.

Conceptual framework

Climate change is a complex topic area and involves a wide range of processes and potential issues. It is useful to have a conceptual framework in which to consider the various aspects of the subject area and to identify the logical relationships between the different components. A simple conceptual framework is presented in Figure 1.

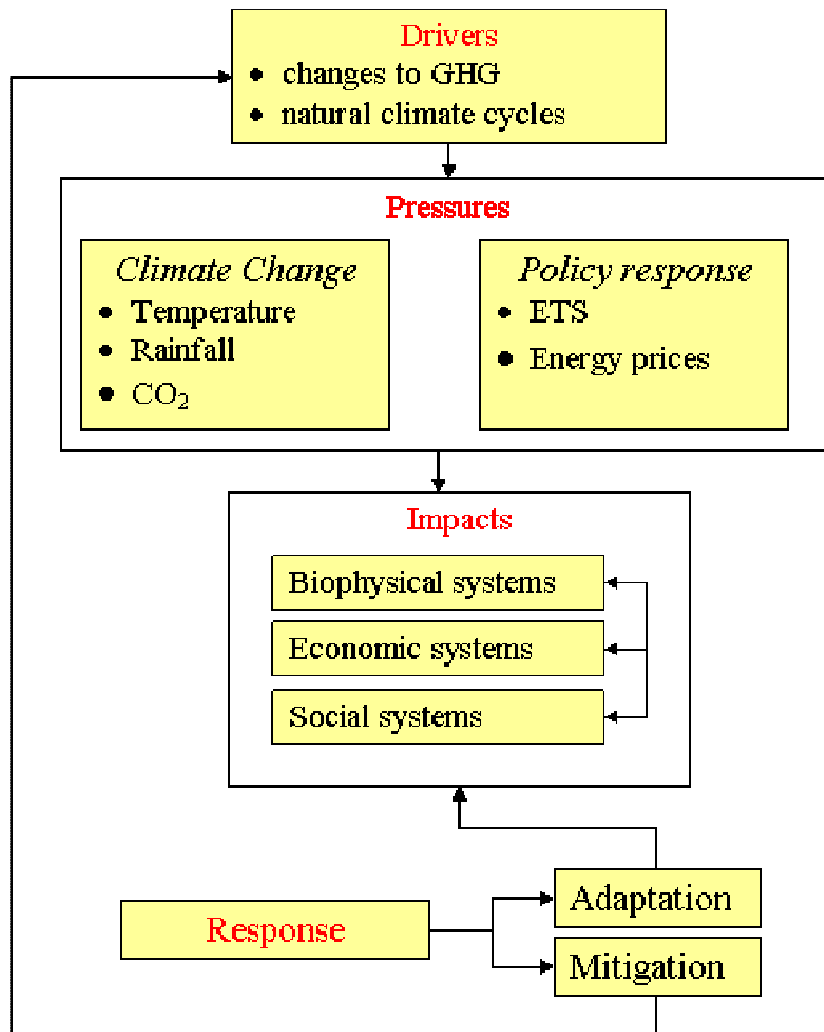


Figure 1. Conceptual framework for climate change pressures, impacts and response

This framework is based on the DPSIR framework for conceptualising interactions between humans and the natural environment, developed by the European Environmental Agency (National Environmental Research Institute (NERC), 1995) and used in recent climate change related projects in central Qld (Clifton & Turner, 2006). The logic underlying this framework is described as follows.

Drivers are the underlying causes of the issue under consideration, in this case, increases in atmospheric greenhouse gas (GHG) concentration, as well as natural climatic cycles that occur at a range of temporal scales (Meinke et al, 20xx). Drivers result in **pressures**, that is, changes in the external environment that have the potential to impact on the systems under consideration. In the case of climate change, pressures include the physical manifestations of climate change *per se* (ie changes in temperature, rainfall, atmospheric CO₂ levels and the secondary climatic consequences of these changes), as well as the public policy responses, such as the introduction of emissions trading schemes, that may be implemented in response to physical climate change. This latter group of pressures have the potential to have a greater short term impact on central Qld agricultural systems through changes to the economic and regulatory environment.

Pressures potentially have an effect or **impact** on the state of, or processes involved in **biophysical, economic** and **social** components of agricultural systems.

Responses are refined as the actions that can be taken by systems managers in an attempt to minimise the adverse consequences of, or capitalise on the opportunities offered by the impacts of climate change. Responses can be categorised as either:

- **mitigation** responses, which are actions designed to directly influence the drivers of climate change, primarily through a reduction in net emissions of GHG, or
- **adaptation** responses, which are tactics and actions designed to minimise the negative impacts of climate change (or capitalise on the opportunities generated), generally through changes to management practices and strategies.

Climate Change Pressures

The major components of the climate change pressure as they are likely to be manifested in central Qld are outlined in Table 1. (various sources). There is considerable uncertainty surrounding the precise nature of changes in climate that can be expected in the region arising from:

- uncertainties surrounding future GHG emissions scenarios
- the imprecise nature of the outputs from the various Global Circulation Models (GCM's) used to generate future climate scenarios, and
- the low spatial resolution of the outputs currently available from GCM's

It is clear that an improved understanding of likely impacts of, and appropriate adaptation and mitigation responses for climate change will be assisted by achieving greater certainty about the nature of climate change in the region, and research to quantify and reduce uncertainty through an analysis of most appropriate GCM's and downscaling their output to achieve greater spatial and temporal resolution will be a priority for the future.

Table 1. Components of the climate change pressure relevant to central Queensland

Component	Likely nature of change	Confidence Level
Temperature	<ul style="list-style-type: none"> • Increased maximums • Increased minimums • Increased days >35°C • Reduced frost incidence 	High
Rainfall	<ul style="list-style-type: none"> • Decreased annual totals • Increased drought frequency • Increased drought severity • Increased drought length • Increased frequency of intense rainfall events (floods) • Increased rainfall intensity • Changes to seasonal rainfall distribution 	Moderate
CO2	<ul style="list-style-type: none"> • Increased atmospheric CO2 concentration 	Certain
Secondary effects	<ul style="list-style-type: none"> • Increased soil evaporation • Increased evapotranspiration • Reduced cloud cover • Increased fire frequency 	Low
Policy responses	<ul style="list-style-type: none"> • Increased energy costs • Economic or legislative incentives to reduce net GHG emissions (includes C sequestrations) 	High High

Impacts of climate change

Tables 2 and 3 provide an overview of the elements of the regions biophysical, economic and social systems that are ‘at risk’, or likely to suffer impact, from climate change and associated pressures. The nature of impacts in terms of degree and direction (increase or decrease, positive or negative) are subject to a compounded level of uncertainty resulting from the uncertainties surrounding climate change pressures and the complexity of interactions inherent in biological systems.

Table 2. Elements of Biophysical systems at risk from climate change & associated pressures

Natural Systems	Cropping Systems	Grazing Systems
Soil <ul style="list-style-type: none"> • Soil erosion • Soil carbon levels & associated soil properties (eg infiltration rates, N fertility) • Soil salinity – resulting from changes in water balance • Surface cover • Soil biology 	<ul style="list-style-type: none"> • Crop growth and yield • Groundcover • Crop adaptation • Crop nutrient requirements • Pest populations • Pesticide application methods • Irrigation water supply • Soil carbon 	<ul style="list-style-type: none"> • Pasture growth and yield • Pasture cover • Pasture quality/feed value • Animal growth rates • Reproduction rates • Animal health • Animal welfare • Pasture quality • Stock water supplies
Water <ul style="list-style-type: none"> • Water balance, including 		

<ul style="list-style-type: none"> runoff and deep drainage • Water quality • Sediment loads • Nutrient loads • Deep Drainage
Air
<ul style="list-style-type: none"> • CO2 • Methane • Nitrous oxides
Biology/Biodiversity
<ul style="list-style-type: none"> • Adaptation and distribution of native species (flora & fauna) • Abundance & distribution of pest species (weeds, insects, vertebrate pests) • Soil biology

Table 3. Elements of Economic and Social systems at risk from climate change & associated pressures

Economic	Social
<ul style="list-style-type: none"> • product prices (grain, beef etc) • product yields • Input prices (eg fertiliser, fuel prices) • Rates of inputs required • Land value • Overhead costs 	<ul style="list-style-type: none"> • farm viability • ability to attract skilled labour • viability of rural communities

Adaptation and mitigation strategies

Table 4 provides an overview of the *types* of adaptation and mitigation strategies that are available to land managers. The selection and implementation of appropriate adaptation and mitigation strategies will require rigorous analysis of their effectiveness under a range of future climate scenarios.

Table 4. Potential adaptation and mitigation strategies

	Cropping Systems	Grazing Systems
Adaptation Strategies	<ul style="list-style-type: none"> • Crop choice • Cropping frequency • Cropping area • Planting dates • Genetics (varieties better adapted to new climate) • Fertiliser rates & application strategies • Plant density/row spacing • Tillage practices to maximise rainfall infiltration & storage • Changes to enterprise mix • Improved water use efficiency in irrigated systems 	<ul style="list-style-type: none"> • Stocking rates • Grazing management practices • Genetics (breeds better adapted to new climate, reduced methane emissions) • Animal species • Pasture species & cultivars • Supplementary feeding strategies • Changes to enterprise mix

Mitigation Strategies	<ul style="list-style-type: none"> • Practices to increased soil C stores • Reduced/ more efficient N fertiliser use • Use of legumes to supply nitrogen • Reduce use of fossil fuels • Use of perennial crops/agroforestry as C sinks. 	<ul style="list-style-type: none"> • Practices to increased soil C stores • Management to reduced methane emissions • Genetics to reduce methane emissions • Reduce use of fossil fuels • Use of perennial pastures/agroforestry as C sinks.
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Principles of responses to climate change

Six principles have been identified that should underpin the development and implementation of future responses to climate change in the region in order to maximise their effectiveness and relevance. These principles have been developed through synthesis of information sourced from the published literature and the views of a range of stakeholders participating in the workshop described earlier (Rockhampton, 25 Nov 2008).

Community engagement.

It is evident the level of community engagement, and in particular engagement by land managers, with respect to climate change in the region is low. While climate change has been the subject of much discussion and debate at a global and national level in recent times, there has been little opportunity for landholders and other community members to engage in discussion, debate and planning at a local and regional level. Some reasons for this lack of engagement may include: a lack of information about potential impacts at a local level; a perception, particularly amongst land managers, that climate change is indistinguishable from the climate variability that they already deal with; and a perception that local action would have little impact due to the global nature of the drivers behind climate change.

A heavy emphasis on community engagement in all future responses will help ensure their relevance and effectiveness.

Risk management approach

The uncertainties associated with the nature and impacts of climate change in the region have been mentioned previously in this report and confer a level of uncertainty to the effectiveness of any response. While some options are available to reduce this level of uncertainty, much will remain. Response actions need to be based on an assessment of the risk of impacts and the effects of the action and should focus on 'no regrets' actions, where positive consequences will result regardless of the future nature of climate change and related pressures.

Local relevance

Response activities should be focussed towards locally relevant systems, enterprises and practices. Developing an understanding of localised impacts of climate change and the value of adaptation and mitigation strategies at a local level will rely on an understanding of the nature of climate change at a local scale. Methodologies are available to downscale global circulation model output to a local (climate station) level and should form the basis of this work.

Outcomes focus

Responses should be ultimately aimed at achieving tangible outcomes. Long term outcomes will in broad terms be those that underlie the vision of FBA and many other agencies, that is, sustainable and productive systems. A program logic approach is suggested to ensure that all activities ultimately contribute to long term outcomes through improved knowledge, skills, management practices and strategies. There are many existing examples where high quality and potentially relevant research languishes in reports and the scientific literature for want of a process to translate this knowledge into on-ground outcomes.

Systems approach

As illustrated earlier in this report, climate change has the potential to impact on a wide range of processes and resource states in natural and managed systems. The various pressures interact in complex ways to determine impacts. Responses should follow a systems approach when addressing these issues with particular emphasis on:

- consideration of the impact of mitigation and adaptation responses on all components (biophysical, economic & social) of natural and production systems
- a focus on outcomes at a whole-farm and landscape scale
- consideration of the interactions between mitigation and adaptation responses
- close integration of research, development, extension and incentives based responses

Integration with other programmes

While there is justification in addressing climate change as a standalone issue to achieve focus and improve community engagement and awareness, the wide reaching and complex nature of climate change impacts and responses dictates that a consideration of climate change should be included in other programmes addressing aspects of land management, natural resource condition, productivity and profitability of agricultural systems.

Recommended adaptation and mitigation responses

In this section, suggested priorities for responding to climate change in the Fitzroy basin are presented in a simplified programme logic framework (Tables 5 and 6). The use of a program logic framework helps highlight the logical linkages between the outcomes required and the activities undertaken to achieve those outcomes.

The logical flow inherent in this framework can be described as follows:

- *Long term (aspirational) outcomes* – a statement of the ultimate consequences desired, generally with a time frame of 20 + years and inherently difficult to quantify or measure
- *Intermediate outcomes* – the shorter term (2 – 20 year) outcomes that must be achieved in order to achieve the long term outcome, analogous to Resource Condition Targets in NRM planning, generally easier to quantify or measure than Long term outcomes
- *Practice change* – the on-ground practice change required on the part of land managers (and other stakeholders) in order to achieve outcomes. Recognises that outcomes cannot be achieved with out on-ground practice change.
- *Outputs* – the tangible products or services, in this case expressed in terms of knowledge, skills and tools, required to be produced to support and provide the basis for the practice change required
- *Activities* – the activities required to generate outputs

Recommended responses are separated into adaptation (Table 5) and mitigation (Table 6) categories here, in view of the fundamental differences in how these responses contribute to reducing climate change impacts. However it should be recognised that all responses contribute to the same biophysical, economic and social systems and should not be considered in isolation since they interact.

Table 5 Adaptation programme logic

Outcome level	Description
Long term (aspirational) outcome	Agricultural systems in the Fitzroy basin have the resilience to sustain and natural resource condition, food and fibre production and ecosystems services under future climate scenarios.
Intermediate outcomes	<ol style="list-style-type: none"> 1. Resource condition (soil, water, biodiversity and air) maintained or improved. 2. The productivity and profitability of agricultural systems maintained at a level commensurate with long term sustainability. 3. Ecosystems services maintained
Practice change outcomes	<ol style="list-style-type: none"> 1. Widespread adoption of land management practices (to be identified) that sustain NR condition, productivity, profitability and ecosystems services under future climate scenarios. 2. Land use matched to land capability at a landscape scale.
Outputs (Knowledge, skills and tools required)	<ol style="list-style-type: none"> 1. Knowledge of the likely nature of future climate scenarios (at a daily timestep) for a range of locations in the Fitzroy basin 2. Knowledge of the potential impacts of likely future climate scenarios on natural resource condition and the profitability and productivity of key agricultural enterprises (beef, grains, cotton, horticulture) in central Qld

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3. Identification and evaluation of the effectiveness of a range of management practices and strategies in minimising the impacts of climate change on natural resource condition and the profitability and productivity of key agricultural enterprises (beef, grains, cotton, horticulture) in central Qld
 4. Understanding of the potential for novel and innovative or new land use options to achieve natural resource, profitability and productivity outcomes under new climatic conditions
 5. Understanding of the potential benefits of and barriers to redesigning land use at a landscape scale to achieve natural resource and productivity outcomes under new climatic conditions
 6. Tools and processes that enable land managers to assess the vulnerability of their enterprises to climate change and climate variability, and help them select and implement appropriate adaptation strategies

Activities

1. Landholder (and wider community) engagement to raise levels of awareness of the nature and impacts of climate change in the Fitzroy basin.
 2. Participatory action research with landholders (and the wider community) to identify and validate potential locally relevant adaptation options.
 3. Downscale future climate scenarios to a daily time step scale for selected climate stations in the Fitzroy basin to use in regionally specific impact assessment and evaluation of adaptation options
 4. Research and development (R&D) using scenario analysis, simulation modelling and field research where appropriate to quantify the potential impacts of future climate change scenarios on natural resource condition, productivity and profitability of agricultural systems in the Fitzroy basin.
 5. R&D using scenario analysis, simulation modelling and field research where appropriate to evaluate the effectiveness of proposed adaptation practices and strategies.
 6. R&D to develop tools and processes that enable land managers to assess the vulnerability of their enterprises to climate change and climate variability, and help them identify and implement appropriate adaptation strategies.
 7. Landholder (and other stakeholder) engagement and capacity building activities to build capacity to identify and implement appropriate adaptation strategies.
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Table 6. Mitigation programme logic

Outcome level	Description
Long term (aspirational) outcome	Agricultural systems in the Fitzroy basin are GHG neutral.
Intermediate outcomes	<ol style="list-style-type: none"> 1. Increase in C stored in soils and vegetation 2. Reduced greenhouse gas emissions from fossil fuel use, fertiliser use and land use change 3. Reduced methane emissions from grazing animals 4. Reduced nitrous oxide emissions from N fertiliser application
Practice change required	Improved adoption of land management practices (to be identified) that result in a reduction in net GHG emissions while maintaining natural resource and economic sustainability.
Outputs (Knowledge, skills and tools required)	<ol style="list-style-type: none"> 1. Improved knowledge of the GHG footprint of a range of existing and potential land use options in the Fitzroy basin. 2. Improved knowledge of the impact of management practices on net GHG emissions and interactions between GHG emissions, profitability and natural resource condition, in particular for practices which <ol style="list-style-type: none"> a. Improve soil C storage b. Reduce reliance on fossil fuels as an energy source c. Reduce methane emissions from grazing animals (per unit of production) d. Reduce nitrous oxide emissions resulting from inefficient use on N fertilisers 3. Improved understanding of the potential opportunities, costs and risks associated with voluntary or legislated emission trading schemes. 4. Rigorous and user friendly tools and processes that allow land managers to assess the GHG footprint of their enterprises and the effect of changes to land use and management practices on GHG emissions, natural resource condition and profitability
Activities	<ol style="list-style-type: none"> 1. Locally relevant research and development activities to generate the knowledge requirements in 1 – 3 above 2. Landholder (and other stakeholder) engagement and capacity building activities to build capacity to identify and implement appropriate mitigation strategies.

Previous climate change work relevant to the Fitzroy basin

The literature contains a number of instances of research into climate change projections, impacts and consequences relevant to the Fitzroy Basin region. (See bibliography at Appendix B). The early work of Howden and others included analysis of impacts of climate change on the performance of cropping and grazing systems in central Qld (eg Howden et al 2001, 2003).

A major project funded by the Australian Greenhouse Office in 2005 with the following objectives, included a significant Fitzroy basin component.

- improving understanding of the implications of climate change for regional NRM, and
- developing tools and processes that help regional NRM organisations incorporate climate change impacts, adaptations and vulnerability into their planning processes.

This project involved seven regional natural resource management (NRM) organisations - including the Fitzroy Basin Association (FBA), Queensland Murray-Darling Basin Committee (QMDC) – and the Queensland Department of Natural Resources and Water. The project consisted of three main components:

1. Identification of the components of the natural resource system of participating regions that were more vulnerable to climate change. The key steps were to develop the 'conceptual mapping' workshop process, (Clinton & Turner, 2006) and a literature review to document climate change projections, impacts and adaptive mechanisms for each participating region (Miles et al, 2005) and then to run 'conceptual mapping' workshops in each of these regions.
2. This stage completed a series of regional case studies which explored climate change impacts on one or a small number of components of the natural resource system that were more vulnerable to climate change. The case studies were designed to provide more objective information on climate change impacts and vulnerability and will be used to support analysis of how regional NRM processes can incorporate climate change considerations. Results of the case study for FBA are reported in Cobon & Toombs (2007) and Cobon, Toombs and Zhang (2007)
3. In the final stage, lessons from the case study were to be used to help develop tools and processes (e.g. thinking models, numerical models, workshop processes, modifications to risk assessment processes) that enable regional NRM organisations to incorporate climate change into their planning, priority setting and implementation.

More recent work has started to evaluate climate change adaptation (Rodriguez et al, 2009) and mitigation (Fensham & Guymer, 2009; Dwyer et al, 2009) strategies.

While the published work is generally of high quality and serves to highlight impacts and adaptation responses, it has generally had little impact on-ground due to one or more of the following factors:

- conducted in isolation from regional stakeholders
- little attempt made to communicate findings to regional stakeholders
- conducted at a spatial and temporal scale that does not enable interpretation or implementation at an operational level.

Current Research, Development and Extension

Federally funded

Federal funding for climate change related RD&E for primary industries is delivered through the “Australia’s Farming Future” initiative, established in late 2008 and administered by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF). This initiative provides funding over four years to help primary producers adapt and respond to climate change.

The stated objective of Australia’s Farming Future is to equip primary producers to adapt and adjust to the impacts of climate change.

The initiative comprises a number of elements:

- The *Climate Change Research Program*, which provides funding for research projects and on-farm demonstration activities.
- *FarmReady* which will help industry and primary producers develop skills and strategies to help them deal with the impacts of climate change.
- *Climate Change Adjustment Program* assists farmers in financial difficulty to manage the impacts of climate change. Farm Business Analysis and Financial Assessments and professional advice and training are individually tailored to help farmers adjust to climate change and to set goals and develop action plans to improve their financial circumstances. Rural financial counsellors can assist eligible farmers to take action to improve their long term financial position. Re-establishment assistance provides farmers who sell their farms with assistance to re-establish themselves.
- *Transitional income support* is linked to the climate change adjustment program and provides short-term income support and advice and training opportunities to farmers in serious financial difficulty, while they adapt their farm to changing circumstances, including climate change.
- *Community Networks and Capacity Building* activities will focus on increasing the leadership and representative capacity of target groups including women, youth, Indigenous Australians and people from culturally and linguistically diverse backgrounds.

A summary of projects funded under the Climate Change Research Programme, and Qld based projects funded under FarmReady is provided at Appendices E and F respectively.

State Funded

The Qld government response to climate change is encapsulated in the recently released “ClimateQ” strategy. This strategy includes all elements of the Qld government adaptation and mitigation response, and includes a description of existing and new initiatives with respect to Primary Industries and Ecosystems, as well as a summary of climate change projections for regions throughout Qld. Previous, recent and new initiatives identified in the ClimateQ strategy are listed in Table 7.

Table 7. Previous, recent and new Qld govt climate change related initiatives in the Primary Industry and Ecosystems sectors, as identified in the ClimateQ strategy

Earlier Actions	Recent and new initiatives
Primary Industries	
Rural Water Use Efficiency—working in partnership with rural communities	Recognising carbon rights on leasehold land
Managing drought	Extending the Rural Water Use Efficiency Initiative (RWUE)
World class climate change science informing primary producers	Identifying the carbon potential of native vegetation
Research to reduce emissions from livestock	Helping primary producers adapt to climate change
Sustainable land management	Identifying the carbon potential of land uses
Commercial forest plantations	
Ecosystems	
Protecting and managing biodiversity	Climate change corridors for biodiversity
Environmental offsets and Ecofund	Improved fire management in national parks
Water quality in the Great Barrier Reef	
Wetlands Program	
Healthy waterways	

Other Activities

A range of RD&E providers including state and federal agencies, universities, regional NRM groups and peak industry organisations are conducting activities related to climate change. The majority of these activities have now been consolidated under the DAFF “Australia’s Farming Future” initiative as described earlier, however isolated activities still occur outside this framework. Some of these activities have been identified through an email survey of RD&E providers, the results of which are summarised in Appendix D.

Providers

The major organisations with interest and capabilities in delivering climate change related RD&E in Qld are listed in Table 8, together with a summary of their major areas of expertise. More detail of some of these providers is provided in the survey responses at Appendix D.

Table 8. Summary of capabilities of potential service providers

Organisation	Sub-unit	Relevant areas of expertise and capability
Qld Primary Industries and Fisheries	Plant Science	RD&E in plant based systems (extensive cropping and sown pasture based systems, including soil carbon/soil health and nitrous oxide emissions)
	Animal Science	RD&E in animal based systems (extensive grazing and intensive animal production, including rangelands management and methane emissions)
	Horticulture Science & Forestry	RD&E re horticulture and forestry systems
	Regional Services	Extension and training, extensive regional presence throughout Qld
	Emerging Technologies	Systems analysis & simulation modelling, downscaling climate change projections, impact assessment, evaluation of adaptation options.

Organisation	Sub-unit	Relevant areas of expertise and capability
Department of Environment and Resource management	Qld Climate Change Centre of Excellence	Climate science and research to inform Queensland's response to climate change. Information and science on climate change impacts, including the application of international research and science to the Queensland context.
Department of Environment and Resource management	CQ Science group	Catchment scale modelling
University of Southern Qld	Australian Centre for Sustainable Catchments	Climatology, catchment scale
Central Qld University	Institute for Resource Industries & Sustainability	Plant production systems, environmentally sustainable development in the dry tropics, environmental resource economics
Qld University of Technology	Institute for Sustainable Resources	Management of soil carbon and nitrous oxide emissions
Sub-regional NRM groups	CHRRUP, DCCA, FRCC, Three Rivers, BCSR	Regional landholder networks
CSIRO	Climate Adaptation Flagship	All aspects of adaptation to climate variability and change. Research themes: Pathways to Adaptation; Sustainable Cities and Coasts; Managing Species and Natural Ecosystems; and Adaptive Primary Industries.
AgForce	Main organisation and AgForward (Training arm)	Climate risk management workshops, Beef and Grain industry networks, Grains BMP
GrowCom		Horticulture industry networks

Gaps and priorities

In Table 9, the desired outputs identified in the programme logic described earlier is compared with recent and current RD&E to derive a simple and qualitative assessment of:

- a. The extent to which the output is likely to be addressed through RD&E currently in progress (Scale of Poor, Moderate, Good), and
- b. The priority for further investment to support this output (scale of Low, Moderate, High) – assessed simply as the inverse of the extent to which the output is already covered by current RD&E.

This approach does not account for the relative priorities of the various outputs (ie there may be outputs that are well addressed by current RD&E but could still benefit from further investment), however it provides some guidance for future investment priorities.

Table 9 Gap analysis of RD&E needs

#	Output from program logic (abbreviated description)	Coverage with current RD&E	Priority for Future investment
Adaptation Outputs			
A1	Knowledge of the likely nature of future climate scenarios	Moderate	Moderate
A2	Knowledge of the potential impacts of likely future climate scenarios	Moderate	Moderate
A3	Identification and evaluation of the effectiveness of a range of adaptation strategies	Moderate	Moderate
A4	Understanding of the potential for novel and innovative or new land use options	Poor	High
A5	Understanding of the potential benefits of and barriers to redesigning land use at a landscape scale	Poor	High
A6	Tools and processes that enable land managers to assess vulnerability and implement adaptation strategies	Poor	High
Mitigation Outputs			
M1	Improved knowledge of the GHG footprint of a range of existing and potential land use options in the Fitzroy basin.	Poor	High
M2	Improved knowledge of the impact of management practices on net GHG emissions and interactions between GHG emissions, profitability and natural resource condition, in particular for practices which:		
M2a	• a. Improve soil C storage	Moderate	Moderate
M2b	• b. Reduce reliance on fossil fuels as an energy source	Poor	High
M2c	• c. Reduce methane emissions from grazing animals (per unit of production)	Good	Low
M2d	• d. Reduce nitrous oxide emissions resulting from inefficient use on N fertilisers	Good	Low
M3	Improved understanding of the potential opportunities, costs and risks associated with voluntary or legislated emission trading schemes.	Poor	High
M4	Rigorous and user friendly tools and processes that allow land managers to assess the GHG footprint of their enterprises and the effect of changes to land use and management practices on GHG emissions, natural resource condition and profitability	Poor	High

The role of FBA

The priority and level of resources that FBA attributes towards dealing with climate change in the region is largely a matter for the FBA board and stakeholder groups, however given the stated role, vision and objectives of the organisation, it is suggested that FBA could play an important and unique role in the following areas:

- engage with and help focus the activities of the various existing RD&E projects in the region
- through regional landholder networks, provide the opportunity to communicate research outcomes to landholders in the region
- engage with relevant RD&E funders and providers to highlight priority areas of future RD&E investment
- coordinate the development of new regionally specific projects as funding opportunities arise
- where resources allow, fund targeted projects that address high priority and regionally specific issues

Suggested modifications to CQSS2

As mentioned earlier in this report, the current version of the 'Central Qld Strategy for Sustainability – 2004 and beyond', identifies climate change as a significant threat to the natural, economic and social assets of the region and defines some targets, indicator and actions in relation to climate change. These are primarily targeted at mitigation through reduction of greenhouse gas emissions. While it is recognised that actions and targets proposed in other sections of CQSS2 are relevant to climate change adaptation, it is suggested that these be made explicit in the Climate Change section. Some suggestions regarding additions and modifications to the current targets, indicators and actions that would broaden the scope of this section of CQSS2 in any future revision are outlined below.

Resource condition targets

Resource conditions targets relating to the Climate Change pressure should be consistent with those set elsewhere and should relate to all resources covered (ie soil, water, air and biodiversity)

Resource condition indicators

Similarly, RCIs that relate to all resources under consideration and that are consistent with other sections of the strategy can be included

Management action targets

The inclusion of a MAT that relates to adaptation measures is recommended, for example:

'Practices and technologies developed and implemented that improve the resilience of managed systems and reduce their vulnerability to a changing and variable climate within x years'

Performance indicators

In addition to carbon emission targets, performance indicators relating to the level of adoption of management practices and strategies that reduce vulnerability to climate change would be appropriate.

Actions

Some additional actions in each action area are suggested below:

Building knowledge

- Develop knowledge of the likely nature of future climate scenarios for a range of locations in the Fitzroy basin
- Develop knowledge of the potential impacts of likely future climate scenarios on natural resource condition and the profitability and productivity of key agricultural enterprises (beef, grains, cotton, horticulture) in the region

- Identify and evaluate the effectiveness of new management practices and strategies that may reduce the impacts of climate change on natural resource condition and the profitability and productivity of key agricultural enterprises in central Qld
- Identify and evaluate novel and innovative or new land use options to achieve natural resource, profitability and productivity outcomes under new climatic conditions
- Develop tools and processes that enable land managers to assess the vulnerability of their enterprises to climate change and climate variability, and help them select and implement appropriate adaptation strategies
- Develop improved knowledge of the GHG footprint of a range of existing and potential land use options in the Fitzroy basin.
- Develop improved knowledge of the impact of management practices on net GHG emissions and interactions between GHG emissions, profitability and natural resource condition, in particular for practices which
 - Improve C storage in soils and woody vegetation
 - Reduce reliance on fossil fuels as an energy source
 - Reduce methane emissions from grazing animals (per unit of production)
 - Reduce nitrous oxide emissions resulting from inefficient use of N fertilisers
- Develop improved understanding of the potential opportunities, costs and risks associated with voluntary or legislated emission trading schemes.
- Rigorous and user friendly tools and processes that allow land managers to assess the GHG footprint of their enterprises and the effect of changes to land use and management practices on GHG emissions, natural resource condition and profitability

Sharing knowledge

Increased awareness of

- the potential impacts of climate change on natural resource condition, productivity and profitability
- management practices and strategies that reduce vulnerability to the impacts of climate change
- management practices and strategies that minimise GHG emissions
- methodologies and tools to assess potential impact and evaluate adaptation and mitigation strategies

Planning, Governance and Partnerships

Help coordinate at a regional level, research, development and extension targeted at minimising the impact of climate change

On-ground action

Support the adoption of management practices and strategies (to be identified) that minimise that adverse impacts and capitalise on the opportunities presented by a changing climate.

Appendix A. Existing Climate Change section of CQSS2

3.4.5 Climate Change

Assets protected

Air *Economic assets*

Land *Social assets*

Great Barrier Reef

Ecosystem Health and Biodiversity

Condition and trend summary

Central Queensland's temperature has increased, on average, between 0.5 -1.5 °C during the last 100 years. This in part is due to greenhouse gases increasing in the atmosphere. Carbon dioxide and methane are the two greatest contributors to atmospheric greenhouse gases, contributing 60% and 20% of greenhouse warming in 1998. Carbon dioxide made up 69% of total national greenhouse gas emissions in 2001. Of the activities that cause emissions of these gases, the most important in Central Queensland are land clearing; coal mining; burning of fossil fuels; and ruminant animals. Existing forests and woodlands, thickening of woody vegetation and regrowth act as a large sink absorbing carbon dioxide. Nationally, emissions related to land use change have declined by 69.2 percent between 1990 and 2000 and by 21.7 percent between 2000 and 2001 (estimate).

Target explanation

While recognising the bigger picture implications of greenhouse gas emissions on regional climate, changes in the amount of carbon stored in the region's soils and vegetation due to land use and land use change, is a more immediate pressure and is the achievable focus of this target. The CQ Regional Growth Management Framework – CQANM, Strategy 3.1.6, also addresses renewable energy and greenhouse gas reduction objectives. Keeping or returning carbon to the soil maintains long-term soil and pasture health as well as supporting broader greenhouse gas reduction. For example, reducing grazing pressure, and thereby increasing ground cover and plant production, in degraded areas can also increase carbon sequestration in the top 10cm of soil. Rockhampton and Gladstone City Councils, and Calliope Shire Council are participating in the Cities for Climate Protection Program.

Insufficient information is available to set regional targets; however the targets set below aim to develop targets, minimise net greenhouse gas emissions, and increase carbon sequestration.

Resource condition target			Priority
To be defined within 10 years by M10 See also R2, R13, R18			1
Resource condition indicators			
Carbon emissions			
Management action targets			
M9	Practices and technology developed and implemented to minimise net greenhouse gas emissions within 10 years		1
M10	Set regional targets for greenhouse gas emissions, particularly carbon maintenance and sequestration within 10 years		1
Performance indicators			
Targets for carbon emissions set			
Actions			Who
Building knowledge			Priority
A136	Develop an assessment, analysis and monitoring framework (e.g. Regional carbon accounting system) for carbon stocks in vegetation and soils, above and below-ground woody biomass and risk within 5 years	R&D	1a
A137	Undertake further trials of property and carbon budgets within 5 years	R&D	1b
A138	Research and develop alternative energies (including agricultural by-products), products and markets within 10 years	R&D	1c
A139	Develop a framework within 5 years for the promotion and implementation of environmental services as a means of increasing carbon sequestration	R&D	1b
Sharing knowledge			
A140	Increase awareness of energy efficient practices and technologies, and the implications of inefficiencies (i.e. Global warming)	QSA R&D	1b
On-ground action			
A141	Implement management actions for vegetation retention, regeneration and improving ground cover and soil health within 5 years	FBA LC/C	1a
A142	Uptake of energy efficient practices and technology by consumers	?	1b
A143	Reduced greenhouse gas emissions, per unit of output, by energy producers	IND QSA	1b

Appendix B. Selected Bibliography

This bibliography includes a selection of the published literature on climate change that may be relevant to the subject of this report and the Fitzroy basin. It includes references cited in the text of this report.

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Appendix C. Stakeholder workshop

Attendees

Title	First Name	Surname	Org	Town	Sector
Mr	Michael	Bent	FBA	Rockhampton	NRM planning
Dr	Steven	Bray	DPI&F	Rockhampton	Pasture Science
Mr	Neil	Cliffe	DPI&F	Rockhampton	Facilitator
Mr	Bruce	Cowie	FBA	Rockhampton	NRM Planning
Mr	Peter	Donaghy	DPI&F	Rockhampton	Agricultural & NR Economics
Mr	Rolfe	Ellem	CHRRUP	Emerald	Sub-regional NRM
Prof	Peter	Grace	QUT	Brisbane	Soil Carbon research
Mr	John	Grimes	DPI&F	Rockhampton	Regional Planning
Mr	Kerry	Heit	DPI&F	Kingaroy	Cropping Systms
Dr	Dick	Holroyd	DPI&F	Rockhampton	
Mr	Paul	Jones	DPI&F	Emerald	Pasture Science
Dr	Susan	Kinnear	CQU	Rockhampton	Sustainable regional development
Ms	Jill	Lyons	3Rivers	Rockhampton	Sub-regional NRM
Mr	Kev	McCosker	DPI&F	Rockhampton	Regional Planning
Prof	Bob	Miles	CQU	Rockhampton	Sustainable regional development
Ms	Kellie	Nilsson	DCCA	Theodore	Sub-regional NRM
Dr	David	Orr	DPI&F	Rockhampton	
Ms	Jan	Paff	DPI&F	Brisbane	Research Policy
Dr	Carol	Petherick	DPI&F	Rockhampton	Animal Welfare
Mr	Stuart	Pilcher	DPI&F	St George	Cropping Systems
Mr	Richard	Routley	DPI&F	Emerald	Cropping Systems
Dr	Joe	Scanlan	DPI&F	Toowoomba	Pasture Science
Dr	Richard	Sequeira	DPI&F	Emerald	Cropping Systems
Ms	Anne	Shepherd	DPI&F	Emerald	Cropping Systems
Mr	Graham	Spackman	GS&A	Emerald	Agricultural Consultant
Dr	Shahbaz	Mushtaq	USQ	Toowoomba	Climatology
Mr	Mick	Sullivan	DPI&F	Rockhampton	Beef production systems
Dr	Cameron	Wearing	FRCC	Rockhampton	Sub-regional NRM
Dr	Xike	Zhang	QCCCE	Toowoomba	Climatology

Initial brainstorming

After an introductory session, participants worked in four groups to brainstorm the issue “Identify actions that FBA and others could implement to enable landholders to cope with climate change.”

Outcomes from this brainstorming activity are listed below.

Orange Group	Blue Group
<ul style="list-style-type: none"> • select animals that perform well (objective selection of cattle) • Drought tolerant plants • Breeding programs for crop adaptation • More diversity in farming systems • Managing stocking rate for ground cover • Manage land to minimise soil loss and look after water resource/quality • Responding to ‘short term’ climate signals (this 	<ul style="list-style-type: none"> • deliver accurate info on soil carbon to land managers • deliver info on how to understand GHG footprint <ul style="list-style-type: none"> ○ effect of different practices ○ economics • Model the climate change scenarios and their effects (focus on what will really make a difference) • Review overseas production systems →

<p>addresses issues of GC, soil, water eg SOI, IPO etc)</p> <ul style="list-style-type: none"> • Develop trust between short term signals and farmer confidence in these • Greater accuracy in predictions • Meteorology about prediction not precision/probability • Responsiveness to seasonal conditions improved (be open to change – not operate by dates/numbers) • Must maintain natural systems (irreplaceable) • BMP for climate variability eg water resource of sufficient size/scale, deep planting of chickpea • Benchmarking for current climate • Reduce/case use of “marginal” land systems • Adapt land use/manage vegetation types according to land capability in light of climate change • Be more proactive and less reactive as a response action (esp in R&D) • Need investment in R&D for climate adaptation • Extension process to assist landholders with opportunities from ETS • Soil carbon opportunities • Advocate for resources to be channelled into R&D for climate adaptation eg environmental restoration • Educated community (broadly) about why adaptation processes are needed • Increase use of decision support tools for better management. 	<p>application to Australian conditions</p> <ul style="list-style-type: none"> • ID skills of “good” managers • ID characteristics of resilient enterprises →education of landholders • ID business strategies for “hard” times • ID animal adaptability <ul style="list-style-type: none"> ◦ Production (Lwt gain, reprod)/GHG emission tradeoffs • R&D re effect of management on increasing or maintaining soil carbon levels • Maintenance & improvement of groundcover • Animal health and welfare • Sequestration • Needs re increasing groundcover <ul style="list-style-type: none"> ◦ Research re pasture cropping ◦ Comparison of pasture types (carbon capture & production) ◦ Perennial crops ◦ Stocking rate/grazing strategies to maintain & improve groundcover • Get rid of ruminants • Strategies to address poor quality forages (resulting from CC, Increased CO2)
<p>Red Group</p> <ul style="list-style-type: none"> • Awareness campaign <ul style="list-style-type: none"> ◦ ‘digestible’ to target audience ◦ Locally relevant ◦ ID gaps – science, management ◦ Focus on younger generation ie highschool age ◦ Get landholders to brainstorm action • Close the gap/integrated RD&E <ul style="list-style-type: none"> ◦ Central facilitator/broker ◦ Foster systems management • Continued investment/action in ‘no regrets’ areas • Awareness of different outcomes for grazing • Improved understanding of effect of ETS (+ & -) on ag systems • Utilise opportunities in global genetics • Influence & advocate R&D innovation • Explore innovative ways to improve WUE (eg agrichar) <ul style="list-style-type: none"> ◦ ID existing & develop new • Carbon neutral catchments – calculate footprints of H2O, energy, GHG • Rainfall use efficiency, soil science • Coastal planning/sea level rise/fish habitat • ID areas to allow fish habitat encroach • Increase investment in fish passage • Enhance climate change leaders • ID ‘hot spots’ for climate responsive investment • Incorporate climate change in regional council plans 	<p>Green Group</p> <ul style="list-style-type: none"> • identifying threshold points for land use change ie \$/t CO2 when crops/varieties will become uneconomic • tools for assessing industries carbon balance • better use of current tools ie carrying capacity assessment, forage budgeting, land capability/condition assessment • economic benefits of changes need to be identified & promoted <ul style="list-style-type: none"> ◦ property level tools • Establish economics of carbon sequestration to promote alternative uses for land in poor condition • Quantify relationships between carbon markets, land type & land condition • Investigate opportunities for multiple uses & alternative enterprises to access new green market opportunities • Identifying critical science gaps in this region ie carbon capture in different grazing systems • Communication of relevant information to industry

Grouping

Participants were then asked to group actions that had been identified into 'like' groupings.

Grouping	Action
R&D, Plants, Forage	<ul style="list-style-type: none"> • R&D strategies on low quality forages • R&D alternative cropping
Research policy & planning	<ul style="list-style-type: none"> • ID critical science gaps • Coastal planning to cater for fish habitat movement • Advocate for investment in R&D for Climate Change • Continue investment in R&D • Investment in R&D for climate adaption • Proactive research applications for Climate Change • Climate responsive "Hot Spot" investment plans <ul style="list-style-type: none"> ○ Short run ○ Long run
Application of management practices	<ul style="list-style-type: none"> • Better use of current tools <ul style="list-style-type: none"> ○ CC assessment ○ Forage budgeting ○ Land capability & condition assessment • Collect best practice for climate variability • Adapt land use according to veg type & land capability • Close the gap/integrated R&D <ul style="list-style-type: none"> ○ Central facilitator/broker ○ Foster systems management • Increase use of decision support tools for better management • Increase investment in fish passage • Limit increase in water allocation in future • Optimise grazing land management • More diversity in farming systems • Maintain/Improve ground cover • Improve (maintain) NR condition
R&D, Ruminants & GHG Emissions	<ul style="list-style-type: none"> • Rumen bacteria that don't produce methane • ID GHG efficient livestock management • Remove/modify ruminants
Breeding & genetics	<ul style="list-style-type: none"> • Select animal and plant spp able to adapt • Breed/select for adaptable/tolerant (heat stress) livestock
Business management	<ul style="list-style-type: none"> • Characterise 3BL resilient enterprises & businesses • ID threshold points for industry ie when crops/varieties will become uneconomic • ID business strategies for hard times • ID key enterprise vulnerability points eg water, fertility etc
Carbon	<ul style="list-style-type: none"> • Establish economics of C sequestration • Landholder extension for ETS opportunities • Develop tools for assessing carbon balance on farm • Research management effects on soil carbon • Quantify relationships between carbon markets, land types and land condition • Carbon neutral catchments <ul style="list-style-type: none"> ○ Calculate footprints of energy, water, GHG, economics • Deliver accurate info on soil carbon • Landholder extension for soil carbon opportunities • Verification (of C balance) • Deliver information on understanding GHG footprint <ul style="list-style-type: none"> ○ Practices ○ Economics
Understanding climate and impacts	<ul style="list-style-type: none"> • More response to short & long term climate signals • Develop predictions of weed and pest distribution & impacts under altered climate • Impact/Adaptation matrix for cropping & NRM • Greater accuracy of prediction <ul style="list-style-type: none"> ○ Better climate models • Use of cutting edge GCM climate model linked with downscale model to

	<ul style="list-style-type: none"> more accurately forecast • Model climate change scenarios and their effects <ul style="list-style-type: none"> ◦ Focus on what will make a difference • Improve responsiveness to seasonal conditions • Improve farmer confidence in climate signals • Homoclimate studies to establish future practices • Review overseas production systems • Application to FBA situation
Opportunities	<ul style="list-style-type: none"> • Evaluate alternative industries to traditional agriculture • Utilise opportunities in global genetics • Opportunities for multiple uses & alternative enterprises • Landscape redesign
Awareness	<ul style="list-style-type: none"> • Communication of relevant Information • Series of awareness & education workshops • Awareness of different outcomes for grazing lands • Community extension on need for adaptation processes • Regional council engagement plans • Ownership & engagement in the climate change debate: opportunities &/or threats

Project Concepts

Participants were then asked to develop project concepts that would address one or more of the actions identified earlier.

Title	Research & Development regarding ruminant and GHG emissions
Outcome required	Same meat/fibre/food produced as current for less methane emissions
How this will reduce risks/capitalise on opportunities	Mitigation impact – less GHG/unit of production Possible economic benefits if penalties for GHG emissions introduced, Profit from sale of genetics
Methodology	<ul style="list-style-type: none"> • review existing info/programs • Measure methane emissions • Determine variability, heritability, productivity synergies/tradeoffs • Breeding program, including GM
Partners	DPI&F, UQ, CSIRO, FBA, Beef CRC, AGBU
Funders	as above + MLA, Federal Govt
Other issues	Existing research programs

Title	Application of management practices
Outcome required	<ul style="list-style-type: none"> • uptake of known solutions to climate variability • catalyst for leading edge projects • Model farms/pilots to show way to others
How this will reduce risks/capitalise on opportunities	<ul style="list-style-type: none"> • maximises use of available knowledge • Build greater resilience and flexibility into agricultural systems • Benchmarks established to measure against
Methodology	<ul style="list-style-type: none"> • Continuation of FBA innovation fund (annually) • “Classic” extension processes • Model farms for each land type • Target ‘young’ farmers/next farming generation
Partners	All the usual – Govt, community, industry
Funders	All the usuals – Fed Govt, State Govt, R&D corps, industry
Other issues	

Title	Breeding & Genetics
Outcome required	Improved efficiency of production under highly variable climatic conditions

How this will reduce risks/capitalise on opportunities	<ul style="list-style-type: none"> • Reduce costs of mitigation • Improving animal welfare
Methodology	<ul style="list-style-type: none"> • review current knowledge • Build on current programs • Use of GM animals and plants • Additional parameters added to national livestock recording schemes
Partners	DPI&F, Universities, CSIRO, Beef CRC, AGBU
Funders	As above + MLA, Fed Govt, GRDC, Breed Societies
Other issues	Overcoming Tradition Measure antagonism between traits

Title	Business Management
Outcome required	Identify characteristics of resilient farm businesses <ul style="list-style-type: none"> • People • Finance/Debt • Management skills • Land use/Capability
How this will reduce risks/capitalise on opportunities	<ul style="list-style-type: none"> • Enterprises maintain profitability in face of increased climate variability and change • Land condition maintained/improved • Healthy ecosystems
Methodology	<ul style="list-style-type: none"> • Benchmarking activities • Case studies • Land condition assessment
Partners	FBA, DPI&F, Agribusiness
Funders	State & Federal Govts
Other issues	

Title	Actioning Greenhouse Gas Reduction
Outcome required	
How this will reduce risks/capitalise on opportunities	
Methodology	Fill gaps in greenhouse budgets (property scale) for key land types (baseline) <ul style="list-style-type: none"> • regrowth • soil C • nitrous oxide • methane Management options analysis for changed practices <ul style="list-style-type: none"> • land retirement • regrowth • grazing system Economics/productivity Regional, ETS implications Detailed FBA region case studies
Partners	DPI&F, QUT, NRW, CSIRO, FBA
Funders	
Other issues	

Title	Understanding Climate Change and its impacts
Outcome required	Improved understanding of the impact of climate change on productivity, profitability and natural resource condition in CQ agricultural industries.
How this will reduce	Required to improve ability of landholders to manage climate change and climate risk

risks/capitalise on opportunities	ie through improved understanding of enterprise options, effectiveness of a range of adaptive strategies
Methodology	Determine most appropriate GCM for use in predicting future CQ climate scenarios (CSIRO, QCCCE) Downscale to localised, daily climate datasets (DPI&F, QCCCE) Use simulation models to determine impacts of new climate scenarios on production, economics & NR condition (DPI&F, QCCCE) Evaluate new/alternative management systems under future climate scenarios (DPI&F, FBA) Deliver new knowledge to landholders (DPI&F, FBA)
Partners	As above
Funders	As above + MLA, GRDC, LWA, Mining industry
Other issues	Need for integration/coordination between organisations

Title	<i>Landscape redesign</i>
Outcome required	Most efficient use of land resources in terms of productivity, profitability and NRM values A Catchment perspective – not constrained by land tenure or existing land use.
How this will reduce risks/capitalise on opportunities	Will give awareness of capability of land and begin to facilitate change
Methodology	Spatial analysis with a range of existing datasets & knowledge
Partners	NRW, EPA, DPI&F, Uni's, FBA
Funders	RIRDC, CfoC
Other issues	

Title	<i>New Opportunities</i>
Outcome required	Understanding what species flourish in our likely future climate (Understanding) what industries have evolved in this (new) climate
How this will reduce risks/capitalise on opportunities	Identifies new opportunities for us Proactive change to minimise risks associated with CC in existing sectors
Methodology	Homoclimate analysis to identify agro-ecological zones most like our predicted future climate Identify adapted plant and animal genetics and thriving industry sectors
Partners	Uni's, Overseas govt departments
Funders	RIRDC, GRDC, AGO
Other issues	

Title	<i>Awareness of climate change impacts</i>
Outcome required	<ul style="list-style-type: none"> increased awareness of climate change within landholder and community groups community consultation with regional planning empowering communities to understand the opportunities and threats of climate change in order to plan and adapt
How this will reduce risks/capitalise on opportunities	<ul style="list-style-type: none"> motivate community to plan and take action changing attitudes assisting people to make practice change first step in the change process
Methodology	<ul style="list-style-type: none"> media case studies community forum incentive scheme FBA reps for planning process

	<ul style="list-style-type: none"> • Field day/training (hands on) • Workshops • Written materials • One on one • Landholder groups • consultation
Partners	Local govt, FBA (network), DPI&F, industry, landholders, state government, local community organisations
Funders	FBA (federal funding), possible to fit into sub-catchment contracts
Other issues	<ul style="list-style-type: none"> • acceptance by community that CC is not a static issue • recommendations may change with emerging knowledge

Workshop Evaluation

A summary of an end-of-workshop evaluation process is given below.

Respondent	Positive	Change
1	very interactive, opportunity to discuss and debate	streamline the grouping process clearer objectives
2	Brainstorming and action sheets session – quickly generated lots of good ideas	<ul style="list-style-type: none"> • democratic process for lumping/splitting didn't work all that well – more guidance needed • Think the process could work well with a group of landholders and enrich what came out of today
3	<ul style="list-style-type: none"> • good process • in-depth analysis of issues raised 	<ul style="list-style-type: none"> • got bogged down trying to force issues into CQSS2 priority areas • Gantt chart might have been more sensible
4	Good positive facilitation	nothing
5	Good mix of people & knowledge to which I'm not usually exposed	Warmer room! Seriously, thought it went OK
6	<ul style="list-style-type: none"> • Excellent cross section of skills, experience & perspectives. • Good input from all involved 	
7	Active participation of all	No indicator at start of the day as to what were the expectations of us by the end of the day

Appendix D. Provider survey questionnaire and summary of responses

Questionnaire

FBA Climate Change Provider Survey

Notes re completion of this survey:

1. Only brief responses are required
2. Use the Tab key to navigate through the form
3. Please complete the survey with reference to the organisational sub-unit identified in Q2.
4. Please return completed survey to richard.routley@dpi.qld.gov.au

1. Organisation	
2. Organisational sub-unit (eg University Faculty, Departmental business unit etc)	
3. Contact person for future discussions regarding climate change projects and activities.	
a. Name	
b. Position	
c. Postal address	
d. email address	
e. Phone numbers	
4. Briefly list <u>completed</u> climate change related projects or activities conducted by your organisation with applicability to the Fitzroy Basin. Include references, web links etc to any publications and project reports if applicable.	
5. Briefly list climate change related projects or activities currently <u>in-progress</u> by your organisation with applicability to the Fitzroy Basin. Include references, web links etc to any publications and project reports.	
6. Briefly list <u>future or proposed</u> climate change related projects or activities to be conducted by your organisation with applicability to the Fitzroy Basin.	
7. Briefly describe the capabilities (skills, expertise etc) available within your organisation that could contribute to future climate change related projects in the Fitzroy Basin.	
8. Briefly describe the interest and capacity of your organisation to engage in future climate change related projects in the Fitzroy Basin.	
9. Please include any other relevant information or comments below.	

Check this box to indicate your permission for this information to be included (in full or in summary) in a publically available report:

Check this box if you would like to receive an email copy of the report:

Thank you for your time!

Survey Recipients

Organisation	Response Received
AgForce	No
Central Qld University	No
CSIRO	Yes
Department of Natural Resources and Water (now DERM) – CQ Region	Yes
Department of Primary Industries & Fisheries (now Qld Primary Industries & Fisheries, DEEDI)	Yes
Qld Climate Change Centre of Excellence (now part of DERM)	No
Qld Murray Darling Committee	Yes
Qld University of Technology	No
University of Southern Qld	Yes

Compilation of responses

1. Organisation: **CSIRO**

2. Sub-unit: Climate Adaptation National Research Flagship

3. Contact person

Louise Matthiesson
 Science Communication Officer
 306 Carmody Rd, St Lucia Qld 4067
 louise.matthiesson@csiro.au
 07 3214 2642

4. Completed climate change related projects.

CSIRO recently published a major national report on climate change adaptation options for Australian agriculture. It includes chapters on all the major agricultural industries operating in the Fitzroy Basin. The report is available for download from www.csiro.au/resources/AgricultureAdaptationReport2008 .

5. Climate change related projects or activities currently in-progress

The CSIRO Climate Adaptation Flagship has been established to provide scientific knowledge and tools to enable Australia to adapt more effectively to the impacts of climate change and variability. The \$25 million research program includes four major research themes: Pathways to Adaptation; Sustainable Cities and Coasts; Managing Species and Natural Ecosystems; and Adaptive Primary Industries. More information is available at www.csiro.au/org/ClimateAdaptationFlagship.

6. Future or proposed climate change related projects.

Many of the Climate Adaptation Flagship's ongoing research projects have applicability to the Fitzroy Basin.

7. Skills & expertise.

The CSIRO Climate Adaptation Flagship can bring together tailor-made research teams from across CSIRO with the necessary skills and expertise to assist organisation to prepare for the impacts of climate change. This includes scientists with expertise in climate projections, impact assessments, coastal vulnerability and urban planning, natural resource management, ecology social science and agricultural science.

8. Interest and capacity to engage in future climate change related projects in the Fitzroy Basin.

The CSIRO Climate Adaptation Flagship works in partnership with businesses, government and community organisations to co-fund participatory research projects. The Flagship Director and Research Theme Leaders would be happy to discuss research needs and opportunities in the Fitzroy Basin.

The CSIRO Climate Adaptation Flagship works in partnership with businesses, government and community organisations to co-fund participatory research projects. The Flagship Director and Research Theme Leaders would be happy to discuss research needs and opportunities in the Fitzroy Basin.

9. Please include any other relevant information or comments below.

More information is available at www.csiro.au/org/ClimateAdaptationFlagship

1. *Organisation:* **Department of Environment and Resource Management**

2. *Organisational sub-unit:* Central region NRW Science

3. *Contact person:*

Cameron Dougall
NRM Officer
PO Box 19, Emerald QLD 4720
Cameron.Dougall@nrw.qld.gov.au
07 4987 9304

4. *Completed climate change related projects.*

1. Hydrology and water quality modelling ongoing projects
2. NRW Bare ground indexx – archive

5. *Current climate change related projects.* As above

6. *Future or proposed climate change related projects :*

7. *Skills & expertise:*

Water balance, spatial mapping and modelling

8. *Briefly describe the interest and capacity of your organisation to engage in future climate change related projects in the Fitzroy Basin.*

Water quantity and quality plus land condition (Leasehold land strategy) are embedded in the business plan

9. *Please include any other relevant information or comments below.*

1. **Organisation: Qld Primary Industries & Fisheries**, Dept of Employment, Economic Development and Innovation

2. *Sub-units*: Plant Science, Animal Science, Emerging Technologies, Regional Services

3. *Contact person*.

Plant Science: Dr Andrew Ward, Science Leader, 07 4639 8834, Andrew.Ward@deedi.qld.gov.au

Animal Science: Dr Peter Johnston, Science leader, 07 3362 9585, peter.w.johnston@deedi.qld.gov.au

Emerg Tech: Dr Daniel Rodriguez, Focus team leader, 07 4688 1437, daniel.rodriguez@deedi.qld.gov.au

Regional Services: Neil Cliffe, Manager Regional Development, 07 4967 0957, neil.cliffe@deedi.qld.gov.au

4. *Completed climate change related projects*: Many completed RD&E projects have been directed at improving the capacity of the agriculture sector to deal with climate variability and change eg grains industry Farming Systems projects, Grazing Land Management research and training.

5. *Current climate change related projects*: The department has a major role in the following projects funded under the DAFF 'Australias Farming Future' programme:

Research projects

- A national research program for climate-ready cereals
- Cropping management adaptation
- Relocation of intensive crop production systems to northern Australia: Costs and opportunities
- Developing improved on-ground practices and industry strategies for adapting to climate change within beef production enterprises across northern Australia
- Soil management - Northern rangelands beef systems
- Soil management - Queensland cereals and sugar
- Reducing methane emissions by supplementing feed with dietary lipids
- Archaeophage therapy to control rumen methanogens
- Reducing nitrous oxide emissions in Irrigated cotton and grain cropping systems

Farmready Programme

- Virtual SmartCane bus tour
- Turf production climate change adoption best practice workshops
- Developing and implementing grains best management practices for managing climate change and climate variability
- Facing Up - Building the capacity of the next generation of northern dairy farmers to meet the climate change challenge
- Climate resilient horticulture for the Gympie district
- Preparing dairy farmers for climate change through uptake of best management practice

6. *Future or proposed climate change related projects*.

Future projects will be developed in consultation with industry and other stakeholders.

7. *Skills & expertise*: QPI&F has world class RD&E expertise in many relevant discipline areas including:

- Climatology
- Crop, livestock and horticulture production systems
- Plant and animal breeding and genetics

- Soil management, including carbon and nitrogen fertiliser management
- Rangelands management
- Rumen microbiology
- Simulation modelling of production and natural resource management in agricultural systems
- Economics
- Extension and training, including an extensive presence in regional areas throughout Qld

8. Interest and capacity to engage in future climate change related projects in the Fitzroy Basin.

QPI&F has an ongoing interest in engaging with industry and other stakeholders to jointly implement strategies to help Qld Primary Industries deal with climate variability and change.

9. Please include any other relevant information or comments below.

1. *Organisation: QMDC / SWIFT NRM*
2. *Organisational sub-unit*

3. *Contact person.*

Rhonda Toms-Morgan
rhondat@qmdc.org.au
07 4622 4600

4. *Completed climate change related projects:*
Demonstration of whole farm emission calculator "Green Gauge"

5. *Current climate change related projects. NA*

6. *Future or proposed climate change related projects*

7. *Skills & expertise.*

1 day workshop introducing science of climate change, carbon trading and energy. Target audience is landholders jointly run with Dr Jeff Clewett, Agroclim Australia.

8. *Interest and capacity to engage in future climate change related projects in the Fitzroy Basin.*

Delivery of Climate Change, Carbon Trading and Energy workshops. Also possibility of working with whole of farm emissions calculations

9. *Please include any other relevant information or comments below.*

1. *Organisation: University of Southern Queensland*

2. *Organisational sub-unit: Australian Centre for Sustainable Catchments (ACSC)*

3. *Contact person*

Professor Roger Stone
Director, Australian Centre for Sustainable Catchments
West Street, Toowoomba, QLD, 4350
stone@usq.edu.au
07 4631 2736

4. *Completed climate change related projects.*

1. Queensland Farmers Federation - Improving the Capacity of Queensland Intensive Agricultural to Manage Climate Change
2. Feasibility Study to Use Satellite Imagery in Determining Area Planted in Support of Regional Crop Forecasting – A Case Study for Winter Crops in the Darling Downs
3. Quantifying Hail Damage for Crop Loss Assessment: Techniques using Remote Sensing and GIS
4. Integrating paddock and catchment planning: a woolgrower driven approach to sustainable management
5. An evaluation of natural resources management arrangements in Queensland
6. Decision support systems for farm forestry

5. *Current climate change related projects.*

ACSC is currently managing the following climate related projects which are relevant to the Fitzroy Basin:

1. Scoping the North Australia Seasonal Climate Knowledge (NACK): R&D Initiative of the Managing Climate Variability Program, Land and Water Australia
2. Scoping the Eastern Australia Seasonal Climate Knowledge (EACK): R & D Initiative of the Managing Climate Variability Program, Land and Water Australia.
3. An In-Depth Appraisal of Potential Climate Change Impact on Rainfall Patterns and River Flows in Selected Catchments
4. 'Extremes, climate modes and reanalysis-based approaches to agricultural resilience' through the Managing Climate Variability II Innovations Round, Land and Water Australia
5. Queensland Cloud Seeding Research Program through the Environmental Protection Authority, Queensland
6. Estimating Catchment-scale Carbon Flows from Primary Industries: A Case of Condamine Catchment

6. Future or proposed climate change related projects.

ACSC has developed a number of new projects with those most relevant to the Fitzroy Basin indicated below (the details of these projects are readily available upon request):

1. Development of Hydroclimatic-Ecological Modelling Capacity to Assess Predictive Capacity of Spatial Ecological Zone under a Range of Climate Scenario
2. Climate Suitable Mapping Tools for Agricultural South East Queensland: A Multi-Layered GIS Approach
3. Using the ENSO Signal to Downscale CGM Outputs
4. Tailoring Australian Farming Systems to Energy and Climate Challenges
5. Designing effective strategies for the protection of riparian and aquatic biodiversity of ephemeral watercourses in agricultural landscapes in the face of climate variability
6. Assessing the Economic Profitability for Pyrolysis of Crop Waste and other Organic Matter into Agrichar, Bio-Oil and Syngas
7. Assessing the Benefits of Soil Organic Carbon to the Net Profitability and Water Use Efficiency
8. Optimal Climate Responsive Policy Options for Moving Towards Carbon Neutral Catchments: An Integrated Approach

7. Skills & expertise.

The Australian Centre for Sustainable Catchments (ACSC) has a strong focus on underpinning the profitability and sustainability of water and catchment management in Australia. The Centre has established a research program based on world-leading practices in regional water and catchment management and climate modelling.

ACSC has 10 'core' staff with national and international reputation and, additionally, draws expertise from over 40 researchers working under different disciplines at the University of Southern Queensland.

ACSC has four major research themes led by prominent university professors, which are relevant to the Fitzroy Basin. They program areas are:

1. Climate Science, Environmental Measurement and Modelling: Developing integrated climate/water resource models to provide stronger predictive capacity for regional land and water planning and management.
2. Sustainable Landscapes: Investigating broader issues concerning the sustainable management of natural resources and connections with communities within our catchments.
3. Sustainable Water Use: Focusing on issues concerning water quality/quantity in rivers and reservoirs; on urban stormwater runoff; on wastewater treatment and reuse; and on groundwater hydrodynamics.

4. Spatial Analysis and Modelling: Exploring new spatial modelling tools to support the development of sustainable land and water management.

8. Interest and capacity of your organisation to engage in future climate change related projects in the Fitzroy Basin.

ACSC is led by world renown climate scientist, Professor Roger Stone. The ACSC staff has national and international experience in climate, hydrological, crop and economic modelling. Particularly, ACSC excels in climate modelling. Some relevant skills and capacity include:

- Use of cutting edge climate models to evaluate climate variability and change impacts on water use, agriculture and ecosystem;
- Modelling climate change and variability and its application to catchment, landscape systems and agricultural production systems;
- Linking seasonal and intra-seasonal climate forecast to agricultural systems and crop modelling and dam operations;
- Customising operational forecasts as web based and stand alone tools to manage climate risk and uncertainty; and
- Developing climate responsive insurance and investment policies.

Other relevant ACSC skills for FBA include:

- Managing climate change and variability by both involving adoption and mitigation to minimize GHG, creating carbon neutral catchments;
- Developing market-based instruments such as carbon trading and other incentive schemes;
- Modelling soil and biomass carbon;
- Production and opportunities with Agrichar;
- Ecosystem modelling, understanding the impact of hydrological regime on the ecosystem;
- Characterisation and modelling of surface water and groundwater interactions;
- Linking hydrological models with climate models to forecast rivers and dam inflows;
- Assessment of sustainable yield of aquifers & artificial recharge potentials;
- Farm and system level hydrologic--economic evaluation;
- Water trading and its impact on managing climate change and variability.

9. Please include any other relevant information or comments below.

ACSC International Linkages:

- WMO Commissions for Climatology and Agricultural Meteorology, Geneva, Switzerland
- UK Government Hadley Centre for Climate Research
- International Rice Research Institute (IRRI), Los Banos, Philippines
- International Research Institute (IRI) for Climate and Society, New York
- International Water Management Institute (IWMI)
- Scor Global Insurance, Winterthur
- Partner Reinsurance, Zurich
- University of Applied Sciences, Deggendorf, Germany
- Wageningen University, Netherlands

Appendix E. Summary of Research Projects funded under the DAFF ‘Australia’s Farming Future’ Climate Change Research Program

(Projects with a high degree of relevance to the Fitzroy basin are shaded)

Theme	Project Name	Organisation	Description
Adaptation	A national research program for climate-ready cereals	CSIRO	This national project on wheat and sorghum will evaluate existing genetic traits for climate change adaptation in different species of crops. It will identify genetic materials with improved response to higher temperature (sorghum) and to elevated temperature and carbon dioxide (wheat).
	Adaptation of a range of wheat types to elevated atmospheric CO2 concentration	University of Melbourne, Victorian Department of Primary Industries and Grains Research and Development Corporation	This project will complement and expand on the work undertaken in the national research program for climate-ready cereals by testing identified plant varieties in the field, using state of the art technology. It will include evaluating a range of wheat traits under elevated carbon dioxide to assess their value to cropping systems' production and sustainability. The traits for evaluation include transpiration efficiency, height and high tillering (more stems per plant), growth, yield and resource use efficiency.
	Cropping management adaptation	CSIRO (+ state agencies including QPI&F)	This project will assist the adaptation of Australia's cropping systems to climate change by evaluating the risk to production and the available adaptive capacity of the industry. This will be undertaken across a number of locations nationally through regional engagement in model development and information provision.
	Relocation of intensive crop production systems to northern Australia: Costs and opportunities	Qld Primary Industries and Fisheries, Department of Employment, Economic Development & Innovation	This project will examine opportunities for businesses in relocating to northern Australia, using the examples of tomato and rice-cotton production systems. It will explore mechanisms that will enhance the resilience and adaptive capacity of these industries to the effects of climate change. It will help identify key drivers for change, as well as emerging opportunities for adaptation and options to improve practices and farm business strategies.
	Agriculture transforming to adapt to climate change: The peanut industry expansion in the NT as a blueprint	CSIRO Sustainable Ecosystems	This project will study the transition of peanut production systems to the Northern Territory. It will assess the environmental implications, review strategies to manage pests and diseases, and analyse the social aspects of this industry transformation. The lessons learned will be collated to provide a blueprint for farmers considering adapting to

			climate change by relocating to other regions.
	Development of effective management strategies to adapt production to mitigate climate change challenges in the wine industry	Grape and Wine Research and Development Corporation	This project will develop, evaluate and distribute new and innovative methods to manage and maintain quality of grape production under conditions of increased heat and water stress. The project will be supported by GRWDC investments to develop winemaking practices that address climate change related challenges, such as high alcohol content in wines and the occurrence of undesirable flavours in immature or overripe fruit.
	Developing improved on-ground practices and industry strategies for adapting to climate change within beef production enterprises across northern Australia	Meat and Livestock Australia (through QPI&F and CSIRO)	This project will identify and evaluate better beef grazing practices and industry strategies for adapting to climate change within beef enterprises across northern Australia (Qld, NT, and the Pilbara and Kimberly regions of WA). Analysis of different management techniques and their impact on the balance between production, sustainability and profitability goals will enable producers, their industry and communities to understand the likely effects of climate change and respond accordingly. The implementation of the most promising mix of management practices in each region will be evaluated through on-property research sites.
	Climate change adaptation in the southern Australian livestock industries	Meat and Livestock Australia, CSIRO and the University of Melbourne	This project will examine the impacts of climate change on the livestock industry in southern Australia. It will examine strategies for adaptation on both the farm and industry scale. It will also address key industry questions around adapting to the impacts of climate change on current production systems and incorporating mitigation options.
	Reducing the impact of heat stress on animal performance and welfare in southern Australia dairy, beef and sheep industries	University of Melbourne	This project will develop information resources to help producers make effective and informed decisions about the management of livestock heat stress. Research will focus on the dairy industry, but the project will produce guidelines for heat stress management, including nutritional interventions and associated welfare issues, which are applicable to other intensive livestock systems.
	Adaptation of fishing and aquaculture sectors and fisheries management to climate change in south eastern Australia—a national case study	Victorian Department of Primary Industries	This project will examine the biophysical, social and economic implications of climate change for fisheries in Australia's south eastern region and facilitate the preparation and adaptation of the sectors to these future changes. The project will provide frameworks, tools and knowledge that can be applied across Australia at a national level and also at a regional level.
Soil Management for	Soil carbon research program overarching project	CSIRO	This project will undertake the technical oversight and management of the Soil Carbon Research Program. It will develop standardised data

C sequestration			collection protocols and undertake carbon content analysis.
	South eastern SA cereals, sheep and beef systems and Australia wide perennial sheep pastures	CSIRO	This project will identify sites and undertake sampling within south eastern SA's cereal, sheep and beef systems. Perennial pasture sites will also be identified and sampling will be undertaken throughout the country — particularly in WA and NSW.
	South west Western Australia: Cereal, sheep and beef systems	University of Western Australia & WA Department of Agriculture & Food	This project will engage with a number of grower groups and collect samples from a number of their sites. It will also undertake sampling at sites where management practices have been in place for a minimum of five years.
	Victorian dairy, sheep, cereal and beef systems	Victorian Department of Primary Industries and the Co-operative Research Centre for Future Farming	This project will undertake re-sampling at a number of ongoing crop and pasture sites around Hamilton, Rutherglen and Ararat. It will build upon work which has previously occurred under the EverGraze program as well as DPI long-term experimental sites at Horsham, Rutherglen and Walpeup. Engagement with ongoing farmer trials will be undertaken with Southern Farming Systems, the Birchip Cropping Group and the South West Climate Change Forum.
	Northern rangelands beef systems	Queensland Departments of Natural Resources & Water and of Primary Industries	This project will undertake sampling at Kidman Springs (NT) to assess the effects of cell grazing. The sites have documented fire and management histories. It will also resample a Toorak grazing trial in north-western Queensland. This sampling will include a range of soil types and rainfalls.
	Queensland cereals and sugar	Queensland Departments of Natural Resources & Water and of Primary Industries	This project will undertake sampling of grain cropping systems at the long-term Hermitage Fallow Management Trial near Warwick in Queensland and sugar cropping systems at Tully and Mackay. No-till grain trials will be sampled near Biloela and Goodger and archived soil will be analysed from a number of historic trials (Biloela, Warra, Nindigully, Mt Murchison and Goodger). Additional sugarcane sites in the Northern Rivers, Mackay and Ingham regions will be sampled – including tilled and permanent beds and across a number of soil types and rainfall levels.
	New South Wales cereals, cotton, sheep and beef systems	University of New England, NSW Departments of Primary Industries and of Environment and Climate Change	This project will undertake sampling at 20 long-term trials with 25 corresponding satellite sites on private land to define amounts and variance of carbon contained in pools of soils from the major land-use/soil type combinations in NSW.
	New South Wales cereals and beef	Murray Catchment	This project will undertake sampling and analysis of paired sites which

		Management Authority	have been under no-till/conventional till and set stocking/controlled grazing practices.
	Tasmanian vegetables and dairy systems	Tasmanian Institute for Agricultural Research, University of Tasmania and Botanical Resources Australia P/L	This project will undertake sampling at a number of broadacre cropping and vegetable sites across the state – including low input pasture/irrigated cropping and short-term perennial/long term pasture. Sampling will also be undertaken on existing sites which have undertaken a change from pasture to cropping and on paired sites which compare irrigated and non-irrigated dairy and beef systems.
Emissions Reduction - Methane emissions	National Strategies and Coordination	Meat & Livestock Australia	This project will ensure that the Reducing Emissions from Livestock Research Program: meets the priorities of the Climate Change Research Program; provides quantifiable short and long term methane emission reductions from livestock; informs stakeholders of the potential contribution of agriculture to national emissions reduction goals.
	Development of a methane measurement system for Australian livestock	CSIRO Livestock Industries	Efforts to develop effective strategies to significantly reduce greenhouse gas emissions have been hampered by the lack of methods to accurately and reliably measure methane production from large numbers of grazing ruminants. This project will explore the use of electronic gas sensor technologies to accurately identify, develop and/or adapt a method for measuring emissions from ruminants. If this project is successful researchers will be better equipped to measure direct and indirect methane emissions from grazing ruminant livestock in a fast and reliable manner for developing and validating methane mitigation strategies in Australian grazing systems.
	Genetic Improvement of Beef Cattle for Greenhouse Gas Outcomes	New South Wales Department of Primary Industries	This project will study the genetic variation between Angus research herds that differ in methane production to evaluate and demonstrate the potential for breeding cattle for reduced methane emissions without compromising animal performance.
	Breeding low methane emitting sheep and elucidating the underlying biology	University of Western Australia	This project will measure methane emissions and net feed efficiency from sheep breeding flocks to investigate the relationship between the genetic parameters for methane production and productivity traits with the objective of generating selection lines of high and low methane emitting sheep.
	Metagenomic analysis of feed utilization and hydrogen balance in Australian livestock for lower methane emissions	CSIRO Livestock Industries	This project aims to understand the structure and function of organisms in the rumen of north Australian cattle. This will form the basis of developing practical ways to redirect feed digestion and rumen fermentation to reduce enteric methane emissions.

Archaeophage therapy to control rumen methanogens	University of Queensland and Queensland Department of Primary Industries & Fisheries	This project aims to establish a collection of viruses that can infect methanogens - microorganisms in the rumen which produce methane. This will establish “proof of concept” evidence that these viruses can reduce methane emissions from ruminal fermentation.
Rumen Microbial Profiling – A tool to investigate methane mitigation strategies	South Australian Research and Development Institute	The purpose of this project is to develop and provide molecular techniques based on DNA profiling of rumen bacterial populations to rapidly evaluate feeding, breeding and management strategies to reduce methane production in ruminant systems.
Novel strategies for enteric methane abatement	New South Wales Department of Primary Industries	This project will investigate (1) chemical techniques to eliminate microscopic organisms called protozoa from the rumen, a technique known to reduce methane production; and (2) the use and efficacy of dietary nitrate supplements to reduce methane production. The impacts on enteric methane emissions and animal productivity over time will be evaluated.
Use of peptide-phage display libraries to discover peptides that are bioactive against rumen methanogens	CSIRO Livestock Industries	This project will screen synthetic peptides (amino acid chains) to identify those that act in methane producing organisms (methanogens) to reduce the production of methane.
Understanding the mechanisms behind the anti-methanogenic bioactivity of Australian plants targeted for grazing systems	University of Western Australia	This project will assess the potential for Australian forage plants to contribute to feedbase management strategies to reduce methane from grazing livestock. It will identify the bioactive compounds within plants which, when introduced into the feeding regime, may result in lower levels of methane production. It will also analyse how the reduction occurs within rumen. This knowledge would then be used to reduce livestock methane emissions through feed base modification.
Methanotrophs in natural ecosystems and their role in ruminant methane mitigation	University of Queensland	This project will investigate the occurrence of methanotrophs – microorganisms in the stomach that can convert methane back to carbon dioxide and water – and evaluate the possible use of these microbes in reducing methane emitted by ruminants.
Reducing methane emissions by supplementing feed with dietary lipids	Queensland Department Primary Industries & Fisheries and University of Queensland	This project will investigate lipid-based feed additives (oils) that provide a mechanism to reduce methane emissions and increase productivity that can be made available to producers in the short term. It will concentrate on cattle breeds used in northern Australia.
Microbial ecology of hydrogenotrophic rumen microorganisms in response to	CSIRO Livestock Industries	This project will analyse bacteria in the digestive tract of ruminants to determine the feasibility and practicality of modifying methane emissions from livestock.

	methane inhibition		
	Manure management to reduce greenhouse gas emissions from cattle feedlots	University of Melbourne	The project will evaluate the effectiveness of manure management innovations in a beef cattle feedlot - specifically those reducing methane, ammonia and nitrous oxide emissions. Indirect nitrous oxide emissions downwind will also be quantified. The potential for achieving reductions in emissions from manure management will be quantified.
	Mitigation of methane emissions from the northern Australian beef herd	CSIRO Livestock Industries	This project will investigate management factors affecting methane emissions from cattle grazing northern forages and detail their potential to reduce emissions. A technique for methane emission benchmarking under northern Australian grazing conditions will also be developed.
	Enteric methane abatement strategies for ruminant production systems in SE Australia	Victoria Department of Primary Industries	This project will: evaluate a range of forages and dietary supplements for ruminant methane mitigation potential; quantify the net abatement achievable in a whole of farm context; and improve enteric methane measurement to quantify and verify emission abatement.
	Demonstration projects for on-farm practical methane management strategies	Meat & Livestock Australia	Livestock production systems in Australia are highly varied with effective abatement measures likely to vary between production systems. Demonstration sites will engage with livestock producers to ensure that research is directed to practical on-farm measures.
	Information integration and delivery	Meat & Livestock Australia	An Information management system for data and capacity will be provided to enable integration and sharing of information between projects, publish research results and effectively relay progress and outcomes farmers, government and industry.
Emissions Reduction – Nitrous Oxide	Nitrous oxide research program coordination	Grains Research and Development Corporation	This project will take a leadership role in the administration and coordination of the Nitrous Oxide Research Program. This will include the management of program governance and reporting.
	Integrated data and synthesis framework for reducing nitrous oxide emissions from Australian agricultural soils	Queensland University of Technology	This project will undertake the management and technical oversight of the Nitrous Oxide Research Program. It will develop standardised data collection protocols, develop a web-based remote data capture program and manage project datasets for national databases.
	Reducing nitrous oxide emissions from sugarcane lands	Sugar Research and Development Corporation and Grains Research and Development Corporation	This project will measure nitrous oxide emissions from sugarcane and grain legume– sugarcane rotations near Mackay, with and without the use of inhibitors. The standardised data will then be incorporated into the broad program dataset.
	Decreasing nitrous oxide emissions in high rainfall legume/wheat cropping systems	Victorian Department of Primary Industries and Grains Research and	This project will measure nitrous oxide emissions from direct drilled and conventionally sown legume/wheat rotations – with and without the use of inhibitors – at a site near Hamilton. The standardised data will then be

		Development Corporation	incorporated into the broad program dataset.
	Fertiliser management strategies for decreasing on-farm greenhouse gas emissions	University of Western Australia, Department of Agriculture and Food WA, and Grains Research and Development Corporation	This project will measure nitrous oxide emissions from direct drilled wheat at Wongan Hills, south west Western Australia that has been grown under a range of treatments. The standardised data will then be incorporated into the broad program dataset.
	The potential of inhibitors for the mitigation of nitrous oxide emissions from animal production systems, in south-eastern Australia	Victorian Department of Primary Industries and Dairy Australia	This project will measure nitrous oxide emissions following the application of urine and inhibitors at the DemoDairy site near Terang, Victoria, as well as numerous additional satellite sites. The standardised data will then be incorporated into the broad program dataset.
	Enhanced efficiency fertilisers as mitigation tools for reducing greenhouse gas emissions from intensive agricultural systems in Australia	University of Melbourne and Incitec Pivot fertilisers Pty and Grains Research and Development Corporation	This project will entail a laboratory based assessment of nitrous oxide emissions from a range of soils which have been treated with nitrification inhibitors. The standardised data will then be incorporated into the broad program dataset.
	Irrigated cotton and grain cropping systems	Queensland University of Technology and Cotton Catchment Communities CRC and Grains Research and Development Corporation.	This project will measure nitrous oxide emissions from irrigated cotton and grain cropping systems between the Darling Downs in Queensland and the Macquarie Valley in New South Wales. The standardised data will then be incorporated into the broad program dataset.
	Winter rain-fed cereals	New South Wales Department of Primary Industries, University of Melbourne, University of New England and Grains Research and Development Corporation	This project will measure nitrous oxide emissions from winter rain-fed cereals under various treatments, including: different row placements of crops; and inclusion of legumes in the rotation. The standardised data will then be incorporated into the broad program dataset.
Emissions Reduction – Biochar	The Minister for Agriculture, Fisheries and Forestry has announced a \$1.4 million research project into biochar, which will target gaps in our understanding of this emerging technology and address uncertainties about its use.	CSIRO led.	<p>The project will draw together top Australian and international experts in areas of biochar, soil science and emissions management and compliment research already being done by partner organisations.</p> <p>Key activities under the project will include:</p> <ul style="list-style-type: none"> a life cycle assessment of biochar from feedstock source to production to sink, including costs, risks, benefits and implications for farmers

			<ul style="list-style-type: none">• categorisation of biochars according to their properties and suggested usage• economic assessment of biochar for both net greenhouse gas emissions and potential profitability to land owners <p>analysis of risk factors in terms of rates of applications as well as the potential production of toxic by-products during pyrolysis.</p>
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Appendix F. Queensland projects funded under the DAFF Farm Ready programme

(Projects with a high degree of relevance to the Fitzroy basin are shaded)

Project Title	Organisation	Total Budget	Description
Virtual SmartCane bus tour	CANEGROWERS	Up to \$71,400	This project will transfer best management practice information into an audiovisual format for distribution to sugarcane growers.
Turf production climate change adoption best practice workshops	Queensland Turf Producers Association	Up to \$40,710	This project aims to promote awareness and enhance producer knowledge of climate change and on-farm adaptation. Workshops will explore the risks and opportunities of climate change and educate producers about adaption techniques and coping strategies.
Developing and implementing grains best management practices for managing climate change and climate variability	AgForce Queensland	Up to \$211,300	The project builds on current grains best management practices and aims to improve the management of climate risk and carbon efficiency in the northern grains industry.
Indigenous training to adapt to climate change in the Fitzroy Basin	Fitzroy Basin Elders Committee Inc	Up to \$138,500	This project supports indigenous people to adapt cultural and natural resource management approaches to minimise the effects of climate change.
Facing Up - Building the capacity of the next generation of northern dairy farmers to meet the climate change challenge	Subtropical Dairy Programme Ltd	Up to \$239,300	The project builds on the capacity of young land managers in areas of preparedness, adaptation and mitigation to climate change to enable them to identify flexible farming systems that will address the increased risks due to a changing climate.
Rural families responding to the challenge of climate change	Toowoomba Focus Group	Up to \$202,600	The project aims to empower the Toowoomba Focus Group to develop strategies to manage the impact of climate change and climate variability on rural families.
CQ Best Practice - Managing climate change from the ground up	CQ Best Practice Group	Up to \$158,000	The project aims to increase awareness of options and increase the uptake of best practice strategies for dealing with climate change.
Climate resilient horticulture for the Gympie district	Mary River Catchment Co-ordinating Committee	Up to \$108,850	This project will prepare growers of macadamias and beans for a changing climate through improved groundcover management to reduce the impact of soil erosion due to increased severity of storms and rainfall.
Preparing dairy farmers for climate change through uptake of best management practice	Queensland Dairyfarmers Organisation	Up to \$238,350	This project is an education package for dairy farmers in Queensland. It will deliver 39 workshops in Queensland over three years to potentially 620 dairy businesses.

Grazier to Grazier: managing carbon flows for resilient pastures in a variable climate	Murilla Landcare Group Inc.	Up to \$75,000	This project is about getting graziers to share information and knowledge about ways to build resilient pastures in a changing and increasingly variable climate.
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