Australian Government
Department of Agriculture, Fisheries and Forestry

Research Project Summaries

Climate Change Research Program

Adaptation Research Program

Internet

Research Project Summaries is available at: daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research

Contact

Department of Agriculture, Fisheries and Forestry

Postal address	GPO Box 1563 Canberra ACT 2601
Switchboard	+61 2 6272 3933
Facsimile	+61 2 6272 5161
Email	info@daff.gov.au
Web	daff.gov.au

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Overview

The *Climate Change Research Program* (CCRP), which ended on 30 June 2012, funded research projects and on-farm demonstrations to help prepare Australia's primary industries for climate change. Research focused on reducing greenhouse gas emissions, improving soil management and climate change adaptation, and involved projects that will lead to practical management solutions for farmers and industries.

Over four years the Australian Government invested $46.2 million in over 50 large scale collaborative research, development and demonstration projects. Total investment under the program was over $130 million and included contributions from research providers, industry groups, universities and state governments. A breakdown of the allocated government funding is below:

- Reducing Emissions from Livestock Research Program—$11.3 million
- Nitrous Oxide Research Program—$4.7 million
- Soil Carbon Research Program—$9.6 million
- National Biochar Initiative—$1.4 million
- Adaptation Research Program—$11.5 million
- Demonstration on-farm or by food processors—$7.7 million.

Research through the CCRP has increased our understanding of the sources of agricultural emissions and the potential for emission reduction and carbon sequestration. This information has underpinned the development of the first approved methodology under the *Carbon Farming Initiative* and has contributed valuable data for a number of methodologies currently under consideration. This will enable farmers to generate additional on-farm income through selling carbon offsets into domestic and international carbon markets.

Filling the Research Gap, part of the $429 million *Carbon Farming Futures Program* under the $1.7 billion Land Sector Package, is building on research undertaken through the CCRP. Research projects are targeting current gaps around abatement technologies and practices identified through the CCRP, and will continue to support the development of offset methodologies that land managers can use to participate in the *Carbon Farming Initiative*.

The following summaries highlight the key findings from adaptation research undertaken through the CCRP. This information should be used by potential applicants to guide applications in climate change research for agriculture under Round 2 of *Filling the Research Gap*.

Potential applicants are advised to contact the lead organisations for each project for further information and are encouraged to refer to the *Filling the Research Gap* Research Strategy (July 2012-June 2017).

Climate Change Research Program

Adaptation Research Program

A national research program for climate-ready cereals

Lead organisation
Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations
The University of Queensland
Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)

Objectives
- comparisons of current and potential future climates for wheat and sorghum crops in terms of changes in the frequency, timing and intensity of temperature and drought stresses affecting yield and recommendations for new traits, trait combinations and trait-agronomic adaptations to climate-change scenarios
- proposals for the effective geographic deployment of existing wheat and sorghum traits (primarily change in flowering time) based on knowledge of trait and gene variation in response to temperature and drought
- identification of useful traits in wheat and sorghum that contribute to potentially superior adaptation to high temperature (both crops) and high carbon dioxide (CO_2) (wheat)
- understanding of interactions between elevated CO_2 and temperature via establishment of field methods (heat/CO_2 modules) to study key physiological and morphological traits in wheat that contribute to high yield and quality.

Location
CSIRO (St. Lucia, Gatton and Perth), the University of Queensland, and AgriScience Queensland research stations.

Key activities
During the three years of the project, researchers from CSIRO (St. Lucia, Gatton and Perth), The University of Queensland, AgriScience Queensland and collaborators in the Department of Agriculture and Food, Western Australia and the University of Western Australia developed specialist facilities (tunnel houses) to evaluate wheat and sorghum genotypes under climate change conditions, undertook almost 40 experiments in controlled and field conditions, and simulated millions of scenarios to inform the research.

Findings/Conclusions
In both wheat and sorghum crops, worst-case climate scenarios potentially lead to poor outcomes in the more marginal, low rainfall environments at the inland edges of the grain belt. For wheat, a partial adaptation to drought and high temperature effects would be a shift to earlier sowing times (but with loss of potential yield) while for sorghum, future climate scenarios indicate that 'mid-season' plantings (late spring / early summer) would face an unavoidable increased risk of high temperatures. However, controlled environment experiments have indicated that there is substantial

genotypic variability for grain set in response to high temperature which provides an opportunity to breed for specific adaptation in both crops.

Four automated closed-system tunnel houses in Perth established an unmatched platform to study interactions of climate and soil factors in climate-change scenarios. The system has been reliable and relatively inexpensive to operate compared to other research approaches.

Generally, under elevated CO_2 conditions and where water is not substantially limiting, many of the 'adaptation traits' that are currently utilised in wheat, still generate the same rankings among wheat genotypes, i.e. breeders will still be able to deploy useful traits in elevated CO_2 environments. However, this needs to be confirmed in field environments.

Overall, the project has demonstrated that there is potential for plant breeding to contribute to adaptation to the future impacts of climate change, particularly via manipulation of the phenology and the heat and drought tolerance of wheat and sorghum. Even in the small range of germplasm tested so far there is reasonable genotypic variation that could be used now by breeding programs, but for both crops, there is a need to improve screening methods (to select new cultivars) and to identify new sources of adaptation for these traits (phenology and heat tolerance per se).

Interactions of elevated CO_2, temperature, drought and nitrogen with growth, including root development in wheat have been novel findings potentially of interest for future research.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Bourgault, M, Dreccer, F, James, A & Chapman, S 2012, 'Genotypic variability in the response to elevated CO_2 of wheat lines differing in adaptive traits', *Functional Plant Biology* (Submitted, provisionally accepted with review).
2. Chapman, S, Chakraborty, S, Dreccer, M & Howden, S 2012, 'Plant adaptation to climate change - opportunities and priorities in breeding', *Crop and Pasture Science,* vol. 63, pp. 251-268.
3. Dias de Oliveira, E, Bramley, H, Siddique, K, Henty, S, Berger, J & Palta, J 2012, 'Can elevated CO_2 combined with high temperature ameliorate the effect of terminal drought in wheat?', *Functional Plant Biology* (Submitted).
4. Farooq, M, Bramely, H, Palta, J & Siddique, K 2011, 'Heat stress in wheat during reproductive and grain filling phases', *Plant Sciences*, vol. 30, pp. 491-507.
5. Inman-Bamber, G, Jackson, P & Bourgault, M 2011, 'Genetic adjustment to changing climates: Sugarcane', In Yaddav, S, Redden, R, Hatfield, J & Lotze-Campen, H (eds.), *Crop adaptation to Climate Change*, Wiley, USA.
6. Palta, J, Chen, X, Milroy, S, Rebetzke, G, Dreccer, M & Watt, M 2011, 'Large root systems: Are they useful in adapting wheat to dry environments?', *Functional Plant Biology,* vol. 38, pp. 347-354.
7. Reynolds, M, Hays, D & Chapman, S 2010, 'Breeding for adaptation to heat and drought', in Reynolds. M (eds.), *Climate Change and Crop Production*, CABI, United Kingdom.

8. Zheng, B, Chenu, K, Dreccer, M & Chapman, S 2012, 'Breeding for the future: what are the potential impacts of future frost and heat events on sowing and flowering time requirements for Australian bread wheat (*Triticum aestivium*) varieties?', *Global Change Biology*, vol. 18, no. 9, pp. 2899-2914.

Further publications detailing the results of this research are in preparation and will be available.

Adaptation of a range of wheat types to elevated atmospheric carbon dioxide concentration

Lead organisation

The University of Melbourne

Consortium member organisations

Department of Primary Industries, Victoria

Objectives

To inform breeders and pre-breeding researchers of desirable traits that enable wheat crops to be better adapted to the challenge of climate change.

Location

Research was undertaken at the Australian Grains Free Air Carbon dioxide Enrichment (AGFACE) facility in Horsham, Victoria.

Key activities

To investigate cropping systems under future atmospheric conditions in an open air field setting, a range of wheat types were grown in the AGFACE facility under the existing or ambient carbon dioxide level (about 380 parts per million) and the elevated carbon dioxide level expected for 2050 (550 parts per million).

Wheat types were chosen to represent a range of traits that were either suggested in the scientific literature as desirable under increasing atmospheric carbon dioxide, or traits that are currently being targeted by breeders and likely to be affected by increased atmospheric carbon dioxide.

Pairs of varieties with contrasting adaptive traits such as tillering capacity, transpiration efficiency and stem carbohydrate capacity were grown under a variety of environmental conditions (manipulated by supplemental irrigation or different times of sowing). Two pairs of wheat lines provided by the Commonwealth Science and Industrial Research Organisation (CSIRO), contrasting in stem carbohydrate accumulation and tillering, were also grown to better isolate the effects of individual traits.

Each of the wheat cultivars were measured at three stages in the growth cycle (tillering, flowering and maturity) for leaf area index, biomass, yield and plant and grain nitrogen. Biochemical and plant physiological measurements were also conducted.

Findings/Conclusions

Comparison of near-isogenic lines showed that greater transpiration efficiency conferred greater yield advantage under elevated carbon dioxide than under ambient carbon dioxide.

Yield gain under elevated carbon dioxide was generally associated with increased vegetative biomass and tillering was stimulated by elevated carbon dioxide in all cultivars. However, side by side comparison of a freely tillering with a restricted tillering cultivar showed that high tillering was not absolutely necessary to capitalise on elevated carbon dioxide if restricted tillering cultivars compensated with greater plasticity in other yield components, such as, increased kernel weight.

These results on specific traits can be used as guidance for selecting traits to be incorporated into breeding programs for future elevated carbon dioxide levels.

Elevated carbon dioxide stimulated grain yield in virtually all investigated cultivars and across virtually all investigated environmental conditions, with an average stimulation of 27 per cent across all tested environmental conditions and varieties during 2009 and 2010 growing seasons. The results also showed that later sown wheat crops had significantly reduced growth and yield compared with wheat optimally sown early during the 2009 growing season.

This stimulation is on average slightly greater than what was reported from higher yielding environments overseas and confirms the potential gain for the Australian cropping industry (all other factors being equal). Such considerable changes will however require appropriate adjustments of varieties and management practices to capture the opportunities to the greatest extent possible and to address the following two points:

- Elevated carbon dioxide increases crop nutrient demands per ground area, but decreases nutrient (particularly nitrogen) concentrations in vegetative biomass.
- Elevated carbon dioxide decreased grain nitrogen and protein concentrations as well as the concentration of micronutrients essential for human nutrition, such as iron and zinc.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Tausz, M, Tausz-Posch, S, Norton, R, Fitzgerald, G, Nicolas, M & Seneweera, S 2012, ‘Understanding crop physiology to select breeding targets and improve crop management under increasing atmospheric CO_2 concentrations’, *Environmental and Experimental Botany* (In press).
2. Tausz-Posch, S, Borowiak, K, Dempsey, R, Norton, R, Seneweera, S, Fitzgerald, G, Tausz, M 2012, ‘Photochemical, photosynthetic and antioxidative responses of two contrasting wheat cultivars to combined climate change effects—A FACE study’, *Environmental and Experimental Botany* (In press).
3. Tausz-Posch, S, Norton, R, Seneweera, S, Fitzgerald, G & Tausz, M 2012, ‘Will intra-specific differences in transpiration efficiency in wheat be maintained in a high CO_2 world? – A FACE study’, *Physiologia Plantarum* (In press).

4. Tausz-Posch, S, Putri, V, Seneweera, S, Norton, R, Fitzgerald, G & Tausz, M 2012, 'Effects of elevated CO_2 on vitamin E concentrations in grains of two wheat cultivars – A FACE study', *Capturing Opportunities and Overcoming Obstacles in Australian Agronomy Proceedings of the 16th ASA Conference*, Armidale, Australia.
5. Tausz-Posch, S, Seneweera, S, Norton, R, Fitzgerald, G & Tausz, M 2012, 'Growth and yield performance of two wheat cultivars contrasting in transpiration efficiency under elevated CO_2', *Field Crops Research*, no. 133, pp. 160-166.

Further publications detailing the results of this research are in preparation and will be available.

More information on the project, including a list of publications and the AGFACE fact sheet, can be found on the Primary Industries Climate Challenges Centre website at www.piccc.org.au/agface

Developing climate change resilient cropping and mixed cropping / grazing businesses in Australia

Lead organisation

Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations

Queensland Primary Industries and Fisheries
Birchip Cropping Group
NSW Department of Primary Industries
South Australian Research and Development Institute
Commonwealth Science and Industrial Research Organisation (CSIRO)
CSIRO Sustainable Ecosystems Western Australia
CSIRO Sustainable Ecosystems Tasmania

Objectives

- assess the vulnerability of cropping and mixed cropping-grazing businesses to climate change by a formal evaluation of existing adaptive capacity and exposure to climate change.
- pre-emptively design more resilient tactical management practices and farm business strategies that are better attuned to farmer's aspirations, regional conditions and expected change scenarios through use of modelling tools.
- support activities to increase the preparedness of farmers and regions to reduce impacts and identify opportunities from expected changes in climate.

Location

Activities were undertaken at a national scale over multiple regions in each state.

Key activities

- assessed regional adaptive capacity and vulnerability to climate change of typical regional farm businesses across Australia.
- assessed likely impacts and adaptive management responses to climate change.

Findings/Conclusions

The results from this study suggest that some adaptation options provide resilience to both modest and more extreme climate change across much of Australia. These adaptation options include changes to the farm enterprise mix to enhance the livestock component and earlier dry sowing, in combination with the use of other crop varieties.

The changing enterprise mix adaptation option improved median yield production by between 2 and 27 per cent for a modest global warming scenario, depending on region and existing enterprise mix. The greatest improvements in median yield were returned in regions with higher water holding capacity soils on the drier margins of the cropping zone.

Some adaptation options showed little production value across all case-study regions. These included amelioration of subsoil constraints and introduction of a fallow into the crop rotation. While production increases were simulated at all sites in response to fallowing, the loss of income from removing parts of the farm from production outweighed the modest production gains in subsequent years. The fallow adaptation option proved viable if yield reduction due to weeds (which cannot be captured with the modelling tools used in this project) were assumed to be at least 10 per cent, or the fallowed paddocks were grazed by stock to reduce feed costs.

The project has shown that crop management adaptations are likely to play a significant role in maintaining or increasing yields, as well as influencing the potential temperature threshold beyond which yield is negatively affected. From data generated by this project, the temperature thresholds beyond which yield is progressively reduced with further temperature increases was around 2.5°C, if rainfall remained unchanged from current conditions, 2°C if rainfall declined by 10 per cent, and 1.5°C if annual rainfall declined by 20 per cent.

The results of this study suggest that adaptation options most effective under temperature increases of 1 to 2.5°C, raise yields by 5.5 to 19 per cent. At higher temperatures, further benefit from adaptation was limited, particularly under scenarios with reduced rainfall.

The results from this study would suggest that the net worth of adaptation could be in excess of $500 million per annum based on the simulated percentage benefit from adaptation.

This project has also successfully mapped regions of low and high vulnerability to future climate change. Across all 24 of the climate futures considered, regions of consistently high vulnerability existed across South Australia, western New South Wales, western Queensland, the south-eastern parts of New South Wales and parts of the Northern Territory.

Regions of consistently low vulnerability were found in the high rainfall zones of Queensland and northern New South Wales, much of the northern and south-western parts of the Western Australian wheat belt and isolated areas of southern New South Wales and eastern Victoria.

Related projects funded under Round 1 of Filling the Research Gap
N/A

Publications

1. Crimp, S, Howden, M, Laing, A, Gaydon, D, Gartmann, A & Brown, P 2010, 'Managing future agricultural production in a variable and changing climate', *IOP Conference Series: Earth and Environmental Science,* vol. 6, no. 37.
2. Hayman, P, Rickards, L, Eckard, R & Lemerle, D 2012, 'Climate change through the farming systems lens: challenges and opportunities for farming in Australia', *Crop and Pasture Science,* vol. 63, pp. 203-214.
3. Nelson, R, Kokic, P, Crimp, S, Martin, P, Meinke, H & Howden, M 2010, 'The vulnerability of Australian agriculture to climate variability & change: Part I -Reconciling the supply and demand for integrated assessments', *Environmental Science and Policy*, vol. 13, pp. 8-17.
4. Nelson, R, Kokic, P, Crimp, S, Martin, P, Meinke, H, Howden, M, et. al. 2010, 'The vulnerability of Australian agriculture to climate variability & change: Part II – Vulnerability assessments that support adaptation', *Environmental Science & Policy*, vol. 13, pp. 18-27.
5. Nidumolu, U, Hayman, P, Howden, S & Alexander, B 2012, 'Re-evaluating the margin of the South Australian grain belt in a changing climate', *Climate Research,* vol. 51, pp. 249-260.
6. Oliver, Y, Robertson, M & Weeks, C 2010, 'A new look at an old practice: Benefits from soil water accumulation in long fallows under Mediterranean conditions', *Agricultural Water Management,* vol. 98, pp. 291-300.
7. Power, B, Rodriguez, D, Harris, G & Payero, J 2011, 'A multi-field bio-economic model of irrigated grain – cotton farming systems', *Field Crops Research*, vol. 124, no. 2, pp. 171-179.
8. Rodriguez, D, deVoil, P, Power, B, Cox, H, Crimp, A & Meinke, H 2011, 'The intrinsic plasticity of farm businesses and their resilience to change. An Australian example', *Field Crops Research,* vol. 124, pp. 157-170.

Further publications detailing the results of this research are in preparation and will be available.

Relocation of intensive crop production systems to northern Australia: Costs and opportunities

Lead Organisation
Queensland Department of Agriculture, Fisheries and Forestry (formerly Queensland Department of Employment, Economic Development and Innovation)

Consortium member organisations
University of Southern Queensland

Objectives
- use crop, farm and regional modelling to investigate the projected effect of climate change and water policy on the relocation of tomato, cotton and rice systems to the Burdekin.

- analyse options for processing tomatoes, cotton and rice in northern Australia and provide relevant local and regional information with regards to the increased risks and the opportunities arising from climate change
- provide advice on effective government policy that would support the sustainable growth of Australian primary industries by:
    1. increasing the preparedness of farmers from vulnerable regions to mitigate impacts
    2. identifying opportunities from expected changes in climate.

Location

Field trials: Burdekin region at Bowen (Queensland)
Regions of interest: Darling Downs (Queensland), Riverina (New South Wales) and Shepparton (Victoria)

Key activities

This project used modelling to analyse possible scenarios.

Processing tomatoes case study:
Climatic analyses and the Decision Support System for Agrotechnology (DSSAT) biophysical model were used to compare future risks to tomato production in northern Victoria and northern Queensland. The length of the production season and levels of tomato growth and production were analysed.

Cotton case study:
Biophysical and economic models (CGE model) were used to explore the impact of climate change on cotton yields and profits in southern Queensland and the Burdekin. This project used the Agricultural Production Systems Simulator (APSIM) cotton model OzCot and collected industry data (e.g. production, water use and alternative cropping systems).

Rice case study:
The Tasman Global computable general equilibrium (CGE) model was used to analyse three possible scenarios of relocating rice production from the Riverina to the Burdekin:

1. rice grown using the fallow period between sugarcane plantings
2. rice displacing sugar cane
3. rice grown on additional land.

Findings/Conclusions

To adapt to changes in climate and reduced availability of irrigation water, businesses and growers in southern Australia, northern New South Wales and southern Queensland may consider relocating their businesses to northern Australia. Some results from this project showed that if industries are to remain in their existing location/s the following things may occur:

- rice production may remain more profitable than in northern Queensland as yields in the north will be lower
- projected increased temperatures and lower rainfall in southern Queensland may cause declines in cotton production

- processing tomato production may also be affected because there may be a risk of decreased season length or a break in the season
- irrigated cropping industries may also need to, or continue to diversify under climate change as there will most likely be lower water availability.

If industries are to relocate to northern Queensland the following things may need to occur:

- based on limited agronomic and financial data, rice production in the Burdekin area could be profitable depending on land and water values
- rice production may be less profitable than in the existing locations because of lower yields, however, access to water is more secure in the north
- rice and cotton systems are more likely to be grown as complementary crops between sugarcane plantings rather than be the dominant crop because of the higher value of sugar cane
- significant investment in processing infrastructure will need to occur.

Overall, this project provides evidence to indicate that movement of processing tomatoes, rice and cotton industries to northern Australia is unlikely to occur rapidly or easily.

Some barriers to moving to northern Queensland include lack of suitable varieties, lack of infrastructure, transport costs, pest and diseases, local reactions to land use change and difficulty attracting new farmers. Also support in terms of infrastructure for processing the product e.g. milling and ginning are critical, but it is also important not to overlook the need for research into agronomic practices that assist in reducing risk to the grower.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Mushtaq, S, Cockfield, G, White, N & Jakeman, G 2012, 'Climate and environmental risk management through structural adjustment and regional relocation: a case of rice industry in Australia', *1st National Symposium and Workshop on Environmental Science*, University of the Philippines, Quezon City, Manilla, 7-8 May.
2. Mushtaq, S, Cockfield, G, White, N, & Jakeman, G 2012, 'Plausible futures for regional development and structural adjustment under climate change: A case of the rice industry in Australia', *Practical responses to climate change National Conference*, Canberra, May.

Further publications detailing the results of this research are in preparation and will be available.

Agriculture transforming to adapt to climate change: Peanut industry expansion in the Northern Territory as a blueprint

Lead organisation

Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations

Peanut Company of Australia Limited
Northern Territory Department of Resources (formerly Regional Development, Primary Industries, Fisheries and Resources)
Northern Territory Agriculture Association

Objectives

- define the environmental and agronomic implications of establishing peanut production systems in the Northern Territory (Katherine), considering climate variability, climate change risks and adaptation options
- identify key social features of the transition process: the steps needed to successfully plan, reorganise and integrate into a new regional community and to manage the impacts of this transition on the old community
- assess potential pests, disease and biosecurity impacts of establishing peanut production systems in Katherine, with a particular emphasis on the landscape design that might result in the best pest suppression for key pests
- develop a blueprint for underpinning successful transitioning of Australian farmers who are strategically adapting to climate change in Australia.

Location

New peanut region: Katherine, Northern Territory
Existing peanut region: Kingaroy, Bundaberg and Tolga, Queensland

Key activities

This project monitored the biophysical and social aspects of the peanut industry's transformation process in both the new and old peanut regions to identify the main influences on, and magnitude of the impacts of transformation.

The Agricultural Production Systems Simulator (APSIM) cropping model was used to estimate nitrogen and carbon cycling, as well as productivity, for current and projected climates. Social surveys were also conducted with key company, government and community representatives on the peanut industry's planned expansion into Katherine.

This project produced a blueprint which provides a status report of the preparedness of an industry for agricultural transformation. It also highlights barriers so that plans or strategies to overcome the barriers can be developed. The blueprint included the development of a framework with 36 attributes grouped in social, economic, environmental and government and/or policy categories at field, farm, industry and regional and/or national scales. To complete the blueprint, data were collected and scored against the attributes and presented in a report card format. The development of the framework and attributes included a literature review in the areas of climate change, agricultural transformation, sustainable development, impact assessment, and environmental reporting. This framework and blueprint method could be applied to other industries that are considering relocating their businesses, and facilitate increased success of this transformation process.

Findings/Conclusions

Through application of the blueprint to the peanut industry's transformation experience, this project has shown that there is potential for mal-adaptations in establishing peanut production systems in the Katherine area (Northern Territory). One is the potential for substantial nitrogen leaching from peanut production systems to groundwaters, which sustain dry season flows and valuable ecosystems in the region's rivers, unless nitrogen fertiliser inputs are carefully managed. Another is that future climates in the Katherine region may be less favourable to agricultural production than they are now, so the advantages being sought through transformation by the peanut industry may diminish.

Biosecurity risks associated with establishing peanut production systems in the Northern Territory are small, and landscape modelling suggests there is scope for reducing pest and disease pressures on future crops through maintaining native vegetation cover of more than 30 per cent.

Social data suggests that it is unlikely that peanut farmers in traditional production areas would relocate to Katherine. Some reasons included:

- dependency on what farmers do now
- level of attachment to their place and their occupation
- lack of knowledge on how to farm in Katherine
- uncertainty of research and development support
- lack of experienced labour.

The blueprint identified the barrier range for the peanut production system to be able to successfully transform to Katherine. Out of the 36 attributes:

- 10 attributes were identified as potential critical barriers
- 8 attributes were identified as being little or no barrier
- remaining attributes had some potential to be a barrier.

Although the Peanut Company of Australia (PCA) had well developed plans to reduce or overcome these barriers PCA decided to withdraw from the expansion in Katherine.

This project suggests that transformational adaptation:

- is costly, risky, unpredictable and cannot be rushed
- must meet multiple conditions for success
- needs to be underpinned by long-term vision, commitment, planning and innovation
- can occur simultaneously with *in situ* incremental adaptation at a new location—they are not necessarily either/or options
- could be integrated into business plans.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Thorburn, P, Marshall, N, Chauhan, Y, Bianchi, F, Jakku, E, Mendham, E, et. al. 2011, 'Australia's peanut industry's transformation to adapt to future climates'. *GREENHOUSE 2011: The Science of Climate Change*, *Conference Handbook*, Cairns, CSIRO, Aspendale, p. 81.
2. Thorburn, P, Marshall, N, Chauhan, Y, Bianchi, F, Jakku, E, Mendham, E, et. al. 2011, 'Can Australia's peanut value chains transform to adapt to future climates', *The Climate Change Research Strategy for Primary Industries Conference,* Melbourne, p. 103.
3. Thorburn, P, Marshall, N, Jakku, E, Gambley, G, Chauhan, Y & Bianchi, F 2012, 'The basis for successful transformation of farming industries as an adaption to future climates', *2012 Proceedings of the Australian National Climate Change Adaptation Conference*, National Climate Change Adaptation Research Facility, Melbourne (In press).
4. Thorburn, P, Marshall, N, Wright, G, Jakku, E, Chauhan, Y, Jones, P, et. al. 2010, 'Transforming Australia's peanut value chains to adapt to future climates', *Change Adaptation Futures International Climate Change Adaptation Conference handbook*, National Climate Change Adaptation Research Facility, Queensland, pp. 320-321.
5. Thorburn, P, Robertson, M, Clothier, B, Snow, V, Charmley, E, Sanderman, J, et. al. 2012, Climate Change and Agriculture in Australia and New Zealand. In: *Agriculture's Contributions to Climate Change Solutions: Mitigation and Adaptation at Global and Regional Scales. Handbook of Climate Change and Agroecosystems*, vol. 2, eds, Rosenzweig, C & Hillel, D, Imperial College Press, London (In press).

Further publications detailing the results of this research are in preparation and will be available.

Development of effective management strategies to adapt production to mitigate climate change challenges in the wine industry

Lead organisation

Grape and Wine Research and Development Corporation

Consortium member organisations

Commonwealth Science and Industrial Research Organisation (CSIRO)
Department of Primary Industries, Victoria
South Australian Research and Development Institute

Objectives

- investigating the suitability of grape varieties, clones and rootstocks to hotter and drier growing conditions
- exploring techniques and practices to manage more variable yields, shifts in ripening times and compressed growing seasons
- delivering knowledge, tools and strategies to primary producers through extension networks.

Location

Barossa, McLaren Vale and Riverland, South Australia
Sunraysia, Victoria

Key activities

This research was underpinned by a number of projects which:

- used field and glasshouse experiments to investigate the potential adaptation strategies to mitigate the impacts of climate change at viticultural sites in South Australia and Victoria
- investigated CSIRO's grapevine germplasm collection to determine the suitability of more than 500 varieties, clones and selected breeding lines to grow in hot conditions and produce high quality wines in Sunraysia, Victoria
- analysed the tolerance of drought and salt conditions on seven rootstocks under deficit irrigation management in Sunraysia, Victoria
- investigated the effect of elevated temperature on grapevine physiology, berry composition and wine quality parameters (on varieties such as Shiraz, Cabernet Sauvignon and Chardonnay) at Nurioopta, South Australia and Sunraysia, Victoria
- used simulated heatwaves (lasting up to five days) on grapevines to determine the short-term effects of temperature on berry composition in Sunraysia, Victoria
- used sub-surface drip irrigation to measure water savings and rootzone salinity in the Riverland and McLaren Vale, South Australia.

Regional climate change toolkit workshops were also held in fourteen winegrowing regions across Australia.

Findings/Conclusions

After evaluating a range of varieties, clones and selected breeding lines under hot conditions, varieties can be identified that have:

- short seasonality to improve water use efficiency
- smaller canopies to minimise transpiration and improve water use efficiency
- long seasonality to ripen in cooler conditions
- optimal berry composition when harvested at earlier maturities.

This project also showed:

- some rootstocks are both drought and salt tolerant
- berry traits (such as total soluble solids, pH and titratable acidity) responded differently across varieties and at various times in the growing season
- elevated temperature causes varietal differences on physiology, berry attributes and wine quality parameters as well as earlier budburst, capfall and veraison.
- thermal effects on sensory traits (taste) of wine are highly season-dependent, however, it is possible to produce wine styles with optimal quality parameters (such as anthocyanin and tannin), desirable flavour and aroma profiles.

This project showed that the grape and wine industry is well equipped to manage the potential implications of climate change through a greater understanding of the dynamics of grape and wine production and an increased access to tools, some of which are currently being finalised.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Bubner, R, Moran, M, & Sadras, V 2010, 'Effects of elevated daytime temperature on berry sensory attributes of shiraz, cabernet franc, semillon and chardonnay', *The Australian and New Zealand Grapegrower and Winemaker*, no. 560, pp. 41-44.
2. Edwards, E, Unwin, D, Mazza, M & Downey, M 2012 'Hot and getting hotter – how will a warming climate impact affect warm climate viticulture?', *Wine and Viticulture Journal* (In press).
3. Moran, M, Sadras, V, Liebich, B & Bubner, R 2011, 'High temperature traits differ across varieties', *Australian and New Zealand Grapegrower and Winemaker*, no. 571, pp. 34-35.
4. Sadras, V & Moran, M 2012, 'Elevated temperature decouples anthocyanins and sugars in berries of Shiraz and Cabernet Franc', *Australian Journal of Grape and Wine Research* (In press).
5. Sadras, V & Petrie, P 2012, 'Predicting the time course of ripening in grapes', *Australian Journal of Grape and Wine Research*, vol. 18, pp. 48-56.
6. Sadras, V, Bubner, R & Moran, M 2012, 'A large-scale, opentop system to increase temperature in realistic vineyard conditions', *Agricultural and Forest Meteorology*, pp. 154-155 and pp.187-194.
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Further publications detailing the results of this research are in preparation and will be available.

Beef production adaptation in northern Australia

Lead organisation

Meat and Livestock Australia

Consortium member organisations

Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)
Northern Territory Department of Resources
Department of Agriculture and Food, Western Australia
Commonwealth Science and Industrial Research Organisation (CSIRO)

Objectives

- to identify and evaluate grazing land management practices for beef enterprises in northern Australia that will assist them to build resilience and adapt to a changing and more variable climate
- to assist industry and other stakeholders to develop strategies and policies that will
  (a) encourage adaptation by cattle producers in northern Australia
  (b) avoid responses that have risks of unintended negative consequences.

Location

South-East Queensland, Maranoa-Balonne (southern Queensland), Fitzroy Basin (central Queensland), Queensland Gulf country, Victoria River District of Northern Territory, Alice Springs region (Northern Territory), Kimberley (Western Australia).

Key activities

The key activities of this project were to:

- describe the existing industry management practices and situation, and identify potential grazing and related management strategies for building resilience and coping with a changing climate for six target regions (Kimberley, Victoria River District, Alice Springs District, Gulf region of north-west Queensland, Fitzroy catchment, and Maranoa-Balonne)
- identify best-bet grazing and related management strategies and guidelines for building resilience for each of the target regions
- develop and implement a plan in each region for evaluation, improvement and extension of a selection of best-bet grazing and related management strategies
- identify the likely biophysical, production and economic impacts of climate change for each region, using the best available climate projections and bio-economic modelling
- identify best-practice future grazing and related management strategies and responses for each region, using the best available climate projections and bio-economic modelling.

Findings/Conclusions

The biophysical modelling indicated that future climate change could bring about either downside or upside risks depending on changes in rainfall. Less productive regions are more susceptible to climate change than the more productive regions. If future climate change brings declines in rainfall this will lead to declines in livestock carrying capacity, productivity and beef turnover, which will have a negative economic impact on northern beef producers.

Current adaptation strategies such as flexible stocking rate management, pasture spelling to improve pasture condition and prescribed burning will remain effective in the future in most regions and under most future climate change scenarios.

The project identified specific improvements to the design and implementation of stocking rate management, pasture spelling and prescribed burning. For example, it identified a risk of overgrazing non-rested areas when implementing rotational wet season spelling, and identified options to minimise this risk. Similarly, it explored the optimum rates of stocking down and stocking up in response to periods of below-average and above-average rainfall, respectively.

The dominant economic effects on the vulnerability of northern beef enterprises to climate change are likely to be manifested through changing levels of carrying capacity and animal productivity—combining to affect beef turnover, the scope for productivity growth and capacity to yield ongoing economic profits. The analysis showed the industry to have limited immediate economic capacity for adaptation; adverse terms of trade, limited recent gains in on-farm productivity and low profit margins create limited margins to absorb any climate-change induced productivity losses.

Social research showed that around 85 per cent of the industry has low adaptive capacity and is highly vulnerable to future climate change. Many northern beef enterprises are already struggling economically and are therefore unlikely to be able to adapt to further pressures imposed by climate change.

Research highlighted areas where the adaptive capacity of northern beef producers could be improved and vulnerability to climate change reduced. These included developing producer networks, enhancing business planning and improving environmental awareness and knowledge of key areas such as pasture and soil condition. Pastoralists that had higher adaptive capacity had stronger networks, a strategic approach to their business, had high environmental awareness and high local environmental knowledge.

Long term strategic improvements in northern beef production may be difficult to implement given the current limited capacity of the industry to adapt to climate change. The immediate priority is to improve the current adaptive capacity and management practices before longer term strategic changes can be implemented.

The main conclusions from the project include:

- management strategies which reduce the risks, or take the opportunities under climate change are consistent with those that optimise land condition, productivity and profitability under the current climate. These strategies of managing stocking rate around long-term carrying capacity, implementing wet season spelling to improve land condition and using fire to control woody regrowth have been significantly refined through modelling and engagement, and should continue to be promoted to individual producers and their advisors. These messages are much better received when presented in the context of managing climate variability rather than climate change
- the potential impacts of climate change need to be benchmarked against other key profit drivers for northern Australian beef businesses to place the message in a whole-of-business context
- assisting beef producers to develop their networks, their interest and capacity in strategic and business planning, and their awareness and knowledge of natural resource management is likely to improve their resilience to the effects of climate change
- an idealised long-term strategic approach to industry adaptation may only be effective for engaging with a minority of producers. It will need to be complemented by approaches that are compatible with managers for whom engagement, adoption and change in management are more likely to occur as a result of short-term (1-3 year) tactical decisions made in response to immediate challenges.

The initial priorities for adaptation are therefore likely to focus on options with the most immediate benefit, while simultaneously strategically planning ahead for what will be required next, and assisting a broader proportion of the beef industry to become involved in the development of adaptation options.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

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5. Pahl, L, Whish, G, MacLeod, N, Scanlan, J & Cowley, R 2011, 'Adjusting stocking rates annually to improve profitability and sustainability of extensive beef enterprises in northern Australia', *Proceedings of the Northern Beef Research Update Conference,* Darwin, p. 159.
6. Scanlan, J, Cowley, R, Pahl, L, Whish, G & MacLeod, N 2011, 'Potential impacts of projected climate change on safe carrying capacities for extensive grazing lands of northern Australia', *International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand*, Chan, F, Marinova, D & Anderssen, R (eds), pp. 815-821.
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Further publications detailing the results of this research are in preparation and will be available.

Climate Change Adaptation in the Southern Livestock Industries (CCASLI)

Lead organisation

Meat and Livestock Australia

Consortium member organisations

The University of Melbourne
Commonwealth Science and Industrial Research Organisation (CSIRO)
Tasmanian Institute of Agriculture
NSW Department of Primary Industries
Department of Primary Industries, Victoria
South Australian Research and Development Institute

Department of Agriculture and Food, Western Australia
Dairy Australia
Australian Wool Innovation

Objectives

- examine the impact of projected changes in temperature, rainfall and carbon dioxide levels on both pasture and livestock production and on greenhouse gas emissions in southern Australian grazing systems through the use of modelling tools combined with Global Circulation Models (GCMs) and local weather data
- simulate the impact of changes to production systems on gross margins in the beef, sheep and dairy industries
- model and evaluate adaptation strategies.

Locations

Modelling was undertaken for 43 locations across Australia. The sites spanned a range of climates, including high rainfall, cool temperate in Tasmania; lower rainfall, temperate environments of southern New South Wales; Mediterranean climates in Western Australia; and sub-tropical climates in southeast Queensland. An additional 46 locations across southern Australia were modelled in partnership with livestock producers.

Key activities

This project combined agricultural production system modelling tools with regionally downscaled GCMs, local weather data and producers' own production and financial data to examine the impact of a range of climate scenarios on farm profitability, productivity and greenhouse gas emissions. Potential adaptation strategies were also investigated. The existing DairyMod and SGS models were expanded to enhance capacity to predict methane and nitrous oxide emissions, soil carbon and the interactions between these. The GrassGro model was also extended to include a larger range of grazing and producer data sets.

A series of modelling studies were carried out to investigate impacts of projected climate change in 2030, 2050 and 2070 and the effectiveness of adaptation and mitigation strategies for southern Australian grazing industries. These studies used a range of biophysical (DairyMod, SGS pasture model, GrassGro and APSIM), farm systems and greenhouse gas modelling tools for simulation on over 40 sites.

Regionally based research and extension staff were trained in the use of models and then worked directly with livestock producers across 46 locations in southern Australia to examine the impacts of climate change on farm productivity and profitability in 2030.

Findings/Conclusions

- The impact of projected climate change on productivity and profitability across southern livestock industries is significant, with pasture growth potentially 15 to 20 per cent lower by 2030, although impacts vary across locations.
- Climate change impacts are likely to be most severe in the lower-rainfall parts of the cereal-livestock zone, while in a limited range of cooler high-rainfall areas climate change may benefit broadacre agriculture.

- Adaptation actions which may help alleviate impacts of climate change vary across regions and industries. In many cases a combination of adaptations is likely to be most effective.
- Some effective adaptation actions are applicable today, such as increasing soil fertility or genetic improvement of livestock. Other adaptations may only become applicable in the future, depending on the degree of climate change.

University of Melbourne

Adaptation modelling indicated:

- Total annual pasture production in southern Australia is generally resilient to climate changes of +1° with 10 per cent less rainfall, but further changes are likely to reduce annual pasture growth.
- Deep rooting and heat tolerant traits will be important adaptations for pasture species in future warmer and drier climates.
- In regions where C4 grasses are not currently grown, substantial warming is still required before C4 grasses will be more productive than the current C3 species.
- Warmer and drier future climates projected for southern Australia will change the seasonal pattern of pasture growth, with higher pasture growth rates in winter and early spring but a contraction of the spring growing season, with an earlier onset of the dry summer period.
- Analysis of historical climate at five sites across Victoria and Tasmania indicates a trend for a greater frequency of short spring growing seasons across sites, but no clear trend of increasing variability in pasture production.
- Changes in the seasonal pattern of pasture growth will impact on animal production and ground cover, even if annual pasture production is maintained.

Mitigation modelling indicated:

- In south eastern Australia dairy farms produce the highest whole farm greenhouse gas (GHG) emissions/ha, followed by beef, sheep and grains.
- On an emissions intensity basis, cow/calf farms emitted more GHG per unit of product than wool, followed by prime lamb, dairy, steers and finally grains.
- A range of GHG abatement strategies that will lower the emission intensity of production are currently available, but will only be widely adopted if they are profitable in their own right.
- Emissions intensity per unit of product can be minimised simply by maintaining a productive pasture base.
- Current breeding for production and fitness traits also results in reduced emissions intensity of ruminant production systems; inclusion of residual feed intake in national breeding schemes should reduce emissions intensity further.
- The non-uniform distribution of excreta significantly influences the annual nitrogen losses through leaching and denitrification from a grazing system. When modelling nitrous oxide emissions from grazing systems, dung and urine distribution should be explicitly modelled and not assumed to be evenly spread across the pasture.
- While changes to methane emissions are mainly influenced by livestock numbers, nitrous oxide emissions may increase with warmer climatic conditions in the medium-high rainfall zone of southern Australia, particularly in less free draining soils. This emphasises that mitigation modelling must include consideration of adaptation and vice versa.

CSIRO

- The uncertainty associated with projected changes in livestock production is large, due to uncertainty in rainfall projections, but trends are discernable.
- The magnitude of climate change impacts will be large. Based on the available projections, there is a real prospect of 15 - 20 per cent overall reductions in pasture growth by 2030 in the absence of adaptation.
- Declines in production and profitability are expected to be significantly larger than declines in total pasture growth, because some vegetation must be left to protect the soil resource.
- Climate change impacts, and hence the need for adaptive responses, are greatest in the lower-rainfall parts of the cereal-livestock zone and tend to be less severe in the south-eastern parts of the high-rainfall zone.
- Beef breeding appears to be less affected than other enterprise types, but not enough to make beef cattle more economically attractive than other enterprises.
- A range of adaptations based on currently-available technologies may be effective in ameliorating the impacts of projected climate changes. The most important of these are:
    - increasing soil fertility, which increases the water use efficiency of pasture growth
    - ongoing genetic improvement of livestock
    - introduction or increased use of summer-active perennials (particularly lucerne)
    - in some locations, the use of confinement feeding to protect ground cover.
- In most situations, a combination of adaptive responses will be most effective.
- It is likely that in 2030, most livestock production systems can maintain profitability through combinations of adaptive responses. However, by 2050 and 2070 livestock production may only be viable in lower-rainfall parts of the cereal-livestock zone with development of new technologies, a complete re-thinking of the feedbase or sustained price increases.

Tasmanian Institute of Agriculture

- Simulation of perennial ryegrass production indicated that annual pasture production is likely to increase under most climate scenarios in the cool temperate (Tasmania) pastoral regions, with increases in pasture growth occurring during winter and early to mid spring.
- Changes to stocking rate and calving date could increase dairy farm profitability under projected increases in pasture production in the cool temperate dairy regions of Tasmania.
- In the more temperate dairy regions of southeast and southwest Victoria, changes to calving date and stocking rate are unlikely to compensate for the effects of climate change, and further changes to the farm system may be required to maintain profitability.
- GHG emissions were assessed on 100 dairy farms throughout Australia. The assessment found that 94 per cent of the variation in total farm GHG emissions could be explained by milk production alone, although the GHG emission intensity of milk production varied between 0.83 and 1.39 kg CO_2e/kg fat and protein corrected milk (FPCM).
- The mean intensity of emissions associated with milk production was 1.04 kg CO_2e/kg FPCM. Emissions intensity of milk production was most influenced by milk

production per cow, feed conversion efficiency and the amount of nitrogen based fertiliser applied.
- The GHG emissions intensity of milk production in Australia could be reduced through strategies that reduce enteric methane production whilst increasing milk production, and strategies that increase the efficiency of nitrogen use.

Findings from regionally based producer modelling

New South Wales

- Shorter growing seasons will require reduced stocking rates to manage ground cover, resulting in reduced profits. The size of the impact increases as projected rainfall decreases.
- Grazing in high rainfall tableland locations above 900 m is largely unchanged, with higher winter temperatures offsetting any decline in rainfall.
- There is no single adaptation which recovers the forecasted reductions in profit. It requires a combination of factors but the most promising are those management strategies that producers already know about, including summer feed lots and continual genetic gain.
- Sheep enterprises appear to be able to handle the increased climate pressure better than cattle.

Victoria

- Lucerne as a pasture base in the low rainfall mixed livestock/cropping zone offers the ability to generate increased profits under future climate scenarios.
- Earlier lambing may become more profitable for winter/spring lambing enterprises. Despite shorter springs, lamb breeding and finishing appears to remain more profitable than quitting all lambs at weaning for winter lambing lamb enterprises in the high rainfall zone.
- Changing from autumn to spring calving in both moderate and high rainfall zones offers little improvement in gross margins, and spring calving beef systems don't appear to gain from calving one or two months earlier.
- Optimising soil fertility, pasture production and utilisation (via increased stocking rate) offers major gains to livestock profitability, both now and in the future.

Tasmania

- By 2030 pasture production is likely to increase in many key production areas in Tasmania, due to increased temperatures and reduced frost frequency, although this may not be the case for some areas in the central highlands and southern midlands.
- Effective adaptive responses will be those that make use of improved opportunities through increased stocking rates.

South Australia

- Most locations are likely to experience increased variability in farm gross margin, due to a shorter growing season, decreased pasture quality and increased variability in pasture growth.
- In many cases later lambing or calving would become more profitable, although this may require supplementary stock feeding.
- Other adaptive strategies include increasing flexibility by varying sale times, confinement feeding, and increased animal trading; and changes to pasture management such as using an annual perennial mix that maintains greater pasture

availability over summer; grazing management systems that improve pasture utilisation, such as controlled, cell or rotational grazing; and adequate fertiliser applications.

Western Australia

- Results are quite varied across the two locations modelled (Kojonup and Ravensthorpe). On balance, increased rainfall variability and increased temperature are expected to result in faster winter pasture growth rate but shorter growing seasons.
- Legume content will increase with increased CO_2 and temperature. While this may increase animal production, the rate of decline of dry pasture residues over summer may also increase, resulting in wind erosion and groundcover limits being reached quicker.
- As a result, confinement feeding is likely to be an essential component of a sustainable grazing system for producers in these areas.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

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2. Bell, M, Eckard, R & Pryce, J 2012, 'Breeding dairy cows to reduce greenhouse gas emissions'. Book chapter in Livestock Production (In press).
3. Crimp, S, Stokes, C, Howden, S, Moore, A, Jacobs, B, Brown, P, et. al. 2010, 'Managing Murray-Darling Basin livestock systems in a variable and changing climate: challenges and opportunities', *The Rangeland Journal*, no. 32, pp. 293-304.
4. Harrison, M 2011, 'Adaptation strategies to shorter growing seasons for lamb enterprises in southern Australia', *Climate Change Research Strategy for Primary Industries Conference*, Melbourne, 15-17 February.

Further publications detailing the results of this research are in preparation and will be available.

More detailed information on the project is available on the Meat and Livestock Australia website at www.mla.com.au/Livestock-production/Environmental-management/Climate-change

Amelioration of thermal stress impacts on animal performance and welfare in southern Australia dairy, beef and sheep industries

Lead organisation

The University of Melbourne

Consortium member organisations

N/A

Objectives

There were five main objectives for this project:

- develop the Heat Load Index (HLI) and Accumulated Heat Load Units (AHLU) for use in grazing dairy cattle under Australian conditions, with an appropriate set of adjustment factors to assess heat load under different farm circumstances
- develop and launch a new web-based risk analysis tool for the Australian dairy industry which can guide farmers and advisers in making strategic and tactical decisions related to managing heat load in dairy herds
- provide guidelines for the improved management of heat stress and associated welfare/production issues
- quantify current heat stress management practices on southern livestock farms, including farmer knowledge of interactions between diet and thermo-regulation
- develop dietary strategies to minimise stress responses and loss of productivity.

Locations

The University of Queensland, Gatton campus, the University of Melbourne, Dookie campus and the University of Arizona, USA.

Key activities

1. management of available information from individual cow observation data and weather data from numerous climate databases
2. develop and refine mathematical algorithms to implement a user friendly web based tool which uses HLI and AHLU values to assist in predicting heat loads in dairy cow herds
3. identify interactions between diet and thermo-regulation of physiological responses and production impacts in livestock.

Response measures included:

- productivity (growth rate, milk yield, feed intake)
- physiology (respiration rate, heart rate, skin and rectal temperature)
- metabolism (glucose and fatty acid metabolism)
- endocrinology (insulin, cortisol, prolactin, Insulin-like Growth Factor 1 (IGF-1), leptin)
- expression of genes involved in insulin-signalling in muscle.

Mechanistic studies were undertaken to evaluate variations in respiration rate, heart rate, skin and rectal temperature during heat stress periods on livestock. For these purposes betaine (doses: 0, 2 or 4 g/day of betaine), chromium (as nano chromium picolinate, nCrPic) and antioxidants (vitamin E and selenised yeast) were used.

Antioxidant supplementation was administered at a control dose with maintenance levels of vitamin E (as alpha-tocopherol acetate at 10 - 20 mg/kg DM) and Selenium (as selenised yeast at 0.05 - 0.1 mg/kg DM) and a high dose group of vitamin E (as alpha-tocopherol acetate at 50 - 100 mg/kg DM) and Selenium (as selenium yeast at 0.25 - 0.5 mg/kg DM).

Findings/Conclusions

The research confirmed the relationship between heat exposure and physiological responses in livestock as well as their effects in decreased productivity. It also verified that reduction in feed intakes during heat exposure periods, is an important and evident sign of heat stress and a factor that results in reduced milk yield.

The results show the magnitude of the changes in productivity (growth rate, milk yield, feed intake), physiology (respiration rate, heart rate, skin and rectal temperature), metabolism (glucose and fatty acid metabolism), endocrinology (insulin, cortisol, prolactin, IGF-I, leptin) and gene expression.

Significant conclusions include: the potential use of Heat Shock Proteins (HSP) as markers of heat stress (HSPs may be useful when selecting animals better suited to excessively hot temperatures) and identification of beneficial dietary interventions as heat stress mitigation strategies in sheep and dairy cattle.

Dietary interventions with nCrPic produced positive results as these increased feed intake and daily gain during heat stress in sheep while reducing rectal temperature and respiration rate.

Dietary betaine was found to ameliorate heat stress in sheep at low doses (2 g/day). However, at higher doses betaine exacerbated heat stress, although it improved metabolism and increase milk yield in dairy cows under thermoneutral conditions.

Results from the project have been incorporated into a web-based tool called Dairy Risk Assessment Program which will be available in late October 2012. The tool aims to assist dairy farmers to predict and manage heat loads in dairy cow herds.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Chauhan, S, Celi, P, Leury, B & Dunshea, F 2012, 'Supranutritional levels of antioxidants maintains feed intake and reduces heat stress in sheep', Abstract submitted to the *2012 ADSA-AMPA-ASAS-CSAS-WSASAS Joint Annual Meeting*, Phoenix, 15-19 July.
2. DiGiacomo, K 2012, 'The physiological and metabolic responses to heat in ruminants', PhD thesis, The University of Melbourne.
3. DiGiacomo, K, Simpson, S, Leury, B & Dunshea, F 2012, 'Dietary betaine improves physiological responses in sheep under chronic heat load in a dose dependent manner', Abstract submitted to the *2012 ADSA-AMPA-ASAS-CSAS-WSASAS Joint Annual Meeting*, Phoenix, 15-19 July.
4. DiGiacomo, K, Dunshea, F, Leury, B, Baumgard, L & Rhoads, R 2009, 'Response of White Blood Cell Stress-Related Gene Expression to Heat Stress in Lactating Dairy Cattle', In *Ruminant Physiology, Digestion, metabolism and effects of nutrition on reproduction and welfare*, Ed. Chillard, Y, *XIth International Symposium on Ruminant Physiology*, Clermont-Ferrand, France.
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6. Henry, M, Kemp, S, Clarke, I, Dunshea, F & Leury, B 2009, 'Effect of level of endophyte-infected perennial ryegrass intake on plasma prolactin and some physiological parameters in Merino ewes', In *Ruminant physiology, digestion,*

metabolism and effects of nutrition on reproduction and welfare, Ed. Chillard, Y, *XIth International Symposium on Ruminant Physiology*, Clermont-Ferrand, France.
7. Xiao, Y, Collier, J, Rungruang, S, Hall, L, Dunshea, F & Collier, R 2012, 'Effects of betaine on heat induced heat shock protein expression in primary bovine mammary epithelial cells (BMECs)', Abstract submitted to the *2012 ADSA-AMPA-ASAS-CSAS-WSASAS Joint Annual Meeting*, Phoenix, 15-19 July.

Further publications detailing the results of this research are in preparation and will be available.

"El Nemo South East Australia Program": Adaptation of fishing and aquaculture sectors and fisheries management to climate change in south eastern Australia

Lead organisation

Department of Primary Industries, Victoria

Consortium member organisations

Fisheries Research and Development Corporation
Australian Fisheries Management Authority
Primary Industries and Regions South Australia
NSW Department of Primary Industries
Tasmanian Department of Primary Industries, Parks, Water and Environment
Commonwealth Science and Industrial Research Organisation (CSIRO)
South Australia Research and Development Institute
University of Tasmania as represented by the Institute for Marine and Antarctic Studies

Objectives

- facilitate fishing and aquaculture sectors to make informed decisions on adapting to climate change
- inform decisions on fisheries management arrangements to ensure they are responsive to a changing environment

Location

Various locations throughout south east Australia. Overall program coordination was in Victoria, with project delivery in Tasmania, Victoria, South Australia and New South Wales.

Key activities

The program comprised seven individual projects. The projects were multi-disciplinary in nature and included a mix of ecological, biological, physical, economic and social sciences.

Oceanographic modelling and a comprehensive biological risk assessment was initially undertaken to build an understanding of the biophysical implications of climate change and associated impacts on key fisheries and aquaculture species. This research provided a platform for the remainder of the program which included workshops with managers and fishers, climate change vulnerability assessments for key species (including socio-economic analysis), testing and review of existing management tools and barriers to adaptation, and development of a range of communication products to extend key messages to the sector.

Findings/Conclusions

A project led by CSIRO undertook a qualitative comparison of two regional models - Bluelink and South Australian Regional Ocean Model (SAROM) using historical data. It was concluded that while each model has strengths and limitations, they are both useful for projecting biophysical changes that fish and fishers may face.

Regional models were used to provide projections of future ocean chemistry for the south east region. The models showed current average pH values between 8.1 to 8.15, with values declining by 0.08 to 0.1 units by 2030, and 0.26 to 0.33 by 2100. This is consistent with global projections.

A comprehensive biophysical risk assessment was undertaken to identify which species are most vulnerable to climate change impacts. This risk assessment, covering 43 key species (35 wild fisheries and eight aquaculture species) found that the region's three highest value state fisheries—southern rock lobster, greenlip abalone and blacklip abalone—are at greatest risk from potential climate change impacts. These species demonstrate little capacity to move at adult stages, have lower physiological tolerances, and have life cycle stages that are strongly affected by environmental associations (e.g. spawning and settlement).

Blue grenadier was also identified as a high risk species. Blue Grenadier is a slow growing, long lived, deep water species. Elevated ocean temperatures may reduce suitable habitat and cause its range to contract.

Draft climate change vulnerability assessments were developed for four high-value commercial and recreational species in the south east (blue grenadier, snapper, southern rock lobster and abalone). This included developing individual species profiles combined with desktop research workshops (involving fisheries managers and industry) to identify potential adaptation pathways and likely barriers to adoption.
A number of barriers to climate change adaptation were identified through industry workshops. These included increased costs and/or loss of revenue, increased need for research and monitoring to address knowledge gaps, protection of existing access rights, and inability to manage entire distribution of fish stocks due to jurisdictional boundaries.

An integrated adaptation framework was developed for fisheries and aquaculture to evaluate future adaptation response options. The framework was tested for the south east bioregion and found that both positive and negative impacts are predicted for a few stressors. Impacts increase progressively from 2030 through to 2100. Acidification is being flagged as a critical stressor throughout this period. Positive impacts are noted for macroalgae and seagrass (although their weighted values are small) with key contributions from temperature and acidification.

A project led by the University of Tasmania used an Analytical Hierarchy Process (AHP) to develop a weighted objective framework for the four key species (blue grenadier, snapper, southern rock lobster and abalone). Results from the AHP survey showed a strong preference across all species around ensuring that any future adaptations sustain environmental and ecological values, particularly through sustaining the harvest population. This framework can be used to assess future adaptation strategies in a consistent and transparent manner.

A custom built model (based on existing Atlantis models) was developed by CSIRO scientists for the south east and used to test different climate change scenarios and management strategies. The model suggests that a regime shift may occur in eastern Bass Strait resulting in a major shift in ecosystem productivity and structure. The cumulative changes in ocean temperatures, ocean acidification and fishing may drive the region towards more pelagic, fast growing and small bodied species.

The highly successful community based climate change monitoring tool, Redmap, has been extended from a Tasmanian pilot project, to include Victoria, New South Wales, and South Australia. 'Redmap Australia' will be launched in November 2012, enabling fishers and divers across the entire south east to monitor and log uncommon fish and other marine life.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Hobday, A, Hartog, J, Middleton, J, Matear, R & Condie, S 2011, 'Understanding the biophysical implications of climate change in the southeast: Modelling of physical drivers and future changes', *FRDC report 2009/056*.
2. Hobday, A & Lough, J 2011, 'Projected climate change in Australian marine and freshwater environments', *Marine and Freshwater Research*, vol. 62, pp. 1000-1014.
3. Lough, J & Hobday, A 2011, 'Observed climate change in Australian marine and freshwater environments', *Marine and Freshwater Research*, vol. 62, pp. 984-999.
4. Pecl, GT, Doubleday, Z, Ward, T, Clarke, S, Day, J, Dixon, C, et. al. 2011, 'Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. Part 2: Species profiles, Fisheries and Aquaculture Risk Assessment. *Fisheries Research and Development Corporation*, Project 2009/070.
5. Pecl, GT, Ward, T, Doubleday, Z, Clarke, S, Day, J, Dixon, C, et. al. 2011, 'Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. Part 1: Fisheries and Aquaculture Risk Assessment', *Fisheries Research and Development Corporation*, Project 2009/070.

Further publications detailing the results of this research are in preparation and will be available.

A series of fact sheets produced by the project are available from the Fisheries Research and Development Corporation website at
www.frdc.com.au/environment/climate_change/Pages/elnemo_frdc_approach.aspx

Consistent Climate Scenarios

Lead organisation
Department of Science, Information Technology, Innovation and the Arts (formerly known as Department of Environment and Research Management)

Consortium member organisations
Commonwealth Science and Industrial Research Organisation (CSIRO)

Objectives
To develop a consistent set of climate projections data across Australia for use in biophysical models investigating different adaptation strategies.

Location
Queensland Climate Change Centre for Excellence, Brisbane.

Key activities
To produce a set of model-ready climate projections for 2030 and 2050, and to generate climate change projections for Australia, two statistical methods were used. One method was based solely on CSIRO's OzClim 'change factor' approach, while the second, more sophisticated method, used 'quantile matching'.

The first phase of the project applied climate change factors to historical data to produce climate estimates for the future. Monthly change factors were calculated based on Global Climate Models used by the International Panel for Climate Change Fourth Assessment Report (IPCC, AR4) and applied to historical climate data sets from the Specialised Information for Land Owners (SILO) climate database to produce projected climate data sets for 2030 and 2050. The projected data were produced for selected emissions scenarios at various locations across Australia.

The second phase of the project incorporated a quantile matching approach to consider projected changes in the cumulative distribution frequency of the climate projections. To calculate the 2030 projections data, observed trends in 10th, 50th and 90th percentile values were incorporated and extrapolated to 2030. To incorporate daily Global Climate Model data, a variation in the quantile matching method was used to calculate quantile matching based projections data for 2050.

Findings/Conclusions
A comprehensive set of model-ready projections of climate variables have been delivered as inputs to biophysical models used in adaptation projects. Variables were: rainfall, evaporation, minimum and maximum temperature, solar radiation, and vapour pressure deficit, with projections based on the following:

- 19 global climate models
- eight emissions scenarios
- three climate warming sensitivities (low, medium and high)
- two projections years (2030 and 2050).

For any location on a 0.05 degree (approximately five kilometre) grid across Australia, or for individual observation stations, the projections data can be provided as daily (weather-like) time series of climate variables. Projections have also been formatted to suit most biophysical models, for example, GRASP and APSIM, and are being made accessible to the public via an automated web portal.

The scenarios developed can be used in localised climate change impact assessment modelling for periods out to 2030 and 2050, and to inform research investigating different adaptation strategies.

A User Guide to help interpret results from the time series of climate data, as well as appropriate meta-data and selected diagnostics, has also been developed. These resources have been made available with the climate data sets for education and quality assurance purposes.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Ricketts, J & Carter, JO 2011, 'Estimating trends in monthly maximum and minimum temperatures in GCMs for which these data are not archived', *MODSIM Congress*, Perth, Australia 12-16 December.

Further publications detailing the results of this research are in preparation and will be available.

More information, including projections data developed as part of this project, can be found at www.longpaddock.qld.gov.au/climateprojections/about.html

The ‘Biosphere’ Graphic Element

The biosphere is relevant to the work we do and aligns with our mission—we work to sustain the way of life and prosperity for all Australians. We use this shape as a recognisable symbol across our collateral.

For more information please contact:

Research and Adaptation Policy

Department of Agriculture, Fisheries and Forestry
GPO Box 858
Canberra ACT 2601

Phone 1800 108 760

Email ftrg@daff.gov.au

daff.gov.au/ccrp