Australian Academy of Science

Theo Murphy High Flyers Think Tank 09

proceedings

Agricultural Productivity and Climate Change

Oaks on Collins, Melbourne
22–23 October 2009

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THE ROYAL SOCIETY

The 2009 Think Tank is supported by the Royal Society – the national academy of science of the UK and the Commonwealth – through the Theo Murphy (Australia) Fund.

GPO Box 783, Canberra, ACT 2601

This publication is also available online at:
www.science.org.au/events/thinktank2009/report.pdf

ISBN 085847 281 3

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Introduction

The Australian Academy of Science's High Flyers Think Tank, *Agricultural productivity and climate change*, was held in Melbourne on 22 and 23 October 2009. The two-day conference brought together recognised experts in agricultural productivity, food security, and climate change, including social scientists who understand the associated human dimensions. Sixty-three early- and mid-career researchers from a diverse range of disciplines, such as soil ecology, genetics, environmental science, agronomy, engineering, economics and many others, participated in the workshop

This annual Think Tank—the second to be generously supported by the Royal Society through the Theo Murphy (Australia) Fund—has come at a time of ever-growing concern over the impact of global climate change. As changes in climate continue, there will be significant biophysical, environmental, social and economic impacts across a variety of sectors—including agriculture. These will affect not only Australia but the rest of the world.

For the first time in almost a quarter of a century, food is back on the political agenda. Reasons include: increased demand for food, driven by population growth and changing food preference with increasing affluence in the rapidly growing economies of Asia; demand for land to grow biofuels; concerns about increased drought and severe flooding; and a decline in productivity growth. The hitherto widespread assumptions that problems of food production have been solved and food security is largely a matter of distribution have been challenged. For example, recent projections of a 60 per cent increase in Australia's population by 2050 mean there will be an extra 13 million Australians consuming resources—including agricultural resources—in a country with finite carrying capacity. This presents enormous challenges.

The emphasis of this year's Think Tank was not on climate change itself, but rather the challenge of achieving agricultural productivity sustainably in the context of climate variability. It was about using the insight and expertise of the various participants to identify and examine potential mitigation and adaptation strategies, in the context of other environmental, social and development pressures.

Normally the question posed by the Academy Think Tanks is: how can science (including social science) and technology, be used to address these important issues under consideration? However, this Think Tank, more than most, addressed some policy areas as well.

The Think Tank also addressed the practical disconnect between the work of social scientists and natural scientists, which is a major impediment to solving the challenges posed by increased population. Breakout group discussions raised the need for sharing of new knowledge due to the relatively new, very complex and uncertain nature of climate change.

The keynote address for the Think Tank was provided by Professor Peter Gregory, recipient of a Selby Fellowship awarded to celebrate the 50th anniversary of the program. Professor Gregory's address, *Food security in a changing climate*, demonstrated how global, environmental and social changes are affecting food systems, and suggested some of the technological and policy responses which might be applied.

The challenge and the vision

Over the next half century, Australia—and the entire world—will face formidable challenges arising from interactions between climate change, water, food security and population. We are endowed with finite natural resources, particularly water, nutrients and the capacity of the atmosphere to take up the outputs of human activities (such as carbon dioxide). These natural constraints, combined with the need to produce food for a population growing in both numbers and aspiration, will require that our food systems evolve and transform in ways that recognise the interconnectedness of all these challenges.

The need for evolution and transformation in food systems creates opportunities for improving the social, economic and environmental health of the entire nation. Transformed food production systems can support vibrant rural communities as well as improving the ecological viability of Australia's landscapes and waterways.

New technologies and new management systems will be needed. Therefore, climate change, water management and the need for food security, tackled together, present opportunities both for business and the economy.

To provide for its own food security and to continue its role as a food exporter, Australia by 2050 will need to produce approximately twice the current amount of food from a similar or smaller land area to that used for production at present. While there is a confidence that Australia can meet this challenge, unless it acts now it will remain at risk.

The outlook

Australia is currently in the secure position of exporting around two-thirds of its agricultural products (DAFF, 2007), but unless significant changes to agricultural practice are made by 2050 it will be necessary to import food. For example, CSIRO's 2050 projections for population growth and wheat requirements indicate that at current production rates—where 60-70 per cent of its wheat is exported—Australia would need to import wheat.[1] Perhaps even grimmer is the realisation that as other exporting nations would be similarly affected, Australia would not be able to meet its requirements through imports. Clearly, Australia will need to improve its productivity, not only for wheat but for a host of other agricultural products.

The projected 35 million people in Australia by 2050 will have significant consequences for our ecosystems, biodiversity and quality of life unless crucial planning and management actions are taken. Australia needs to have a leadership role in addressing its food security challenge.

Australia has a history of improved productivity in agriculture and in the past it met the challenges, such as new fallowing systems, new crop rotational systems and introduction of phosphorous fertilisers. The original 'green revolution' produced new technologies for farmers, thereby creating food abundance. But now productivity growth is potentially in decline and there are new challenges ahead, such as have emerged through the droughts of the past decade.

Gordon Conway has argued that a 'doubly green' revolution is what is needed to transform agriculture.[2] This requires that agrarian policy should both protect the environment and boost production. This includes calling for researchers and farmers to forge genuine partnerships in an effort to design better plants and animals, as well as find alternatives to inorganic fertilisers and pesticides, improve soil and water management, and enhance earning opportunities for the poor.

Australia will need:

- To adopt a holistic approach. Only an innovative combination of technological, social and adaptive governance supported by evidence-based policy, can effectively cope with the challenges.
- To engage in meaningful dialogue with industry, policy, science, and better engagement with the rural–urban components of the Australian community, along with improved understanding of issues on both sides.
- More efficient and effective knowledge generation and management systems.
- Broad mitigation strategies which include the rural sector.
- To manage demand as well as supply.
- Resilient systems, that is, robustness to external shock.

Australia has both a national and an enlightened self-interest in a global context, where every nation needs to face not the same challenge, but challenges of a similar kind. Because Australia has significant expertise—agricultural and environmental research—and extensive experience of climate variability, it can play a leading role in these areas internationally. So what can Australian stakeholders, both the urban and rural components of the Australian community, expect?

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[1] ABARE (2007) analysis indicates that Australian production of commodities such as wheat, beef, dairy and sugar could decline by an estimated 9-10 per cent by 2030 and 13-19 per cent by 2050. Australian exports of these commodities are projected to decline by 11-63 per cent by 2030 and 15-79 per cent by 2050. http://www.abareconomics.com/publications_html/ac/ac_07/a1_dec.pdf

[2] Conway, G. (1997). *The Doubly Green Revolution: food for all in the twenty-first century*. London: Penguin Books.

What can Australia offer?

While the challenges are great, Australia is in a better position than most to respond to these challenges, and Australian science is already on the cutting edge of a number of fields. Various speakers noted that Australia is able to offer expertise in a number of scientific and technological areas:

1. Varieties and techniques for yield improvement such as better crop varieties, better water-use efficiency, and improved pest disease resistance.
2. Assessment of the greenhouse gas sequestration/mitigation potential achievable through changes in rural land use and management.
3. Social science strategies that encourage adaptive governance and stakeholder engagement.
4. Effective natural resource monitoring and forecasting.
5. Measurement of adaptive capacity and resilience of communities.
6. Prediction of climate change and climate variability, which are required by agricultural producers, resource industries, water management components and the general public.
7. Cross-disciplinary collaboration between physical and social sciences.
8. Integrated information and knowledge network.
9. Efficiency in utilising more of the produced food to avoid waste, and improve environmental flows.
10. Life Cycle Assessment certification, providing a market advantage.

All of these involve the potential for significant advances and, given the right resources, are fully achievable over the next 10 or 20 years. Australia's agricultural research history certainly demonstrates that we have the capacity to lead the way, as evidenced in the advances made in dryland farming which Australia has shared with the world.

The full potential can only be realised if Australia considers investing more resources and introducing some new institutional arrangements to face these challenges. Moreover, given the uncertainties and complexities of future climate scenarios, there is a need to develop more resilient agricultural systems to cope with the range of possible changes—a point well made in recent years by CSIRO Sustainable Ecosystems.[3]

Recommendations

1. Develop a national policy on food security which is linked to other current and future government policies and initiatives. Climate change adaptation and enhanced food security go hand in hand; therefore any policy which supports agricultural adaptation also enhances food security.
2. Support national research and knowledge management strategies through full implementation of the National Research, Development and Extension (RD&E) Framework (being driven through the Primary Industry Ministerial Council and the Council of Rural Research and Development Corporations' Chairs) to support food security policy. The current framework needs to go beyond the agricultural and fisheries focus, to include post-farm gate and environmental areas. Australia's forestry, agricultural and land-management systems have significant potential to store or sequester carbon in their vegetation and soils and offset large amounts of greenhouse gas emissions over the next 40 years.[4] This is critical for increasing productivity and ensuring sustainability.
3. Provide continued research capacity support for the unique Australian soils, climate and vegetation, as well as for pest and disease reduction in plants, such as emerging new rust viruses.

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[3] See Howden, M. et al. (2003) *An overview of the adaptive capacity of the Australian agricultural sector to climate change – options, costs, benefits*. http://www.cse.csiro.au/publications/2003/AGOAgClimateAdaptationReport.pdf

[4] See http://www.csiro.au/resources/carbon-and-rural-land-use-key-findings--ci_pageNo-2.html

4. Develop a long-term, ongoing and permanent national natural resources and environment monitoring system for the whole landscape, incorporating soil, water, vegetation and biodiversity. Understanding agriculture–climate interactions well enough to support adaptation and mitigation activities requires major improvements in data collection, dissemination and analysis.

5. Australian communities need to be engaged in the planning and implementation of social/structural adjustment such as water-use habits, and Australian governments need to develop policies and mechanisms to provide support during transitions to new systems that are more adapted to the emerging climate. Community-based adaptation strategies can help rural communities strengthen their capacity to cope with disasters, improve their land-management skills, and diversify their livelihoods.

Introduction

Purpose of Think Tanks

The purpose of the Academy's High Flyers Think Tank series is to bring together early- and mid-career researchers from a broad range of relevant disciplines to engage in thinking about novel applications of existing science (including social science) and technology to issues of national significance, and to identify gaps in knowledge that should be addressed. The High Flyers Think Tanks are a unique opportunity for career development and network creation amongst the nation's next generation of research leaders and their institutions.

Think Tanks are one of the premier events of the Academy's calendar and this year's, the eighth that the Academy has held since 2002, is generously supported by the Theo Murphy (Australia) Fund which is administered by the UK Royal Society, and the Selby Scientific Foundation.

Previous Think Tanks

Previous Think Tanks have culminated in reports to government that have been timely, well received and instrumental in influencing policy development. Past Think Tank topics (found at www.science.org.au/events/thinktanks.htm) have been:

2002 – Australia's national research priorities
2003 – Safeguarding the nation
2004 – Emerging diseases – ready and waiting?
2005 – Biotechnology and the future of Australian agriculture
2006 – Innovative technical solutions for water management in Australia
2007 – Extreme natural hazards in Australia
2008 – Preventative health: Science and technology in the prevention and early detection of disease

2009 Think Tank: *Agricultural productivity and climate change*

There is wide agreement among the international scientific community that the global climate has not only been changing, but will continue to change, and that human-induced increases in concentrations of greenhouse gases will continue to drive climatic changes across the globe. These changes are likely to be associated with a range of biophysical, environmental, social and economic impacts across many sectors throughout the world. Agriculture is one such sector and vital not only for Australia but for the world.

Rather than focusing on climate change science itself, this year's topic used the insight and expertise of participants to identify and examine potential adaptation and mitigation strategies, in the context of other environmental, social and development pressures. Participants were well placed to tackle this problem, having been chosen from a diverse range of disciplines to include geographers, economists, and other social scientists, soil ecologists, environmental scientists, agronomists, aquaculture specialists, geneticists, modellers and systems analysts, engineers, entomologists and many others.

Think Tanks are primarily about applying science and technology to problems, identifying gaps in knowledge and proposing novel solutions. They also involve thinking strategically with respect to Australia's role and place within such fields of research.

The proceedings began with presentations by the theme speakers who then led interdisciplinary breakout discussion groups. As in the past, the Academy found it helpful to structure these discussions using an outcomes matrix (see below) which comprises four outcome areas and four 'toolboxes' or strategic response areas that are underpinned by research to address challenges in the outcome areas. Each toolbox was examined for potential applications in each of the four outcome areas.

Outcomes matrix for *Agricultural productivity and climate change*

Tools to address challenges and achieve outcomes / **Outcomes**	**Policy** **Examples** • governance • emissions trading • policy obstacles • complementary measures • adaptive capacity • regulation	**Knowledge management** **Examples** • cross disciplinary participation • ICT • science value chain • change/adoption & adaptation	**Technologies** **Examples** • emissions/mitigation management • crop/stock/farm/social technologies • spatial science technologies • abatement technologies	**Planning** **Examples** • meteorology/ climatology forecasting • market projections • risk management • cost benefit analysis • preparedness
A. Productivity growth Innovation; efficiency, business (farm to corporation); competitive advantage **Speaker A – Kate Grenot**				
B. Resilience Flexibility; adaptability; population; regional; community, family; individual; preparedness **Speaker B – Lesley Head**				
C. Sustainability Natural resources & landscape management, water; energy; carbon; materials; soils; river health; erosion; catchment management; biodiversity **Speaker C – Michael Robinson**				
D. Global climate Avoid dangerous climate change; extreme events; global implications **Speaker D – Michael Raupach**				

Outputs

The two days' proceedings were taped, transcribed and made available on the Academy's website. This includes all presentations (verbal and PowerPoint slides), breakout group reports, general discussions, and this final report of the proceedings. This report summarises the major outcomes and provides contextual information. Generally, major issues and gaps in knowledge are identified, and recommendations or a 'way forward' provided. These outcomes form vital and current information that can be used to underpin policy development and research prioritisation processes.

Instructions for breakout groups

The Chair of each session was requested to give a keynote address of 20 minutes (followed by 10 minutes of questions) that provided a perspective on an outcome area from their field of expertise. The speakers also chaired a breakout group comprising participants with expertise in one or more tools, assisted by a rapporteur.

Each breakout group was made up of 16 researchers from across Australia with a variety of research interests, and included scientists, technologists and social scientists. The breakout sessions provided an opportunity for detailed discussion of important scientific directions and developments and exploration of their possible applications. Participants were encouraged to think broadly on how to use their toolbox of policy, knowledge management, technologies or planning to address challenges and achieve the following outcomes:

- productivity growth
- resilience
- sustainability
- global climate.

To assist the discussion, some generic questions were also provided to all participants:

1. What tools do you have to offer?
2. How can your tools address challenges in the outcome areas?
3. How do your tools interact with the other tools?
4. What are the impediments to effectively employing your tools?
5. What are the risks of unintended or undesired consequences of the use of the suite of tools under consideration and how do you manage those risks?

The role of each rapporteur was to capture the outcomes of their group's discussions. It was also useful to record any further related issues that were considered by the group to be relevant, together with any problems, gaps, strengths, past lessons and priorities. With the Chair's guidance, each rapporteur prepared a PowerPoint presentation (15 minutes plus 5 minutes for discussion) for the combined meeting on Day 2.

A list of the early- and mid-career participants is provided in Appendix A.

Speakers and chairs

Professor Kurt Lambeck AO FAA FRS

President, Australian Academy of Science

Kurt is a distinguished Professor of Geophysics at the Australian National University and President of the Australian Academy of Science. His research interests cover the disciplines of geophysics, geodesy, geology, climate and environmental science, and space science. He has been at the Australian National University since 1977, including ten years as Director of the Research School of Earth Sciences. Kurt was elected to the Australian Academy of Science in 1984 and to the Royal Society in 1994. He is a foreign member of the Royal Netherlands Academy of Arts and Sciences (1993), Norwegian Academy of Science and Letters (1994), Academia Europaea (1999), the Académie des Sciences, Institut de France (2005), and the US National Academy of Sciences (2009).

Kurt's recent work has focused on aspects of sea level change and the history of the Earth's ice sheets during past glacial cycles, including field and laboratory work and numerical modelling. Past research areas have included determination of the Earth's gravity field from satellite tracking data, examination of tidal deformations and the rotational motion of the Earth, the evolution of the Earth-Moon orbital system, and lithospheric and crustal deformation processes.

The Hon Joe Helper MP

Victorian Minister for Agriculture

Joe Helper was born in Germany in 1959, and moved with his family to Melbourne in 1971. He started his working life as a motor mechanic and also worked for a number of state and federal MPs and the Victorian Public Service. In 1996 Joe returned to his trade when he became the proprietor of Newstead Motors. Having run his own business, Joe understands the important role played by small business in communities throughout Victoria. In October 1999 Joe was elected to the Victorian Parliament as the Member for Ripon. Building on his interest in regional issues, in 2002 Joe was appointed Parliamentary Secretary for Regional Development. Following the state election in 2006, Joe was appointed Minister for Agriculture and appointed Minister for Small Business in 2007.

Dr Sue Meek FAICD FTSE

Chief Executive, Australian Academy of Science

Sue has 25 years experience working in a variety of capacities at the interface of industry, academia and government. Her particular interests are in promoting awareness and understanding of science and technology, and the formulation of policies and programs to stimulate the conduct and application of research and development. Sue held the position as Australia's inaugural Gene Technology Regulator from December 2001. This statutory appointment was established to administer the national regulatory system for the development and use of genetically modified organisms. Immediately prior to that, she was Executive Director, Science and Technology in the Western Australian

Department of Commerce and Trade. In this role she was responsible for the development and implementation of state policies on science and technology and public sector intellectual property management, and the administration of grant programs to support innovation and the development of research infrastructure.

Sue has a PhD in marine biology; Masters in oceanography; and an honours degree in microbiology. She is a Fellow of the Australian Institute of Company Directors and of the Australian Academy of Technological Sciences and Engineering. Sue is an inaugural member of the Centre for Environmental Risk Assessment Advisory Council.

Professor Peter Gregory

Director and Chief Executive, Scottish Crop Research Institute

Peter was appointed Director of the Scottish Crop Research Institute at Invergowrie, Dundee Scotland, in 2005. In the decade before that, Peter was leader of a research group at the University of Reading investigating root-soil interactions and the introduction of integrated nutrient management into systems of crop production. The main areas of research were in characterising the physical and chemical environment of the rhizosphere, investigating the appropriate use of fertilisers and manures in Nepal, modelling water and nutrient uptake in agroforestry systems in Kenya, and characterising the movement of the weevil Sitona lepidus to roots of white clover.

Peter's current research includes: non-invasive imaging of roots and root-soil interactions with x-ray computed tomography; improving resource use efficiency at the root-soil interface; effects of dwarfing and semi-dwarfing genes on root growth of temperate cereals; root growth in response to soil drying; and global environmental change and food security. His research is conducted at two scales: the rhizosphere, a very active region for physical and chemical changes in soils, where his research is concerned with the quantification of the processes leading to these changes; and the global scale, with interests in global environmental changes and food security. This research is undertaken as part of the activities of Global Environmental Change and Food Systems and with staff at the University of Dundee.

Dr Kate Grenot FAICD

Chair, Rural Research and Development Council

Kate has a PhD in science, a Masters degree in science and technology policy, and is a Fellow of the Australian Institute of Company Directors. She is currently Chair of the Australian Government's Rural Research and Development Council, established in 2009 by the Minister for Agriculture, Fisheries and Forestry. She is a former Director of the Grape and Wine Research and Development Corporation (Chair, Audit Committee), the Industry Research and Development Board (Biological Committee), the Royal Botanic Gardens and Domain Trust (Chair, Finance Audit and Risk Management Committee) and Wirra Wirra Vineyards. Kate is a former Associate Director of Coopers and Lybrand (Government Services) and has a research background in plant physiology (ion channels, signal transduction), science policy and industry development (Sydney, Harvard, Sussex).

Professor Lesley Head FAAH

School of Earth and Environmental Sciences, University of Wollongong

Lesley is a Professor of Geography at the University of Wollongong, with a research specialisation in Australian human-environment interactions over both prehistoric and contemporary timescales. At the University of Wollongong, Lesley is head of the School of Earth and Environmental Sciences, and Director of the Australian Centre for Cultural Research. She will shortly take up an Australian Laureate Fellowship to expand her work on the cultural dimensions of sustainability – agriculture and food production will be one aspect of this. Lesley is a Fellow of the Australian Academy of Humanities and current President of the Institute of Australian Geographers.

Dr Michael Robinson

Executive Director, Land and Water Australia

Michael has been the Executive Director of Land and Water Australia since 2006. He has worked in research, communication, business development and policy, in Australia and New Zealand, and is passionate about good quality research informing sustainable and productive landscape management. He currently leads the National Climate Change Research Strategy for Primary Industries and is a member of the Primary Industries Standing Committee Research and Development Subcommittee.

Prior to joining Land and Water Australia Michael was Chief Executive Officer with the Cooperative Research Centre for Greenhouse Accounting. He has also worked with CSIRO in business development, management and communication roles, focusing on environmentally sustainable forestry and landscape scale management issues. Trained as a scientist, his PhD examined the sustainability of using wastes to fertilise plantation forests, and was completed in 1999 with CSIRO and the University of Melbourne.

Dr Michael Raupach FAA FTSE

CSIRO Marine and Atmospheric Research

Michael is a research scientist in CSIRO Marine and Atmospheric Research. He is a Fellow of the Australian Academy of Science and a Fellow of the Australian Academy of Technological Sciences and Engineering. From 2000 to 2008 he was an inaugural co-chair of the Global Carbon Project of the Earth System Science Partnership. He contributed to the IPCC 2007 Fourth Assessment. His research encompasses global and continental carbon and water cycles, carbon-climate-human interactions, land-air interactions, fluid mechanics and particle transport. He is a frequent contributor to the policy and public debate on climate change.

Welcome

by Professor Kurt Lambeck, President, Australian Academy of Science

I would like to welcome you to the Academy's Think Tank. These Think Tanks are annual events. They are made possible through the Theo Murphy (Australia) Fund, with the cooperation of the Royal Society of London, whose Executive Director, Stephen Cox, is with us today.

I would also like to extend a special welcome to Professor Peter Gregory, Chief Executive of the Scottish Crop Research Institute. He will deliver both the keynote address this morning and a lecture tomorrow, in honour of the 50th anniversary of the Selby Fellowship.

I also welcome Dr Clive Noble, who is representing the Victorian Minister for Agriculture. The Minister is unable to come, but I believe that we have a very good substitute in Clive, who is the Chief of Science and Technology, Agriculture and Fisheries with the Victorian Department of Primary Industries. We thank him very much for stepping in at the last moment.

The topic this year is agricultural productivity and climate change. I believe that this is both a topical and an urgent subject. When I look at some of the papers that cross my desk, I see a number of messages. They may not always be complete or even correct but, when I take these together, I see alarming trends that should really shake us out of a certain complacency that has developed in our understanding of food security globally.

Some of these messages include, in no particular order, the decreasing amount of arable land available for agriculture; this is a global trend. I learned in China last week that, from 1998 to 2005, there was a decrease of over 6 per cent of arable land. Extrapolating that over a 50-year period results in not much arable land left. Globally, it has been estimated that the arable land per capita has decreased by something like 50 per cent over the last 40 years, and predictions are that there will be a further 50 per cent reduction by 2050.

Another constant message relates to the energy-food nexus. Rising energy prices are leading to increased production in biofuels, with further loss of land that would traditionally be used for food production, or resulting in land clearing, with the concomitant loss of habitat and carbon sinks. It has been estimated that the production of biofuels has already driven the cost of food production up by something like 30 per cent. That is not taking into account increased energy costs that are also driving up the costs of agriculture and food production. Considering that a very large part of the population spends more than 50 per cent of its income on food alone, these price rises quickly lead to a very unsustainable situation.

An increased intensity of farming would be an obvious response to this. But this has its own problems, in that the remaining arable land is put under increasing pressure through excessive or increased use of fertilisers and pesticides. This then leads to the consequential contamination of waterways and coastal zones. In the aquaculture area, ocean fish stocks are shrinking and are being taken up by the expanding aquaculture industry, but again this is placing additional stress on coastal and riverine environments.

Then I understand that there is an emergence of new rust viruses, to which the current wheat strains have little resistance. If I interpret correctly what I have been reading, I would have to come to the conclusion that this is likely to present a major threat to the wheat crops of not just Australia but the world. I think there may be another sleeper in this, and that is what I understand to be the declining importance of agricultural science in many of our universities and research institutions.

Of course, all of these things—and I am not saying that these are necessarily all correct, but they are some of the messages that I am hearing—are occurring in the shadow of climate change. With some 40-45 per cent of the world's food coming from irrigated lands, the food supply has become increasingly susceptible to changes in climate: changes in rainfall distribution, changes in run-off as mountain glaciers shrink, and increasing stress of plant crops to rising temperatures. Then, of course, the real elephant in the room is the growing global population—not just growing in numbers but also growing in aspirations to attain living standards that we cannot deny them.

Putting these things together, I come to the inference that, by 2050, for example, food production will have to double on possibly about half the arable land available—and that is even ignoring the aspirations of the developing world. So I believe that there is a real challenge. The world has faced this challenge before and the outcome of that, of course, was the green revolution, which was led by a combination of cheap energy leading to cheap fertilisers and the growth of more productive crop strains.

One may anticipate that science and technology again will come to the rescue but, in my mind at least, there are remaining questions. Will the high energy prices and decreasing raw materials mean that radically new solutions have to be urgently found? For example, will the unfounded reluctance to embrace the genetic modification of food crops retard the necessary research that is required to yield productive crops in a changing climate environment? Do our universities still have the capability to address the range of agricultural issues that we as a nation—and, I believe, as a world—are faced with? Do Australia's research laboratories still have the in-house knowledge and experience to address urgently, for example, the threats from these emerging rust viruses?

So, my question is this: has a certain complacency set in, after the success of the green revolution, whereby we are now ill-equipped to handle what appears to be a rapid confluence of events that threatens the food security of the world? This is where I think the Think Tank today comes in. If some of the issues that I have just raised are valid and if there are other issues that are perhaps equally valid or more important, where do the solutions lie? How can science and technology be used along with social science issues to avert worst case scenarios? What can and should Australia's role be in finding solutions? What sustainable solutions can be found in a mix of technology and practice combined with genetic solutions and social changes?

So your challenge is a major one:

- first, to identify the important issues and, using your different skills and backgrounds, to come up with novel ideas that may have escaped the attention of those who have been focusing on these issues until now; and
- second, to identify any gaps in knowledge or our ability to effectively respond to the looming food crisis.

The Academy has a strong commitment to providing developmental opportunities for early- and mid-career researchers, not only to ensure that Australia remains internationally competitive in its contributions to global science, but also to enable it as a whole to benefit from the advances of science and technology, irrespective of where they occur. The Think Tank serves two purposes. It has the purpose of finding specific solutions, but it also has the purpose of providing you with opportunities through networking to develop your own interests in research and to direct that research at societally important problems.

For the Think Tank this year we have tried to bring together early- and mid-career researchers from a wide range of fields. I hope that you will all find during these two days people who are working in related but not the same areas. And that you discover that there may be solutions in what somebody else is doing in a totally left-field to your own problems.

This morning we will focus on scene-setting with a series of presentations, and then breakout groups will work through the issues and report back to us tomorrow morning. Your real challenge is that you have 24 hours ahead of you to reach your recommendations. We look forward to your insights and conclusions. Again, thank you very much for coming here and for putting your time into this effort.

Opening address

Climate change and agriculture: a challenge and opportunity for science

Dr Clive Noble
Chief of Science and Technology, Department of Primary Industries, Victoria

I bring the apologies of the Minister for Agriculture for his inability to attend today. He is accompanying the Premier on a visit to Western Victoria to make an important announcement this morning. I'm very pleased to attend and speak to you on behalf of the Minister.

I know that previous Think Tank events have been very successful in providing a forum to encourage diverse and lateral thinking for our next generation of researchers.

There is no question that climate change is considered to be one of the major challenges that we face as a society, particularly for us in the primary industry sector. But, of course, any challenge creates a range of opportunities. I thank the Academy for using this Think Tank to provide an opportunity to explore how science can contribute to the topic of agricultural productivity and climate change. However, we should remember that such opportunities to contribute place a requirement on us as scientists to step up to the mark.

Australia is seen as one of the countries that prospectively will suffer most from what we know and perceive as climate change. From a Victorian perspective, we envisage that we will need to go through some major changes because of the extent to which climate variability, climate change, climate shift, or whatever you want to name it, might impact on our agricultural sector. We have all heard of the discussions that are occurring at a political level with such things as an emissions trading scheme and the question of whether or not agriculture is included. Of course, that discussion reflects the complexity of climate change, including what the scale of impact might be, how we might adapt, what it might mean in terms of food production—the quantity, location and cost of it—and whether the industry, in its broader sense, is really going to be able to respond and adapt.

These questions create a significant challenge to science to identify implications, options and solutions. Such a challenge also provides science with the opportunity to demonstrate its worth by providing many of the answers that our community seeks and needs. But, of course, that brings with it some significant responsibility in the science we do, how we do it and how we work together to apply its findings.

From a policy perspective, over the last several years the Victorian government has placed a high priority and focus around the issue of climate change. Within the last 18 months the government announced a new initiative called the Future Farming strategy, aimed at enabling farm businesses to become more productive, competitive and sustainable as they enter an era of unprecedented change. Climate change, with its implications and our responses to them, is a major component of the Future Farming strategy.

Similarly, the Victorian government has been working on a climate change green paper to reposition Victoria's policy in light of recent national activities. That paper outlines the long-term strategy to deal with climate change and priority action areas to effectively manage the changes ahead. After a period of consultation with the broader community, the government is considering the feedback and will release a white paper—in other words, its forward policy position and priorities—early next year. But, even then, the continuing issues for us include: What other information do we need? How will we address it? How might we mitigate and adapt? And what might the broader community need in terms of future assistance from government?

There is no question that the climate challenges facing agriculture are significant, diverse and complex. We will need a multitude of solutions or options, which will need to be multidisciplinary in nature and integrative in their application. I am sure that we have all heard of the increasing convergence of technologies and the need to take a systems approach, and I think this is true for what we will need to do in dealing with climate change.

The considerations here in Victoria include the variable rainfall that we have had over the last 10 or more years. To some extent, in the west of the state, in the Wimmera, we have been fortunate over the last couple of months to get some significant rain, and it looks like being a quite successful cropping season. But there are other areas of the

state, such as the north-east, where that has not been the case. There continue to be challenges for the agricultural community because of the more variable rainfall and temperature patterns expected. Many other considerations are front of mind, such as what shifts in climate might mean for aspects such as pest and disease introduction and distribution.

The implications for production and regional communities in Victoria are quite profound. Without adequate preparation to make changes to the way we farm, we run the risk of seeing a decline in Victoria's farm production. For example, the dairy industry could suffer a 4-5 per cent drop in its production by 2030 and 10 per cent by 2050. With the dairy industry being a major component of Victoria's agriculture and, indeed, from a national export perspective, a drop like that would have major ramifications across not only agriculture but the broader community. Similarly, we need options for our cropping systems as we could potentially see a 25 per cent reduction in wheat yields in northern Victoria.

Naturally, one of the sources for answers regarding the future for agriculture in Victoria is from R&D and practice change. In my own department there are a number of such projects that we are undertaking. They include some of the more strategic science research—such as molecular breeding, including exploring possible genetic modification solutions that may enable characteristics such as drought tolerance in wheat; and enhanced biomass for bioenergy applications—through to more applied research such as the FACE project that examines free air carbon dioxide enrichment implications in the field. Such research is being done both in Victoria and as part of national and international programs, a collaborative approach that is fundamental to addressing an issue as broad and complex as climate change.

In Victoria's Department of Primary Industries there is also research being done in relation to reducing methane production from dairy cattle. It is interesting that some of this work has shown that you might be able to change methane losses by as much as 30 per cent through simple changes in the diet of dairy cattle.

Research such as reducing methane production from cattle is of course addressing the issue of mitigation, but the other side of climate change is adaptation. Adaptation, certainly in the short and longer term, is going to be a major component in increasing production in a changing climate. The Evergraze project, which looks at getting the right plants in the right place for the right purpose, is a good example. This is a national project with the focus in Victoria on better water use and the effect of pasture combinations on animal production and water use. This project has been extended to incorporate broader climate change issues, such as greenhouse gas emissions and altered rainfall patterns, to explore production options.

Changes in climate also threaten agricultural production in other ways, such as increased occurrence and severity of bushfires, like the bushfire disaster in Victoria earlier this year. An increased incidence of bushfires can increase the risk of smoke taint for our wine grapes. Our research is thus also exploring how to protect our horticulture industry from these secondary effects of climate change.

These are just some of the many projects underway in Victoria.

The focus for this Think Tank is to explore your thoughts, drawing on the range of science backgrounds that you bring. This range of backgrounds is important because, as I said earlier, what is needed is a multidisciplinary approach. Specifically from this workshop we are seeking your thoughts on the roles for, and opportunities arising from, science in addressing climate change. These in turn can influence a government's future planning and priorities. An important aspect to include in your discussions will be not only the existing capabilities that can be brought to bear, but also identifying any key gaps in our capabilities.

The issue of scientific capability to support Australia's primary industries has an increasing level of national focus. In recent times, all of the primary industry ministers at the state and federal level, together with the broader rural industry corporations and universities have agreed to establish a National Primary Industries Research, Development and Extension Framework. This framework essentially recognises the need for us to take a more consolidated, coordinated and collaborative national approach to the issues facing our primary industry sector. The framework will establish a set of priority RD&E strategies for each of the industry sectors, collectively 'owned' by government, industry and the various RD&E providers around the country. In addition to identifying RD&E priorities, each industry strategy will specifically include identifying gaps in capability across the country and collaborative approaches to address those gaps. Hence, given this national framework approach, I can assure you that your ideas on capability gaps have avenues through which gaps and opportunities can be addressed.

In concluding, I would like to read something to you to assist your thinking in today's Think Tank. One of the things we are doing in my department is putting more emphasis on examining where the primary industries sector might be heading over the next 20 years or so, and how this might influence the types of services and capabilities required from a Department of Primary Industries. This approach requires more of the strategic push the boundary thinking. As part of this 20-year thinking we ran a workshop with senior national primary industry leaders, to seek their views on the possible future shape of the sector. In addition, we ran a similar workshop with people such as yourselves from the XY generation, as this is the group that will be the leaders in the future.

The following is one of the scenarios produced by the XY generation workshop. They titled this scenario 'Farmer Joe Goes Bananas':

> *It was strange to see an amazing range of exotic fruits and foods in the farmers markets of Port Melbourne with a 'grown locally' sign on them; but there it was. As a result of climate change, there had been a remarkable and rapid shift of production into areas that now could be defined as almost 'subtropical'. Parts of northern Victoria almost came into this zone. Frustrated by the continual decimation of crops by pests, rots and other diseases that had, via mangoes, crossed the biological bridge from the Northern Territory into Queensland and beyond, Farmer Joe and his partner, Tim, moved south. They were encouraged in this move through the results of research into new climate-adapted GMO crops. These had helped evolve a whole new range of production possibilities in northern Victoria. The requirement to micromanage water almost naturally led towards innovative approaches to production and technology. Biodynamics were just a small step from that point and were what consumers, who were distrustful of large agrifood companies, wanted. These systems focused mindsets and saw the district become a centre for ecological production systems. Many of these systems now were being used in the development of an amazing array of urban foods. Whoever would have thought that the heat island effect of larger cities might actually have a beneficial upside and that Queenslanders might be star attractions at the Victorian farmers markets?*

Bear in mind that we deliberately encouraged the workshop group to push out their thinking—exactly the sort of approach we will need to explore as we consider what we need to do, what we can do, and what the opportunities are, in the face of the challenge of climate change into the future.

On behalf of the Minister for Agriculture I welcome you to Melbourne. I congratulate the Academy on running today's Think Tank. I certainly look forward to the outputs of your thinking and deliberations today.

Keynote address

Food systems and future environmental change

Professor Peter Gregory
Director and Chief Executive Scottish Crop Research Institute (and Selby Fellow)

It is a great pleasure to be here. My thanks go to the Australian Academy of Science and to the Selby Foundation. It is also a great pleasure to see many faces that I recognise from the various bits of work that I have done here in Australia.

My talk today is avowedly global in nature and it will cross disciplines. I am a soil scientist by training and the reason that I'm a professional soil scientist is that, at about the age of 15 or 16, I became interested in food and food security because at that time people in India were starving.

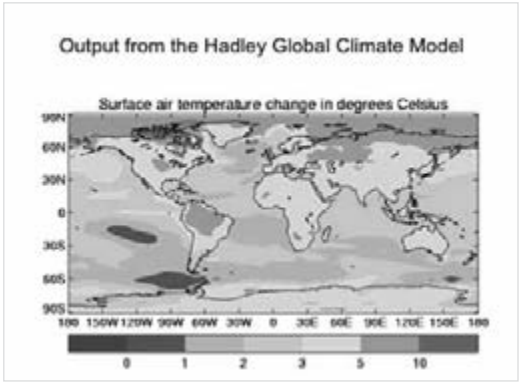
That is the motivation behind the work that I do—trying to do something about that. I guess that for many of you there would be similar motivations too. So I am going to talk today about a global program: Global Environmental Change and Food Systems (GECAFS).

As we have heard from two speakers so far, food is very much back on the agenda. 'Silent tsunami' was the headline in *The Economist* just over a year ago. So food is back on the agenda and back in people's thinking.

Last year there were riots in many countries of the world, which sharpened the minds of politicians. If food is in short supply, people living in the countryside tend to die. But if people are in cities they can get themselves organised and they riot. That brings it home very vividly to politicians. The increase in population, which we heard Kurt Lambeck talk about earlier, is going to occur principally in cities from now on. Considering that over half the world's population now lives in cities and that most of the future increase in population will be in cities, this sort of violence is not what wins votes for politicians. So they have to do something about it and that's why food security is now very high on political agendas.

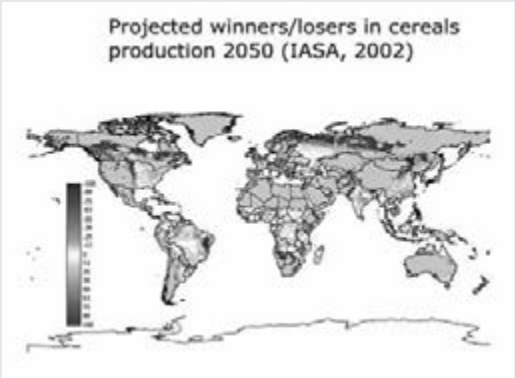
One of the contexts for this meeting is that food systems are already failing a large number of people in the world. If I had been giving this talk three years ago, I would have said that it was about 800 million people. With what has happened in the last couple of years, this has now increased to around a billion people who are short of the food that they need. The number on the bottom left-hand corner of the slide is the 2005 number. So food systems are already failing many people and millions are food insecure, and that is without what we project will happen in terms of climate change.

I am going to talk a little about the impacts of climate change on crop production and I am also going to talk about food security and food systems. I will give an example of what we have been doing within GECAFS in relation to the Indo-Gangetic Plain. I will challenge you to think about your own ideas of food, as a prelude to the discussions that you might have later today. Then I will talk a little about the future.



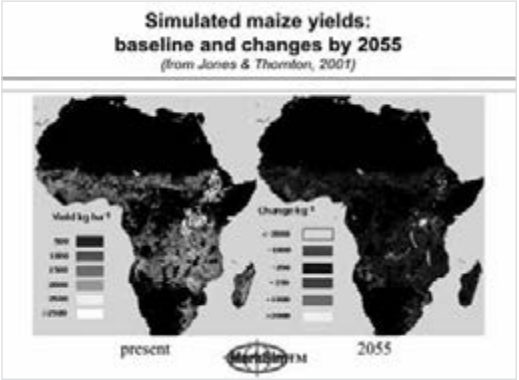
This map is from the Hadley Centre in the UK but it could equally well be from the centre here in Melbourne. It shows projections of climate change—temperatures in particular—around 2050 or so. Whether or not it is accurate in terms of every precise point is irrelevant. The main thing is the overall pattern of events, with particular substantial warming in the north and in South America. For example, the mean annual temperature in Dundee, which is where I come

from, is now already 1.2 degrees warmer than it was in the 1970s. That is 1.2 degrees on a base of around eight—so, proportionately, a substantial increase in temperature in northern latitudes.

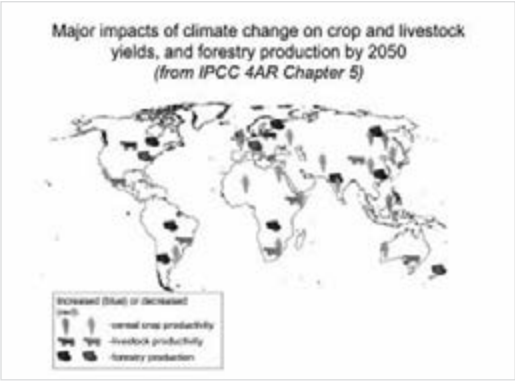


Bringing such climate change projections together with crop models leads to outputs shown in this slide. This was produced for the Johannesburg food summit in 2002. The map had a major political impact because it showed that climate change was going to make the production of food worse in sub-Saharan Africa, parts of South America, India and China—areas, as shown on the previous map, where food was in short supply already.

So there were going to be losers. The losers were going to be the poor, those already suffering from hunger. The winners, the areas of green, were large parts of the United States, a little bit of poetic justice on the western edge of the corn belt, and the major area of green up in the north—except that the people who made the map, of course, weren't soil scientists, because anyone who is a soil scientist knows that those peats are not going to support those sorts of cereal crops. So the end result is a compression of the zone in which cereal crop production is likely to be possible on a global scale. But, despite the health warnings and the glaring scientific defects in some aspects of it, this sort of map has great impact. It shows that there are potential winners and there are opportunities—but there are also losers.



This slide shows a similar sort of exercise that was done for Africa. This is a specific example with maize but most of the modelling exercises to date emphasise the negative effects of climate change on cereal production in sub-Saharan Africa.



These sorts of models have fed through into the IPCC report. This slide is taken from the 2007 IPCC report. It shows the winners and losers as a result of climate change in relation to crop production as well as animal production. Again, those areas already short of food are the predominant losers from climate change. But this is all rather simplistic.

A summary of what we have just seen is shown in this slide, where we take some sort of environmental change, run a model and say that there will be an impact on food production. But, as the riots showed, those people were not actually protesting about food production, they were protesting about their own lack of food security: their own lack of access to the foods that they wanted. We have known this for some time. If you come from the social science community, you will say: 'Well, I already knew all that.' My view of food security is quite different from that.

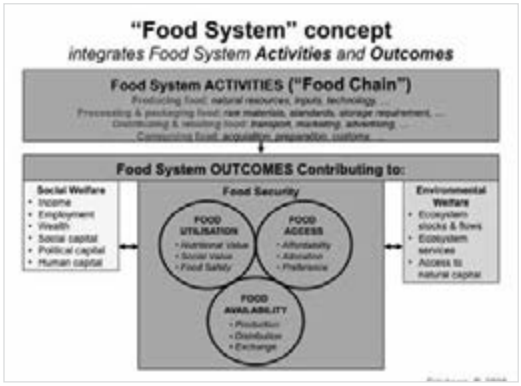
This slide is from the Millennium Ecosystem Assessment, published in 2004-05, which looked at food security in about 100 villages in southern Africa. Certainly, climate and environmental change figured as major factors affecting food production. Incidentally, equally important were issues about who owned the farmland and who had property rights. But the factors on the left of the slide primarily acted to restrict access to food and, in this survey, it was these factors that determined whether people did or did not have food. If you lump these factors together, they say that if you are poor and you do not have money in your pocket then you cannot get access to food, and that is a major contributor to whether you are food secure or insecure.

We come to a definition of 'food security'. This definition comes from a number of documents from the UN's Food and Agriculture Organization (FAO). There are a number of definitions of 'food security', but I think this is quite a useful one for the purposes of this workshop. You will see that it does not mention 'production' at all—personally, I think that is a bit of an oversight—but actually talks about how you get 'access to food'. It also goes on to talk about that food being nutritious, meeting your dietary needs and some of your social preferences so that you can have an active and healthy life.

Again, I think one of the reasons that rich countries of the world are now becoming interested in food security is not just the question of those who do not have enough food but also, within our own societies, those who have access to food without it doing them any good in terms of leading an active and healthy life. Particularly where I come from in the UK—Scotland—there are distinct groups within our society who suffer considerable health disbenefits as a consequence of having access to food that is really rubbish. So there is a much wider debate going on here.

Food security is underpinned by food systems. GECAFS has brought together the various elements of the international global change research community with organisations like FAO, the World Met Office and the Consultative Group on International Agricultural Research to take a look at what food systems are and how they can be made more secure.

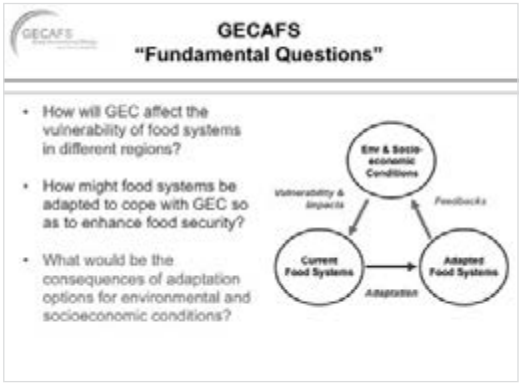
Food security, just to take the definition that I gave you before, can be broken down into three elements. There is the issue of food availability—in other words, do you produce it in the first place and distribute it to where it is needed, particularly cities? Do you have access to the food: can you afford it and how is it allocated? In some societies there are strict societal rules dictating whether you have access to certain sorts of food, and it is allocated according to various hierarchical rules. Then there is a whole set of issues around utilisation—the nutritional value of the food, which I have just alluded to—and food safety. Interestingly, in the UK, our Department for Environment, Food and Rural Affairs (Defra) is placing much more emphasis on issues of nutritional value and food safety in its definition of food security.



This food security, which in some ways may be an abstract sort of concept, is underpinned by a number of activities. We produce food, we cook it, process it, package it, distribute it to supermarkets, retail it and then consume it. All of these activities together contribute to whether we are food secure or insecure. These interact with a number of social

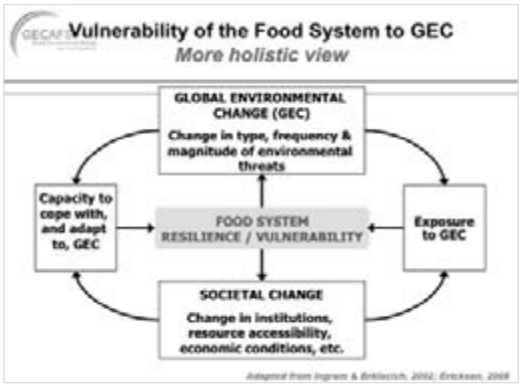
issues such as income, whether you are employed, the social capital you may have, and a number of environmental issues. I will come back to this in a moment, but climate change would go in there together with other issues such as what other goods and systems we want from our ecosystems. Within GECAFS, we have found this to be a very useful way of thinking about food security and food systems and a means of bringing together the disciplines that are represented here today to talk about food.

Back in the 1970s, when I was an undergraduate student, my professor of international development used to say that he had never seen a man with money in his pocket starve; I think that is equally true today. Whether or not you have access to food depends to a large extent on whether you have education, employment and access to markets. There is a good relationship between the proportion of money that people spend on food and their per capita income. Basically, the poorest people globally will spend a greater proportion of their income on food than the rich and the wealthy. Until the food crisis of last year, people in the UK spent, on average, 8 per cent of their income on food; it rose last year to just over 10 per cent. In Australia 18 per cent of household income is spent on food.

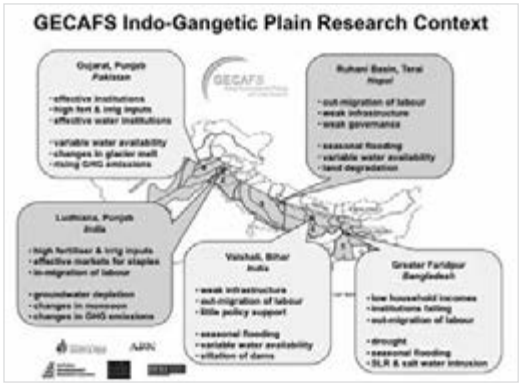


The fundamental questions that GECAFS has sought to answer are: how is climate change going to affect these food systems; will different regions of the world be more vulnerable? How might they be adapted to cope with this change? What will the consequences of that adaptation be? What will be the feedbacks on to the environmental and socioeconomic conditions?

We have moved away from what I talked about earlier, which is this rather simple view of the world that climate change has an effect on production that then gets people thinking about the resilience or vulnerability of communities. How vulnerable are we as a society and elements within our society going to be? This is affected not just by what is happening to food production but particularly by what happens within society. What changes, for example, in governance and institutions are likely as a consequence of the perception of change? This will have a fundamental effect on our abilities to cope with changes. Institutional arrangements and ability to access resources all have an effect on the resilience and vulnerability, and they also affect the ability of societies and sections within societies to cope with or adapt to the environmental changes that come along.



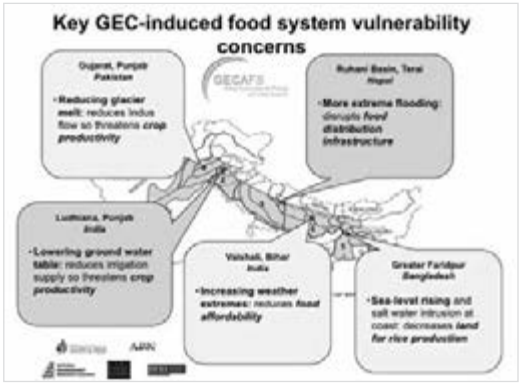
I will give a quick example to get you thinking about this. Within GECAFS, what we did at the outset was to set up three case studies in different parts of the world. Those studies were in southern Africa, the Caribbean Islands, and the Indo-Gangetic Plain. The choice of these three areas was determined by their having very different sorts of food systems. But, even within a region such as the Indo-Gangetic Plain, there are different characteristics. The way the research program worked was not to decide what research needed doing and then find a place to do it, but to go to the place and have a series of discussions with the policy-making communities, those producing and retailing food and so on, and to work out what the current situation was and how it might be affected by environmental change and, therefore, what needed to be researched.



The Indo-Gangetic Plain divides quite conveniently into five areas. The Punjab in Pakistan is characterised by pretty effective institutional arrangements for the production and distribution of food, high fertiliser and irrigation inputs into their production systems, and effective institutions for distributing water—although there is some argument about that. Incidentally, it took us about two years in this process to get to the point where the policy-making community recognised that there were any threats from environmental change because it is too far away from them in terms of their immediate policy-making requirements. However, in terms of their concerns about climate change and changes which might occur, there are issues already about variable water availability. They are aware that the glaciers are melting; that is why the Indus is flooding at the moment, but that might not be the case in the future. Also, there are general concerns about rising greenhouse gas emissions.

Compare that with what is going on over on the Terai in Nepal. In that region, there is massive out-migration of labour. It is all very well talking about producing crops, but many of the people get more money by selling their

labour in the cities. So there is massive out-migration of labour and very weak infrastructure. Why is there weak infrastructure? The roads and the paths get washed out and the bridges get washed away during the monsoon period. So, having access to food is highly problematic. That also brings with it the fact that there are weak institutional and governance arrangements. The global environmental change issues are quite different too: already there is seasonal flooding with a huge variation from year to year, variable water availability, and land degradation.



In a global environmental change context, what you might propose to do for adaptations in one place will be very, very different from what you might do in another. We need to understand that, if we are to have effective mitigation and adaptation operations. Out of the discussion that I have just outlined very briefly, came these key global environment change-induced, or climate change-induced, food system concerns that have then led to research programs. So you can see that in Punjab India the major issue is around productivity; in the Terai of Nepal it is around distribution and infrastructure; and in Bangladesh, the principal concern is more in relation to sea-level rise. People further up the Indo-Gangetic Plain are not experiencing sea-level rise, but they are certainly experiencing the effects of it because the people who live in Bangladesh are moving in that direction. Many of you may have seen the reports in the newspapers that the reason people in coastal regions are moving north is because India is building a border fence to the west to stop them moving into India.

To conclude and draw this together, I want you to think about your own food. What do you like? How would you describe the food that you consume in your household or when you go out to dinner? What is it that you want? If we went around the room, I guess that you could give me a phrase or two to describe food, as you perceive it, that you want. If you go on to the website of Woolworths Supermarkets, as I did the other day, you will see that it is pretty switched on to what it thinks you in Australia want, and it is a successful company as a result.

Here is a slide from a professor of retailing who advises major supermarkets in the UK on what he thinks people in the UK want from food. Actually, we want everything, and we want a variety of things, depending on how the mood takes us. At one level we would like to say, 'We consume things locally. I go to the farmers market or I buy in the supermarket something stamped "local" that I could pick up in the farmers market'. But, actually, we are also quite happy to buy food from other parts of the world and, as a result, our diets are much more varied. We want to eat 'healthy'. I want to eat stuff that is really good for me. But, when I finish doing that, I actually do like the chocolate éclair. This is just to illustrate our fickleness. What we want from food, when we have access to it, relates not just to it being nutritious but also to the fact that it serves other roles for us societally.

In the UK, our televisions are full of programs of chefs cooking. In the UK in the 1970s, the average preparation time for the family meal was 45 minutes; now it takes 10 minutes. So we substitute with watching cooking programs on the television. On Friday night, supermarket chains in the south of England clear the shelves at the entrance to their stores and restock them with whatever has been on the cooking program that week, because that is the night that the men will go shopping with their wives and buy the ingredients so that they can be the chef on Saturday night. This is all part of what we are dealing with in these issues of food in the more prosperous societies.

I would also like you to think about what role food has, as part of your wider thinking about the world. I was at a GECAFS meeting just a couple of weeks ago which I found incredibly stimulating and out of which came three different sorts of views of food and the world. The first is the view that food is a commodity. There is a view, which is fairly widespread, that food security is a matter of having access to food and that access can be improved by global trade: if we had much freer trade, if the World Trade Organization could get the agreements it wants, many of the issues of food security would be overcome. That plays, in some people's minds, into the idea of a globalised world, where things can move around. To a large extent it gives an opportunity for multinational corporations to be involved with global trade. For some, that is a very positive thing to be doing.

I guess that there would be another group represented in this room—particularly those who have been thinking about sustainable agricultural production, which many of us are being encouraged to do on the production side—where we increasingly see food and crop production as one of a number of elements of services from land. So it is one of a number of ecosystem goods and services. We also want our land to produce fresh, clean water; we want it to filter it for us and to have the reservoirs necessary to be able to get the water that we need in our cities. We also want biodiversity because we like to get out of the cities to watch the birds, the butterflies and everything else. Of course, we also have views about what landscape should look like—aesthetic values to do with recreation, spiritual values and so on. That is another view of the world and it is another view of the role that food occupies: one of a number of services.

A third view, which is coming through quite vocally at the moment, is that food is a right. Like any other human right, food is a right; and people have a right to determine what food they will eat. They have a right to be able to say, if the ham came from Parma, 'This is Parma ham,' and nobody else can call their product 'Parma ham,' in the same way that you have labels on wine bottles saying that the wine they hold comes from this specific region. There is a whole series of issues of so-called 'food sovereignty': who actually owns the right, as it were, to call something a particular type of food; and who has the right to both produce it and consume it?

These three views about food have within them inherent contradictions and conflicts. Somehow we need to find ways of resolving those, if we are going to move forward on food security.

The GECAFS research program was a failure at one level because, when we set it up, it was all about the three study regions; we thought that was where it was going to have impact. I am saying this because there is a fashion at the moment, certainly within the UK, to talk about the impact of your research. When you send your research proposal in, you have to say what impact it will have. When we wrote saying what GECAFS was going to do, it was going to have impact on the three regional studies—and actually it has had little impact there. Where it has had impact is at the global level and in the thinking about food policy. So you will see that the ideas that I have been talking about now come through increasingly in policy-related documents.

The slide shows one from Defra in the UK. You will also find these ideas in documents issued by FAO, the new Dutch program and the European Union and so on. So the ideas, I think, that I have been trying to get across to you are beginning to find some sort of resonance.

I would like to thank a few people from the GECAFS project, Carlton University and Arizona State, who have contributed substantially to my thinking in these areas.

I will finish with a word about the future. The demand for food is going to continue to increase—we know that—and, in terms of increased production, it will come about mainly through intensifying production. I think we are going to see a much greater emphasis on regional food security. Australia is probably large enough to be a region in its own right. But new institutional arrangements will be needed, if we are not to see those riots occurring again. Many of the interventions that individual governments made last year as a result of the food crisis actually had the opposite effects to those desired; they didn't solve the problem. We need much better institutional arrangements.

We have already had some mention of adaptation and mitigation. But the adaptation will not just be in terms of crop production; there are many other adaptation and mitigation options that need to be thought through in relation to the distribution of food, the way it is marketed and who has access to it. Finally, of course, the increasing demands that we are thinking about in relation to food, energy and water all come together to affect the way in which we are going to use our land in the future.

Productivity growth

Promoting productivity in the agriculture and food sector value chain: Issues for R&D investment

Dr Kate Grenot FAICD
Chair, Rural Research and Development Council

I would like to acknowledge Mark McHenry, who joins me here as a Rural R&D Council member. The Council is delighted to be attending this Think Tank.

My task is to bridge where we were in the previous session through to where we are now in Australia. I will have a policy orientation and I am only going to look at the past 200 years. Let's start in a fun place because this is a hard topic.

An Essay on the Principle of Population

An Essay on the Principle of Population, as it Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin,M. Condorcet, and Other Writers.

Thomas Malthus
London

Printed for J. Johnson, in St. Paul's Church-Yard

1798

About 200 years ago, about the time that a colony came to Australia, Malthus wrote *An Essay on the Principle of Population*—which Kurt Lambeck described to us as the elephant in the room.

'I think I may fairly make two postulata.

First, That food is necessary to the existence of man.

Secondly, That the passion between the sexes is necessary and will remain nearly in its present state.

These two laws, ever since we have had any knowledge of mankind, appear to have been fixed laws of our nature, and, as we have not hitherto seen any alteration in them, we have no right to conclude that they will ever cease to be what they now are ....'

Thankfully, we know that several major global initiatives are now seeking to address the global population challenge, in a context of increasing physical constraint and this is, I guess, where the issues relating to climate change and climate variability are cutting in. Let us now look at the bottom right-hand side of this map and think just about Australia. Without taking a protectionist or nation-specific point of view, let us look at our responsibilities as a policy community to do the best we can in this global context and for our domestic constituents.

So, from Malthus to Australian colonial history. We have Banks landing at Mrs Macquarie's Point in Sydney and, in 1779, writing back to England, saying, 'There is rich soil—small in comparison to the barren but sufficient to support a very large number of people. No beasts of prey. Our oxen and sheep will be okay. There are fish, grass, some eatable vegetables—a sort of wild spinage.' The country was well supplied with water—'an abundance of timber and fuel, sufficient for any number of buildings.'

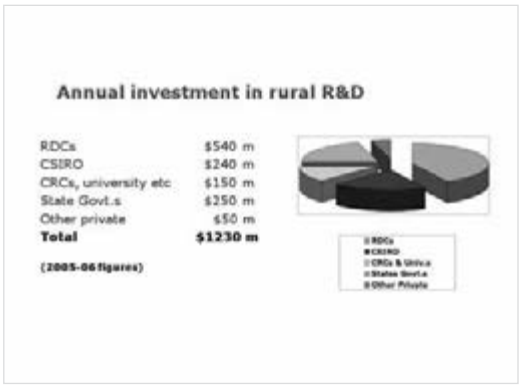
In 1788 we have a record of the first farm: 5 acres of corn in Sydney, near the Harbour Bridge, to which other things were added. Less than 200 years ago, the Governor plants a botanical garden and introduces fruit and vegies before distributing them across the country, as we spread out to farm. In that context, Australia's first scientific institution was established in 1832 by the then director of the Sydney Botanic Gardens, Cunningham, to catalogue collections—arguably the origin of Australia's systematics and taxonomy research contribution.

About 100 years later, only one lifetime ago (think of the people that you know who are now about 90), the first Australian government advisory committee for science was put together. It was chaired by the prime minister and included three ministers, all ministers for agriculture, and a statistician: how many people, how much stock, what area under management and what will we do in order to generate primary and then secondary industries? Agriculture, fisheries and forestry is now in the portfolio of the Minister for Agriculture, Fisheries and Forestry. This is where our Council fits in at the forefront of nation-building consciousness.

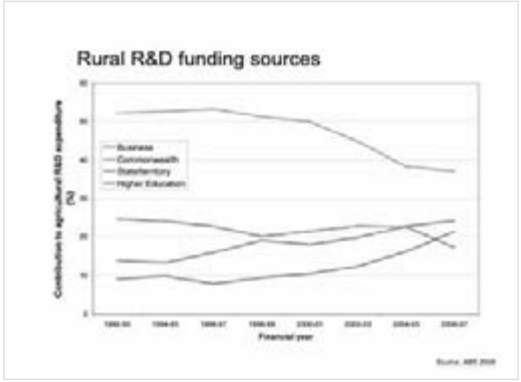
From there, we have had an evolving system. This included two periods—post Depression and again post-war—when food security was very much on the Prime Ministerial agenda. These were also times when there was the perception of 'cataclysmic risk'.

If we think back: post-Depression, under Prime Minister Bruce, the Australian parliament as we know it today was forming, the first Senate structures were put in place and provisional Parliament House was built.

Post-war, CSIRO was established, as was the international Food and Agriculture Organization (FAO).



Today we have a complex $20 billion National Innovation System, that also supports health, ICT and many other sectors or our economy. The agriculture, fisheries and forestry component has retracted to about 7-8 per cent of that system over 90 years. That is where we are now. Only 2-3 per cent is directly what we call 'farm sector driven'. So, as you consider productivity objectives, it is important to note this national, historical trend.



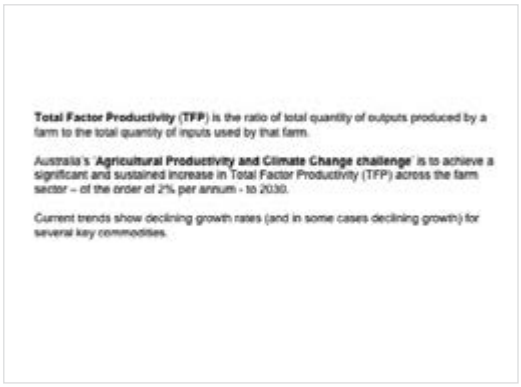
About $1.6 billion out of Australia's $20 billion national innovation system is currently spent on rural R&D. Within that, about $½ billion is spent through the Rural R&D Corporations, which sit within the AFF portfolio. Most other funds are managed in other parts of the Australian government. We can advise the Minister about them, but we will

need a whole-of-government approach if we are to optimise the benefits that can flow from this collection. We know that state and territory expenditure on rural R&D has been declining. We know that business expenditure has been increasing, but it is still very low relative to OECD averages. We can see that the Commonwealth contribution has been in relative decline. We can see that higher education expenditure has been increasing, but the increase in rural fields of research has not been as high as increases in other areas of research endeavour.

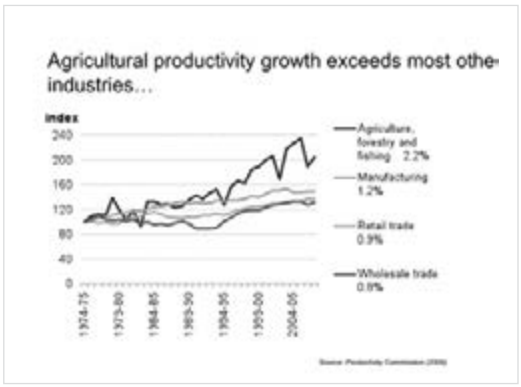
For example, overall growth in gross expenditure and R&D in this country for the period 1996-97 to 2004-05 was about 40 per cent; in agricultural science it was about 22 per cent; and in Earth sciences there was negative growth of about 19 per cent.

So, in that context, another national advisory council has been established this year—the Rural R&D Council. We have an advisory role to the Minister for Agriculture, Fisheries and Forestry on matters of R&D, in order to do the things stated on this slide. Specifically, we are to develop a National Strategic Rural R&D Plan and, with that, a performance monitoring framework. I offer that to you and to the Academy as an opportunity. We are in an establishment and consultation phase now. The next 12 months will be a planning phase. After that, we will have to go into early implementation. In terms of system improvement, there may be some 'low-hanging fruit' that can be harvested along the way. We are operating in a pluralistic, busy policy space. But, if there are outputs from this workshop or any other Academy initiatives that are relevant to this issue, we have an opportunity to consider them and possibly take them forward. We seek to work cooperatively with others to advance these issues.

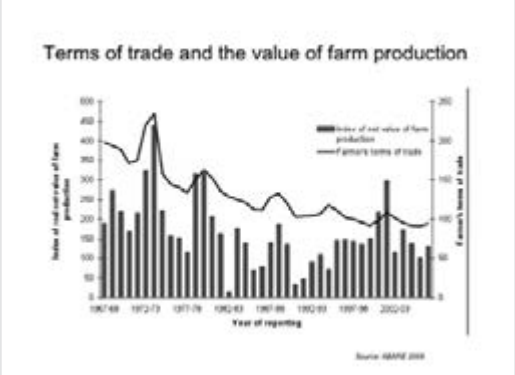
We have been working with ABARE, the Bureau of Agricultural and Resource Economics, to understand the productivity challenge in greater detail.



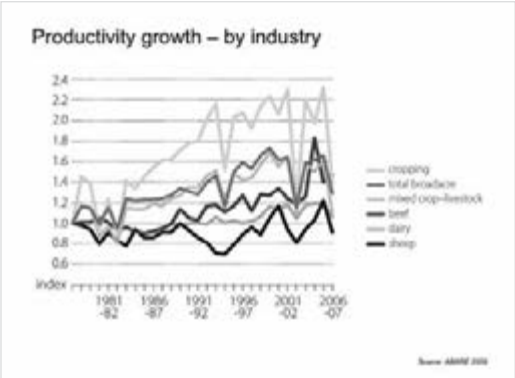
ABARE measures total factor productivity, a ratio defined in this slide. They tell us that we need to greatly increase productivity over the period ahead.



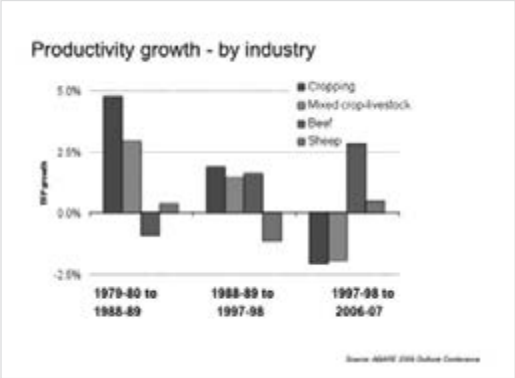
However, current trends show declining growth rates and, in some cases, declining growth for several key commodities.



Some argue that agriculture was doing quite well relative to other industries.



But in terms of trade we have been in decline. Many of the gains in net value of farm production were, in fact, offsetting more difficult conditions for those who were selling product. We also know that there is huge variability in these data across primary industries, seasonally and across time, depending on environmental conditions—and that also needs to be taken into account. But, generally, there is concern that the overall trend is towards a slowing in growth rate.



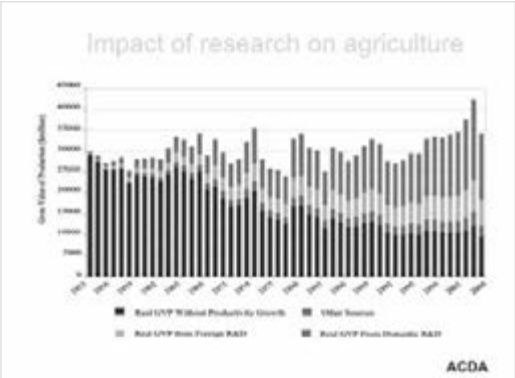
This is another slide that looks at how, across different industries, productivity is increasing or decreasing.

This takes us back to our consideration of the scale of the challenge. Whether you take an orientation that is poverty related or commercially driven, we know what we have to do 'double the output and halve the inputs' over the period ahead, and that's a big, collective challenge.

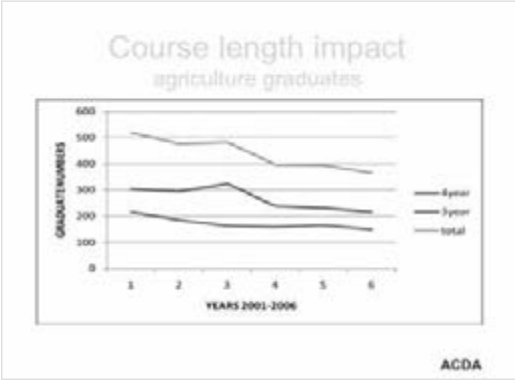
ABARE tells us that they think there are three important ways to increasing productivity: increasing adoption of currently available innovations; adoption of new innovations; and industry exit of underproductive farms.

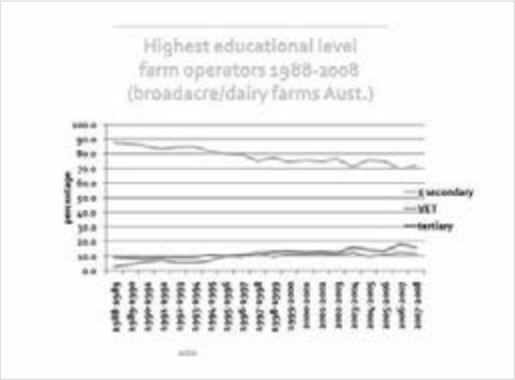
In 2007 the Minister signed off on some general national rural R&D priorities. These are currently used alongside the national research priorities as a mechanism to monitor rural R&D activities. The Rural R&D Council starts with these as a given.

This slide lists some general issues as we consider the application of these priorities. There are questions about the appropriate extent of government intervention. There is the cross-portfolio challenge of establishing a coordinated national approach, given the extent of variation across commodities. There is a range of industry structures: some are statutory authorities in the corporations model and some are services bodies with a strong marketing orientation. 'Trends in the ownership of rural assets' is a big one and, of course, varies by industry. We had a reference previously to multinational corporations and increasing offshore ownership of domestic assets. What will that mean for the distribution of production around the planet in the future? This brings implications for intellectual property. There is pressure on land use. We have heard reference to 'energy' and I would add to that mining. And the rest of the world's science base is accelerating faster than ours in this field at this moment. There are also significant concerns about our capacity for global technology transfer—wonderful intent, but a glaring issue.



In fact we have a looming capacity deficit. These are data from Mullen and Crean who have reported a serious decline in enrolments in agriculture-specific courses.

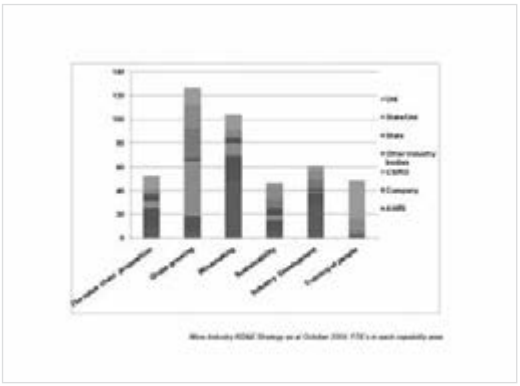


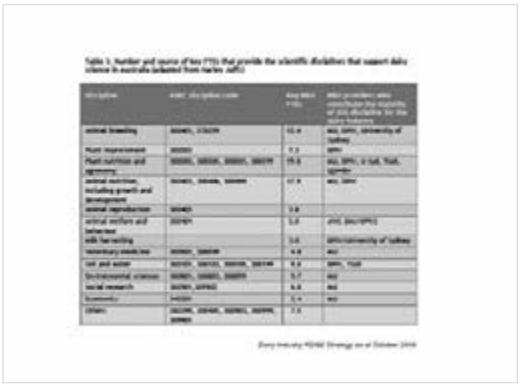


So while we have seen some growth in educational attainment in the AFF sector between 1988 and 2008, if the previous slide is correct, then that rate of growth will slow.

Thankfully, we have a major government intervention at the moment, led by the Primary Industries Ministerial Council. This Council of state ministers and the federal minister is currently setting in place 14 primary industry strategies and seven cross-sectoral strategies, one of which is climate change and variability.

The Rural R&D Council also will build on this framework. I would like to talk to you about how we can do that in terms of science. But, before I do, I need to raise with you the issue of systemic adjustment, which Clive Noble touched on. It goes to the end of his speech where he talked about generation XY's view of the world in the future. I would like to draw your attention to how the Future Fund approaches the long-term adjustment question. The Fund is also seeking to serve commercial and public-good objectives, to balance long-term interests and short-term claims and to enable systems to adapt without increasing risk. They restated their beliefs and principles in doing this in April 2009, in response to recent global financial uncertainty. They believe in a diversified allocation across classes for their assets, a focus on long-run total portfolio risk and dynamic management of the portfolio.





Our portfolio, through the National Research, Development and Extension Framework, will be generating R&D capacity and performance metrics over time. It will provide a mechanism to identify food system vulnerability concerns and to monitor the success of our attempts to tackle particular areas.

We know that we have great skills in this room and elsewhere—competitive skills at the moment—to do so.

And thinking globally, I strongly believe that the scientific community is by far the best positioned and equipped to build international linkages in rural research, complementing our strong commitment to international (aid-oriented) agricultural R&D. We would be delighted to work with the Academy on the internationalisation issue. We note, for example, the history of Academy leadership in the establishment and maintenance of Australia's representation in international unions.

What, then, are the key issues for today's Academy Think Tank? How do we ensure that we have the right range of projects to ensure access and collaboration with leading international groups to access international funds, knowledge and markets and to jointly address global needs? What are the instruments that will help us to maintain and, where necessary, develop world-class science and technology platforms, multidisciplinary capability and so forth. And how to keep world-class researchers rewarded—to keep you enthused, to help you build your groups, your labs, your careers? How do we make sure that this RD&E framework integrates with developments in natural resource management in particular, given that the resource portfolios are typically separate from the primary production portfolios at both state and national level? How do we work across value chains in a manner that distributes risk and increases reliance on renewable resources?

And why the Academy? Firstly, because scientists have a critical role to play in policy debate—we must ensure that basic scientific principles are applied to the data on which policy relies. Secondly, I go back to Lindblom, who in 1959 in his seminal work *Muddling Through* talked about the 'rational approach to policy development', which of course the Rural R&D Council will endeavour to achieve. He concluded that pluralism has an important role to play, especially where a collection of well-informed identifiers and potential effectors of change pursue policy objectives of primary importance to them. So please join with the Council—we are comfortable with the notion of a pluralistic approach, in seeking to promote productivity in the agriculture and food sector value chain in Australia.

So please note, High Flyers, that you have, from the Rural R&D Council's perspective, support for your role in this process as research scientists and social scientists. We will be doing all that we can to support your endeavours.

Discussion

Question: Christine Storer, Curtin University. I guess your key activity at the moment is setting plans and priorities. Can you give us some outline of where you are with that and how that might impact on us?

Kate Grenot: The rural R&D system, through the RD&E framework, has in place highly evolved priority-setting processes, which involve practitioners at farm level, scientists and research managers. At the micro level there is a high degree of capability in our system of leadership to develop what the Council believes will be very robust priorities for a particular industry. The issue that we are facing is how we get system-wide priorities. We have the 2007 Rural Research Priorities at present and they should be the ones that we use for the next 12 months or so.

Question: Jonathon Sobels, Flinders University. Given that one of your key goals—I think it was point no. 3—was to do with taking the national resource management across into agricultural production, can you give me some idea of why the Land and Water Resources R&D Corporation was folded?

Kate Grenot: I will give you a personal view. The Council has no formal view on this. This decision was taken separately to Council deliberation. I was advised of it, but the decision had already been made. I phoned Michael Robinson and we had a chat. The Council is very supportive of the climate change strategy, particularly its being well positioned and secured.

My interpretation is that, even though Land and Water Australia and also the Rural Industries R&D Corporation were separately legislated for in the Primary Industries and Energy Research and Development Act that established all the other R&D corporations, there has been a timing issue here. With the environment matter—the climate change department, the energy related department, now investing such large amounts money in this system and the issues of land and water now being dealt with in so many ways—I think there came to bear enormous pressure on LWA. It may be that what we are all dealing with here is, as Kurt Lambeck described, a confluence of activities. That has crept up quite quickly in the last three to five years, even in the last 24 months, and LWA is a casualty of that.

Question: Bob Williamson, University of Melbourne, but also, in this context, Secretary of Science Policy for the Academy. The Academy will do its best to take the conclusions of this meeting forward to government and it very much appreciates the way in which you pointed to the need to do so. But you mentioned the need for a whole-of-government approach and a state-Commonwealth approach. I come from the medical research area. The Academy and, indeed, the sector have a great many policies, many of which have been implemented. But one of the things that we have failed to do has been to get a whole-of-government approach. Our dealings for the most part are with Minister Carr, although to some extent they are also with Minister Gillard. Here we are dealing with a different sector. What tips do you have about how we might be able to achieve a whole-of-government approach in this area?

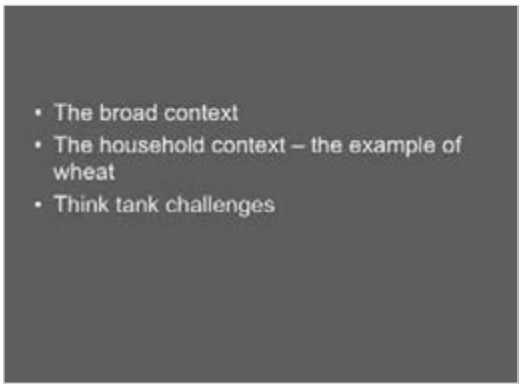
Kate Grenot: At this precise moment, Kurt Lambeck may be able to answer this question better than I can. We are fortunate to have the Chief Scientist on our Council, and I know that Professor Sackett is keen to ensure that we achieve whole-of-government coordination. The practicality is that our Minister has a remit that requires a focus on pre-farm gate. Post-farm gate is largely the remit of Minister Carr. Capacity issues go to the remit of Minister Gillard—and that is before you get to climate change and so on and so forth. So, through the Office of the Chief Scientist, we have requested consideration of the establishment of a formal mechanism. There are many coordinating mechanisms at a meta level, but currently there is no national mechanism. We hope to be able to report back to constituents on that soon.

Chair (Sue Meek): Could I just ask a follow-up to that? How does the RD&E framework, which Clive Noble referred to, integrate into the national activities?

Kate Grenot: What we have—and we have had this consistently, probably for about 20 years—is wonderful integration nationally at the industry-specific level. This is enabling the Rural R&D Council to work in the coordination space. The framework has the potential to be a very effective national asset. It identifies areas such as Victoria and dairy, and South Australia and wine, and it distributes the development tasks around the nation.

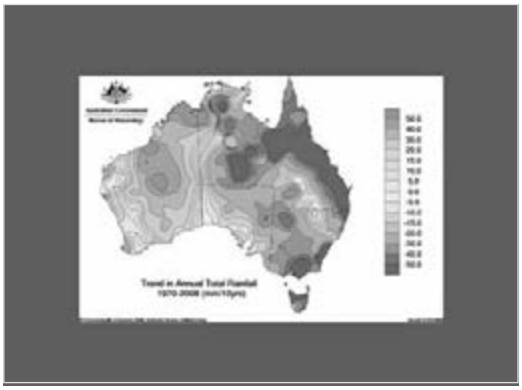
Resilience and agriculture: the human dimensions

Professor Lesley Head FAAH
Director, Australian Centre for Cultural Environmental Research (AUSCCER), University of Wollongong



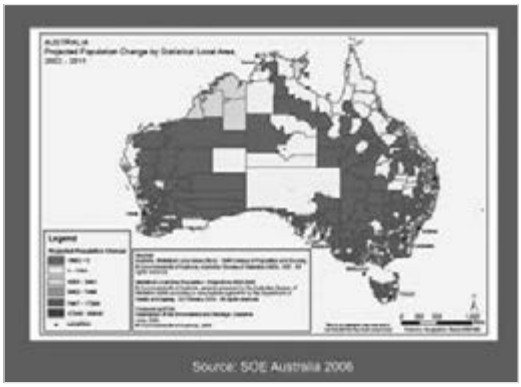
I will spend most of my time addressing the household context and use the example of wheat from our current research project. Like the other speakers, I will end with some challenges for the Think Tank.

I am going to stretch the metaphor of the tank, seeing that we are all here to think about it.



We know the background very well. The trend in total annual rainfall over the last few decades is very much a drying trend through most of our agricultural areas—the Ord River region excepted—particularly in the east. This is

projected to continue, with some regional variability and quite a lot of uncertainty about the specifics, which need not concern us.



I would like you to compare that to the *State of the Environment* report projection of population change through to 2011. These are nationwide population trends and projections. The red areas on this map show the population decline and they correspond very closely with most of our good agricultural areas. It goes with population intensification in the coastal mega cities of the east, south-east and south-west coasts. The number of farmers is declining at a rate of 2.2 per cent per annum, and over the last few years there has been a considerable increase in median farmer age.

It is well known that the regions experiencing the greatest demographic threat are the dryland sheep and wheat regions, which are precisely those areas that have been identified as highly vulnerable under climate change scenarios.

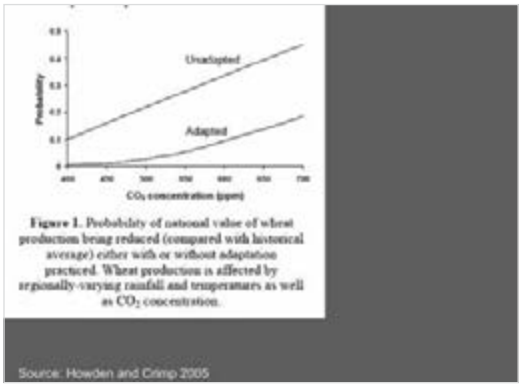
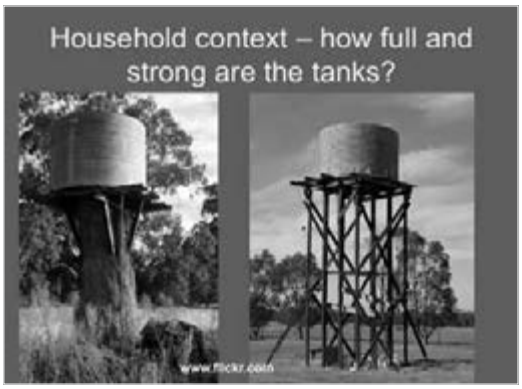


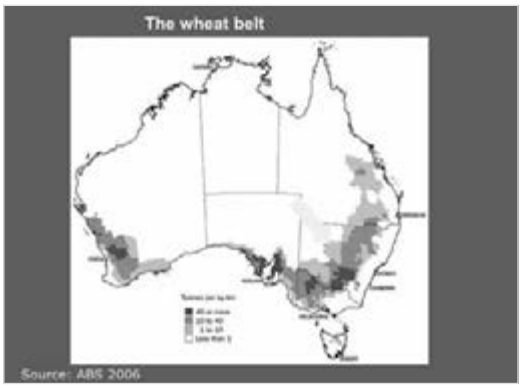
Figure 1. Probability of national value of wheat production being reduced (compared with historical average) either with or without adaptation practiced. Wheat production is affected by regionally-varying rainfall and temperatures as well as CO_2 concentration.

Into this context go our ways of thinking about adaptation measures. Adaptation measures in the form of different varieties or changed planting windows have been modelled to reduce the impacts of climate change by almost 50 per cent. This graph shows the probability of wheat production being reduced, either with or without adaptation,

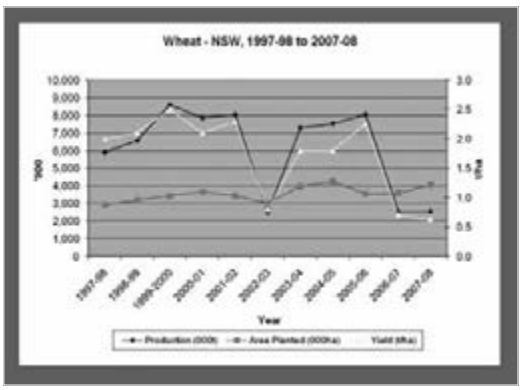
under increasing CO_2 concentrations. This is an agronomic view of what 'adaptation' is. The top line is unadapted and the bottom line is adapted. I am going to focus most of my attention on, and ask you to think about, what is the social distance and what are the social processes that happen in between those two lines? What is going on in farming households to get from one of those lines to the other?



I am using the household context of wheat farming during the 200607 seasons, a period of very great drought. Here I acknowledge my colleagues Jenny Atchison and Alison Gates. Our work joins a growing body of literature that argues that adaptation studies in agriculture, particularly of the developed world, have focused on agronomic and top-down perspectives. These are important but they need to be fruitfully complemented by more fine-grained social and cultural perspectives that pay attention to how this is negotiated in everyday life. To take the wheat example in Australia, adaptation to climate change will be undertaken by the almost 30,000 farmers who grow it.



We are using methods in the ethnographic tradition to show how farmers filter and manage many different risks and many different expressions of climate. It is really important, I think, to resist monolithic constructions of what climate change and even adaptation are, before they become too entrenched in the literature. We have had some really good examples of that this morning. So our case study comes from southern and central New South Wales. Again, it would be a different story, even within wheat, if we went to northern New South Wales to the durum pasta wheat areas and to the south-west of Western Australia. So, variability is an important and big part of this story.



We know that drought is a regular feature of Australian wheat farming in particular, and of farming generally. The long cycle of drought over the last seven years or so, with extremely poor harvests in the summers of 2002-03, 2006-07 and 2007-08, is unusual within living memory. It does provide a research window onto the climate change scenarios of more frequent droughts: how are farmers experiencing this process? So I want to consider whether climate change is just another risk for Australian wheat farmers and how it can be incorporated into existing risk management strategies.

Between December 2006 and December 2007, we worked with 25 farming households in the southern part of the New South Wales wheat belt. We also had examples where we could work with several generations of the same family working on the same land, so we could look at successional issues, generational differences and so on. You will remember this time also as a period of shift in the national conversation about climate change. We are talking, as it happened, not only about a period of drought but about the period of the release of the *Stern Review*, Al Gore's movie (*An Inconvenient Truth*) and, of course, the lead up to the last federal election.

Here is one of these farmers. Somewhere in the New South Wales wheat belt, Anthony looks and talks like any other stoic and laconically good-humoured farmer dealing with the vagaries of the worst drought in living memory.

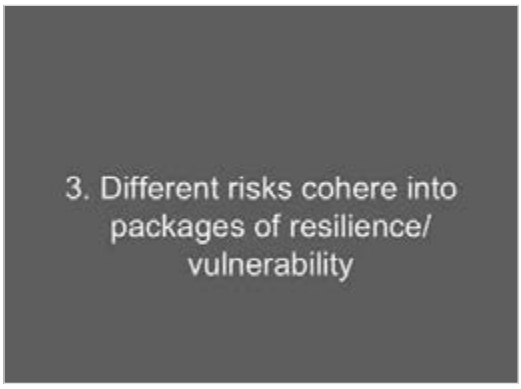
But when Anthony rises early he turns on the espresso machine with one hand and the computer with the other. Before the coffee is brewed, he has checked the price of wheat on the Chicago Board of Trade website along with the weather forecast and a host of other domestic financial information. It's a morning ritual repeated with minor variations amongst many of the farmers of his generation.

I am going to summarise six points from our work that hopefully will stimulate some discussion. The first point is that the local or 'household' context is not an isolated parochial context; it is very much embedded and networked into the global situation.

There are very diverse approaches to risk. We named these on a continuum between what we called 'strategic' and 'reactive' approaches to risk at the household level.

At the reactive end of the spectrum, Susie, who lives at the far western, and thus the driest, edge of our study area, joked that she and other farmers should belong to Gamblers Anonymous because of the inherent risks in cropping. In positioning herself as the victim of external factors, she is at one end of the continuum of risk. Susie says, 'We may as well plant our money in the ground because at least at the end of the year we can dig it up again.'

At the other end is Charlie's family, who exemplify what we call a more 'strategic' approach to risk, where risk contains elements of opportunity, particularly business opportunity. Charlie's dad says, 'The weather is just a risk that you've got to manage because that's just what happens if you're farming,' and Charlie's mum says, 'When there's a certain period of anxiety about the future then there's always new ideas that come out of that.' So we have very different perspectives here.

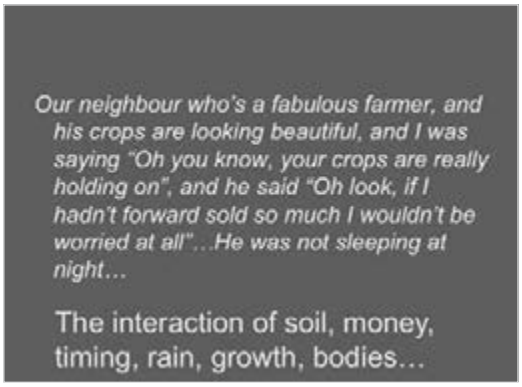


We found quite clearly that different sorts of risks tend to cohere into packages, if you like, of resilience and vulnerability. So, while they vary with geographic, socio-cultural and economic factors, the approaches to climate risk more or less parallel approaches to financial and other social risk.

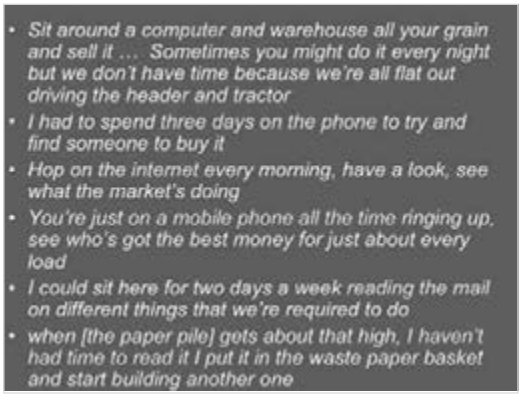
The reactive farming households tend to be further west, in the drier country. In the wheat context, they are very much pinned to rail as their transport option. They tend to use a farmer model of their identity and their goals, compared to strategic farmers, who think of themselves more as a business, particularly a farmer business. The reactive people tend to see debt as a burden, whereas strategic households tend to see debt as a development opportunity. Strategic households are much more likely to have an upcoming generation, like Charlie himself, being tertiary educated either in agriculture or often in a business context related to agriculture.

So there are packages here of vulnerability and resilience tied very much into the need for mental health and related social support services, as Margaret Alston and her co-authors have detailed in their various reports on the social impacts of drought; there was one in 2005 and one in 2008. So it is a bit of a mixed story: both vulnerability and stress, but also enormous strength and capacity. We need to be very careful in trying to generalise from that.

But it is connected to the fact that these big picture things that we are talking about—climate change and drought risk—are experienced as just everyday experiences. In fact, they have expression in individual bodies, if you like. A good example of how this all interacts to bodily effect is provided by the forward selling of 2007. The promise of early rains encouraged or prompted many farmers to forward sell their crops—encouraged by the banks, it has to be said—and, when that promise was not fulfilled, it led to a great deal of stress.



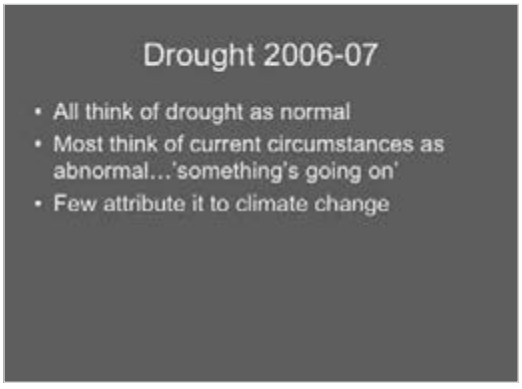
Here, one stressed-out farmer, talking about her neighbour, said: 'Our neighbour who's a fabulous farmer, and his crops are looking beautiful, and I was saying "Oh you know, your crops are really holding on", and he said "Oh look, if I hadn't forward sold so much I wouldn't be worried at all." He was not sleeping at night.' In fact, the woman who was telling us this was speaking in the context of her own husband who had chronic headaches and health problems. So there is very much an interaction of physical and embodied processes here.



In terms of the everyday situation, we need to remember the costs at the household level of juggling it all in what is now a deregulated industry. But the particular cost is to spend a lot of time on the phone and the internet. So it is the cost of information-processing in a farming household as well as getting out into the paddock, as these quotes indicate. People talk about the build-up of mail, and we all know that feeling with mail in our email boxes as well. So there is quite a lot of stress, work and labour in the everyday context in just processing all this information. While they are certainly globalised in their sensibility, the farmers' management of risk and uncertainty is embedded in the social intricacies of their daily lives.

When we come to the perception of climate and drought, it is really important to remember that, if you are a farmer in the New South Wales wheat belt, the key time frame through which you experience climatic processes is the season: the timing and intensity of the autumn break, the reliability of winter and spring rains, and the presence or absence of frost at key times of the year.

This is not to say that these farmers do not have a good handle on long-term climatic processes and the concept of long-term climatic cyclicity; they certainly do. But that is separate to the time frame in which they have to make decisions, such as: 'When am I going to plant; how much am I going to plant; how much fertiliser do I need to buy for the next season?'

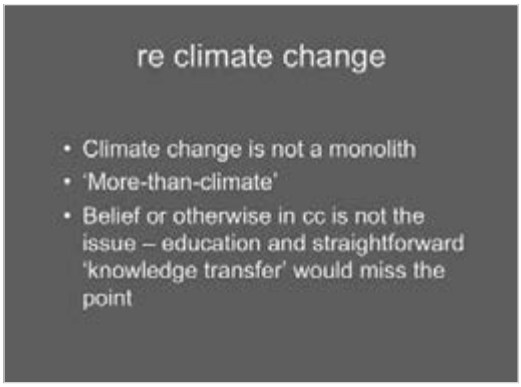


Because we are in this emergent time of national conversation, we took the opportunity to ask the farmers what they thought of climate change, if it did not come up in our conversations generally.

This group of farmers all think of drought as normal. It is very well established in their psyche that, if you are a farmer, drought is something that you live with. Almost all of them think something different is going on at the moment and that these circumstances are abnormal, even for a drought. But very few of them are willing to attribute it unequivocally to climate change. So, in that respect, they are just like all the rest of us, in that we are experiencing climate change as something 'more than climate'. We really need to think of getting away from a monolithic view of climate change. It is now a much bigger package than just climate. It includes a public discourse, it includes potential financial instruments and it includes a shifting global political context. The thing we are all adapting to now is a hybrid entity that somehow comprises 'more than climate', and in much the same way that we are gathered here today—we are not here directly because suddenly it got drier or hotter; we are here because there is a political landscape as well as a climate landscape around the issues.

Interestingly, there was no direct correlation, if you like, between whether the strategic farmers or the reactive farmers were more likely to believe in climate change. There was quite a lot of diversity of view about whether climate change was actually happening. For example, our strategic farmer on the left of the slide who believes in climate change says, 'There will be lots of opportunities, but you just don't know with the climate what's really going to happen', whereas a strategic farmer who does not believe in climate change says, 'A lot of people use it as an excuse for failure.' The reactive one in the bottom right says: 'Well, Mother Nature overrules everything, so it's not up to us. We can't do anything about it.'

Let me wrap up with some points of provocation and discussion.



We really need to think of climate change not as a monolith, a big single thing that will hit us in the future, but as a complex set of processes in which we are entwined already and in which these farmers and we as policy-makers, scientists and so on are entwined. One way to think about this is that it comprises more than climate, and British geographer Mike Hulme has written quite extensively on this topic. So, belief in climate change by farmers is not the issue. If we had a very straightforward approach in our outcomes in terms of education and knowledge transfer we would miss the point. It is not just our telling people what is going on.

In terms of cultural resources and cultural research, I hope I have demonstrated something of the value of more fine-grained social analyses in the cultural geographic and anthropological traditions. There is a major methodological issue, as geographer Diana Liverman has raised, in the context of the IPCC: how do we scale up these very fine-grained localised studies into something that matches the scientific scale of national and global modelling? I think Peter Gregory's talk started to identify those issues as well.

It is very important for us to contribute to identifying the existing cultural capacities in agricultural Australia. We can identify and name vernacular capacities and resources—great strengths that are already there. I think we really want to get away from a victim mentality of agriculture. For that reason, it is really interesting to note the Wentworth Group's release this week of the report on terrestrial carbon, where they were also trying to find a constructive place for agriculture to contribute to the solutions of mitigation. Politically, I think that is a very constructive thing as well.

All the improvements that we are talking about—environmental restoration, so developing agricultural productivity without sacrificing or making worse the degradation that is already there—are very labour intensive. So how will that match an inland that is becoming de-peopled? What support will be needed for a peopled inland?

As most of our population continues to huddle on the coast with less and less shared experience of agriculture, how might we engage urban populations to make this a shared responsibility, since the food and fibre are being produced on our behalf? How can we make this a total engagement for the nation?

Discussion

Chair (Sue Meek): Lesley has given us some very important contextual information, and it illustrates that science alone is not sufficient to analyse and make decisions on how to respond to complex issues like climate change.

Question: Sandra Eady from CSIRO Livestock Industries. I was interested that the difference you found between the attitude to risk to their industry—the 'reactive' and the 'strategic'—was geographically different. I would have thought you would have the same range of attitudes within a region, but not necessarily such a strong difference between the regions. Is that because the wetter, more productive areas are encouraging the return of young people, who perhaps are showing more innovation, or is it because those businesses have a greater financial capacity for exploring R&D options and innovation?

Lesley Head: I have generalised fairly grossly. I suppose the caveat should be that we were trying to talk about these as approaches rather than as households but, to personalise the point, we zoomed into particular people. I hate to sound like an environmental determinist, but there is a key sort of congealing of a number of different factors in the

wetter areas. Transport is key. Farmers in the wetter areas have lots of options. They can put their wheat in a truck, send it to the feed mill down the road and sell it there or direct sell it to some specialty millers. They have lots of different options that relate to their locational advantage; whereas the western farmers are still pinned basically to the rail network because of the cost of road transport. So it is very much financial. It is not locational in the sense that, because it is drier, these are the attitudes but in the sense that this is where the economics of transport and moving things are active and also what range of other opportunities exist in this region for selling into the domestic market. So a lot of wheat in the eastern area is going into stockfeed.

Question: Kirrilly Thompson from the University of South Australia. I really enjoyed your talk. In one of your final slides you noted that the issue is not whether farmers believe in climate change and you suggested that the solution was not just to keep throwing scientific information at people. I am really interested to know what you think is the key issue at stake in creating behaviour change and climate adaptation.

Lesley Head: I do not want to suggest that it is not important to keep talking about the science and having a broader education of the general public and not just the agricultural public. I suppose I am trying to emphasise what our research shows: the enormous sorts of structural issues of changing your everyday life are extremely complex and it is not just about getting 'head knowledge'. We all know that air travel is part of the problem of climate change—most of us flew here. We have not found a way to structure academic life that does not depend on academic mobility. So it is not just an issue for farmers; it is an issue for all of us as to how we link this 'head knowledge' with the structures of everyday life as well as political and economic life.

Question: Michelle Watt, CSIRO, Canberra. I wonder whether you could go back to the term 'adapted'—you showed the graph at the beginning of your talk. How would you define that from the point of view of these Australian farmers that you surveyed?

Lesley Head: I do not want to dodge the question, but there is a major debate to be had about what we mean by 'adaptation'. There is a huge conceptual debate in human prehistory and in biology about what 'adaptation' means and we are only starting to have that in the context of adaptation to climate change. I think it is a term that has been thrown around. As a number of authors have written recently—Steve Dovers from the ANU is one of them—we have not really started to engage with what that concept means. If I were trying to map out what we were trying to get to, I probably would not use the term 'adapted'—and 'resilience' is another problematic term—but start to move towards terms like 'resilience', 'social and environmental health', sustainability'. I do not think we should be aiming to ever get to a state that we call 'adapted', because in an evolutionary sense that is just where we happen to be at any point in time. We should not think of our goal necessarily as 'being adapted', but we should talk about a range of more flexible and healthy sustainable approaches.

Question: Scott Chapman, CSIRO, Brisbane. Can you comment on the generational views? A lot of the grain-cropping areas, particularly in eastern Australia, were populated and developed quickly during the 1950s, '60s and '70s; and the '60s and '70s, in particular, were decades of good rainfall outcomes. When you talk to farmers in those regions—in Kingaroy, for example—their long-term experience is from the '60s and '70s. I do not know whether they are starting to accept now that 'normal' is what we have had in the last 20 years. I just wonder whether the older generation of farmers have adjusted their view of 'normal' and whether the younger generation of farmers now think 'normal' is what we have had for the last 10 or 20 years.

Lesley Head: This is a really interesting issue as well and there could be lots of research to be done on that topic. In my field-work area, the drought that the old timers hark back to is the mid1940s drought, which was the last time there was a total failure of the wheat harvest. There was some interesting dialogue between grandfathers, fathers and sons. I suppose, as a generalisation, the younger people are usually better educated in a formal sense and so are taking on board climate change more as part of the new reality. However, referring to the slide I showed with 'this is a drought but something else is going on', a lot of that is coming from the older people. They are harking back to either their own experience or that of their fathers and grandfathers. So I think a shift is happening. Our field-work happened to capture a very dynamic time and it will be interesting to go back in a few years time and look at these longitudinal studies; they will be really important as well. Like everyone else, I think they too are trying to make sense of it. This is why I find that the political rhetoric around a lot of farming is quite at odds with our experience. There is not resistance to climate change and there is not this huge number of climate sceptics out there in the agricultural community; it is very different to the political rhetoric. But, in terms of sifting their experience, this group is quite open to the fact that, yes, something could be changing.

Question: Andrew Moore, CSIRO. Your talk had in it an implication that rural depopulation was, in itself, a bad thing. But it is something that has been going on for decades in Australia and much longer in, for example, Europe—it is a worldwide phenomenon—and nobody who has invested enormous sums of money into it, including Europeans, has found a way to slow the process. At the same time, we have been talking about the need for agriculture to produce twice as much with half as much input. I guess the harsh way to ask my question is: why is labour the only resource that is not going to be expected to be used more efficiently? Following on from that, perhaps the social research agenda should start finding viable social structures in a less-populated rural inland rather than trying to find ways to preserve the existing population numbers.

Lesley Head: One obvious solution is that we can move to corporate farming, as is happening in many areas. In terms of 'labour intensive', I probably did not make it clear enough that I am not suggesting that farming itself needs to become more labour intensive but that, if we are going to match the sort of environmental restoration response to the climate change challenge, in some ways we will need more people living and working in rural areas. They may not be working on farms, but I think the exacerbation of the continual flight to the cities is a sort of conceptual abandonment of the inland that I think really needs to be thought through carefully. I am not suggesting protectionist regimes where we pay people to maintain landscapes or whatever. Certainly, you have thrown down an interesting challenge for social research: what structures might be useful?

Question: Kate Grenot, Rural Research and Development Council. To complement Lesley's response, there is something called the National Rural Advisory Council which comes from 1992 legislation. Currently it is seeking to shift its focus from exceptional circumstances traditions, which is about preserving traditional models, towards more innovative solutions.

Managing our agricultural landscapes sustainably

Dr Michael Robinson
Executive Director, Land & Water Australia

My task is to talk about agricultural landscapes and their sustainability. What are the challenges for us?

I will unashamedly use and point out the mural at the bottom of this slide. This is a mural by Annie Franklin that was painted for Land & Water Australia. It really has provided for me and the organisation a vision about what we want for our agricultural landscapes. It shows the diversity of landscapes right across Australia coexisting happily together, which I think is something that we should bear in mind. I will be using slices of this throughout my presentation.

We can use that as a vision. So I will articulate a vision of where we actually want to go; then I will try to outline at a pretty high level what the challenges are to that sustainability; and I will pose to you: do we, in fact, have a burning platform? I think today is really an appropriate time for us to be having this conversation, and I thank the Academy for putting it on. But I also thank all of you for being here to contribute because what comes out of this, I have no doubt, will have an impact. Several people have approached me already, saying, 'We really want to know what's going to come out of that two-day Think Tank and take it on board.' I also want to make a couple of comments about improving the research system, because I think that is timely in our rethink and it certainly will feed into Kate Grenot's work.

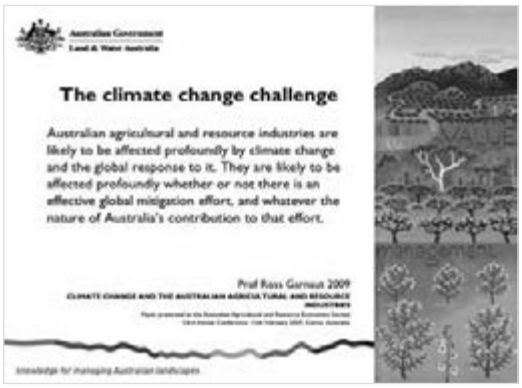
My view is that it is pretty hard to dispute this sort of vision and it is pretty high level, but I want to point out some particular aspects of it. While I am here today to talk about the environmental sustainability of our agricultural landscapes, I do not think you can have that full conversation without talking about the social sustainability or,

indeed, the economic sustainability of that. They are all integrated. It is very difficult to have that conversation in isolation; it is also very difficult to actually put it into practice in isolation. So, if we are talking about environmentally sustainable landscapes, we need to keep our eye on social sustainability and economic sustainability.

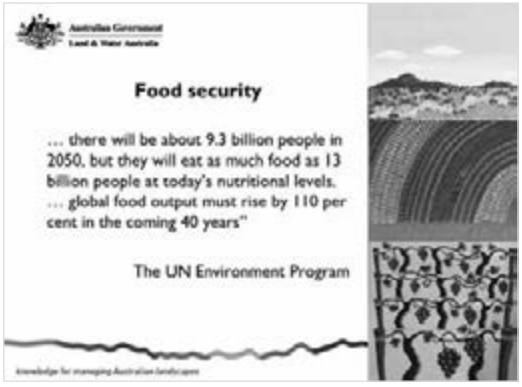
'Economic sustainability' is about profitability. It is not just about productivity growth. You can have great productivity growth and still not be profitable. That is probably something about which we will be challenging our agricultural industries, particularly with the introduction of a Carbon Pollution Reduction Scheme (CPRS) and higher input costs in the future. We might get productivity growth, but will we get profitability?

The next point I want to make in this vision statement concerns the term 'valued'. I do not think, as a community— whether a regional community, the Australian community or, in fact, the global community— we have really valued, put a value on or understood the value of, our rural and regional landscapes and our production systems. I will come back to that throughout the talk.

The final point here is about landscapes. I think we need to have a conversation about landscapes as opposed to a particular farm or a particular bit of conserved land. We should be operating and thinking at the landscape level, and I will return to this theme throughout.



To kick off thoughts of a burning platform, here is a quote from Ross Garnaut earlier in the year at the AARES conference in Cairns. He is really saying that Australian agriculture is facing some serious challenges, not only the challenges that climate change will bring us but the challenges around our responses to it—our responses, regardless of whether they are global or domestic. He is really talking about the policy response. In many respects, I believe that as a farming community we will not have to worry about the physical impacts of climate change for the next 10 or 20 years, but we should have an eye on the policy response right now.

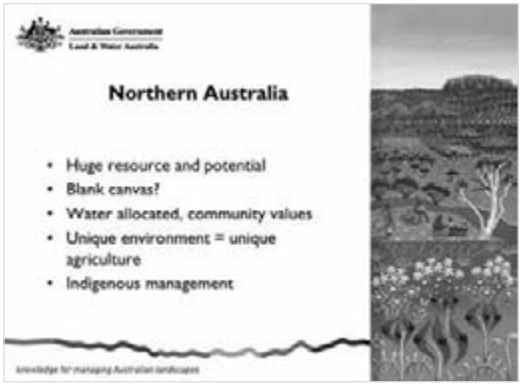


We have heard plenty of talk about food security today, so there is no need to go over this slide again. Whatever the correct number is, in the next 40odd years we will need to increase our food output in the order of about 100 per cent.

As for the rest of the burning platform, most of these have already been mentioned today. Surface water availability probably has not been mentioned yet. We are going to have declining availability of surface water, in large part due to increasing urban demand for water—and we know that agriculture is not winning that tug of war. But also, with climate change, the distribution of water is going to change in connection with where and when it falls across the landscape. 'Groundwater availability and quality' is a major issue around the world. Certainly, if you visit China, you will hear about the issues they have with groundwater there. But we have our own issues here, where we really have no good understanding of the resource. The over-allocation issues that we face in this country are enormous.

We have heard also about the availability of arable land and how that is declining rather rapidly. That will be an issue for us, whether it is urban encroachment or biofuels. We need to have the debate about whether it is more important to grow biofuels or food on agricultural land. 'Soil loss and quality decline': there is plenty of evidence of that around. 'Nutrient loss': do we have enough nutrients? Are we just exporting nutrients off our agricultural land and do we have enough fertiliser to replace it; and do we want more fertiliser and, if so, what are the costs of that? We have also heard about R&DE investment. This is more of the context that says: 'Gee, doubling our food output in the next 40 years is going to be hard, with all these trends or supporting factors going the wrong way'.

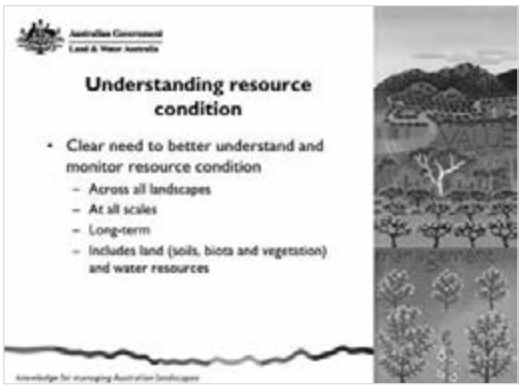
Now I will give you just a summary of the natural resource challenges.



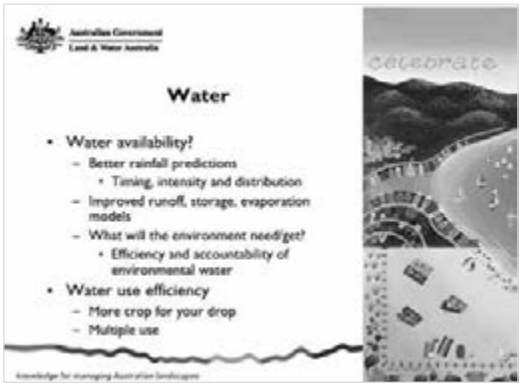
I decided to start with northern Australia, in large part because it is a blank canvass. There is huge potential up there, or so we think or imagine. I could put up a very complex diagram of the ecosystem, with all its fluxes and flows. In order to develop it—that is, if we want to develop it—we need to understand all those fluxes and flows.

But the point here about water allocation is really important. There is a growing acceptance, particularly I think within the scientific community, that all the water in northern Australia is actually currently allocated—small 'a' allocated. It is all going somewhere for some function or purpose. Even if it goes out to the ocean, it is serving an ecosystem function. It might be supporting the shrimp or barramundi industry or looking after the dugong. It is all serving a function. If we were to take that water out for consumption purposes—that is, for agriculture—it will come out at some cost. We need to have debate in the community about what the pros and cons or our values are between looking after the shrimp, the dugong or whatever it might be versus the production of food. We need to have that debate and understand what our values are.

Again that will be something that I keep coming back to throughout this talk and it is important for us to think about it, noting also that these community values are dynamic in time. Unique environments are going to need unique agriculture. But the other point about northern Australia is Indigenous management. It is really important that we engage the Indigenous community in our management of agricultural enterprises and in Australia more generally. For example, findings from a research project that we invested in several years ago indicated that, when you involve an Indigenous community in the management of natural resources, the health of that community improves enormously. There are some real win-win opportunities here, both for the environment and for our Indigenous communities.

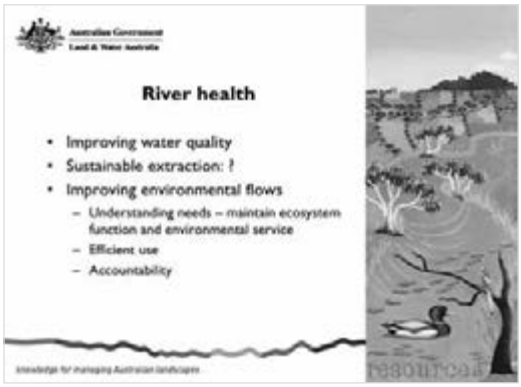


Understanding resource condition is a big challenge for us. How can we manage it if we do not know what it is like? So we absolutely need to do a decent 'audit'—dare I use that term. But we did have a National Land and Water Resources Audit for 11 years; it was shut down in the middle of last year. It probably had not achieved its goals; it probably was not funded to. In the first five years it produced a whole bunch of black books, which were an attempt to document the condition of our natural resources. In the second five years, we learned from the first five years and said, 'We really don't know; we really haven't got the data.' The data across state boundaries is far from compatible and full of holes; the *State of the Environment* report also showed that. So we need to have a national system for doing this. There is some discussion about it now and some effort and finances have gone into water, particularly in the Murray-Darling Basin; but we need to improve our effort here. That monitoring needs to be long-term; it cannot be just a one-off thing. So that is a big challenge for us.

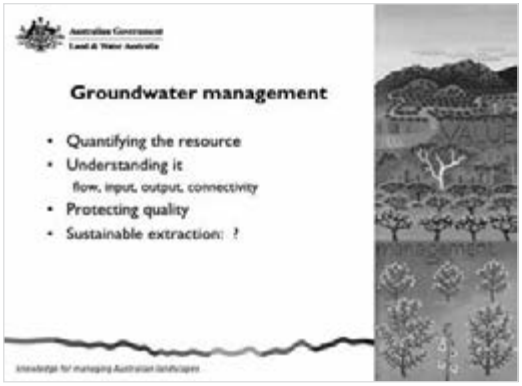


Water, of course, is a huge challenge. I have mentioned water availability, but it is really about better rainfall predictions and what flows from the rainfall. So, under climate change, we need to know when and where the rain will fall, its intensity and what that means for run-off, for storage and, ultimately, for water availability at the farm gate. Contrast that with what our environment is getting, about to get or needs. At present we are buying back a lot of water for the environment, but it is not based on great or even enough science. We need to be smarter about the environmental water that we are purchasing and be more accountable with it to ensure that it is achieving what we think it should be achieving. Again this comes back to values: what should it be achieving; what is the ecosystem function that we want to achieve with that environmental water? Water use efficiency, of course, is an obvious one. We will need to do more with less; there is no question about that. That includes thinking about multiple-use water—that is, re-use and recycling. So there are some big challenges there.

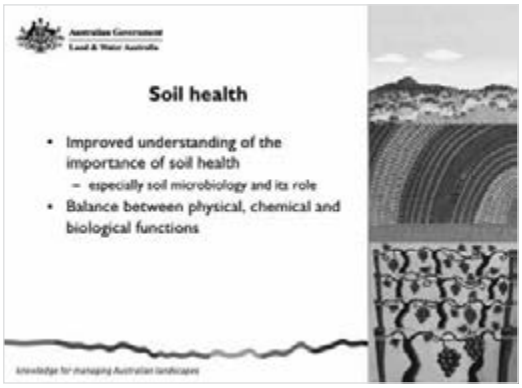
To me, landscape management is almost a holy grail. The vision statement mentions landscapes. How do we manage a whole landscape—not a farm, not a paddock, not a conserved bit of forest on the ridge top that the farmer just wants to lock up and leave? How do we manage the whole landscape? How do we do that? What tools could we offer up as a scientific community to allow integrated holistic decision-making that is multidisciplinary and across multiple land uses that change in time and space? Those tools should be able to give us an idea of the net triple bottom-line outcomes so that we can make trade-offs not just on a block of dirt but across the whole catchment as to what we want to see in those net triple bottom-line outcomes balanced across that whole landscape. But we have to do that in the context of land-use change, which other people have touched on already in referring to urban encroachment. Peri-urban production will be a challenge for agricultural scientists and for the community, particularly as we will probably demand lower footprint foods and want to reduce our transport distances—I will come back to consumer preferences—and there is no question that we will need new and changed production systems as we get into the future.



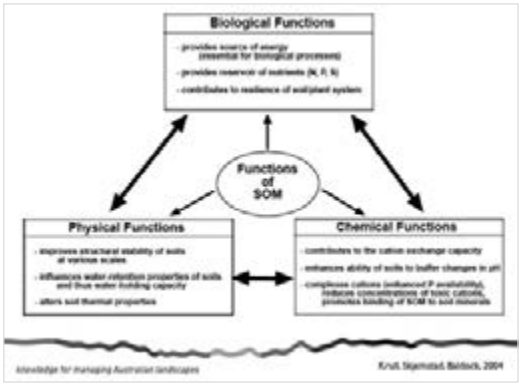
I suppose that river health is an obvious one for us all, so I will not talk about it for too long. We do need to improve its quality. A lot of work has been done in this area, but I think there is still a way to go. I find it interesting that I have left the term 'sustainable extraction' on the slide, because there are very few rivers in the south where we probably have the opportunity to go down to a sustainable extraction level. I would imagine that with most of our rivers we have exceeded that. How do we get it back up? This links to the 'environmental flows' question, which is the next dot point. We need to understand the needs of our environment better.



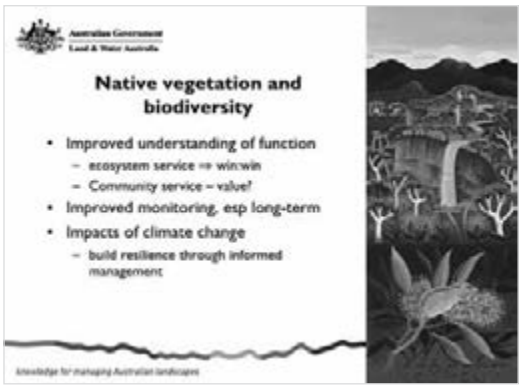
Groundwater management is a major issue. It has been a sleeper, probably until about three years ago. In this country we really need to do a better job of quantifying the resource. I think the sustainable yields project from CSIRO was an amazing effort, in the time they had, in quantifying what we had and in making future predictions. But I think we are still a long way off the proper level of understanding that we need about how our groundwater systems work—how connected they are, what their inputs are and what their flows are like—so that we can understand what our sustainable extraction limits might be. How do we protect the quality of those groundwaters so that we are not degrading them?



In my view, soil has been the forgotten area of agriculture for the last 15 years. I think we got to a point, perhaps in the early 1990s, when we thought: 'We know a fair bit about soil. We've got minimum tillage or no tillage systems now. We're right.' I think it is coming back on to the agenda and I think it needs to come back on to the agenda, particularly understanding soil health.

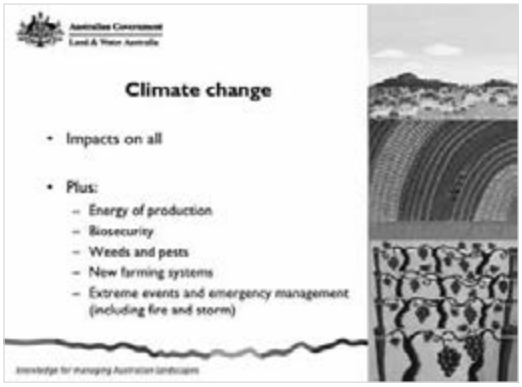


Here is a sort of cartoon for you – from one of Evelyn Krull's reports. I think we got to the point where we were happy with our understanding of the physical and chemical functions of soil. But, in my view, we really do not have a good handle on the biological functions of soil, so that we understand the role of organic matter in soil health and its role in resilience and soil function. It is an expanding area of work, but we need to expand on it more. If you want to be trendy, you can just replace 'soil organic matter' with the word 'carbon', which I think is overrated.

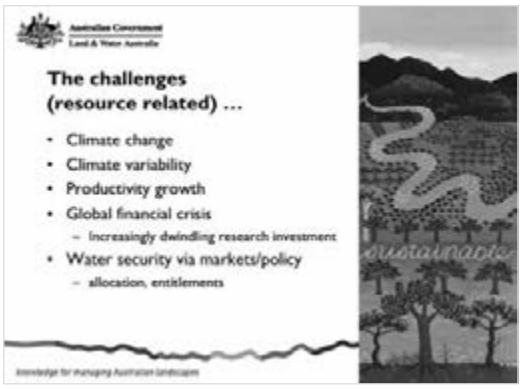


Again, this concerns ecosystem function. We need to understand the function that biodiversity plays and, from an ecosystem service point of view, I think we need to look at win-win opportunities. Think, for example, of integrated pest management. How can we get the win-win opportunities from our native vegetation and our biodiversity to enhance agricultural production and our native vegetation?

The other point here is about community service: the value that the community puts on having native vegetation. This is really relevant to northern Australia. For example, in our Tropical Rivers and Coastal Knowledge Program, we had a study looking at how the community values, say, the virgin landscapes of northern Australia. How does the Northern Territory or the Darwin community value it versus the community in Sydney? How important is the management of that highly valued landscape to the community in Sydney? What about the citizens of the US or New York? They sit there very happily, knowing that there is this wonderful native vegetation preserved in northern Australia; but does that impact on our decision-making? There is no question that there has been a grossly inadequate response to the long-term monitoring needs there and, with the impacts of climate change, building resilience is really important.



I have one slide on climate change; it impacts on everything, but I have put this slide up so that I can add all these other dot points. 'Energy of production': agriculture will need to reduce its energy inputs and be far more efficient energy users, as the cost of energy will go up. Biosecurity, weeds and pests have already been mentioned and they are major issues that we will need to address. Then there is 'new farming systems'. The last one is 'extreme events'; how do we manage them? We heard from Clive Noble this morning about smoke taint in wine grapes. These are very real issues that will have an increasing importance under climate change and we will need to manage them.



I have included this slide for a bit more context. Our natural resources are not independent of our other resources or related challenges. We are talking about climate change. Variability, I think, is really important. In fact, I do not think farmers give two hoots about whether climate change is real or not—because, as Lesley Head said, they are interested in the next four days' or few weeks' or the season. Most of them base their decisions on a risk management profile, of which the coming season's climate is one of the key drivers. Whether it is 0.1 of a degree warmer on average this summer is irrelevant to them; what the actual temperature will be and what the actual rainfall is are the most relevant things to their decision-making. Productivity growth, which Kate Grenot talked about, is in decline and we need to reverse that. I put the global financial crisis there because of its impact on research investment—and I am living proof of that. 'Water security': I did not include 'markets' in the other slide about water, but what we do about over-allocation and the mess we are in with entitlements will be really important to the agricultural sector.

'Policy settings': there will be a huge impact, particularly with emissions trading. But the other point I want to make here is about long-term consistency or security in the models of delivery to our agricultural or rural and regional communities. For example, we have catchment management organisations that have been around for about 10 years and they have been really hard done by under 'Caring for our Country', with lots of uncertainty and lots of changes to that model. That does not help us to deliver to our rural and regional communities.

'Social resilience and sustainability': we have to improve that, and Clive talked about structural adjustment. Capacity, labour and education have been mentioned.

'Consumer preferences': agriculture will need to think more beyond the farm gate. What is the market actually asking for? Health and nutrition will drive some of their decision-making, particularly in more affluent societies and particularly as developing countries become richer. That will lead to the need for better labelling and certification of products so that they know how it is grown, where it is grown and what its footprint is.

I will make some quick comments on the research system.

It is busy; it is complex. If you were starting from scratch in this country, you would not come up with this diagram. There are 19 Cooperative Research Centres and 15 Rural Research and Development Corporations—and that is with us off the list. There are 20odd universities involved in agricultural or natural resource management research. We have CSIRO and three flagships. It is busy. It is also competitive in nature. My personal belief is that in this country, with $1.2 billion expenditure per annum, we cannot afford to be so competitive and so fragmented. It is not efficient. Quite frankly, you have 15 executive directors like me running around and you have 15 boards. That is expensive and it is not necessary.

Do we have the balance right between industry pull and science push? I think probably across the board we may have. It is not as bad as you might think. I think the RDCs have got the balance wrong, but that's okay because others are doing more of the science push. It is the same with strategic and applied. I will make a plea around knowledge management, which is something that Land & Water Australia has always been passionate about. We do not do it anywhere near well enough. Part of that is that we are too afraid to actually resource it to the level where it needs to be.

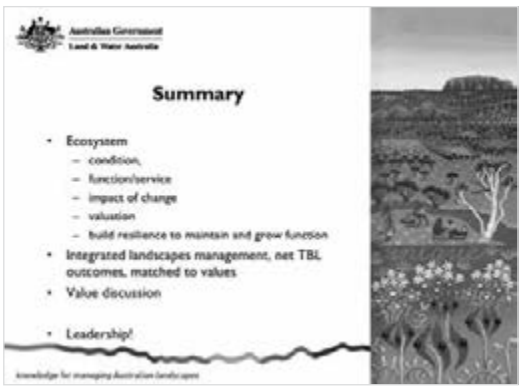
'Funding': We need to reverse the decline in and the short-term nature of our funding. I was in New Zealand three weeks ago reviewing the establishment of a new greenhouse gas agriculture research centre where they have just been guaranteed 10 years of funding. Why can't we do it? The Kiwis are doing it.

'Efficiency gains': collaboration, coordination and communication will be essential. I think we do have to move to a nationalisation and the work that is being done by Kate but also the National RD&E Framework that I am involved in, which Clive also mentioned, will be a very important step. But I think the logical outcomes of that process will be some rationalisation.

'Knowledge management': there is a need to improve knowledge management.

'Industry and policy linkages' are incredibly important. 'Leadership' is also incredibly important.

'Policy, industry and research': we actually have to communicate. We are bloody good at silos. Let's communicate, but let's communicate going in a certain direction. 'A shared vision': it would be really great if we all were on the same page going in the one direction—and that will take some leadership.



I have talked a lot about ecosystems—their condition, their function, what service they provide, what value we put on them as a community and what the impacts of change will be. We have to be informed if we are to manage. We need to build resilience. The take home message is that integrated catchment management is absolutely essential; you cannot operate on this patch of dirt in isolation to the rest of the landscape. We need to have this value discussion as a community and we need to start with some serious leadership. You all should take it upon yourselves—it is why you are here—to lead in your own right.

Discussion

Question: Doug Bardsley from Adelaide Uni. We have been looking at peri-urban agricultural systems a little bit in relation to the climate change perspective. A couple of speakers have said that farmers are probably more interested in climate variability than climate change. I think farming groups are starting to look strategically into the long term and how they can survive on the peri-urban fringe or with water resources. They are owning climate change and seeing real value in articulating the risks associated with it so that they can go to decision-makers and say, 'Look, unless you protect our land and protect our water, we are going to see real challenges.' I wonder whether that is your experience or this is a unique situation.

Michael Robinson: In my probably limited experience, I think there is a bit of that going on. But I think we need to emphasise that discussion with industry and policy, because I do not think those bigger structural adjustment and new farming systems questions can be addressed by farmers or small groups of farmers alone. We are going to have to see some significant changes and I do not think it will be possible, say, for a farming group or a particular farmer, unless he is doing very well and thinks very strategically—here we are talking about a very few or a small proportion of farmers—to make those adjustments, particularly if you are talking about whole new industries. Let's say that we are going to shift the grain-growing areas whichever way; you are going to need infrastructure support. That is a discussion for industry bodies, the government and the policy-makers. I think Clive outlined DPI's interests in structural adjustment. It is very much on the agenda, and I think it should be on the agenda at that level. If it is driven from the bottom up, that is even better.

Question: Evelyn Krull, CSIRO Land and Water. I really appreciated your talk and also that you mentioned soil. One of the areas that you brought up concerns me and that is growth. We seem to be reactive, in the sense that we believe estimates such as 'We are going to reach this level of population growth by 2050 and we have to react towards it and increase productivity.' However, there will be a finite limit to how much we can get out of our soils, particularly in Australia where some of our soils are mere hydroponic experiments and we just add more superphosphate and nitrogen to it to make the plants just stick in it and grow. The need for increased productivity and growth will affect climate change negatively through our putting more energy into fertiliser production. I wonder whether we should be courageous and mention that we are afraid to invest in it. Are we too risk averse to challenge the whole subject of population growth?

Michael Robinson: Before you got to the end of your question, I thought, 'Yes, you've just got the elephant in the room: what are we going to do about population growth?' Peter, do you mind me throwing this to you? This is a huge issue and we do not talk about it: can we seriously feed 13 billion people? That is the question.

Peter Gregory: The assumptions are that the population will continue to grow to around 9 or 10 billion, and we know that there are very considerable uncertainties around that. None of us will put our hand up and say, 'We don't want to be there'—or, as Malthus said in his statement, none of us will put our hand up and say, 'Well, actually we're going to abstain from sex and we're not going to reproduce our species.' So I think we have to go along, as it were, with the notion that the population is likely to increase, at least in the foreseeable future. What do we do about it? I think, morally, we try to feed those people. If we cannot do that, then obviously they will not be there. But will we be any better off watching the process of their not being there? I do not think we will.

So I think we also have to get to grips with saying, 'Okay, what do we know about how populations bring themselves under some sort of control?' In many places where we have done that, a number of factors have been involved; but, as I understand it—social scientists will be in a much better position to say this than I am—out of all the many variables, the one thing we know that does contribute to that is the education and liberation of women and their ability to operate in many ways within societies. That is probably one of the things that we actually have to focus on.

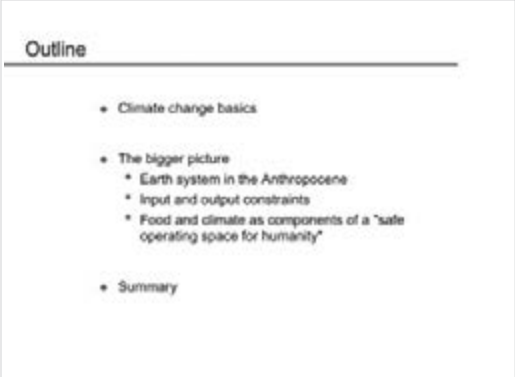
Kate Grenot: I would like to refer the Future Fund website to anyone who is interested in this issue. The statement has been made that the shift that is occurring at the moment takes us towards a position where governments may now have a right or a responsibility—'responsibility' is a better word—to intervene to protect citizens. This is both dangerous and interesting at the same time. So the debate is starting, and the Future Fund website is the only place where I have seen someone attempt to espouse it. It is a complex issue but, for this room, there is a lovely opportunity to take what has been described here as a more elemental approach to the finite nature of the resources, picking up the themes in Michael's talk, as a basis for saying, 'We can only get so much from this continent; what is that amount?'

Global climate

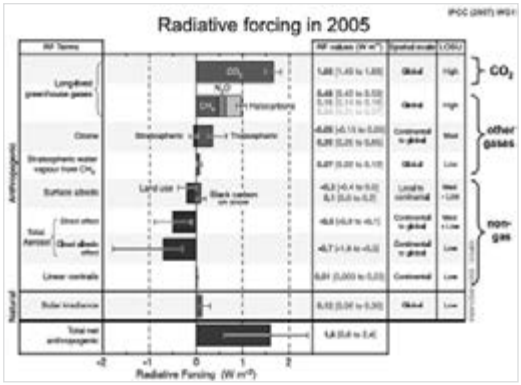
The six-sided problem of climate, carbon, nutrients, water, food and people

Dr Michael Raupach FAA FTSE
CSIRO Marine and Atmospheric Research; ESSP Global Carbon Project

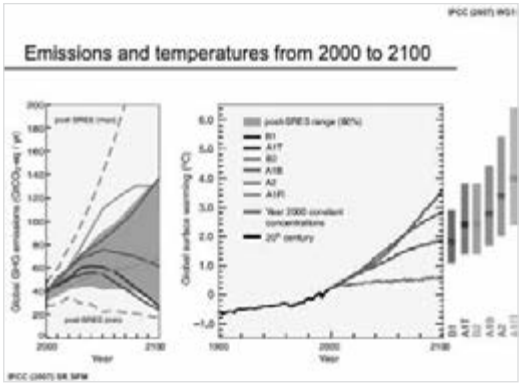
In preparing this talk I realised that I had taken on a very large challenge! The segue to this talk has already been provided by several things said in this session—in particular Lesley Head's statement that it is about more than climate, and the discussion after Michael Robinson's paper which was introduced by Evelyn Krull's question concerning population.



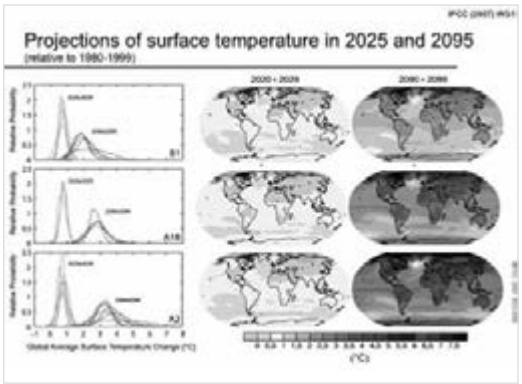
First, I would like to look at some climate change basics. All of you, I am sure, are well aware of these, but I want to highlight a couple of points about the climate situation that we are facing at the moment, and then to look at the bigger picture—the Earth system in what has been called the 'Anthropocene'. This is the era in which human activities are starting to change the metabolism of the planet. I'll use this view to look at constraints on the global system, both on the input side and on the output side, and to identify a few that will be important in the context of agricultural productivity.



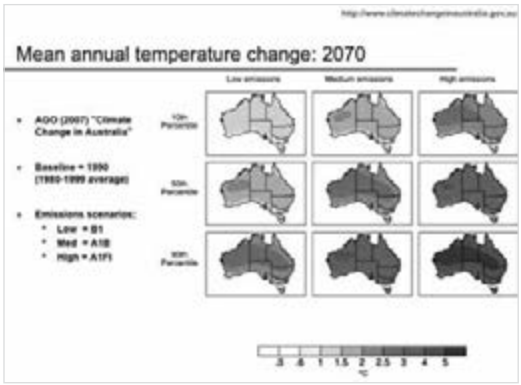
The proximate cause of climate change is that we are putting gases into the atmosphere that change the radiative forcing, or the energy balance of the planet. This table from the IPCC in 2007 shows, at the top, that the largest contribution is from CO_2. But a group of other 'non-CO_2 greenhouse gases', including methane and others, make significant contributions. The third important group, shown in the bars nearer the bottom, are the negative contributions coming principally from aerosols. The very important point about those aerosol contributions is how uncertain they are. The end result is that the net climate effect of all human activities on the planet at the moment is roughly equal to that from CO_2, because the other two groups of contributions—the non-CO_2 gases and the aerosols—are approximately cancelling. This is essentially fortuitous and probably will not continue for very long because, as we move into this century and people clean up air quality for all sorts of good reasons, the negative aerosol contribution will diminish. The aerosol brake will come off climate change, if you will.



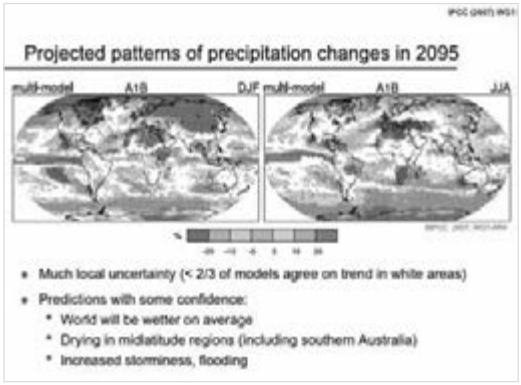
From a range of emissions scenarios—shown in this famous IPCC slide—we know that climate change will lead to temperature increases which, depending on which scenario you choose, range from less than 2 degrees to nearly 6 degrees. That is the range of uncertainty, and it comes from three factors: stochastic variability within any one climate model, variability between models, and variations of the forcing scenarios. The last of these is the largest source of uncertainty.



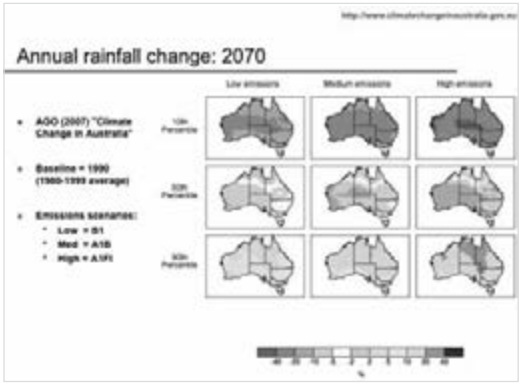
We also know very well that warming and many other aspects of climate change are not globally uniform; we have to disaggregate to see the main trends. A simple latitudinal disaggregation shows that a disproportionate amount of warming will occur in the far northern hemisphere, in the Arctic regions. That has important consequences for climate feedbacks, which unfortunately we do not have time to consider.



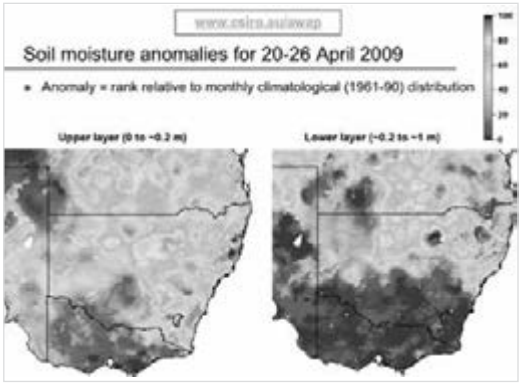
This is how temperatures will evolve for Australia. In this array of graphs, the columns show low, medium and high emissions scenarios; the rows show what could be expected at the 10th percentile, the 50th percentile—the median—and the 90th percentile of warming. Everything gets hotter. By 2070, even in the median scenario, we are looking at temperatures across most of the continent being somewhere around 3 degrees higher than they are now. Of course, with the enormous range of climate variability superimposed upon that, we are looking not only and perhaps not even primarily at shifts in means but much more so at shifts in extremes.



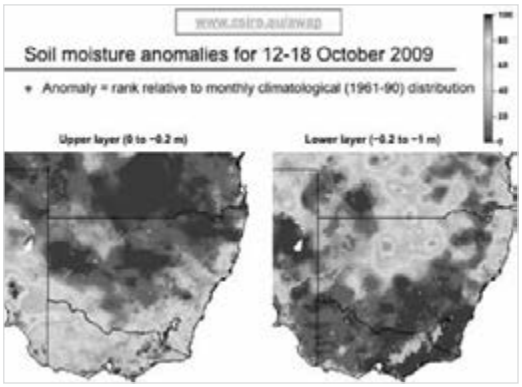
I have said that we do not know much about rainfall. This slide, again from IPCC, reminds us of how little we know. The world, as it gets hotter, will get wetter on average—that is a straight consequence of thermodynamics—but it will not get wetter uniformly. The big signal that comes out of this slide—perhaps the only signal that systematically comes out of studies of future regional changes in rainfall—is that there will be belts of drying in the mid-latitudes. One of those belts of drying, of course, coincides with southern Australia.



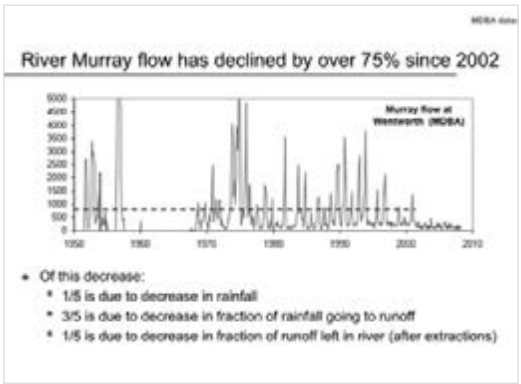
Corresponding with that, rainfall projections across the country are proportionately more scattered than for temperature. The median emissions scenarios show drying over most of the continent, particularly in the south. However, if we are lucky enough to go to the 90th percentile of the protections, most of the continent will, in fact, get wetter. That is the range of uncertainty that we are facing at the moment.



It is useful to compare these projections with present trends. Our group runs a project on water availability for the continent; the results are on the web. This slide shows the soil moisture about six months ago for the southern part of Australia, for an upper soil layer (down to about 0.2 of a metre) and a lower layer down to over a metre. In the lower layer you will see the pronounced long-term drought in southern Australia that we all recognise well now.



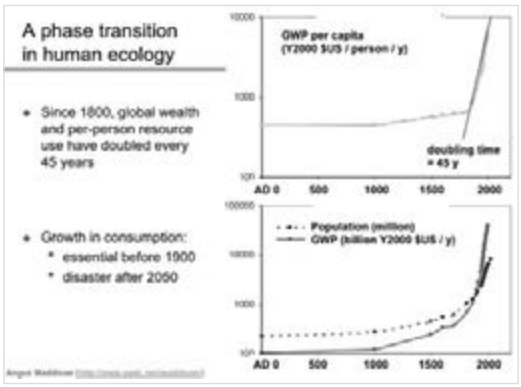
In contrast, here are the same results from just last week. There is a good deal of variability in the upper layer, with some regions doing well. But, in the lower layer, most of south-eastern Australia is still subject to that big drought, except perhaps in the mountain headwater regions, which is good news for the flow in the Murray for this year.



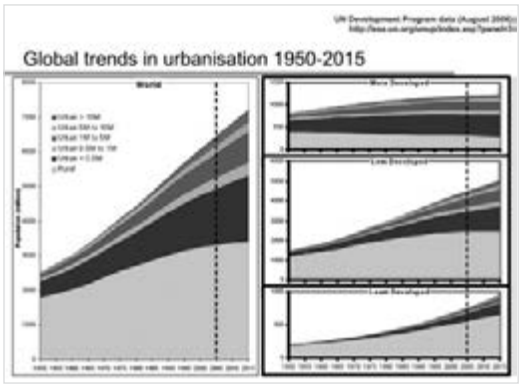
We are well aware of the consequence of the decade-long drought for the River Murray. I find the numbers on this slide to be staggering: the flow in the Murray, gauged at Wentworth, has declined not to 75 per cent but by 75 per cent since 2002. It will be very interesting to see what will happen in this coming season as a result of the rains that

have yielded good upper layer soil moisture in some areas. However, as this season unfolds, there is some probability that the drought is not due to an unlucky run of variability but rather to incipient climate change.

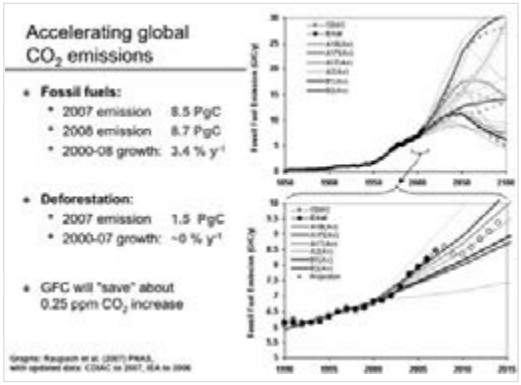
That completes our brief summary on climate change. Moving to the bigger picture, it has become common to speak of the era since the beginning of the industrial revolution as the Anthropocene, the new geological era in which humans are making such an impact on the planet that they are altering the planetary metabolism itself. One of the hallmarks of this is the fact that, if we could watch Earth from far away—if, say, we were an intelligent species on Alpha Centauri with very good sensors—we would see the planet begin to glow with a new light source, that of human activity.



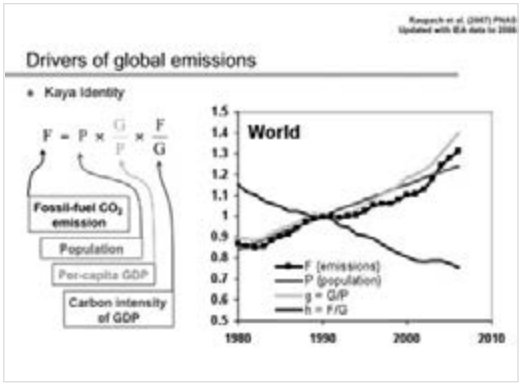
For me, the graph at the top of this slide is one of the most striking demonstrations of the development of the Anthropocene. It shows the income per capita averaged across the world for the last 2000 years. Real income was more or less steady for most of those 2000 years at $US600-$US800 on average—of course, with vast inequities in distribution. But starting in about 1820, with the beginning of the industrial revolution, income started to double every 45 years. It has continued to do that ever since, and shows no sign of stopping.



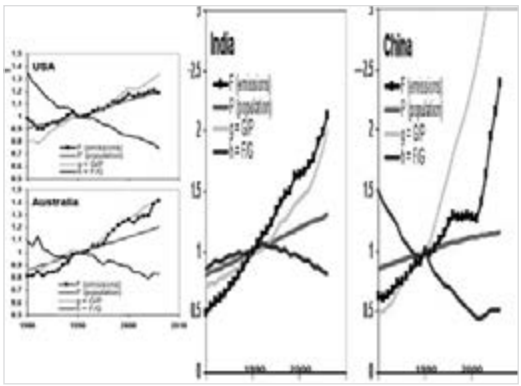
Turning to population, this slide shows a number of aspects of the global population trend, from UN data. We see not only that global population is increasing (we all know that) but also that more people are now living in cities than in the country and that the switchover point occurred around 2005. The majority of that growth is occurring in small cities, of less than 0.5 million. The population fraction in the megacities—Mexico City, Tokyo and so on—is in fact quite modest, relatively speaking. Those cities are growing rapidly, but their contribution to global population is still about less than 10 per cent.



We come now to emissions. This graph shows the trend in emissions over the last 150 years and extending out to 2100, under a number of emission scenarios. The important point is that CO_2 emissions have been growing faster than most of those scenarios would have us accept. I want to draw your attention to what is going to happen as a result of the global financial crisis (GFC), shown by the open circles in the lower part of the slide. We are going to have a decrease in emissions of around 2.5 per cent this year, as a result of the GFC. Is that a lot? No. Assuming that things continue to pick up and continue in the way that they have been going in the past, that is going to save us roughly six weeks worth of emissions, equivalent to emissions being stopped cold for six weeks and then resuming. Hence, if things evolve this way, the GFC will be a minor blip. Our challenge is to use the opportunity of the emissions downturn associated with the GFC to bring about more fundamental structural change, which will make the emissions downturn a long-lasting decrease in emissions without the negative economic effects of the GFC.

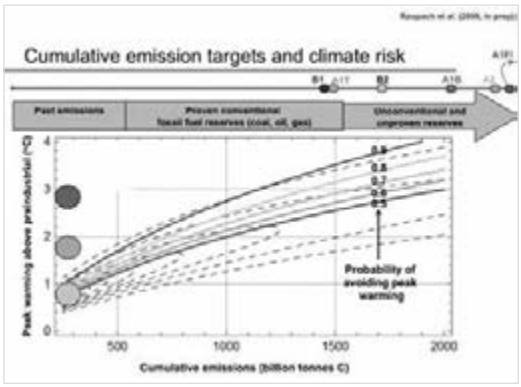


What drives emissions? Here the squares on the black line represent the emissions over the last 20-or-so years. The coloured lines are the contributions to those emissions from three different factors: the population in red, income per person in green, and emissions per unit wealth generation (income) in blue. Historically, the emissions per unit wealth generation have been improving. That is a great thing, but they have to improve faster. The other two terms, income and population, have been growing over that period at about the same rate until the last five years or so, when wealth generation has really accelerated. The major reason for that, of course, is found in South-East Asia and, in particular, China.

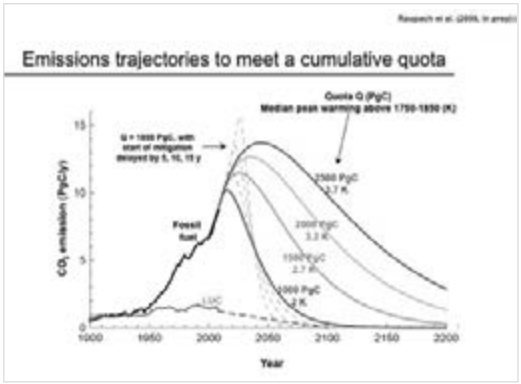


We can break that out for a number of countries and regions. Here is the same graph for the US and Australia, and for China and India, where both incomes and emissions are growing extraordinarily rapidly. Growth is slower in the US and Australia. The reason that Australian emissions are growing is two-fold: our wealth per person is growing; and our population is increasing relatively quickly. We have an immigration policy that is causing Australia, not uniquely but rarely among developed countries, to have a rapidly increasing population. We love immigrants, unless they come by leaky boat!

This leads to the question of climate targets and risks and, more generally, to what we can call input and output limits. A new view has recently been put regarding the challenge of mitigating or stabilising climate. This is based on the idea that, for practical purposes, there is a total cumulative amount of CO_2 that we can emit since the beginning of the industrial revolution, and still keep the planet safe. In a paper published in *Nature* by Myles Allen and colleagues about six months ago, that limit was put at around 1000 GtC (billion tonnes of carbon in CO_2). We have emitted about half of that amount so far.

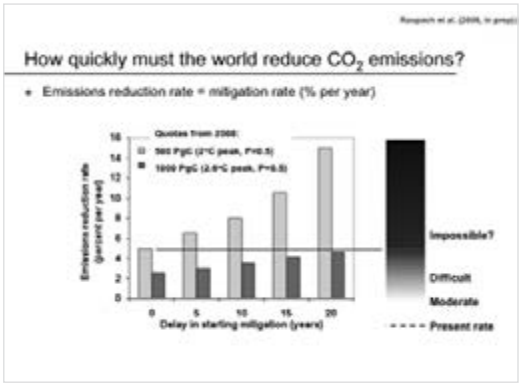


This set of curves shows the cumulative amount that we might throw into the atmosphere since the start of the industrial revolution, plotted against the resulting temperature increase at various probability levels, shown in the different coloured curves. These, of course, represent different levels of climate danger. Temperatures of 3 degrees or so above pre-industrial temperatures represent serious climate danger. One definition of 'dangerous climate change' (necessarily a subjective concept) is exceedance of a warming of 2 degrees above pre-industrial temperatures. Past emissions on this curve take us to about 500 GtC, and proven conventional fossil fuel reserves to over 1500 GtC—well above the cumulative emission threshold of 1000 GtC, which corresponds to a peak warming of 2 degrees with 50 per cent probability. There is also a large reservoir of unproven conventional reserves. Hence, we will not avoid dangerous climate change by running out of fossil carbon. We have to find other constraints.

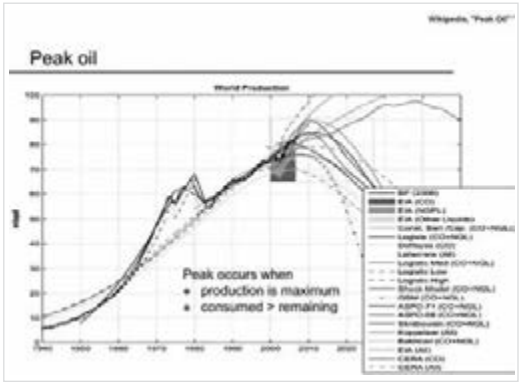


This is what global emissions trajectories might look like at various levels of this cumulative cap on CO_2 emissions. The black curve is the contribution from past fossil fuels and the coloured curves are future emissions which would bring us to a cumulative emission at a number of different totals, with approximate corresponding peak temperatures above pre-industrial. The red curve, corresponding with a 2-degree warming, is the curve we need to follow to avoid the normal definition of 'dangerous climate change'. This curve requires us to have global CO_2 emissions peaking in the next three to five years. That is one of the reasons why most climate scientists, including me, are very agitated about getting the emissions downturn to occur as soon as possible.

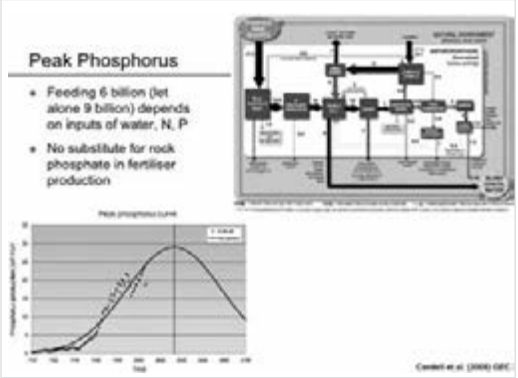
One of the consequences of this logic is that we are about now at peak CO_2, just as we are about now at peak oil. The difference between CO_2 and oil is that oil is an input resource: there is a hard constraint from the fact that we cannot use any more than is there. In the case of CO_2 we can use effectively as much as we want, other than through a decision to avoid dangerous climate change as we, the global community, choose to define it. So the nature of the constraint is quite different.



The consequences of failing to turn emissions downward rapidly are shown here. The rates at which we need to mitigate—to reduce emissions each year—increase very rapidly with each five-year increment of delay in starting the mitigation task.



The concept of a peak in use is applicable to many finite resources. The longest-standing example is oil. The peak arises when production is at its maximum, which is also close to the time when the amount consumed equals the amount remaining. Most predictions for oil have that point occurring between now and 2020, and many analysts believe that the longer time frames for reaching the peak are too optimistic.



There are also peaks in quantities relevant to agriculture. One is peak phosphorus. The only source of phosphorus is rock phosphate, a finite resource. This resource-use curve for phosphorus is based on accepted theory developed in the oil industry but now applied in many other areas. It suggests that peak phosphorus will occur some time in the next 20 years. That has major consequences for agricultural productivity, and raises the question: can we satisfy all of these requirements together, as we must?

Finite-planet constraints

input limit
output limit
other constraint

Quantity	Peak value	Peak time	Nature of constraint
Climate	2 degK from 1750	~2070	output limit (agreement)
CO_2	1000 PgC from 1750 500 PgC from 2005	2020	output limit (agreement)
Fossil fuel: Coal Oil Gas Other	1000 PgC, 160 used 400 PgC, 130 used 220 PgC, 40 used >1000 PgC, 0 used	>2100 2010-2030 >2050 >>2100	input limits (physical)
Water	—	—	regional constraints: depend on use and climate change
Nitrogen	?	?	output limit (+ input limit from gas?)
Phosphorus	1 Pg P?	2030	input limit
People	9 billion	~2070	human ecology
Food	for 9 billion?	>2070	from population and preferences

This final slide is an attempt to summarise a number of what could be called 'finite-planet constraints', through the lens of looking at peak values in production or throughput. Here are eight different constraints that have been mentioned both here and in previous talks: climate, CO_2 in the atmosphere, fossil fuels as a resource, water, nitrogen, phosphorus, people and food. Some of these constraints, such as oil and phosphorus, exist on the input side—we cannot extract enough to put into the human system, because the resource is limited. Some exist on the output side, because the consequences of the outputs of these quantities from human activities will be highly undesirable.

The overall consequence of this, I believe, is that we have to ask two questions, respectively about population and growth. The first is: can we sustain a population of 9 to 10 billion at a standard of living to which all aspire? The second is: if we cannot, how do we redefine 'growth' in a way that will make everything fit? One way or another, these are hard limits that exist because of the finite capacities of the Earth system. So our challenge is to find a path through the next 50 years that will stay within these constraints and at the same time produce acceptable outcomes for humankind. I do not think that is an easy challenge at all. I also think we need to ask fundamental questions about both population and growth.

Discussion

Question: Jonathon Sobels from Flinders Uni. I am thinking that different ways of viewing some of these constraints might also need to include the alternative to mainstream economics in terms of steady state economics, and how that also might play into how we set some of these limits or some of the approaches to dealing with these limits.

Mike Raupach: For me, that is the essence of the growth question. It means transferring humans' natural abilities and desires to fulfil themselves into arenas that can be kept, in terms of physical inputs and outputs, in a steady state.

Question: Kate Grenot, Rural Research and Development Council: You have described this as a massive challenge—which, indeed, it is—and you have put some boundaries around it, which is incredibly helpful. Agriculture and agricultural responsiveness is only one component of achieving the change that is required here, and research is one component of doing that. Do you have any thoughts from your considerations of this about the relative role of nation states and the structures that exist to get this turnaround that you would like to see in the next few years? Where do you think the relative effort should be applied? Is it in the international fora or is it domestically? How do we distribute the balance of effort, when we only have finite hours over the next 36 months, say? If it were up to you, how would you split your time?

Mike Raupach: That is a complex question. The glib and also truthful answer has to be that it needs to go in at all of those levels because we are dealing with a problem that has multiple scales, in terms of governance and management. Lines of power run both from the top down and the bottom up. It is an emerging system as well as a governed system. So the answer has to be 'all of them'.

How do we distribute the effort between top-down and bottom-up approaches? I think that will depend on the particular aspect of the set of challenges that we are talking about. In the case of climate change and carbon, it seems to me that there has to be a high degree of top-down constraint applied. That is not only in terms of setting limits on the amount of carbon that we can emit and enforcing those limits through a price on carbon—an emissions trading scheme and so forth—it is also through providing the resources from the top that will enable the right behaviours to come up from the bottom. That includes R&D for the right sorts of renewable technology. For other areas like water, the issues focus themselves at a regional and local level—I am here defining Australia as a region—so the governance needs to be applied at those levels. The same comment applies to the need for support and motivation for good bottomup initiatives.

Question: Stephen Cox from the Royal Society. This is an advert on the population issue, which has come up quite regularly today. Just a word about the very recent edition of the *Philosophical Transactions of the Royal Society*—commonly called *Phil. Trans.*—which is entirely on population. That is certainly worth having a look at, in particular the editorial. If you do not read any of the rest of it, it is worth reading the editorial. It is written by Roger Short, who is based in Melbourne. I think it gives some really interesting perspectives on what is the 'elephant in the room' in all of these discussions.

Rapporteurs

Dr Robyn Bartel

**School of Behavioural Cognitive and Social Sciences,
University of New England**

Robyn has science and law degrees, a Master of Higher Education from the Australian National University and a PhD in environmental regulation from the University of Melbourne (2003). She is an active contributor to public inquiries and a founding member of the Australian Environmental Law Enforcement and Regulators Network. Her empirical research evaluating the implementation of environmental law and models of regulatory efficacy in agriculture has made a significant contribution. Robyn's research encompasses regulation and regulatory agencies, as well as the social, institutional and natural landscape in which all are situated. Her most recent research has been aimed at understanding farmer attitudes, behaviours, practices and responses to environmental regulation.

Agriculture must meet some key challenges in order to maintain productivity and food security in the face of forecast climate and attendant environmental change. These will need to be met in a policy context which is extending the reach of formal regulation ever further into on-farm environmental management, through legal instrumentation and in concert with market-based initiatives. Robyn's research background in this area would provide a valuable contribution to the Think Tank.

Dr Sandra Eady

Principal Research Scientist, CSIRO Livestock Industries

Sandra is a geneticist with expertise in developing national breeding programs and implementing them on-farm. Her current activities, in CSIRO's Sustainable Agriculture Flagship, expand her expertise in farming systems to the area of life cycle assessment, determining the carbon and water footprint for agricultural products, on-farm greenhouse gas (GHG) emissions profiles and opportunities for biosequestration of carbon. Sandra is also a member of the Technical Options Development Group, established by the Department of Climate Change, to explore policy options for emissions abatement in agriculture.

Australia has the opportunity to offset a significant proportion of our GHG emissions by storing carbon in the landscape, an opportunity that has both benefits and trade-offs, issues that need to be given consideration in the design of policy instruments. Sandra's work focuses on the impact that GHG abatement will have on agriculture, both through the direct effect of an emissions trading scheme on farm profitability and the imperative for land-use change that a strong market for carbon will trigger. She can contribute a broad systems perspective of how varying GHG abatement options will intersect to influence rural land-use, and can bring an individual enterprise perspective on carbon intensity of agricultural production and possible on-farm options for abatement.

Dr Georgina Kelley

Vegetation Scientist, Bureau of Rural Sciences (BRS)
Department of Agriculture, Fisheries and Forestry

Georgina has extensive expertise in the role of vegetation in natural resource management, and her current research interest is in how vegetation contributes to the delivery of sustainable ecosystem services in a production landscape. This research interest is being explored through a range of projects including the Australian Vegetation Assessment, status of revegetation in Australia and assessment of resource access under the Environment Protection and Biodiversity Conservation Act. She is also contributing to the development of tools to assist decision makers and land managers to address the challenges of achieving sustainable production under changing and uncertain conditions. Prior to joining BRS, Georgina spent 10 years as a researcher and lecturer in plant ecophysiology at Charles Darwin University and the University of Western Sydney.

Georgina has an extensive knowledge value and importance of vegetation in agricultural landscapes and natural resource management issues, and a strong understanding of the broad range of issues facing land managers, including climate change. As a research scientist with wide experience in Australia's production landscapes, she will bring to the workshop a background in research, a strong understanding of the needs of land managers, a collaborative and creative approach to problem solving as a well as sound experience in the importance of data and information to support evidence-based decision making.

Dr Caroline Ummenhofer

Climate Change Research Centre, University of New South Wales

Caroline received a joint honours degree in marine biology and physical oceanography from the University of Wales in Bangor, UK, and in 2008 completed a PhD in climate science at the University of New South Wales (UNSW). She was an ARC Postdoctoral Fellow at the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems at UNSW and now holds a UNSW Vice-Chancellor Postdoctoral Fellowship, as well as a CSIRO Visiting Fellowship with the Centre for Marine and Atmospheric Research in Hobart. Her research focuses on climate variability and change across the Indian Ocean and Australasian region and links to large-scale ocean and atmospheric modes of variability.

Caroline's work exploits connections between Indian Ocean temperatures and regional rainfall variability, how this advances seasonal rainfall forecasting and ultimately improves agricultural management. Interdisciplinary research involving agricultural modelling to assess effects of climate on major wheat-cropping areas in south eastern Australia provided vital insights into key challenges faced in agriculture. This was further compounded during recent engagement with stakeholders in the agricultural sector. Combining collaborative research with real-world applications is an inspiring and rewarding experience for Caroline.

Breakout groups

Breakout Group 1: Policy **Chair** Kate Grenot **Rapporteur** Robyn Bartel	**Name**	**Discipline/background**
	Douglas Bardsley	Geography/environmental studies
	Robyn Bartel	Regulator/social science
	Sarah Bruce	Productivity/sustainable farming systems
	Timothy Cavagnaro	Soil ecology/plant biology
	John Davis	PhD studies on coastal/marine stewardship
	Nadine Marshall	Social scientist
	Andrew Moore	Decision making tools for grassland agriculture
	Saffron O'Neill	Social scientist
	Dean Revell	Interactions between livestock/land management
	Katinka Ruthrof	Climate change/forest woodland health
	Sandra Savocchia	Plant pathology/viticulture
	Ronald Smernik	Soil organic matter
	Jonathan Sobels	Social scientist
	Alison Southwell	Agricultural systems & extension
	Ernesto Valenzuela	Quantitative economics/modelling
Breakout Group 2: Knowledge management **Chair** Lesley Head **Rapporteur** Georgina Kelley	**Name**	**Discipline/background**
	Jennifer Atchison	Environmental science & wheat cultural geography
	Michael Bange	Cropping systems/agronomic management
	Steven Crimp	Climate variability & cropping systems
	Raphael Didham	Drivers of global change on biodiversity
	Elske van de Fliert	Social scientist/communication specialist
	David Francis	Sustainable aquaculture practices
	Sigfredo Fuentes	Instrumentation/monitor crop performance
	Chris Guppy	Soil fertility/sustainable nutrient management
	Munir Hanjra	Development economist
	Tamara Jackson	Water & energy trade-offs in irrigated agriculture
	Georgina Kelley	Role of vegetation in natural resource management
	Leo Lymburner	Land cover remote sensing
	Sarah Park	Assessment of climate change impact
	Libby Pinkard	Climate change & role of forests
	Susanne Schmidt	Develop management & plant selection tools
	Christine Storer	Community responses to climate change

Breakout Group 3: Technologies **Chair** Michael Robinson **Rapporteur** Sandra Eady	**Name**	**Discipline/background**
	Alisha Anderson	Biosensor technology for assessing food & grain quality/new pest control strategies
	Craig Birchall	Agronomy of cropping systems
	Clayton Butterly	Soil ecology/sustainable use of soils
	Scott Chapman	Productivity & field crop breeding
	Saul Cunningham	Entomology
	Sandra Eady	Livestock geneticist/GHG abatement
	Neil Huth	Development of plant & soil models
	Andrew Jacobs	Plant functional genomics
	Mark P McHenry	Integrating agricultural production systems with climate change mitigation
	Eric Peterson	Engineer/desalination systems
	James Petrie	Omega-3 Land Plants project
	Randall Robinson	Ecology & environmental management
	Douglas Rowell	GHG emissions from agricultural systems
	Saman Seneweera	Plant responses to climate change
	Hayden Sprigg	Wheat production adaptation
	Todor Vasiljevic	Sustainable utilisation aqua/ agricultural resources

Breakout Group 4: Planning **Chair** Michael Raupach **Rapporteur** Caroline Ummenhofer	**Name**	**Discipline/background**
	Karl Behrendt	Bioeconomic modelling & systems analysis
	Yann Chemin	Remote sensing & agricultural modelling
	Mike Furlong	Insect ecology/sustainability of agricultural productivity
	Ros Gleadow	Mitigating effects climate change on productivity
	Christopher Grof	Advancing biotechnological tools
	Matthew Hipsey	Hydrological interactions with biogeochemistry
	Evelyn Krull	Carbon & nutrient cycling
	Rick Llewellyn	Socio-economic tools for sustainable farming
	Darryn McEvoy	Geographer/climate risk assessment
	Simon Reid	Control infectious/zoonoses of stock
	Michael Renton	Modelling agro-ecological systems
	Carol Richards	Sociology of agriculture and natural resource management
	Chris Stokes	Systems ecology
	Kirrilly Thompson	Applied cultural anthropology/risk & safety
	Caroline Ummenhofer	Climate variability & change
	Michelle Watt	Genetic improvement of wheat

Free-roaming group	Name	
	Kurt Lambeck – President, AAS	
	Sue Meek – Chief Executive, AAS	
	Michael Agostino – Secretariat, AAS	
	Fiona Leves – Secretariat, AAS	

Biographical information for the early- to mid-career researchers is in Appendix A.

Reports from breakout groups

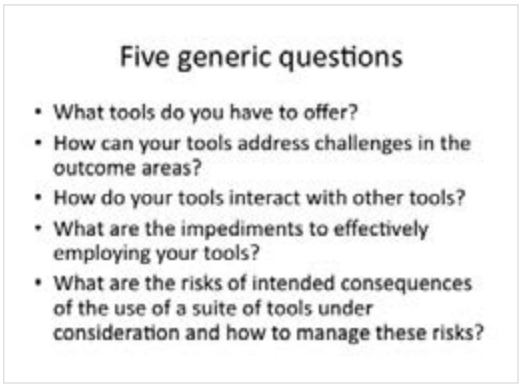
Group A – Policy

Rapporteur: Dr Robyn Bartel

I would like to thank the Academy for this opportunity and also express gratitude on behalf of my group. I am sure all here are appreciative of this rare opportunity provided by the Academy to engage in such a unique dialogue around these important issues of our time, and especially the opportunity to formulate recommendations from our discussions with the representatives of the scientific community present.

All credit for the content of our report should go to group members and all blame for errors of translation to me: there will be biases, errors of omission, errors of commission and please also consider that there will be large error bars on occasion.

The structure for our discussion was to advise how the issues in the left column may be best addressed using the tool of policy, with some policy issues already identified before the Think Tank listed in the right column. Our group identified some other areas on which we focused in our discussions and I will present these shortly.



We were also charged with providing answers to these questions in each of the outcomes areas. So, how can the tool of policy address global climate, sustainability, resilience and productivity and growth, and what does policy have to offer, with what consequences, including those unintended?

The answers to these questions will be presented towards the end of the presentation as these five questions provide a nice architecture to sum up and summarise our major conclusions.

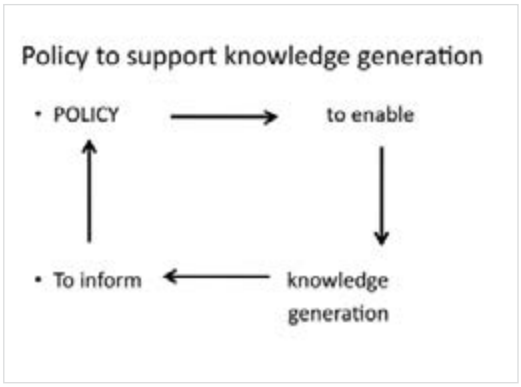
First I will provide a picture of the process which provided the answers.

I am using this picture as a metaphor for the grass roots stage of our discussion, in which we drew on the group's experience to identify policy issues from the floor.

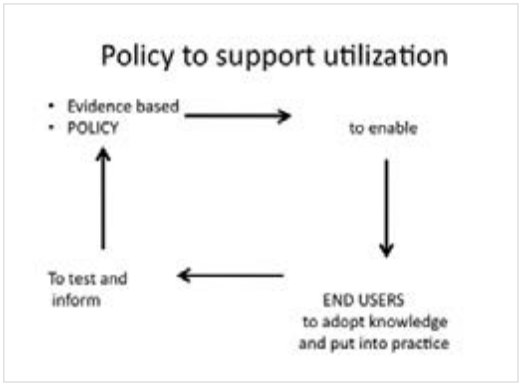
Many more issues were mentioned in passing but these were the major areas on which our discussion focused.

These issues coalesced nicely around a number of areas recommended by Nelson and co-authors in their recent food policy report recommendations provided in the Think Tank materials (Nelson et al., 2009), particularly their recommendations around research and extension.

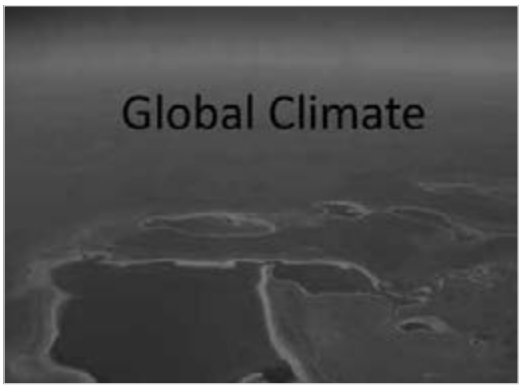
And also on community adaptation.



For those who prefer a pictorial representation of the space in which our discussion focused, I provide two diagrams, one mainly about the relationship between the scientific community and those responsible for funding research for evidence-based policy.



And the second mainly about the relationship between the scientific community and those responsible for utilising research.



So, to our discussion of the outcomes areas. We will consider them in reverse order, beginning with global climate.

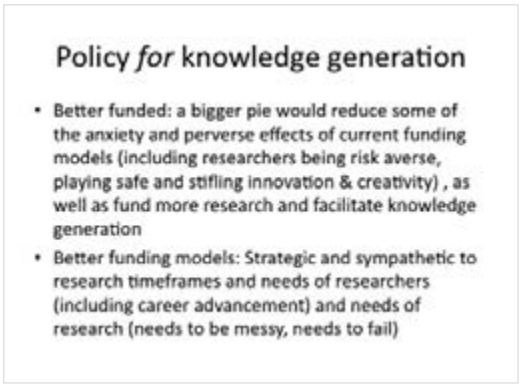
It was appreciated that we have huge knowledge gaps in many areas of not only global climate and climate change but environmental change generally, as well as the social and economic consequences.

This is contributing to a climate of fear around climate change which has severe negative consequences beyond mere ignorance.

Uncertainty, of course, can be a major impediment for evidence-based policy; if it is not sufficiently well evidence-based then it will not reflect real-world conditions, nor be able therefore to be successful in meeting policy objectives or aims. It is also an impediment to our ability to respond to climate change effectively in terms of being psychologically debilitating and perhaps also in compromising the ability of society to respond effectively in both the practical and political spheres. Of course policy failures are also politically costly.

There can be long lag times between identifying environmental and social problems, getting the science on it, informing the policy and then getting change on the ground. Transition periods can be long and ugly, so perhaps we need to accelerate this process.

Perhaps firstly we need policy to support the timely provision of better information to enable decision-makers to make better and more well-informed decisions, including evaluations of the impacts of those decisions to re-feed into the policy cycle. Climate change is about more than just climate change and so evidence-based policy can achieve more than climate change mitigation or adaptation with this in mind.



Policy to support knowledge generation and provide information to decision-makers and other actors in the system, would provide better and more secure funding for research.

Funding should be focused on the research that is needed and which will be most effectively utilised and have the greatest long-term yield in raising overall capacity and learning in vital areas.

It was here that the most significant gaps were identified.

The gaps are identified on the left and the marrying solutions on the right of the slide.

It is recognised that the public purse has increasing claims made on it which are characterised as competing, perhaps in the interests of those making the claims. However, there is evidence to suggest that meeting a number of aims is possible through increasing R&D funding and facilitating alternative sources of funding (eg, from the private sector). Perhaps there needs to be greater recognition that there are interrelationships between some of these so-called competing objectives so that government can resolve or defuse competing priorities and perceived conflicts amongst interest groups.

As a result of the current system, however, we identified that researchers were becoming risk averse in a very competitive environment and were focusing on career advancement, perhaps at the expense of doing blue-sky innovative and creative research. But research needs to be exploratory; it is long term, it takes time and it actually needs to fail. This can be especially true for time-consuming multidisciplinary work—which we desperately need to bridge the physical sciences and the social sciences—alongside the specialist disciplinary work; and we need curiosity-led as well as commercial research—locally focused as well as with international collaboration.

Currently there can be undesirable results arising from interactions with funding bodies. At the starting point, aims can be hastily conceived and perhaps insufficiently well articulated or, as we may see them, inappropriately targeted. At the other end, political imperatives may mean that there are deaf ears to what the research actually finds out. So perhaps we need to see a maturing of the policy cycle to learn from others in the target setting as well as to learn from failure, and to accept that failure is a normal part of learning and is actually a good thing.

From the funding bodies' perspective, failures may have generated a lack of trust between government and researchers. This can translate into micro-management administrivia, which is very costly and corrosive. To give more responsibility to researchers, we also need increased engagement and communication so that the relationship with government is two-way. We also need to reduce the costs because there can be high transaction costs in research.

A lot of funding is public sector dependent and can be a bit confusing. We may actually wish to make it more confusing in the sense of adding extra players and looking for other funding alternatives—for example, in the supply chain, as with supermarkets.

We therefore need to have better funding models, which are strategic and sympathetic to research time frames and the needs of researchers and of research as well as government.

Of course, some of the gaps identified are opportunities, and perhaps climate change is an issue that can be used to springboard a number of initiatives with significant positive multiplier effects for Australia.

Perhaps we need an advocate or lobbyist role for researchers in this cycle—to manage media liaison, to provide advice to government and public communication and to transfer information to the end-users and practitioners in

agriculture. We need to engage users early on in the research development as well as with the research outcomes, since participation and ownership is the key to adoption—and, of course, we need to sing in the real world.

There also need to be increasing moves made towards a whole-of-government approach (both within and across agencies, departments and federally), and whole-of-society engagement in the issues, and that the knowledge generators have to learn also about communicating.

It was here that a further gap was identified.

There are gaps in communication between funding bodies and knowledge generators, and between generators and utilisers. Research outcomes do need to be better utilised. Government is a funder that provides the ability to do the research; it is also an end-user of the research outcomes in translating it into policy. To drive the policy input process, research findings need to be communicated more effectively to policy-makers as well as to end-users, including those in agriculture. It also needs to be better focused, including long term, to encourage students to address knowledge deficits emerging in these areas. So, we need to have greater communication to enable the content and the process of policy generation to be improved.

Again, perhaps this gap presents a window of opportunity for communication to be improved for the benefit of all involved.

One obvious opportunity is public participation, which can assist in two-way learning between knowledge generators and knowledge appliers.

Public participation forms part of sustainability. The picture on this slide is meant to illustrate metaphorically the inherent tensions in the concept of sustainable development, here, the rows go on seemingly forever—however, there are limits in a finite world and, of course, the sustainability of the black plastic is questionable.

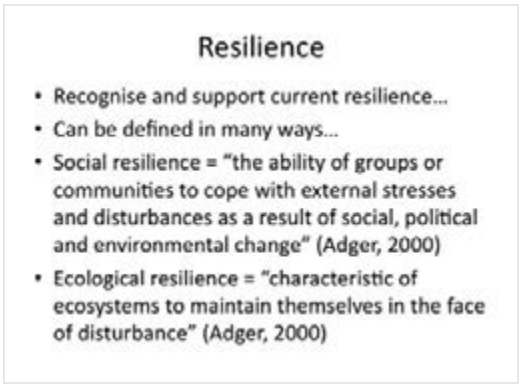
However, there is no real need to go over old ground of definitions and critiques thereof. Instead, let's just focus on one of the major principles of sustainability, that of public participation.

The 2002 OECD 'Improving policy for sustainable development checklist' also includes effective stakeholder engagement as a primary consideration.

We identified a gap with the need to focus on supporting public participation, because not everyone is able or willing to participate. Before 'public participation', there needs to be a step to enable people to be flexible, proactive and willing to take risks and engage in the process. If people are feeling vulnerable, or are already feeling disenfranchised or burnt out from past experience, they are less likely to engage in public participation. To do this part better we need to understand the needs and motivations of end-users as well as respect their knowledge—practitioner knowledge. This can be from a wide-ranging set of sources in the agricultural sector.

There is a link, therefore, between two of the outcomes here, between requiring resilience before public participation can be fully realised.

Some species are more likely to be resilient under forecast climate change; for example, some cattle breeds may be, due to their ability to handle heat stress. How resilient will humans be and how can we improve this resilience?



Resilience can be interpreted as including social and ecological resilience, and the two are related. The definitions here are from Neil Adger (2000) in *Progress in Human Geography*.

Policy *for* Resilience

- If feeling vulnerable unlikely to engage
- Need policy to support learning and motivation for learning, raise interest to/in change
- Based on understanding needs and motivations of end users as well as respect for practitioner knowledge/s – corporate as well as family farm
- Bring back extension for capacity and confidence-building
- Group based learning model as well as individual learning
- Also traditional formal learning – pre-tertiary and tertiary support for rural education – who educate and what educate (curriculum) – and careers in agriculture

Policies can be made to improve resilience.

Policy *for* Resilience

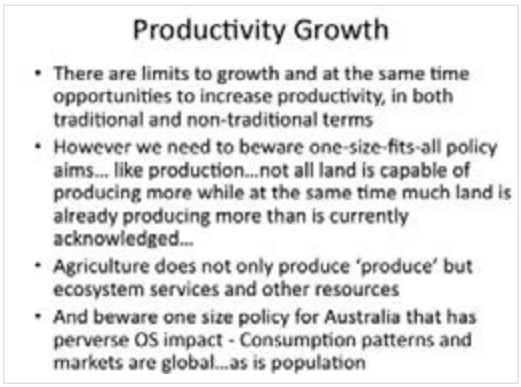
- Lag times – environmental/social problem – science – policy – social change
- Transition periods long and ugly but normal (always in transition?)
- Need to accelerate adaptability and adoption of changed practices, support importance of diversity (including biodiversity but also mix of policy tools)and reduce risks of diversification
- Need flexibility but also recognition of natural limits and constraints which may need policy acknowledgement /life
- Especially when considering aims of increasing productivity with a declining resource base and inputs with other constraints being imposed by climate change

Decision-makers need to be cognisant of natural and psychological constraints on change and rates of change. But they should also be willing to attempt to speed up the rates of change to more resilient states so that society can become more resilient over time, whilst also being aware that resilience may be difficult to maintain under forecast scenarios.

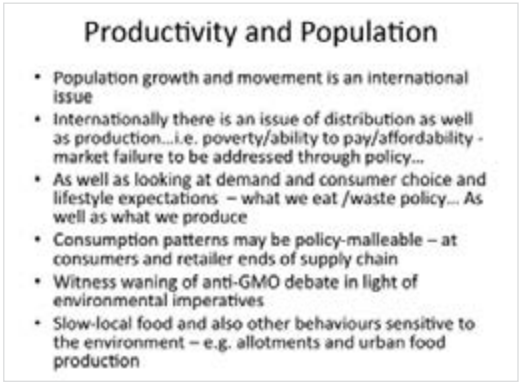
Elephants?

There was mention of several elephants in the room in the course of discussion over the duration of the Think Tank. Our group's discussion discovered several more…

These elephants emerged in the discussion of resilience and in the last outcome: productivity growth.



It was acknowledged that Australian agriculture is highly productive in a traditional sense while at the same time being supported by off-farm income and government assistance. Policies in this space need to be beware of unintended consequences, particularly in the international arena, but also domestically, especially if policy is not more open to non-traditional products (ecosystem services, amenity etc.), particularly in the face of competition for land use in agriculture (mining, residential).



Further elephants were the issues of population and consumption. With the question of population numbers, there was a lot of discussion that people bring in gains as well as drains on the system. So maybe there is a little bit of a limit to our assumptions in this area, perhaps on both sides. One of these was the assumption about productivity being an aim in itself and that we should beware of a one-size-fits-all policy aim, like productivity growth, because population and production issues are not uniformly distributed, nor are they universal. We also need to be aware of the demand side and the types of things that agricultural landscapes are supplying.

Policy for *Post*-productivism?

- Need to look beyond traditional 'productivism'
- Beyond productive private property parcels to multiple use…multiple objectives of land and therefore of policy…including of urban land
- Diversification will spread risk and reduce reliance and enhance resilience
- Need policy for whole landscape and wide range of coexisting land uses, blurring/evolving of public/private agriculture/NRM divides and increasing importance of production of ecosystem services…
- Recognition of existing multifunction landscape and role of Government assistance in both current and possible future landscapes

Perhaps we need to look to post-productivist theory and policy. We did get into a discussion about the post-productivity debate and the need to look beyond traditional productivism—moving beyond the productive private property parcels to multiple use, multiple objectives of land use, with policy to support that and to recognise what is happening already in our landscapes, both rural and urban.

In summation, here are the answers to the five questions for each of the four outcomes:

Global Climate

What tools do you have to offer?	Evidence-based policy and policy cycle improvements making policy adaptive and dynamic and sympathetic to local conditions
How can your tools address challenges in the outcome areas?	Fill gaps in knowledge, address uncertainty, reduce fear and provide more effective policy, since based on real-world understanding (of both biophysical and social aspects)
How do your tools interact with other tools?	Need inputs from and feedback to knowledge, technologies and planning
What are the impediments to effectively employing your tools?	Lack of funding and unsympathetic (to research and to evidence-based policy and policy learning) funding models mean that policy may be insufficiently evidence-based and therefore ineffective and wasteful (time and money) as well as generating political fatigue and disengagement and resistance in the community
What are the risks of intended consequences of the use of a suite of tools under consideration and how to manage these risks?	Need to be able to live with and incorporate research and policy "failure" into the policy learning cycle.

Sustainability

What tools do you have to offer?	Policy cycle improvements to improve public participation in target formulation as well as research and policy implementation and monitoring
How can your tools address challenges in the outcome areas?	Public participation provides ownership of the issues, shares the burden of understanding, responding and responsibility for dealing with the issues and increases acceptance of policy even when personally unpalatable, also provides two-way conversation so that can incorporate practitioner knowledge
How do your tools interact with other tools?	Need inputs from and feedback to knowledge, technologies and planning
What are the impediments to effectively employing your tools?	People not able or willing to participate because feeling vulnerable, oppressed, disengaged, distrusting of government
What are the risks of intended consequences of the use of a suite of tools under consideration and how to manage these risks?	Need to know how to manage public disagreement, dissatisfaction and consequent disinclination for further participation

Resilience

What tools do you have to offer?	Policy to improve public and policy learning, including in extension, group level problem-based two-way learning, as well as formal learning in primary through to tertiary and research levels
How can your tools address challenges in the outcome areas?	Aim is to achieve situation where people feel less vulnerable so that they can and do engage and participate and adopt practices, and thereby gain adaptive capacity and (further) resilience
How do your tools interact with other tools?	Need inputs from and feedback to knowledge, technologies and planning
What are the impediments to effectively employing your tools?	There is a wide variation of need and of industries within agriculture which will need specific targeting
What are the risks of intended consequences of the use of a suite of tools under consideration and how to manage these risks?	Resilience may include diversification which may also carry its own risks, although smaller perhaps than the risk of being over-reliant on one industry, product, input, practice or policy, so the benefits and costs of diversification need to be appreciated

Productivity growth

What tools do you have to offer?	Policy to appreciate existing diversity of production in the landscape, of ecosystem services as well as traditional production, to raise supply but also reduce demand and address distribution questions
How can your tools address challenges in the outcome areas?	Benefits of multi-objective/function landscape diversifies income and raises resilience, growth while reducing demand and also looking overseas to do this to ensure that domestic policy does not have negative poverty or economic consequences
How do your tools interact with other tools?	Need inputs from and feedback to knowledge, technologies and planning
What are the impediments to effectively employing your tools?	Population and production (be it traditional or post-production) issues are neither universal nor uniformly distributed so need to be sensitive to local constraints, including socio-political constraints
What are the risks of intended consequences of the use of a suite of tools under consideration and how to manage these risks?	Green revolution came with costs as well as benefits so any "factor 4" revolution needs to be monitored and evaluated carefully and mindfully, population and demand-side issues can be politically complex

The way ahead from our discussion may not be as clear as this picture suggests, nor as clear as we may desire.

However, we have identified some strong areas on which to focus: we are unashamedly **rural** in our focus, whilst recognising the links with urban areas and across the globe; we are particular interested in strengthening the **science-policy nexus** with a view to **long-term** environmental, economic and social sustainability; and developing future **security** for Australia in terms of food security, environmental and social health and wellbeing, and innovation and R&D for the future; in bringing a **multidisciplinary** focus to this endeavour; concentrating also on **communication** so that research may be incorporated into policy and be adopted on the ground; which of course requires attention be paid to **participatory** models, focusing on **learning** and **capacity building** with a whole of **landscape** focus which is **scale sensitive**.

So, we have made some writing on the wall, now to read it and translate it into action.

Recommendations - general

- Policy to raise overall R&D funding
- And direct to: long-term multi-stakeholder / participant collaborative multi-disciplinary/ disciplinary research as well as of uptake through resilience-raising, capacity building and public participation; increased learning including policy learning and focus on education including public education and extension.

What are our recommendations? There could be many but we chose to make just a few. First of all the general.

Recommendations - specific

- Increased funding according to research sympathetic principles
- Policy and Funding for public participation and enabling participation through extension/ learning on-ground and policy learning
- National body/role for advocacy and advancement and communication of agricultural science
- Multilateral agreements to support OS research with Australian researchers - Development AID $ / Policy to leverage natural competitive advantages e.g. stable institutional structures & supportive informal norms of collegiality

And more specifically.

Policy is only one of four areas being addressed at this Think Tank. Policy cannot be separated from these areas and needs to have input from and feedback to each of them.

What is important is the relationship.

Thank you.

Discussion

Chair (Bob Williamson)**:** There are many points there. I will ask the first question. Just suppose for the sake of argument that I am the Treasurer or the Finance Minister and I say, 'Well, there's lots of great stuff there, but I'm afraid there's no new money involved. What can you shut down so that we can increase this?'—within agriculture, because it is all sector based; you are not allowed to take money out of somewhere else.

Robyn Bartel: I will segue nicely off the end of that question and say that that is part of the problem with the siloing of expenditure and not thinking strategically; not thinking whole-of-government and not integrating some of these issues so that all departments have to address the same issues—that is a first point; and to see that you will get leverage from funding in one area to assist in another. So, if you are going to improve agricultural interests, you are also going to improve social resilience and rural communities; it has a lot of social welfare and public health benefits. It is seeing those interrelationships and, therefore, not siloing things. Seeing them as competing kinds of public choices and as competitors on the public purse is part of the problem; so it is acknowledging the interrelationships.

We need our research to be put forward and communicated effectively to policy-makers and government—the things about whole-of-government and integration are very important—so that they see this is not just their putting $5 million into research and then saying goodbye; it has a lot of spin-off benefits and consequences that are value adding.

Question: Mike Raupach, CSIRO Marine and Atmospheric Research. Robyn, you mentioned post-productivism. Could you please expand a little on that and then say how this would play to the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) in an environment where increasing productivity is the driver of most Australian policy?

Robyn Bartel: I will make another disclaimer and say that this is a highly contested area in the literature. Our points about post-productivity basically arise out of thinking that landscape use should not have tight boundaries around it: this parcel of land is used for X and this other parcel of land is used for Y. The thinking is that we have a paradigm of productivity, where we have private land that is used for productive personal-private economic gain—and that is what it is supposed to be used for—without acknowledging that it does do other things. In a policy environment that is moving towards valuing and supporting those other things, maybe it is an idea that we recognise that more explicitly and also support those other things that the land can provide, such as ecosystem services.

One of the advantages is that it is recognising what is already happening, with a blurring of the boundaries between how private land is used for public good and also how public land is used for private gain. We know there has always been a blurring there, and regulation in the urban environment with planning regulations is probably a prime example. But there have always been regulations impinging on private productivity in the agricultural sector. It is just the way we think about it. So landscape is 'multifunction'. If we support that 'multifunction', it may be that we are being more respectful of biophysical realities and, therefore, enabling sustainability a bit more effectively.

Chair (Bob Williamson): Do any members of the group want to add anything?

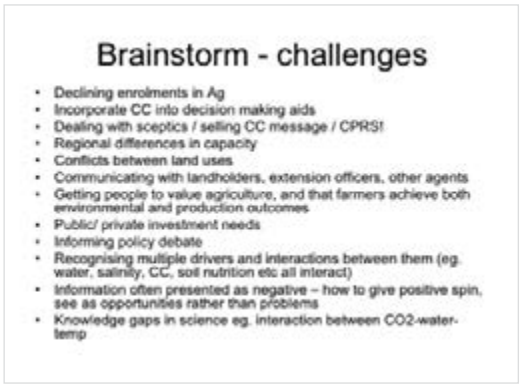
Question: Douglas Bardsley, University of Adelaide. Yes. I would extend it. I think there were some really interesting discussions on this idea of post-productivism; maybe it is extending it. It is a little challenging in relation to Australia's sort of dominant politics in agriculture and there is a bit of a gap in that cycle that we saw there between the feedback. A lot of people here are doing research in that post-productivist paradigm. The information they are developing, the new knowledge, is feeding into a dominant trade-related, export-related paradigm, which is just a mismatch with the current science. So I think some really interesting questions for researchers come through there.

Reports from breakout groups

Group B – Knowledge management

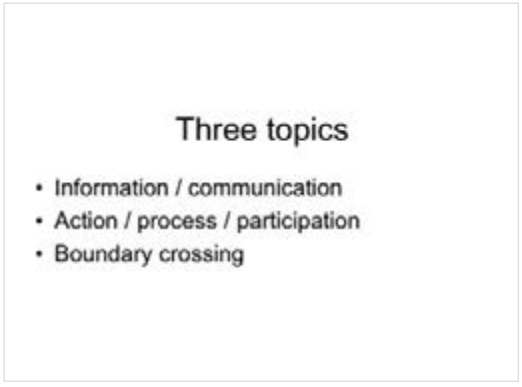
Rapporteur: Dr Georgina Kelley

I would like to reiterate Robyn Bartel's disclaimer that all ideas are from our group and all omissions and errors are mine.

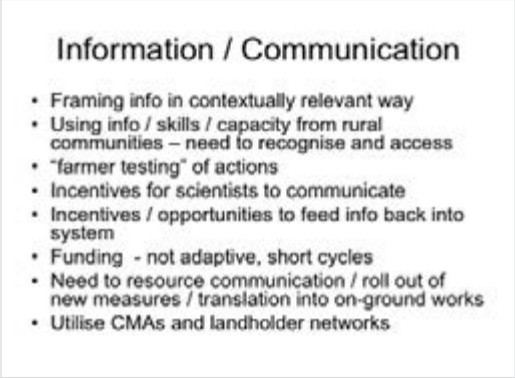


We started off as each group probably started: brainstorming what our main challenges in the area of knowledge management would be. We came up with a whole raft of things that were highlighted over and over again. How do we deal with declining enrolments in agricultural sciences, how do we encourage the next generation of agriculturalists and researchers? How do we incorporate climate change more broadly into decision-making aids? How do we deal with the sceptics, who seem to be really good at getting their message out at the moment? How do we sell the message of climate change, which is just presented to us as a problem? How do we help to sell something as problematic on the surface as the Carbon Pollution Reduction Scheme? How do we deal with regional differences in capacity and conflicts between land uses on a whole range of scales from local to more broadly? How do we get our message most effectively to the people who need it? Obviously, there are landholders and extension agencies; but there are other agents as well, such as policy-makers. How do we get people to value agriculture? How do we get them to understand that farmers and landholders achieve not just production outcomes but also environmental outcomes?

There is the need to influence the public-private investment interface. How do we inform policy debate more effectively? We have to recognise that this is a complex problem—I am not telling you anything new—with multiple drivers and complex interactions between them. How do we overcome the negative message that climate change is often presented with—how do we spin it? How do we deal with the knowledge gaps—how do we get them recognised and then filled?



Because that is a pretty long list—it is nowhere near comprehensive, of course—we distilled them into three topics. There is overlap, naturally, between them all, but we thought we could look for solutions under these three broad categories.



Under the first topic, how do we look at information and communication? One thing that came out again and again was that we need to make information contextually relevant. It is no good giving a landholder in northern Australia information that does not apply to their particular landscape. How do we access and use the information and skills that not just landholders but rural communities as a whole have? How do we access landholders as a means of testing and implementing new ideas? What incentives can we give to scientists to communicate? What are the opportunities to feed information back into the system?

The funding system seems to be problematic more often than not; it is not adaptive. We talk all the time about 'adaptive management' in agriculture, yet our funding is not adaptive. It is not adapting to our needs as they change and the needs of the end-users of research. There are short cycles, cross-disciplinary research not being recognised and so on.

We need to resource communication in the rollout of new measures. Often that is left off the end. We do this fantastic research and come up with solutions and, after three years, we publish a couple of papers and then that is it. How do we meet that nexus and translate it into on-the-ground works? Can we utilise organisations like the Catchment Management Authorities and landholders networks? Michael Robinson touched on this in his talk: we have this fantastic network, which is a decade old, of CMAs. How can we tap into that network? How can we encourage that particular system to continue?

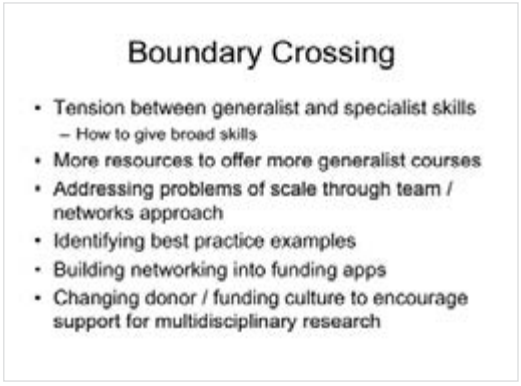
Under the second topic 'action process participation', again there is overlap between the previous and the next topic. But what are some of the actions that we can take to encourage participation? One solution that we came up with was to let us identify multiple lines of getting information out, not just going to the landholders. What about our tapping into that value-adding chain past the farm gate—mills, infrastructure systems? We need to look at the rural-

urban divide. Australia romanticises its rural landscape, but we are very urbanised and we need to encourage that appreciation of the rural landscape and what it achieves.

There is a dislocation these days from production systems. We go to Woolworths and buy our meat in a nice little tray under plastic wrap and we forget how that all comes about. But, recognising that consumers are a really powerful lobby group, can we tap into that to effect change?

I mentioned before that the sceptics are really good at getting their message across. We need to be better at getting across the idea of what it is going to cost us if we do nothing about climate change. Can we encourage better awareness of the carbon cost of the things that we use every day? Eco-labelling has come up before. How do we tap into the role of government and legislation to try to effect some of this change? We need to look at the value of communication with all levels of decision-making.

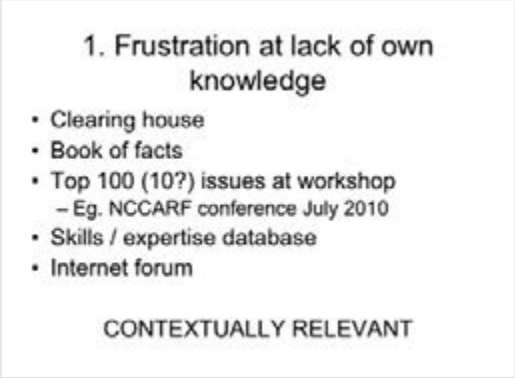
We talked about declining agricultural enrolments and how to create incentives to get people back into agricultural science. How do we encourage that awareness of the production landscape and its value? We talked about how to tap into the youth market, into schools. How do we retain quality teachers at secondary and tertiary level? Can we tap into these new modern social networking technologies?



The third topic was: how do we cross those boundaries? Robyn spoke about the tension between generalist and specialist skills. How do we give broad skills to people? How do we increase resources so that institutions can offer more generalist courses and give our graduates more generalist skills as well as specialist skills? Can we address the problems of scale through team and network approaches so that we have a team of people who are specialised at working within different scales that can then create a network that covers all the scales? How do we identify what best practice examples are? Can we build networking into funding applications? Can we get it recognised, as part of the funding system, that networking is really important? How do we get to change that donor-and-funding culture that does not seem to encourage true multidisciplinary research?

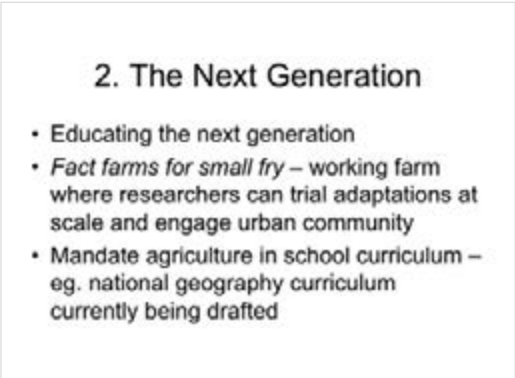
Now you are probably all asleep because you have heard it all before. I think by afternoon tea yesterday we had come up with pretty much nothing new. We realised that we had been going over things that everyone has heard before. These are all motherhood statements. We seem to be having the same conversation and coming up with the same kinds of issues.

There is a whole raft of natural resource management issues and these are just a few: salinity, deforestation and catchment management. We have been through it all before. Does climate change really give us an opportunity, a space, whereby we can tackle these again? Can we get it right this time?



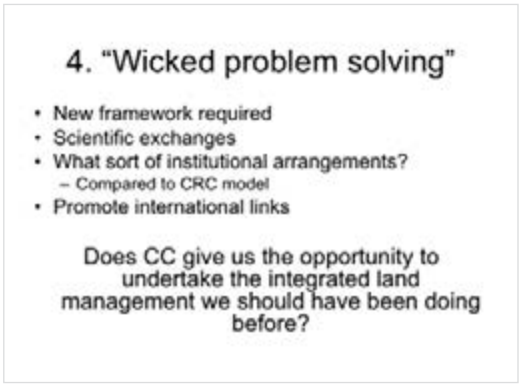
So we tried to throw out what we knew and the same old beefs that we had and we tried to see what was really at the heart of the problem, and what new things we could come up with. There was overwhelming frustration at the lack of our own knowledge or our own consistency of message. How do we consolidate the knowledge that we have? How do we make sure that we are on message and have access to the information that is not part of our own expertise? How do we have access to the information to talk in, for example, landholders' own language and give them the information that they need?

These are some of the solutions that were suggested. One was a clearing house for information—a whole lot of other examples of this being done before are out there. We could have a book of facts on the key points about climate change and how they relate to agricultural productivity, which we could then have at our fingertips. Can we use a forum like NCCARF (the National Climate Change Adaptation Research Facility) to create a top-10 issues list; 100 is perhaps a bit of a shopping list—that we can then use to feed into policy to say, 'This is where we need to focus'? Other organisations already have skills and expertise databases. Can we find some way of bringing those together across the disciplines so that people have access to the people that they need information from? Again, on the technology bandwagon, can we set up an internet forum? But, above all these things, the message that came out was that we need to have contextually relevant information.



How do we really get that next generation of people on board? We decided that it is not just about educating the next round of agricultural scientists; it is about making sure that the next generation appreciates agriculture and the production landscape and what it means for Australia as a whole. Can we set up fact farms for small fry: a working farm that not only gives us as researchers the opportunity to trial our adaptations and ideas at the farm scale but also lets us engage the urban community? We can pack the kids off for a week at the equivalent of a dude ranch and give them an opportunity to see how a working farm operates. What opportunities are there for us to get agriculture into the national consciousness at the school level? The national geography curriculum is currently being drafted; is that an opportunity for us to get agriculture mandated into the high school curriculum?

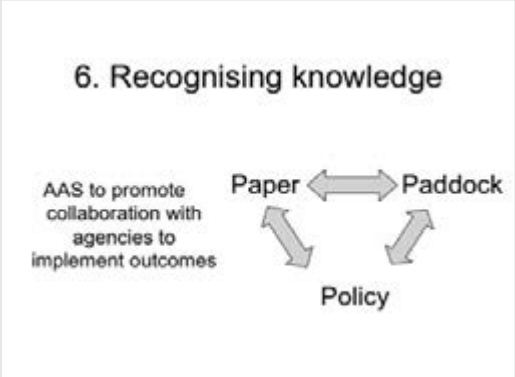
What new opportunities are there for productivity? Robyn touched on this topic as well. I am glad to see that there are some ideas that are common amongst the groups. What about incentives to get small landholders in peri-urban areas into production? I do not mean the lawyers who have their 5-acre blocks in the peri-urban areas who are out on the weekend growing cabbages. I mean accessing that land, which admittedly is some of our most productive land, that is getting urbanised on the fringes of our big cities; can we somehow bring that into the production network? We talked about the push to buy local, the Slow Food movement, and the change in consumer attitudes to where we get our food from. Can we tap into that consumer consciousness and set up some kind of share farming or cooperative approach to utilising that land to be productive for our cities? What other mechanisms are there to promote community gardens in urban areas? We recognise, of course, that there is a lot of land-use conflict in the more urbanised areas; but how do we build that into promoting productivity in urban areas?



Climate change being a 'wicked' problem is not new to anybody, but does climate change give us a new opportunity to tackle the way we do things? Can we throw away everything that we thought we knew? Michael Robinson displayed a slide that showed us our research network. I found it a little frightening to see all of those institutions that were listed. How do we get things done? Can we create a new framework that promotes scientific exchanges, some kind of new institutional arrangement, perhaps on a Cooperative Research Centre model but a different kind of

institution that can promote international links? Perhaps climate change gives us the opportunity to undertake some of this integrated line management that we should have been doing before. Can we create a new framework to do that?

Often we hear that blue-sky research is not recognised and promoted. But what came out of our discussion yesterday is that there are many difficulties in getting funding for applied research and, following that, getting the knowledge from that applied research out into the community and to people who will use it. The ERA (Excellence for Research in Australia) framework does not really promote this kind of thing. You get incentives for publishing in high-impact A-class journals rather than for publishing in Catchment Management Authority newsletters. The networking is not recognised. Can we come up with a new set of indicators to measure the impact of applied research? How do we construct enduring networks? I understand that CSIRO has been working on science health indicators—I am sure that there is someone who understands that better than I do—but can we establish a new framework of indicators that can encourage applied research and create that kind of impact factor outside of the high-level journals? Perhaps the Academy, in conjunction with other academies, can create a new journal that does just that: promotes that kind of interdisciplinary applied research and gets that message out beyond the scientific community.



Another thing that came out of our discussion was recognising the knowledge not just of scientists but also of landholders. Lesley Head mentioned yesterday that landholders themselves have a very particular engagement with climate change. Week to week and season to season, they are the ones who experience how the climate is changing. We need to tap into that. We need a cycle that goes both ways, paper to paddock and back again, and we need to include policy in that cycle as well. Policy needs to feed in both directions. So it is encouraging the cycle—again, Robyn touched on this—and how we promote these collaborations to implement the outcomes.

Another idea that came up is: let us think of a new way of valuing our producers. We throw 'subsidies', for want of a better word, at our producers in several forms: drought assistance, adjustment assistance and a whole raft of other payments or grants. Can we encourage a new way of valuing landholders and producers by scrapping those and paying them a base salary, as we would pay a public servant for doing their job, based on implementing best practice? Obviously there are problems—for example, how do we define 'best practice' and how do we scale the payments? But it would be sending a positive statement about the value of agriculture. It is about efficiency in the government payment system, valuing agriculture and keeping people producing where they should be.

We can probably sum up all of this as 'the right stuff'. We need information and knowledge to go to the right place to the right people at the right time. It needs to be the right information and, above all, we need to have it in the right context for people to be able to use it. We need to see climate change as an opportunity and not a problem. Thank you to my group and to the chair.

Discussion

Question: Kirrilly Thompson from the University of South Australia. You raised the issue that we need to get the results of our research out to the public. I agree with that wholeheartedly and I think we should all take some responsibility for that. But, just to play devil's advocate, are we the right people to do that? You had the 'right people' in your last slide. Some of us might be the right people but perhaps not all of us. For example, should we have a budget line in each of our projects or our centres where we can fund a communications person with expertise in that area who can get our messages out in digestible and effective forms?

Georgina Kelley: That is a really good question. It demonstrates how it is really hard to present a whole afternoon's discussion in the space of 15 minutes, because that was something that we talked about: can we somehow influence the funding cycle or the funding system and include outreach extension—communication—as you said, as a budget line? Your project runs for three years and you have a further part of your grant that then funds either a specialist or

the investigators themselves to invest time and effort into communicating with the most appropriate people to set up—within your landholder newsletters, other stakeholder brochures and that kind of thing—communicating that information at the different stakeholder levels. We touched on that yesterday and it would be something to follow through in terms of an action that we can take.

Question: Jonathon Sobels from Flinders Uni. I notice from your presentation that the word 'forum' came up a number of times. This is probably more of a statement than anything, but I would like to emphasise the importance of the creation of fora, particularly public fora, where you can get the stakeholders around the table where personal relationships can become part of the debate. I think too often we try to do things remotely. It is the creation of a physical place where people can come together that creates the opportunity for collaboration, communication and all those other good things; it also tends to create a context. So I would just emphasise that as a pathway.

Secondly, the fact farms for small fry idea follows on from a group in the UK called Linking Environment and Farming (the LEAF group). It essentially started out as a lobby group, but it actually does this on a very broad and large scale in the UK, getting people to come onto farms and having demonstration days. But it also audits farms for natural resource management, which fits in with Douglas Bardsley's post-productivism idea that the farming or rural landscape is now as much about biodiversity in natural resource management as it is about producing enough food for people to eat.

Georgina Kelley: I think the message is that there is nothing new under the sun. It is good to know that it happens elsewhere, that there is a model for it and it works. It is something that we can pick up and run with, without having to reinvent the wheel.

Chair (Bob Williamson): Does anyone else from the knowledge management group want to add anything to Georgina's talk?

Question: (Unidentified)—I would like to add a little on the communication role. Communication is often seen—this came across in previous comments—as how to get research outcomes to the users. But I think communication also has an enormously important role to play in getting the earlier context of the researchers with the rural communities setting the research agendas, knowing what practices are already being carried out. Rather than only collaborating with experimental farmers, it is really knowing what is out there in the larger group of different typologies of growers in a certain industry; having our research agendas informed by those communication processes at an early stage and continuing over the project; and also resulting in better communication messages of getting research outcomes out of those.

Georgina Kelley: I think Robyn touched a little bit on that too in the policy context—that, yes, we need to be informed on what is needed as well as informing on what can be done.

Reports from breakout groups

Group C – Technologies

Rapporteur: Dr Sandra Eady

Having listened to the two previous rather free-ranging and stimulating discussions on the policy and knowledge management areas, I am feeling a little like 'Bob the Builder' up here. We are scientists and we are in the fixing mode, so we focused on how to fix things and what the solutions were.

The structure that we followed in terms of summarising our discussions was to list, with a little bit of background, each of the issues that we covered, tease out a particular recommendation, and give an example of something that is already happening in that space or an example of what could be done. The issues were loosely divided into science, sustainability and then social issues. So, as we work through these lists of issues, you can expect to see the science ones at the fore before we move to sustainability and then social.

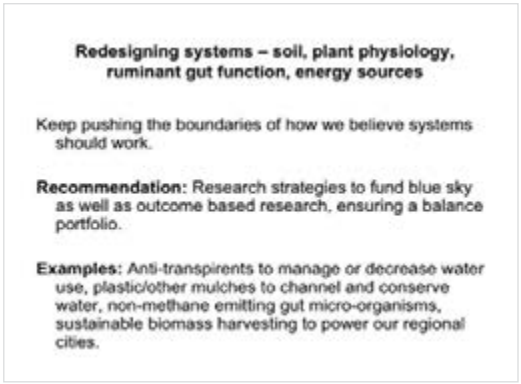
The issues are in bold at the top of each slide.

The first issue is basically that we need to be able to 'rev-up' our biology, plants and animals, to achieve a four-fold increase: to double production with half the input. Basic research is still progressing at the cellular level to understand plants and animals and to understand whether we can pull apart the normal framework of adaptation and evolution to reengineer our creatures to do things faster, at that accelerated rate. The recommendation is to keep a strong focus on our work on GM and marker-assisted selection and molecular understanding of biological processes, because that is where the key breakthroughs will come from. We need to be prepared to look at the risky

'unknown unknowns', which is one of the more useful phrases that man left us with! An example of how to do this would be to improve our basic understanding of the genes and mechanisms that drive the Krebs cycle so that one day we can make it more effective.

We need lots of fundamental research on what happens under climate change. What is the impact of higher carbon dioxide on plant growth? What is the impact of climate change on prevalence of diseases? A recommendation from our discussions was that a high R&D priority should be given to understanding some of the basic biological reactions to climate change. This is expensive work that needs coordinated funding. It really is quite complex and expensive but necessary. An example of this is that the interaction of photochemical ozone and increased carbon dioxide may cause stomata to stay open on plants, which leads to poor water utilisation, which negates any great effects of having a higher concentration of carbon dioxide. Dome experiments, which have been the way we make high carbon dioxide atmosphere to grow plants in, need to be field validated, as energy balances can have a totally overriding effect on what we have found under the small dome. So it is this gradual progression from the small dome to a larger dome to the real world and understanding what is happening.

The issue here is that we need to make the most of technological advances. This is like every researcher's wish list. The infrastructure, in a sense, is to create and measure environment and biological responses. So it would be new and inventive ways of monitoring field activities—'a sensor in every plot'. We do not have a recommendation in this instance but there are lots of examples: hand-held soil carbon sensors; methane monitors for sheep and cattle; cheap wireless long-life powered sensors to measure everything; and unmanned miniature helicopters to do image transects. Use your imagination; there will be technologies that we need to be keeping our eye on to underpin our research.



We then moved a little more into systems thinking and redesigning systems: soil, plant, physiology, ruminant gut function and energy sources; that is, to keep pushing the boundaries of how we believe that systems should work. This is a bit tricky and scary for scientists because you often think, 'Well, can we actually change that complex biological system?' Looking at methane-producing bugs in ruminants, I keep saying, 'The rumen is a really complex system; it's going to be hard to do this.' So we need to keep pushing ourselves to make sure that we are really extending the boundaries of how we believe that systems might be able to operate. Some examples are: anti-transpirants to manage or decrease water use; and plastics and other products, such as mulches, to channel and conserve water. Can we absolutely transform our soils? I know that the soil people will nervously say, 'What's she talking about?'—but it is this challenging of how we think systems should work that is critical. Can we harvest biomass in our landscape to provide power generation for our regional cities?

We then spent a reasonable amount of time talking about a slightly different paradigm, and that was the efficient use of existing production as an offset or an alternative to more production; the science and the technology needed to prevent losses, once we have grown that food—in the field, in the storage of food products—so that by the time it gets to the market, where people are using it and it is being presented for use, we are able to maximise the efficiency of that food system and end up with as little of it as possible going into waste. That also includes the distribution of food. Is it a matter of not having enough food or is it that we have enough food but it is not getting to the right places? So once again it is a focus on developing new technologies to aid in lowering food waste: smart food preservation, recycling technologies, pest and spoilage monitoring and supply chain optimisation. These are the sorts of spaces where we should be looking for technological research solutions.

If you can get the message through that it works, there is a big buffer in the system in terms of our resource use. A good example of that has been the reduction in water use of households in Brisbane and Melbourne. So there is a reasonable amount of resource buffer there that we can make the most of.

How well are we informed about productivity levels and landscape trends? How is climate playing out? Do we really know these things? Is production being monitored in appropriate frequency and scale? How often is ABARE putting through good statistics on agricultural production? Are our metrics right? At the moment we are frantically mining decades of field research through long-term monitoring site data, which is essential to validate our prediction models. Long-term monitoring is more and more important as we move into a changing scenario. Who is going to undertake that long-term monitoring in the future?

So a recommendation is that our R&D organisations, the whole collection of them, sort out who is going to do this long-term monitoring and that a 10-year and not a 2-year budget commitment is made for these activities. A good example of this is the need to know about soil carbon trends. To understand these trends we are going back to the field stations mainly run by state departments of agriculture, with long-term monitoring sites. They are being closed at the moment, so we have this issue of that enormous investment in agriculture since the 1950s being mined. If we do not keep doing that basic investment, we will not have anywhere to move forward from.

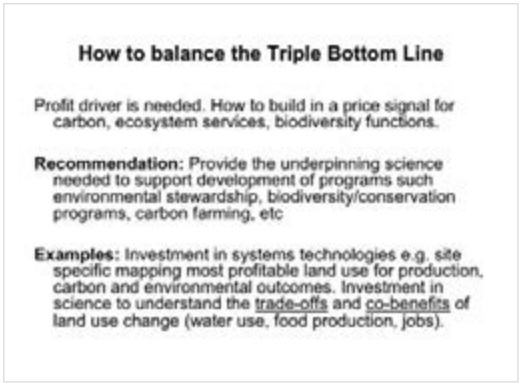
This issue is about making sure that the intersection of climate models with production and ecosystem models is robust. The current merging of models is a really active space and it needs some attention. People were making comments in our discussion group about some instances of where the climate models have been put together with production models and the outputs 'do not look right'. So a really strong recommendation is that we get greater collaboration happening at that interface and that there is exploration of the predictions coming from model integration, with really important ground-truthing activities, because you are putting together complex climate change, production and ecosystem models and the outputs need validation.

Can we prepare our farming communities for inevitable climate change? Are there some new Goyder lines that should be drawn? What will be our competitive position in producing key exports compared to that of other nations? The recommendation is that we need some critical and regional modelling to understand better the effects of climate change on farm enterprise gross margins and we need to build international linkages to make sure that we understand Australian impacts, in the context of the global impact of climate change.

Adoption rate of new technologies: this is a really hard one and it is always there. How do we manage this? We need better adoption of new technologies, we need better adoption of old technologies and we need more widespread adoption in countries that would also benefit from Australian technologies. A recommendation? There isn't one. How do we do it better? We need to put some really serious innovative research into how we do it better. How do we get those ideas to hatch? Then, moving on to the international: how do we build synergies and collaborations with international groups?

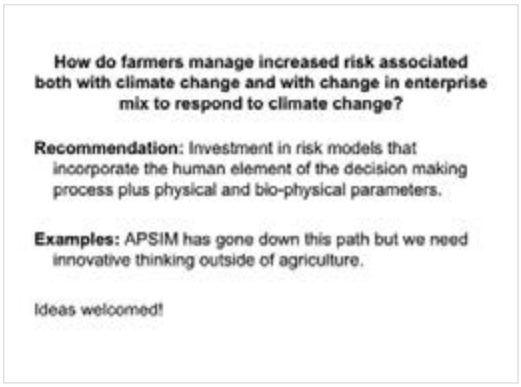
The information superhighway, including mobile phone reception, needs to make its way well into the bush. Farmers need capability to link into markets, organise logistics and use sophisticated tools to support business decisions. So bring on the rollout of national broadband and mobile phone reception. As scientists, we need to build a suite of tools for farmers to use and—as has been mentioned in the two previous presentations—we need to learn from technology adopters. Who are the current technology adopters? They are the kids running around with their iPhones, downloading apps. That works. They twitter. I have never joined an 'internet forum'; Twitter is the hip internet forum. We need to use modes of communication that work and understand why they work. Rather than building the 'Answer to the Universe' model, which we expect a farmer to use, why don't we think about building iPhone apps to support farmers?

How to balance the triple bottom line; can we use a profit driver? This is the post-productivity debate. It is about how we use a price signal for carbon to achieve both carbon storage and ecosystem services/biodiversity functions, so that land is used in an optimum way.

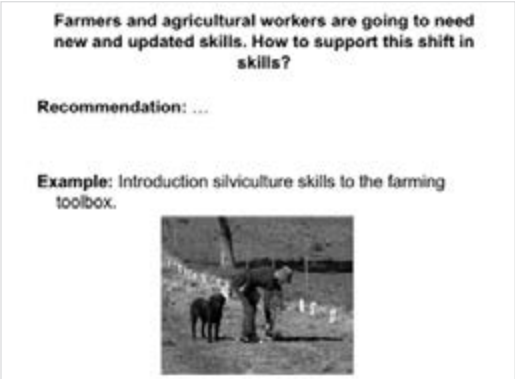


Underpinning science is needed to support the development of programs, such as environmental stewardship, biodiversity, conservation and carbon farming. We need investment in systems technology: site-specific mapping using GIS tools, looking at profitable land use for the production of carbon, and environmental incomes. We need to understand the trade-offs and the co-benefits of land-use change because we are going to see it in Australia; even with a relatively modest price of $20/tonne for CO_2, we are going to see it. We need to understand what is going to happen to water use, food production and jobs.

How can we create more resilient farming systems and business models? Diversification and resilience in farm incomes: how can we go outside the current business norms? So it is about tools and synching and science in an endeavour to support these.



How do farmers manage increased risk? Once again, we have not done a lot of work on risk modelling. What can be learned from the finance industries, the mining industries and other businesses that have to manage risk and variables and in their business space? APSIM (the Agricultural Production Systems Simulator) has gone a little bit down that path, but we need lots of innovation in that space. Farmers and agricultural workers will need new and updated skills; how do we support this shift?



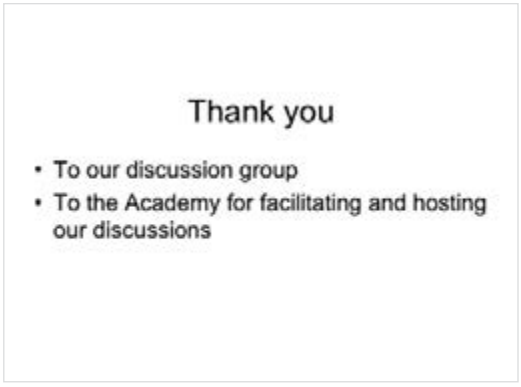
We have known for years that on the New England Tablelands, if you plant shelter belts of trees, you get more lambs, and you are paid for the investment in spades with greater lamb survival. But people do not do it—and they do not do it because their knowledge framework is livestock production. They rarely grow a crop for fodder, let alone do something as foreign as growing trees. Up-skilling of our farming communities is needed.

It is important to have a balance between appropriate rural adjustment for non-viable farming enterprises and maintaining rural communities. Larger and more efficient enterprises will be the trend but will lead to depopulation. Even efficient farmers cannot work in isolation. Some really interesting work can be done in the area of understanding the support structures that are needed to make communities viable. What do you need? Do you need a doctor, a school, a bank? Who is it that you need in a community to make it work? A good grassroots example of this is Nundle, a small town near Tamworth in northern New South Wales, where a local grazing family made an investment in their town to make sure that the town did not die. They brought in business, tourism and events of national importance, like the Great Nundle Dog Race, to build their community.

Can we use consumer pull? We have talked a little about consumer pull. We need some good metrics and science around carbon footprints, but we also need to express that in information that means something to people. So here

are some suggestions—and these are patented! Push the half-flush button and save enough water to grow a tree for five days; eat chickpeas instead of that fillet steak and you have helped stave off the death of the Barrier Reef for 2.6 seconds. (Please do not quote! These are guesstimates not facts.) Perhaps we should be expressing good environmental choices in terms of 'units of quolls saved from homelessness and certain death'. Fear and guilt might work for households and mums, and for the 'bogans' it might be greed. But we need to find what the motivators are that will turn people on to making sensible environmental decisions.

We need to act now in a meaningful way. Our science needs to inform and underpin the important policy decisions that are being made now—and that is a scary space for scientists. As a community of generally cautious scientists, we need to be prepared to be fearless in offering our best science into the mix for policy development, even though it is incomplete. As an example, some brave scientists contributed to a project that CSIRO ran recently to estimate the GHG mitigation and carbon biosequestration opportunities from rural land-use change.



On behalf of our Chair, thank you to our discussion group, and thank you to the Academy for hosting our discussions.

Discussion

Question: Saul Cunningham from CSIRO Entomology. I was in the group, so this is an additional point from the group. I guess that I am thinking about this point of imagining that we are at PMSEIC, trying to make a brief and impactful pitch to government about what matters. An issue that we talked about a bit was framing the question, and I think at the moment we have two quite separate questions going on. One of them is about global food security, where the recommendations from the technology point of view might be all about sending Australian food to other countries and having an impact. The other is about the profitability of Australian agriculture, where the recommendations would be quite different. It has been a bugbear of mine throughout the whole meeting and I know that many people are sick of hearing me say it, but I think there is an important issue of getting the message clear by identifying what it is that you are trying to achieve at the end.

Question: Dean Revell of CSIRO. This is probably more of a comment generally, than to your group. A comment about applied research has been raised a few times. You started talking about our being problem solvers. I think there are a couple of interesting things here. Our messages that do get heard are stating the problem. Another group mentioned the certainty and the fear with having a problem and how you react to it. It is beyond the individual's capacity to deal with some of these big problems; climate change is a classic and probably GM is another one. But I do not think we are so good at offering the 'what next', whether to the public or to the practitioners. That then touches on the concept of applied research being seen as a 'lesser' in a lot of the environments in which we work. If it were in the medical profession, applied research would be called clinical studies and would be seen as a pretty cool and necessary part of the research pathway. But for some reason we get to state a big problem and then do not really follow it up as much with practical testing as well as, I guess, the solutions, so people start to tune out.

Sandra Eady: I think also the audience that we have here is a narrow representation of those people who are influencing farming decisions. There is a whole wealth of people who work as consultants, agronomists and stock-and-station agents all through the countryside that are really quite important parts of that applied process.

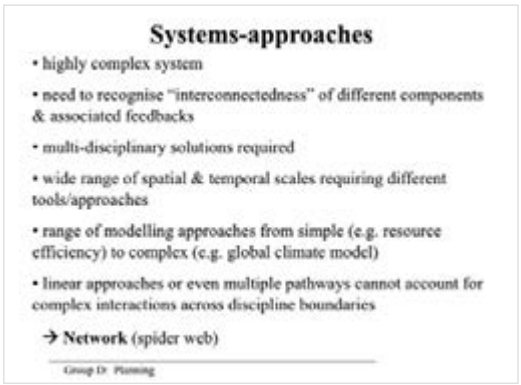
Question: Scott Chapman from CSIRO. I agree with Saul on the trouble we had defining the problem. But one thing that came up in a meeting with a bunch of crop scientists a couple of weeks ago was that plant scientists and livestock scientists do not have the agenda in this area and we need to build better links with climate scientists to grab hold of our part and have some influence. I think one of the biggest effects is that maps have big impacts on people. They love seeing maps of how the whole world is going to fall apart and they go and zoom in on it—Saul and I talked about that. But one way around that is to do what we have been doing in systems research in agriculture for a long time, which is to use benchmarking sites that represent particular systems. Peter Gregory gave us a nice example of those in his talk. If you build your science and your information around those, that is a much more powerful way of selling your message, with trust, reality, reliability and belief in the precision. The precision of maps is hopeless. That is one of the messages about how we can sell science in that way rather than to let maps rule us. We need to get away from pretty pictures driving policy.

Group D – Planning

Rapporteur: Dr Caroline Ummenhofer

Our group looked at planning and fairly early on we decided that we would not stick to the guidelines and the questions that we were being asked. We decided to let a much more free-flowing argument evolve. That, by necessity, means that I have had to exclude quite a few things that came up in the discussion in order to distil it down to the few key messages that came out of the really good discussions we had. So, with that, I call upon the group to jump in later on with anything that I have missed.

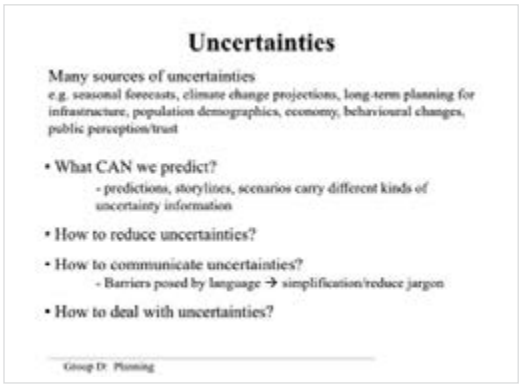
These are the key aspects that planning needs to accommodate: we need to use an integrated systems approach; we need to be aware of uncertainties—and, as we are going to see, there are many of them; and resilience and flexibility need to be put into planning. Another key aspect that has also come up with previous groups is knowledge transfer and implementation. I will now go through these in turn.



Systems approaches are really important because, as we all know and appreciate, we are dealing with a highly complex system. We need to recognise the many interactions between different components of the system, as well as the feedbacks between these. We need to recognise this interconnectedness in the way we target our planning.

So, overall, multidisciplinary solutions are required. These are required also on a variety of scales, both spatial scales and temporal scales. The tools that we employ to assess those and that we use in the planning approaches need to be targeted towards this very wide range of scales encountered.

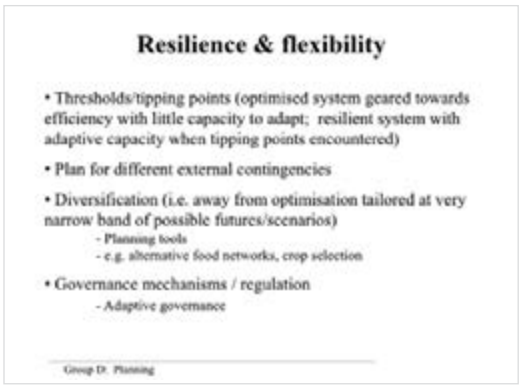
Modelling approaches also range from the very simple, like resource efficiency input/output models, to the very complex, like global climate model simulations. We thought that linear approaches or even multiple pathways about expected future scenarios are not the way forward, because they cannot account for all the complex interactions that we see in the system. All these interactions cross discipline boundaries, so we rather thought that we need a network approach—a spider web—to really assess the system. This also applies to the planning stages.



There are many uncertainties associated with many sources—this is just a list of examples—ranging from seasonal forecasts, climate change projections, long-term planning for infrastructure, population demographics, economic behaviour, behavioural changes and public perception and trust. This just shows you the wide range of uncertainties that we have to deal with.

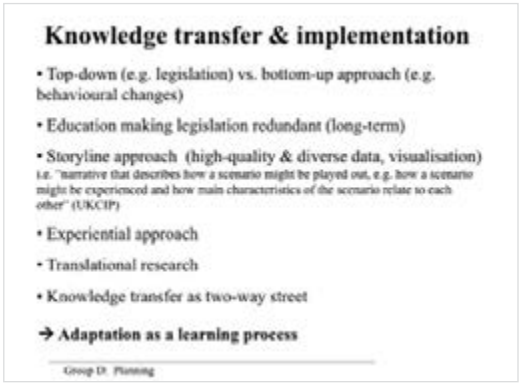
So what can we actually predict? When we made a list of what we can and cannot predict, the list of 'what we can' was decidedly short. Actually, there were many more items where we would like better predictions. I will say more in a moment about the uncertainty of information that is associated with different kinds of predictions and story lines. The scenarios are very different and it needs to be acknowledged that we assess these different kinds of uncertainties with different tools.

A key aspect that planning needs to accommodate is how we reduce and communicate uncertainties. Communication has come up a lot in previous talks. One of the barriers that we saw, especially in communicating uncertainties, is posed by language. Specialised discourse excludes a lot of practitioners and a lot of members of the public, and we need to be aware of that. We need to simplify our language and reduce the use of jargon, especially in communicating uncertainties and, as we are going to see later, in communicating our science. Another aspect is how to deal with uncertainties. Once we have communicated, 'These are the uncertainties,' how does an end-user actually deal with that?



Resilience and flexibility is a key aspect that planning should incorporate. There are thresholds and tipping points that could be crossed. As soon as you have a system that is optimised towards efficiency, it has very little capacity to adapt. Adaptive capacity in resilient systems is necessary when tipping points are approached and/or crossed.

For the future, we have to plan for very different external contingencies. One way of doing that is by diversifying, moving away from optimising towards a very narrow band—a very specific possible future scenario—and having available a much broader range of tools. This applies first to our planning tools: the tools that we use for planning should be diverse. In addition, the actual tools used to make the system resilient should be diverse as well. Examples for these could be crop selection and alternative food networks. Governance mechanisms and regulation again should have built into them resilience and flexibility. One of the key aspects to enable that to occur is adaptive governance, and I will come to that in a short while.

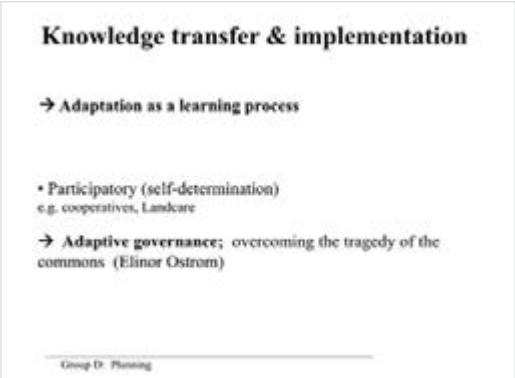


Knowledge management for implementation has cropped up again, as in all the previous presentations. It is a key concept that we need to be aware of and deal with. There are two ways: a top-down approach perhaps using legislation, or a bottom-up approach using behavioural changes. These are obviously connected and need to be tackled together.

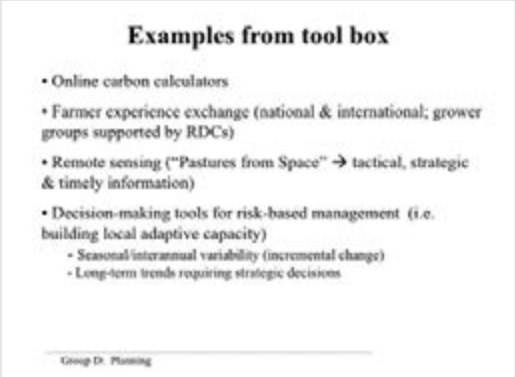
One point that we came up with is that education can make legislation redundant. Once behavioural changes that have been instigated through education take hold, they might make a top-down approach—which initially had to be chosen on a short-term basis—redundant. However, this is a long-term goal.

One key point for knowledge transfer and implementation is a story-line approach. This has been mentioned previously and it is very popular in Europe at the moment. It comes down to a narrative that describes how a scenario might play out in future; how a scenario might be experienced. So it is a description of 'a future world '. It takes into account different characteristics that this future scenario will have and their relationship to each other. That comes down to a lot of what has been said previously in that there needs to be a contextual framework—a very much applied method of how end-users can deal with future changes. We see the story-line approach as a very good opportunity to really provide very detailed and relevant information at the right time to the end-user. This enables them to adapt and really relate to the changes in a timely fashion. The story-line approach should be taken in the context of high-quality and diverse data—not just based on models but also using and incorporating observations and data. It should also incorporate visualisation tools to help understanding.

An experiential approach is very important and can be combined with a story-line approach. Translational research on how knowledge is transferred—what works and what doesn't work—is important. Again this has come up previously: we see knowledge transfer as a two-way street. It is very important that knowledge transfer goes both ways: that is, that there is feedback from end-users about what they need and want and when they want it, in order to target research towards the goals that are of use to them. Also, adaptation overall has to be seen as a learning process in the context of the two-way street.



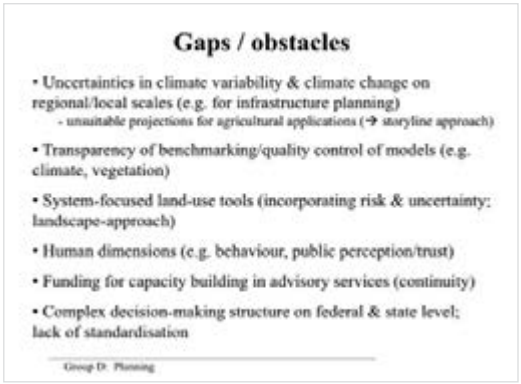
In addition to the previous points, one very important key message that came out of our group discussions was the need for participatory action. End-users and the public need to feel a part of making decisions and taking action, according to self-determination theory. Examples of that are cooperatives or land care. Where people feel that they are taking action, it gets them away from feeling like a victim. Instead, they can harness some of the opportunities that we see with climate change and also contribute towards solutions to problems. The key term there is 'adaptive governance', overcoming the tragedy of the commons. This is a very topical issue and this has just been shown by Elinor Ostrom winning the Nobel Prize for Economics for her work on overcoming the tragedy of the commons.



So what are some of the examples from our toolbox? How do we do all these things? Again these are just some brief examples that we came up with. As you will see, most of them follow on from the previous points that I have made. Online carbon calculators are one way. These could be used either for providing carbon footprints or for a farmer to look at the carbon content of the soil and adapt management decisions towards that. Farmer 'experience exchange', both nationally and internationally, again putting this into an experiential context and having farmers talking to peers and exchanging information. One example would be grower groups supported by Rural Research and Development Corporations.

Remote sensing can be used and it is already used by the CSIRO program 'Pastures from Space'. It is providing tactical, strategic and timely information. Timely information is a key issue. Farmers need to know information in a timely manner so that they can target their responses to it, and 'Pastures from Space' is an example of where that is done. Decision-making tools for risk-based management and building local adaptive capacity provide other examples. To help with seasonal inter-annual variability, decision-making tools can help with incremental change; however, there are also long-term trends that require strategic decisions supported by the appropriate decision-making tools.

All these, as you will appreciate, really empower the agricultural community to make decisions; they aid them in decision-making towards dealing with climate change.



Some of the gaps and obstacles that we have identified were uncertainties in climate variability and climate change on regional and local scales, which is especially important for infrastructure planning. A lot of projections might be unsuitable in their present form for agricultural applications, so the story-line approach there would be helpful. A key point is transparency, benchmarking and quality control for models. Planning models, vegetation models and many others need to be more transparent. System-focused land-use tools that incorporate both risks and uncertainties in a landscape approach need to be developed further. The human dimensions are still very little understood, so behaviour, public perception and trust need to be better researched. Funding has come up previously and we feel that, in particular, capacity building and advisory services being continuous is very important. A point we saw as an obstacle is complex decision-making structures at a federal and state level and a lag of standardisation that hampers much of the research planning.

In summary, successful planning needs to be multidisciplinary, collaborative, participatory and diverse, and it needs to provide continuity.

Discussion

Question: Andrew Moore from the CSIRO. I want to pick up the point that you made about diversification. Most farms are diverse in one way or another. A vital element of diversification in Australian agriculture is the mixed cropping and livestock farm. The reason that I raise this is that there are thousands of farmers out there who do not much like sheep but have them on their farms and are bloody glad that they have had them there over the last eight to ten years. If, however, we start imposing a carbon price on agricultural emissions of greenhouse gases, those people will be placed under a pretty strong incentive to go to continuous cropping—that is to say, to a more efficient but less resilient system.

Question: Sandra Eady of the CSIRO. We will get into a debate here. I think we will see a shift to more resilient systems. The modelling that we have done looking at how you can sequester carbon in the landscape suggests that the areas that would go to carbon and environmental plantings are largely the lower value grazing areas. So I suspect that we are not going to put high-quality dairy and grain-growing land under carbon plantings, but I suspect that more of our grazing systems will become much more resilient. If we get the policy right, we could end up with a mosaic of land management on properties, which avoids some of the bad parts of the blue-gum plantation scenario, where whole properties are bought and planted to blue gum. I think there are enormous opportunities for Australian farmers and landholders.

General discussion

Chair: Professor Kurt Lambeck

We now come to the difficult part of trying to sum up the remarkable amount of material that we have been able to cover in the last 24 hours. So far, what we have done and what has come out of the summaries has been very much the filling in of the elements of this four-by-four matrix that we have. I see the problem now being to convert this matrix and to extract the eigenvalues—in other words, the four main messages—out of this, which we then can use in various ways to make sure that the messages that come out are put into wider circulation.

I propose to spend the first few minutes on any other questions that you may want to raise. Then we will have two attempts at summing up, one by Peter Gregory and another by Michael Raupach. We will leave a few minutes at the end of that for any final inputs on those summaries. I will start off by asking whether there are any general questions or issues that have not been covered that people might like to address.

Carol Richards: I am just thinking about what perhaps has been missing from the four presentations this morning. We have not heard very much about the role of transnational corporations. We have heard about farmers, government and input into policy. I think transnational corporations are interesting to think about in this context because increasingly they are having a role in the governance over the agrifood supply chain. We are seeing that with supermarkets and agribusiness, particularly through systems such as certification, agri-environmental governance and so on. You find that Coles and Woolworths tell farmers that they need to purchase apples that weigh 130 grams and are 90 per cent red or green. So there is a form of governance that is occurring in Australia and elsewhere that is beyond actual governments.

Christine Storer: I have a quick comment to add. We have talked about the role of consumers, but the retailers are a very powerful voice. I think getting them on board would probably help.

Michael Robinson: To add to that, we talked a little about the balance between public and private investment and research, and I think that is what you are alluding to. I do not think we resolved it, but it is an issue that needs further discussion.

Kurt Lambeck: It needs not only discussion but also resolution because, while these apples look good, they usually have no taste—or nutritional value, I suspect.

Unidentified: I just want to mention a point that relates to powerful communication. Demonstrating the value of different resources quantitatively to the general public, the agricultural community or whoever you are communicating to, is very powerful. To look for solutions, you can use a quantitative framework to draw on simple examples, such as the half-flush providing enough water to water five trees, or more complicated examples. This group, because it extends beyond just researchers, has the ability to form more complex quantitative frameworks, which would be very powerful for communication purposes.

Kurt Lambeck: One of the things that has struck me is that, in the discussion and the summing up, the emphasis has been very much on modifications of what we know. I have heard very little about what we perhaps should be doing in the future. Have any way out ideas been discussed at the various meetings but not reported here that may provide directions for future solutions or approaches?

Karl Behrendt: One particular issue that comes to mind for the future is the three tiers of government and the planning processes that occur for managing a multifunctional landscape, and also at the farmer level in terms of managing a multi-objective farming system. At the moment, a whole heap of inconsistencies lie between the national objectives and the national policy and what can be implemented at ground level.

Sandra Eady: I think that is an aspect that we often overlook. Mention was made in our group that things can come in from left-field and clobber farmers, such as some decision their local council makes or a decision BHP makes to do coal-mining exploration on their farms. These types of things can really come in from left-field and upset what is a system that is moving and progressing in a satisfactory manner. There are some really basic examples just at the household level, such as the number of photovoltaic installations that have been put in Uralla, the village that I live in, but which have not yet connected people in because Country Energy have not got around to sorting out how they are going to do it. Often it is these sorts of structural issues that determine success or otherwise.

Susanne Schmidt: I think we have a serious problem in that there is something that overarches the vision, the knowledge and the appreciation of agriculture in this country. That is that farmers are seen more as environmental vandals because they are constantly in the media in connection with bad news, such as their using too much water, pumping out too many greenhouse gases, degrading the soil far too much and wrecking the reef. It is all those sorts of things. However, as a medical person, you constantly have nice plugs in the seven o'clock news such as 'yet another child rescued in the hospital'. There is just so much more positive spin-doctoring. It is so much more about wonderful gods in white who make us live longer and healthier and all the rest of it. Agriculture, with all its fundamental linkages or where it is an integral part, such as with good food and the sustainability and long-term future of the planet, is happily ignored. It has just slipped out of people's attention as we have moved from an agricultural society into a technological and medical sort of society.

Kurt Lambeck: Perhaps the answer to that would be that it is often said that the reason the medical research fraternity enjoys such good support is that all the politicians are getting older and they all want to live forever. Perhaps the advice should be: if they eat properly early in life, they will live much longer.

One of the points that I have not really heard much discussion on is the role of genetically modified organisms. Did this issue come up in the group discussions and are there any messages that should be coming across? I would have thought an issue that should have come up is: how do we deal with this problem of making genetic modification of organisms more acceptable to the community? After all, it is something that the world has been doing since the year dot.

Kate Grenot: We had a response in our group. Saffron referred to a UK example. Perhaps she could add some insight as to how that proceeded.

Saffron O'Neill: In the UK there was a wide debate on genetic modification some time ago and it was hijacked by Channel 4, a commercial television provider, that ran a series of programs on things like 'Frankenstein foods'. With this kind of message getting out to the public, it really skewed the debate and it has polarised things somewhat for the last few years. So far, as I have seen around climate change, the media in Australia is pretty skewed, so there needs to be some serious, open, honest and intelligent media engagement going on.

Kurt Lambeck: That TV channel is well known for doing that sort of thing. Of course, they did the same thing with the *Great Climate Swindle*.

Unidentified: From the other side of the debate, a good friend of mine worked on a long-term program looking at genetically modified organisms in the UK. He had to quit the program because his results—which were that they were having significant impacts on insect populations and bird life—were not being accepted by the research program. So probably both sides of the debate need to be open about the impacts of these on organisms.

Scott Chapman: I guess there are not many breeders and molecular biologists here, so, as a physiologist breeder, I might comment. I think the GM debate is virtually over in this country, as long as it does not have one of these media-generated explosions. I know that CSIRO is trying very hard to have a constructive engagement on that and there are a lot of engagements not only with us but also with rural research councils and things like that. My feeling is that we can still have an organic type industry, but one thing we have to think about is that 'clean and green' seems to mean 'clean and non-GMO'. I think the 'clean' is going to become really important because a lot of products in the

world are not being produced safely—and that is not just in connection with biotoxins but also high quantities of elements and things coming from countries that are not managing groundwater quality and things like that. I think that will be the next 'nexus', if you like: Woolworths might be importing broccoli and can guarantee that it does not contain *E. coli*; but, if it contains massive levels of cadmium, people will start to get worried. I think that is where the next round of debate might come from. From a GM point of view, I think most of that argument is over and it will pass by, I hope.

Andrew Moore: My observation is that nobody really seems to care that we are growing GM cotton. I think there are two points about that. The first point is that cotton is not food. It is actually GM food and not GM crops that are the issue. The second point is that, if people do show concern about GM cotton, the response on the part of the cotton industry is to say, 'Look at all the sprays we are not making.' So which genetic modification has an impact on the debate?

Ros Gleadow: Just on that GM debate, I agree. I think the debate is pretty much getting to be over, although it is not quite over. As a plant physiologist, one of the questions I have is that GMOs are not necessarily the answer to everything, because we do need to know what genes to put in and what the downstream effects are on other plant metabolites and nutritional factors—and we do not really understand that. So it is not a panacea, but it is a very important tool that we need to use.

Yann Chemin: I just want to know whether anybody knows how much GM food produced is exported as against consumed internally in Australia; also, how much of our biologically grown food is consumed internally and how much is exported? What are the ratios? I am just not clear. From what I have heard, people in Australia are more interested in biological food.

Michael Robinson: That is pretty easy to answer. The only GM food produced in Australia is cottonseed oil and canola oil. That is it and there is no other, although there probably will be. I guess you can work out the ratio pretty quickly. As for the organic one, I am not sure; I suspect that it is very small.

Munir Hanjra: I'll just put another issue on the table, which is the future of food. Should we be moving beyond conventionally grown food, GM or non-GM, to non-conventional food grown in petri dishes and supplied to you for the year for just $100, at the level your body needs to perfectly match its nutritional requirements? For example, there are some experiments in the Netherlands on seaweeds. What challenges and opportunities does that offer to agriculture?

Kurt Lambeck: Does anybody wish to comment on, add to or try to answer that? No, there does not seem to be much enthusiasm for that particular one.

Summing up

Dr Michael Raupach FAA FTSE

CSIRO Marine and Atmospheric Research, Global Carbon Project

I have deliberately kept to just one slide, partly in an attempt to keep the summing up short and partly because I have tried to reflect what was said in those four excellent reports from the breakout groups.

I think there are three eigenvectors and not eigenvalues to our matrix; therefore, it is a singular matrix. The first is that there is more going on here than climate change. That point was made yesterday by Lesley Head and I think it has come up in several ways, ranging from local scales—there are multiple pressures on farmers, climate change is just one of a spectrum of pressures—to global scales, where we face a series of finite planet limits, only one of which is climate change, and these are all connected. But there is much more going on at both of these scales than climate change alone, so the solutions have to be similarly diverse.

A second major vector in this space is the set of challenges that we face. We face challenges in population. We have debated that over the last couple of days in several ways: growth, with the sustainability or otherwise of future growth trajectories and more general sustainability issues than those reflected by economic growth alone. This leads us to challenges of most certainly doing more with less. The 'Factor 4' challenge has been mentioned several times: twice the food from half the inputs. There is a major question as to whether we can actually do this, globally and in Australia. If not, where else do we stress the system to make things work to accommodate everything? Are we heading for some major crash if this kind of challenge cannot be met? What do we do to avert that major crash?

This leads to what I think is by far the most important set of points emerging from our matrix, which are the opportunities. I have identified three here. I think more could be identified, but three have come out for me, appearing many times in the discussions.

The first one is the need for a holistic approach—and the opportunities that that holistic approach provides—to the problem of agricultural productivity and climate change. That approach recognises that food, ecosystems and other aspects of human sustenance—including the rights that people have to food and the communities that they live in that produce food and, in many cases, distribute and depend on it for economic sustenance—are all intertwined.

We are faced with a set of problems in bringing this holistic approach about, which have indications or the seeds of solution in the idea of adaptive governance, which has been referred to a number of times in this meeting. I think it is a key idea. It is not a simple idea; it is not a panacea. Adaptive governance potentially covers resource use, the production of food and the food systems that are involved in producing, consuming and distributing food. The key

points about adaptive governance are: that it involves participation by stakeholders, it involves feedbacks between the information that those stakeholders are receiving about the problems and opportunities they are facing—and the forms that are used to solve those problems—and that the governance structures are evolved rather than imposed. The notion of evolution of governance is critical here.

The second major opportunity or set of opportunities that we have, relate to knowledge management. One of the tyrannies we have to break is the tyranny of too much data. This means the evolution of ways of distilling data and achieving the knowledge and the wisdom from that data, which is of the greatest relevance to the situations to which it is being applied.

We have three major imperatives in our knowledge management. We need understanding. That comes from research and the application of research on-farm and on-ground, as well as the dialogue between those two modes. Secondly, we need communication as a central tool of our knowledge management. That communication is between generators of scientific and other forms of distilled knowledge and those who are using and taking up that knowledge. The communication is necessarily two-way because the environment within which those users of the knowledge are working is a critical component of the information that needs to go to the knowledge generators. Third, we need empowerment. We need the ability for that knowledge to transform the systems to which it is being applied.

All of this together provides an opportunity—I think this really important point was made in at least one and maybe two of the breakout group reports—of using climate change to fix long-standing problems in Australia's natural resources, not just in the way we manage our landscapes but also in the rural communities that live on them. As an example, we can envisage a transformed rural landscape that perhaps contains more people.

The increasing population that we are inevitably going to have in this country needs to live somewhere. The question of whether it is going to live in cities or the country is wide open. We can imagine a revitalised rural landscape for Australia: one that contains more people, with those people being employed in ways that are different from the ways that employment occurs at the moment; one where rural communities are being revitalised; and one where this joint challenge of increasing agricultural productivity in the face of climate change, in fact, is the spur to a lot of transformations that are absolutely essential in this country. Prime Minister and members of your Prime Minister's Science, Engineering and Innovation Council, that would be my suggestion to you as a framework for a fundamental research program that can drive the challenge of this country forward.

Discussion

Kurt Lambeck: I am a little puzzled. You talk about 'the tyranny of data' and there being too much data. Generally we are being told that we do not have enough information. What is the problem?

Michael Raupach: What I was alluding to there is that there is a hierarchy: from data, to information, to knowledge, to wisdom. As we ascend through that hierarchy we gain in the usefulness and the applicability of the information that we have, but we lose bytes; the number of bytes necessary to store the essence of the problem is reduced. You can encapsulate, we submit, in a very few words. Data, as we know now, goes to petabytes and exabytes. The tyranny of data is that we have too many petabytes and exabytes and not enough wisdom.

Kurt Lambeck: The tyranny is that we do not have the mechanisms to handle the data.

Michael Raupach: Exactly.

Kurt Lambeck: It is not the data itself.

Michael Raupach: It is not the number of exabytes; it is in the flow in moving up to the wisdom.

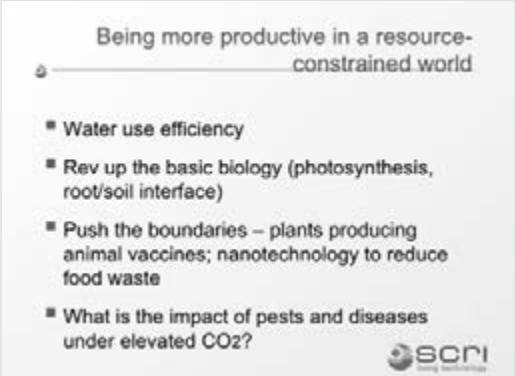
Kurt Lambeck: The reason I bring it up is that I would not want that to be seen as an argument for ceasing any further monitoring, which of course is something that we desperately need. I think there is potential for misinterpretation with those words.

Michael Raupach: Yes. I will take that on board.

Professor Peter Gregory

Director and Chief Executive, Scottish Crop Research Institute

Some of the things that I am going to say will overlap with some of the points that Mike has made. I have tried to pick out just three major points from the many things that have been said over the last couple of days.

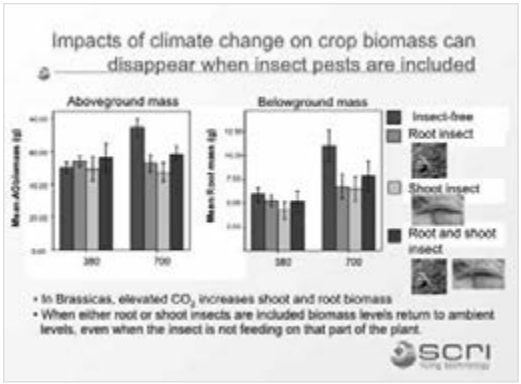


I think one of the big things that we have been talking about in many different forms is being more productive in a resource-constrained world. It has always seemed to me that Australia had the potential to lead the way in this because, in your dryland systems, you have been talking about water-use efficiency for years and your farmers understand this idea. You had simple ways of putting it across, basically based on French and Schultz and subsequently modified—I get several papers from Australia to referee about water-use efficiency. So, at that level, you have had a great start. It is a shame that your irrigated farmers do not have similar concepts.

This notion of producing more and producing efficiently is there, I think, and there is a real opportunity to make use of that. Somebody said, 'Let's rev up the basic biology.' Yes, we need to do that. We need to do that not just because of the growing population; it is a sensible thing to be doing, anyway. There are all sorts of areas there where there are big opportunities for basic biology. Photosynthesis was mentioned earlier. I would say, of course, that there are also things going on in the soil where we can base really good opportunities.

Then there are things like 'pushing the boundaries'; that was another phrase that somebody used. For example, we could have plants that produce the vaccines that animals need to combat diseases. We do not do it at the moment, but it is perfectly possible to think of doing that, using not just genetically modified organisms but also what we know from ethnobotanical studies and other studies of molecules within plants, getting the value from various molecules in plants. We are already starting to use nanotechnologies of various sorts. But there are new layers in plastics, for example, in which supermarkets wrap their chunks of meat, which detect whether that meat is going off. That is getting away from the tyranny of the sell-by and use-by date. That would have a massive effect on food waste. At the moment, many people throw food away based on the use-by date, not on the basis of whether the food is edible or not.

Finally, another point that I want to highlight is that, while we do have models that bring together crop models and climate models, they nearly all ignore pests and diseases. Why is that important?



Here is a result. This little experiment is from my own institute. We grew brassicas. The important point is that, if you grow them in elevated CO_2, the shoot growth and the root growth increase. But if you put in some chewers—of the roots or the shoots—then all the effects disappear. You have wiped out any benefits from the elevated CO_2 because these bugs will eat the things better.

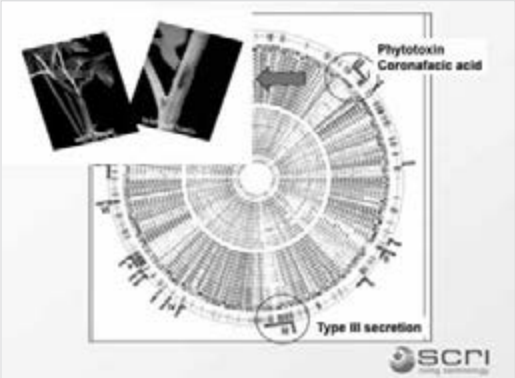
There has been a lot of talk here about this next thing: how do we engage with the public; how do we get our messages across? To keep me sane, the thing that I used to do a lot of in my spare time was calling barn dances or 'bush dances', as you call them in Australia. When I was a PhD student, regularly on a Wednesday night I used to travel to a holiday camp on the east coast of England to call bush dances. So there I was, calling, 'Right-hand turn, left-hand turn, do-si-do.' At that moment the band interrupted and I turned around and said, 'Everybody swing.' When I turned back, 300 people were going like this…I failed in the communication. But to you I have painted a picture—and you are all looking at me at the moment, you are not looking down. I have painted a picture. All the blokes in the room are thinking: 'Oh god, he called bush dances? What a berk.' I have told you something about me. I have personalised it. I have people in there. I have a picture in your mind and, in that case, it is a picture of miscommunication. But I think it is absolutely vital, when we are trying to engage with the public, that we try to paint a picture. Somebody mentioned that in one of the breakout group reports and I could not agree more.

The other thing is: why are the climate sceptics better? Somebody said, 'Their story is better.' It is a bad story, but they say it better. That leads to the issue: what is the story that you are trying to put across?

Chris Clark is here from ABC's *Landline*. He has 10 minutes on his program to tell a story. If he is interviewing you, you can help him by being clear about what your story is. It is not telling him your results; it is being clear about what the story is so that he and others can assist you, whether it is your communications office or whatever.

If you go into a Marks & Spencer supermarket in the United Kingdom and you want to buy smoked salmon, you go to the smoked salmon counter and there is 'Loch Beauty' smoked salmon. There is a beautiful picture of the Scottish

Highlands and of a Scottish loch because they are selling you Scottish salmon. 'Loch Beauty' does not exist, it is completely fictional. It is an incredibly successful marketing device that has painted the right picture. So go on the media train, of course, but try to move your results into picture form.



Here is a way that bioinformaticists have come up with to convey huge amounts of information, in a rather beautiful form. Around the outside is the genome sequence of a particular disease that we are interested in, compared with what is in the circles, which is all of the other genome sequences that we have for bacteria. Scientifically, it is interesting because we can see which genes of the organism we have are of interest relative to all of these others. Out of this picture—this pictorial way of expressing the data—we also get real scientific understanding. We find, in fact, that this plant pathogen has more of its genome in common with human gut pathogens than with any other plant disease. So pictures are important scientifically and I think there are great new pictures coming through from the bioinformatics communities and the computer scientists. The professor of print design at my local university used these at an exhibition in Singapore and they sold out, so they are commercially useful too.

The stories and the way we tell them are important because the policy-making community certainly needs our scientific advice, but they are getting pressures and information from other sources too, particularly through their politicians and the public, to whom the politicians are answerable. So getting your stuff into newspapers and onto television for my generation is important; getting it onto the web and mobile phones, through Twitter and Tweet, is important for the generation below you. I do not know what you look at—maybe a combination of things. So there are different stories and there are different media.

I just want to say something about 'profitability'. With what we have been talking about over these days, I do not think it is a contrast between profitability here in Australia and food security somewhere else in the world. These things are intimately linked and we need to find a way, again, of expressing that in what we do. Australia is not isolated from the rest of the world; it has a damn good quarantine system, but it is not isolated from the rest of the world.

Finally, in relation to specific policies, I think that policies to assist in the reduction of demand, through coping with waste and doing things more effectively and efficiently, is as important as the whole question: how do we increase the supply?

Discussion

Question: Kirrilly Thompson from the University of South Australia. I have a comment Peter; you enunciated the tyranny of the use-by date and I think you also touched on the tyranny of packaging of supermarket products. I have been thinking about how we might change that or turn it around. We have a model from the Heart Foundation; they give their tick of approval to foods that are good for heart health. Might we be able to have a tick of approval for products that are good for climate health, and, if so, who would regulate that?

Peter Gregory: I am sure that the big supermarket chains, if they thought their consumers wanted that, would adopt it; they would find a way of doing it. As you probably know, they made a move into sort of carbon labelling but backed away from it when they found out how difficult it was. But they are still thinking about it and they do still want it to happen because their consumers are telling them that they do want some measures of that sort. So, yes, I think that sort of thing is useful for certain sections of the consuming community.

Kurt Lambeck: I had a quick look at the Australian this morning and on the front page there are comments reported as having been made by the head of the Department of Treasury. He is reported to have said that the golden age is there for Australia until 2050 at least. It is very much an economist-driven view. He says that the economy will continue to grow in the way it has been growing, at least until that period; that Australia will be able to support a population of 35 million; and that these people will be going into the big cities. He foresees a doubling of the population of Brisbane and, if I remember correctly, a 50 or 60 per cent increase in the population of Sydney and Melbourne. But all the issues that we have been hearing about—water and how this can be done in a changing climate with food supplies etc.—are not mentioned. What sort of message should we be giving to the public in response to this sort of thinking? Is somebody prepared to stick their neck out and risk the wrath of their employer?

Mike Raupach: Yes, it is a sticking out of the neck. To counterbalance messages like that one from Ken Henry, I think we the scientific community—not just this workshop and perhaps not only the Academy of Science—need to be pointing out that there are some physical, chemical and biological limits to the number of people that this country can support in the lifestyle to which we are all accustomed. This is a long-standing debate, but the fact that there are limits is incontrovertible.

An example of those limits is provided by the current competition between ecosystem services and food, particularly with irrigated food production in the Murray-Darling Basin. So it needs to be pointed out that, if Australia decides to have a population of 35 million, 50 million or whatever by 2050, there will be consequences for most certainly the ecosystems and the biodiversity and probably for the quality of life in both rural and urban environments because of pressures from, for instance, decreased water availability. These are trade-offs that the country has to decide on. We can go for growth, we can go for environmental sustainability, or we can go for a well-designed mixture of the two.

Peter Gregory: I think Australia has a real opportunity to lead the way, but it is not going to do so if it just relies on simplistic economic models such as the one that was proposed. I am not an economist but, as I understand it, one of the problems with many economic models is that in their formulation they do not take much account of time and resources, the very things that we as biologists regard as absolutely essential in any model. Therefore, there is a disconnect between the standard Treasury-based economic models and what we as biologists are trying now to communicate, albeit very imperfectly.

Whether Ken Henry is right about 35 million or not, I do not know. But I do not think it is right to carry on with the same sorts of economic models—economic models that nobody used to predict the global financial crisis that

we now have; that nobody, as far as I know, used to predict the food crisis that we had; and that certainly never predicted the fluctuating prices of oil that we have experienced over the last couple of years. So I think there are some severe problems with the economic models that are being used. Somehow we as biologists need to get together with those people.

Kurt Lambeck: Thank you all very much for your contributions. I think it has been a remarkably successful discussion so far. I hope that we can find a mechanism to continue this discussion into the future. Thank you to the speakers, to the chairs, to the rapporteurs and to the organisers of the meeting for making it a successful event.

Some conclusions and recommendations

While it is accepted that climate change will impose new and more challenging demands on agricultural productivity, the issues remain complex. In the course of the two-day workshop, a number of conclusions arose from the discussions presented in this report. The main findings are that:

1. While climate change is one of the major challenges that Australia will face as a society, this is a very complex phenomenon. From the agricultural productivity perspective, climate change needs to be seen not as a single monolith to hit Australia in the future, but as a complex set of processes in which all stakeholders— farmers, scientists and policy-makers—are already entwined.

2. Climate change brings with it significant, diverse and complex biophysical, environmental, social and economic challenges across the agricultural sector. There are multiple pressures on farmers, and climate change is just one in the spectrum of pressures. There are also global-scale issues, such as population growth and sustainability, where we face a series of finite planet constraints—water, nutrients and carbon dioxide absorptive capacity—all of which are interconnected.

3. Food security—which encompasses the issues of food availability, access, and nutritional value—has re-emerged as a significant concern. These food issues interact with such factors as personal income, employment, level of education and institutional arrangements. Together they will also affect resilience or society's ability to adapt to the environmental changes that come along. With projections for Australia's population of 35 million by 2050, the demand for food will continue to increase. Therefore, given the drying trend in total annual rainfall in Australia over the last few decades, there needs to be better efficiencies. This includes considering multiple-use water—re-use and recycling—and reduction in agricultural energy inputs.

4. Because there is much more going on than climate change alone, the solutions have to be similarly diverse. Science alone is not sufficient to analyse and make decisions on how to respond to the multiplicity of complex issues associated with climate change. Many solutions or options are required, and these have to be multidisciplinary in nature and integrative in their application. For example, new institutional arrangements may be needed, and there are many adaptation and mitigation options that need to be thought through in relation to food distribution.

5. There are gaps in knowledge in many areas, not only global climate and climate change but environmental change generally, as well as the social and economic consequences. Therefore, policy to support knowledge generation and provide information to decision-makers should also provide better and more secure funding for research.

6. A whole-of-government approach needs to be developed to deal with the complex issues. That is, we need to take a more consolidated, coordinated and collaborative national approach to the issues facing the primary industries sector. For example, while the Rural R&D Council—which was formed this year—can advise the Minister for Agriculture, Fisheries and Forestry, a whole-of-government approach as well as a Commonwealth-state approach is needed in effectively managing R&D funds.

7. Science needs to inform and underpin the important policy decisions that are being made. Scientists have a role to ensure that basic scientific principles are applied to the data on which policy relies. Here further gaps were identified: gaps in communication between funding bodies and knowledge generators, and between generators and utilisers. Government is a funder that provides the ability to do the research; it is also an end-user of the research outcomes in translating them into policy. To drive the policy input process, research findings need to be communicated more effectively to policy-makers as well as to end-users. Scientists need to be prepared to be fearless in offering the best scientific advice—even though it might be incomplete—into the mix for policy development. A recent example is the contribution by CSIRO scientists in assessing greenhouse gas sequestration/mitigation potential likely to be achieved through change in rural land use and management.

8. Funding itself needs to be adaptive, that is, it should adapt to needs as they change, both for the researcher and the end-user of the research. For example, it should avoid short cycles and recognise cross-disciplinary research. A high R&D priority should also be given to understanding some of the basic biological reactions to climate change. This is complex and expensive work that needs coordinated funding. Research also needs to be better focused, including long term, to encourage students to come through tertiary training to address knowledge deficits emerging in these areas.

9. These challenges also create a range of opportunities. One of these is the need for a holistic approach to the problem of agricultural productivity and climate change. It recognises that food, ecosystems and other aspects of human sustenance, are all intertwined. The issue then becomes how to bring the holistic approach about, and one solution offered was 'adaptive governance'. This can cover resource use, food production and the systems that are involved in producing, consuming and distributing food. It engages with stakeholders and involves an evolution rather than an imposition of governance structures. A second major opportunity relates to knowledge management. Here we need understanding (which comes from research and its application), communication (between the generators of scientific and other forms of distilled knowledge and those who are using and taking up that knowledge), and empowerment (the ability for that knowledge to transform the systems to which it is being applied). All of this together provides an opportunity of using climate change to fix long-standing problems in Australia's natural resources, not just in the way we manage our landscapes but also in the rural communities that live on them.

Recommendations

1. Develop a national policy on food security which is linked to other current and future government policies and initiatives. Climate change adaptation and enhanced food security go hand in hand; therefore any policy which supports agricultural adaptation also enhances food security.

2. Support national research and knowledge management strategies through full implementation of the National Research, Development and Extension (RD&E) framework (being driven through the Primary Industry Ministerial Council and the Council of Rural Research and Development Corporations' Chairs) to support food security policy. The current framework needs to go beyond the agricultural and fisheries focus, to include post-farm gate and environmental areas. Australia's forestry, agricultural and land-management systems have significant potential to store or sequester carbon in their vegetation and soils and offset large amounts of greenhouse gas emissions over the next 40 years.[5] This is critical for increasing productivity and ensuring sustainability.

3. Provide continued research capacity support for the unique Australian soils, climate and vegetation, as well as for pest and disease reduction in plants, such as emerging new rust viruses.

4. Develop a long-term, ongoing and permanent national natural resources and environment monitoring system for the whole landscape, incorporating soil, water, vegetation and biodiversity. Understanding agriculture–climate interactions well enough to support adaptation and mitigation activities requires major improvements in data collection, dissemination and analysis.

5. Australian communities need to be engaged in the planning and implementation of social/structural adjustment such as water-use habits, and Australian governments need to develop policies and mechanisms to provide support during transitions to new systems that are more adapted to the emerging climate. Community-based adaptation strategies can help rural communities strengthen their capacity to cope with disasters, improve their land-management skills, and diversify their livelihoods.

[5] See http://www.csiro.au/resources/carbon-and-rural-land-use-key-findings--ci_pageNo-2.html

Appendix A Early-mid career participants

Dr Alisha Anderson

CSIRO Food Futures Flagship and Division of Entomology

Alisha completed her PhD in the Climatic Adaptation group at the Centre for Environmental Stress and Adaptation Research, Monash University in 2005. Her thesis topic was the fitness trade-offs involved in genetic adaptation to environmental stresses, and used Drosophila melanogaster *as the model organism. Alisha moved into the field of insect olfaction in 2005 when she was awarded a highly competitive CSIRO 'Emerging Science' Postdoctoral Fellowship. She currently leads CSIRO's Cybernose® Project in the Food Futures Flagship which is developing biosensor technology for measuring quality in the agricultural and food and beverage industries. Recently, CSIRO awarded her a highly prestigious travel and development grant Julius Career Award, which recognises a small number of the organisation's top young scientists.*

Alisha's scientific background working on climatic adaptation and insect olfaction coupled with her current position leading the Cybernose® Project, gives her the necessary foundations to contribute to ideas to enhance Australia's agricultural productivity under a changing climate. Her contribution will be especially relevant to the area of developing new technology for assessing food and grain quality and also in the area of new pest control strategies to reduce the loss of crops and the cost of pest control in changing climates.

Dr Jennifer Atchison

Lecturer, School of Earth and Environmental Sciences , University of Wollongong

Jennifer is an environmental scientist whose recent postdoctoral research examined the cultural geography of wheat in Australia, focusing on the transformation and mobility of wheat as a food and industrial substance, and on the experience of climate change in the everyday lives of wheat farmers in NSW. Her research interests include the geography and sustainability of food production, and the ethno and archaeobotany of Australian plants. Her PhD work examined the late Holocene and post contact vegetation history of the Keep River region in the Northern Territory.

Jennifer's most recent research on wheat contributes to a larger research project on the cultural ecology of Australian plants, whose aims are to provide more integrative and cross-cutting thinking on the complex issues of food provision and environmental sustainability. In this research, a wide range of geographical methods including historical analysis, ethnography, and empirical and spatial techniques are utilised. Jennifer can contribute to the Think Tank by providing perspectives on the social and cultural dimensions of change, adaptation and risk management amongst Australian wheat farmers.

Dr Michael Bange

Principal Research Scientist, CSIRO Plant Industry

Michael investigates approaches to improve yield, quality and resource use efficiency of cropping systems. He has significant hands-on and leadership experience in cropping systems, agronomic management, plant and crop physiology, simulation modelling, systems, and post-harvest research. Achievements include: development of technologies to manage climate variability through delivery of decision support tools; integrating research approaches to improve resilience of existing cropping systems; and investigating opportunities for cropping in new regions (eg northern Australia). Michael's abilities undertaking, leading and applying research have been recognised with significant leadership roles within CSIRO, the Australian Cotton CRC, a Fulbright scholarship, adjunct associate professorship with the University of Sydney, and numerous industry awards. He has attracted $9 million competitive funding, and published extensively in industry publications and journals.

Michael has a keen interest in ensuring sustainability and as a researcher passionately seeks to develop science and understanding of the impacts of climate on crop productivity and resource use to develop resilient systems. He currently leads a team of researchers that are specifically investigating mitigation and adaptation strategies in cropping systems. His understanding of issues in rural Australia, impacts of climate variability and strategies for coping, along with a genuine interest in the workshop theme means that he would contribute significantly.

Dr Douglas Bardsley

Senior Lecturer, Geographical and Environmental Studies, School of Social Sciences, University of Adelaide

Douglas trained as an agricultural scientist, a social geographer and an educator. His research interests over the last 15 years have focused on agro-ecological risk management, links between conservation and development, and education for sustainable development. His research has been undertaken both in Australia and the UK, and has involved fieldwork in different contexts in Australia, Thailand, Nepal, Egypt, Turkey, Switzerland and the European Union. He has completed a review of vulnerabilities of natural resources in the Adelaide and Mt Lofty Ranges to projected climate change, and has worked with regional stakeholders to help develop adaptation policy. More recently he has been working on a review of the implications of climate change for migration in the Asia-Pacific region.

Douglas has been researching issues of risk management for agriculture for the last 15 years. More recently his work has focused on climate change adaptation, particularly the roles of vulnerability analyses, participatory approaches to develop adaption policy, and futuring science to guide decision-making. This work has been published widely and would be able to draw from this professional background to discuss the future of climate change adaptation for agriculture in Australia in the context of environmental and socio-economic change.

Dr Karl Behrendt

Lecturer in agribusiness, School of Agricultural and Wine Science, Charles Sturt University (CSU)

Karl started as a lecturer in agribusiness with CSU in 2008 and this year became a Research Centre Fellow with the EH Graham Centre. His PhD (2008) is based on research on the bioeconomic modelling of pasture resource management and development. Prior to joining CSU, Karl operated an agricultural research and consulting firm, which serviced rural clients throughout the central west of NSW. He has also worked as a rural financial counsellor, farm management advisory officer at Tocal Agricultural College, and as an economist with NSW Agriculture. His current research interests include the bioeconomic modelling and analysis of agricultural and ecological systems, agribusiness planning and risk management, and the development and use of decision support tools in agriculture.

Karl believes he would bring to the workshop both industry experience and a developing background in agricultural and ecosystems research. Working as a private consultant to primary producers over the past 12 years has provided him with an insight into how producers may adapt to climate adversity while concurrently aiming to enhance their productivity. His more recent research has enhanced his knowledge about the broader societal issues of food security, regional stability and wealth.

Mr Craig Birchall

Lecturer, Sustainable Grains Production, Agronomy and Soil Science, University of New England (UNE)

Craig's career has included extensive experience in the grain industry of eastern Australia, including:

- *seven years with NSW Department of Primary Industries involving cropping systems research and extension in northern and southern farming systems;*
- *five years as a commercial agronomist involved in on-farm decision making and grower education; and*
- *six years with UNE running a graduate certificate course for agronomists and others in grains industry, focusing on sustainable grain production and the application of best management practice and the latest research results.*

Research interests include the agronomy of cropping systems, particularly crop nutrition and physiology and water management.

Craig has broad experience in addressing issues in applied farming systems agronomy in the northern and southern grain growing regions of eastern Australia. In addition, he has experience in agricultural extension, and working with farmers and their agronomists. Craig also has familiarity with a significant proportion of the agricultural research that is being conducted in the northern region.

Dr Sarah Bruce

Senior Scientist, Climate Change and Water Sciences Program, Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry

Sarah's research background is in the improvement of productivity and sustainability of farming systems. Projects included factors limiting canola productivity in conservation farming systems; factors influencing the productivity and sustainability of intercropping crops with perennial pastures; and the application of Agricultural Production Systems

Simulator (APSIM), a farming simulation model, to a novel intercropping system. Currently she is working at the science–policy interface in the development and management of techniques and approaches to improve the adaptability of farming systems to climate change and variability. She represented the Department of Agriculture, Fisheries and Forestry in the USA in 2008 to build on linkages with the USA where drought and climate variability are part of the operational environment, and to facilitate an exchange of information on drought preparedness, climate change and variability.

Sarah can contribute her understanding and experience in communicating the uncertainties of the science of climate variability and climate change to government policy-makers and farmers. A challenge to maintain and increase agricultural productivity under climate change partly lies in the effective communication of the uncertainty of science to policy-makers and industry; and the recognition that science is only one of the factors used by decision-makers.

Dr Clayton Butterly

Postdoctoral Fellow, Department of Agricultural Sciences, La Trobe University

Clayton joined the Department of Agricultural Sciences at La Trobe University in 2008 after completing his PhD in soil science at the University of Adelaide. Prior to this he was involved in research projects of the CRC for Plant-Based Management of Dryland Salinity at the University of Adelaide, and the Department of Agriculture and Food in Western Australia. Clayton's current research examines the role of organic matter in soil pH change in agro-ecosystems. He is particularly interested in the sustainable use of soil and land systems, and is an active member of the Australian Society of Soil Science.

Clayton has research experience in soil biology and nutrient cycling as well as the major issues facing productivity and sustainability of land such as drought, dryland salinity and acidification. In addition, he has worked in a number of states (WA, SA and VIC) and comes from a farming background which brings a unique understanding of Australian agricultural production systems and fundamental scientific processes. He is interested in understanding the wider issues of climate change and would like to participate in identifying future challenges to agricultural productivity and strategies pending a change in climate.

Dr Timothy Cavagnaro

Lecturer, School of Biological Sciences and Australian Centre for Biodiversity, Monash University

Timothy's teaching and research interests are in soil ecology and plant biology. In particular, his research focuses on climate change impacts on agricultural and natural ecosystems. Members of his research group investigate the role of soil microbial communities in the cycling of nutrients, and the consequences for plant growth, food security and soil health. His research seeks to inform debate on how best to adapt to and/or mitigate climate change, especially in agricultural ecosystems. Prior to moving to Monash in late 2006, Timothy was a research scientist at the University of California Davis, and before that, a postdoctoral researcher at the University of Adelaide, where he also completed a PhD.

Timothy's research focuses primarily on climate change impacts on agricultural ecosystems. He has several research projects investigating the impacts of climate change on agriculture, including soil carbon sequestration and crop responses to climate change. Timothy actively contributes to both national and international climate change policy development. He is lead author of an invited, peer reviewed report identifying climate change impacts on California agriculture for Governor Schwarzenegger, helping shape legislation (Assembly Bill 32), and has co-authored a report to the Australian Government *Garnaut Climate Change Review*.

Dr Scott Chapman

CSIRO Plant Industry

Scott has a PhD (1990) from the University of Queensland, and was a Research Fellow at there from 1994 to 1996. He has been with CSIRO since 1996 and currently Principal Research Scientist (Crop Adaptation). Scott has broad training in the areas of crop and plant physiology, crop simulation modelling, plant breeding, quantitative genetics and crop–climate interactions. Most of his research has been directly engaging with field crop breeding programs (public and private) to improve the yield of crops, particularly under conditions of drought and heat stress. His research has been directly supported by more than $7 million from international and national grant and research agencies.

All of Scott's research has been in the area of improving productivity of crops in the face of abiotic stresses like drought and heat. He works with international and national research agencies in a range of crops (wheat, sorghum, maize, rice, sugarcane and sunflower) and sees climate change as requiring urgent application of this research and

the increased training of new scientists in Australia and elsewhere. He currently leads a new project of Climate Ready that aims to identify new traits and options to improve productivity of wheat and sorghum under increased heat and increased CO_2 conditions.

Dr Yann Chemin

Senior Spatial Hydrologist, International Centre of Water for Food Security, Charles Sturt University

Yann gained a degree in international agricultural development from the ISTOM/International Agri Development Institute (France, 1995), and Masters in land and water resources management from Cranfield University (UK, 1996) and DTSc on remote sensing and GIS applications from the Asian Institute of Technology (Thailand, 2003). In 2003 there followed a short course on supercomputer programming (Kasetsart University, Thailand), which became a fundamental tool for his doctorate on evolutionary algorithms applied to remote sensing and agricultural modelling. Scientific interests include evapotranspiration mapping by remote sensing, supercomputing for agricultural science, evolutionary algorithms and data assimilation.

Adaptation to climate change requires serious effort on the agricultural and geographical sciences to meet variations of soil moisture and air humidity within the next human population generation so as to cope with the seed responses and farming practices optimisation along the years of changing conditions. While this is a multi-disciplinary effort, a meeting point for decision-making is often in the shape of a well informed map, so as to provide arguments for discussion and argumentation on path identification.

Mr Steven Crimp

CSIRO Sustainable Ecosystems

With a background in climatology and environmental science, Steven is evaluating options to increase resilience of Australian cropping systems to climate variability and change. He joined CSIRO in 2006 as a climate applications scientist tasked with assisting farmers and farmer groups to improve on-farm climate risk management. During this time he has led a range of research projects working with farmers to enhance current management practices to cope with the challenges of climate variability and change. Current research activities centre on evaluating options to increase resilience of Australian cropping systems to climate variability and change, and include:

- *examination of the vulnerability of Australian cropping and grazing industries to climate change;*
- *identification of feasible adaptation options for case study farms across both summer and winter cropping areas of Australia; and*
- *quantitative assessment of the benefits of using seasonal climate forecasts and climate trend information to enhance on-farm management.*

Steven can contribute to the workshop in a number of ways, including developing and implementing practical concepts of vulnerability, resilience and adaptive capacity from the farm to policy scales, in order to increase the societal value of climate impacts science.

Dr Saul Cunningham

CSIRO Entomology

Saul's research for his honours degree (1989) and PhD (1995) focused on animal pollination in undisturbed forests, first in south-eastern Australia and then in the Costa Rican rainforest. Since returning to Australia his focus has shifted to the mixed landscapes of agriculture and other vegetation that dominate so much of the Earth's surface. In this context he has been interested in understanding how we can manage landscapes for good conservation outcomes while still supporting productive agriculture. These questions have been his pre-occupation for the past 10 years he has been with CSIRO. In particular, his research has examined the way that good land management can support the public benefit of biodiversity conservation and, at the same time, provide private benefits to farmers through ecosystem services like crop pollination and pest control by natural enemies.

Saul would be keen to contribute either through discussion in a workshop environment, or by presenting some of his relevant research (especially around biodiversity and ecosystem services to agriculture). Climate change has not been the focus of his published research, but he is involved in a nascent project examining the expected impacts of a shift towards more cropping in Australia's high rainfall zone.

Mr John Davis

Lecturer, School of Sustainability, Murdoch University

John is currently completing his PhD in policy research on coastal and marine stewardship. Since obtaining his degree in agriculture he has had extensive experience in rural community development in south Asia and Africa, Landcare in Western Australia and taught in a university in Indonesia. His experience has given him an appreciation of the need for holistic approaches to challenges faced by communities. He is the social scientist in a multidisciplinary research project funded by ACIAR which is investigating the potential for pasture legumes to contribute to livelihoods of people on communal lands in the Eastern Cape of South Africa, and how to do this with active stakeholder engagement.

John brings to the Think Tank interdisciplinary perspectives, gained by immersion in a variety of cultures: perspectives which are important for 'wicked problems' like mitigation of greenhouse gas emissions and adaptation to climate change. His PhD research explores the linkages between place, persons, community and policy and how policy works to enable local initiative. He has experience working with other partners from scientific, economic, social and cultural disciplines. He is interested in how meeting the challenge of changing climate not only safeguards agricultural productivity but also the natural heritage.

Professor Raphael Didham

Professor of Ecology, School of Animal Biology, University of Western Australia

Raphael was recently appointed to the School of Animal Biology at the University of Western Australia, with a joint research position at CSIRO Entomology. He received his PhD from Imperial College London in 1997 and completed a postdoctoral fellowship at the University of Delaware, before holding a faculty position at the University of Canterbury. The goal of his research is to quantify the synergistic effects of multiple drivers of global change on biodiversity and ecological resilience of remnant natural ecosystems within production landscapes, with a particular focus on conserving invertebrate biodiversity and maintaining natural pest control services.

Raphael can bring to the workshop a wealth of ecological research experience and conceptual synthesis of the science underpinning the interactive effects of multiple drivers of global change on biodiversity and ecological resilience. The major thesis of his work is that addressing individual components of global change separately, such as water shortage or climate change, will not lead to better prediction and management of human impacts on biodiversity or productivity. Complex effects occur frequently and to meet the future challenges we need to take a quantum leap beyond the current focus on independent drivers of global change.

Associate Professor Elske van de Fliert

Principal Research Fellow and Deputy Director
Centre for Communication and Social Change, School of Journalism and Communication, University of Queensland (UQ)

Elske is a communication specialist and ecologist with a doctorate from Wageningen University, The Netherlands. She worked for two decades on participatory research, learning, and communication in agricultural development, mainly in Asia, for a range of international organisations, including UNFAO and CGIAR. She joined the UQ in 2006, and currently leads two ACIAR-funded multidisciplinary research projects in Vietnam and Indonesia. The main research interests include communication for development and social change, collaborative inter-stakeholder RfD models, and multi-focal impact assessment for sustainable rural development.

The effects of climate change on agriculture require the industry to apply adaptive strategies to safeguard sustainable production. For this, strong communication platforms and processes are needed to:

- provide information in appropriate formats on emerging constraint and potential options/solutions to and amongst stakeholder groups;
- facilitate dialogue amongst stakeholder groups to achieve mutual understanding and address conflicting interests; and
- monitor, evaluate and assess impact of policies, interventions and practices in a participatory manner to encourage sustainable and organic adaptation and change.

Contribution to the workshop will be through the identification of needs and opportunities for such communication platforms and processes, and by sharing experiences from similar situations in other countries.

Dr David Francis

Research Fellow, School of Life and Environmental Sciences, Faculty of Science and Technology, Deakin University

Originally from Scotland, David immigrated to Australia in 1982. He went to Deakin University's Warrnambool campus in 1999 and obtained a PhD in aquaculture in 2007. His key research focus is on the development of eco-friendly, sustainable feed ingredients for aquafeed production, that permit the maintenance of the health beneficial qualities associated with fish consumption. As mankind's insatiable appetite for fish as a source of protein and omega-3 fatty acids increases, fisheries are being exploited at an alarmingly increasing level. However, aquaculture, widely regarded as the solution to this problem, is currently an unsustainable practice. In part, this is due to its reliance on the use of fishery products for the production of farmed fish feeds (aquafeed).

Aquaculture is a rapidly growing industry in Australia, representing more than 40 per cent of gross fisheries production. For aquaculture, climate change introduces a multitude of challenges that will ultimately impede productivity and future growth. These are associated with effects on biological processes and food web alterations. David's knowledge and expertise of this rapidly growing, nationally important sector will be of great benefit to the workshop's theme where he will effectively contribute to industry specific mitigation solutions and adaptation measures.

Dr Sigfredo Fuentes

Lecturer, School of Agriculture, Food and Wine, University of Adelaide

Sigfredo studied at the University of Talca in Chile for an honours degree in agriculture specialising in horticulture. He came to Australia in 2001 to work as an irrigation specialist for Darling Irrigation Pty, and in 2005 received his PhD from the University of Western Sydney (UWS). He was also a postdoctoral fellow at UWS and the University of Technology Sydney, before his appointment as lecturer at the University of Adelaide, where he is investigating the effects of elevated CO_2, water supply and temperature on grapevines.

Sigfredo will be able to bring a broad perspective to the workshop, particularly on how major economically important woody crops (such as grapevines and forest trees) will respond to the expected changes in water availability, elevated CO_2, and temperature. His expertise in advanced instrumentation and computing to monitor crop performance in the field is directly relevant to how we can study the consequences of climate change on long-lived plant species using remote sensing and other approaches. He will also contribute an international perspective through his experience in Chile and his still-strong links with the University of Talca.

Dr Mike Furlong

Lecturer, School of Biological Sciences, University of Queensland

Mike is an applied insect ecologist with a PhD from Imperial College, London, and postdoctoral appointments at Rothamsted Research (UK), University of Maine (USA) and the University of Queensland (UQ). He took up his current position at UQ in 2005. His research focuses on the sustainable management of agricultural insect pests in developing countries and Australia, and incorporates fundamental ecological studies for the design and implementation of wide-scale management strategies. Current research examines the effects of temperature on trophic interactions between insect pests, their biological control agents (predators and parasites) and crop plants.

Given the potential impact of climate change, the sustainability of agricultural productivity is central to Mike's research, which is beginning to unravel the likely impacts of climate change on essential ecosystems services. Simulation models provide a mechanism by which these can be predicted and tested. Application of this research in regions of marginal agricultural productivity in Australia (eg canola growing regions) and his considerable overseas experience in related agricultural systems provides him with a unique perspective and a wide range of experiences which will enable Mike to make an important contribution to the workshop.

Dr Ros Gleadow

Senior Lecturer, School of Biological Sciences, Monash University

Ros completed her PhD in botany at the University of Melbourne in 1999. She founded the Monash Cyanogenesis Group in 2005 and has also worked at the Universities of Copenhagen, Arizona and California. She took a break from active research to raise three children and during this time became a pioneer in the use of multimedia in higher education. Her research focuses on the effects of climate change on plant defence. Ros has served as ecophysiology, education

and Science Meets Parliament representative for the Australian Society of Plant Sciences and collaborates with Pacific Seeds (drought effects on sorghum toxicity), CassTech (commercialising cassava in northern Australia) and AusAID (food security, Mozambique).

An overlooked consequence of increased atmospheric CO2, and concomitant changes in climate is the change in plant composition. Typically, concentrations of natural toxins increase and protein decreases when plants are grown in future emission scenarios. This would have serious consequence for human and animal health. This important area has yet to become part of the climate change debate and should be considered when attempting to mitigate the effects of climate change on food production. Ros' links with aid agencies, agricultural companies and international researchers help her to approach the issue from a fresh perspective.

Professor Christopher Grof

Professor of Plant Science, School of Environmental and Life Sciences, University of Newcastle

During his appointment at CSIRO Plant Industry (1993 to 2008) Christopher initiated, developed and supervised a number of innovative research projects in sugarcane physiology, biochemistry and biotechnology. These projects were aimed at addressing key sugarcane industry issues including sucrose accumulation, genetic transformation and raw sugar quality. He was appointed Professor of Plant Science at the University of Newcastle in 2008, and has since secured $1.8 million in funding through ARC Linkage to establish a research program in conjunction with collaborators at the University of Queensland and industry partner Pacific Seeds. Christopher has a strong interest in advancing Australian agriculture using the entire gamut of biotechnological tools available and founded upon a strong platform of fundamental scientific understanding.

Christopher's extensive experience in key Australian crops, sugarcane and more recently sorghum, coupled with the ongoing application of innovative strategies to maximise the productivity of these crops, ensures that he has the appropriate experience to contribute to future strategies aimed at maximising agricultural productivity in a changing environment. As climate change models foreshadow increases in temperature and drought conditions, understanding of plants possessing C4 metabolism will maximise our chances of maintaining agriculture productivity and sustainability.

Dr Chris Guppy

School of Environmental and Rural Science, University of New England

Chris completed undergraduate and postgraduate studies in agricultural science and soil fertility at the University of Queensland in 2004, before taking a position in soil fertility at the University of New England. His research interests are in soil fertility and sustainable nutrient management, particularly phosphorus which is one of the key constraints to future agricultural sustainability. He is currently involved in the Nutrient Management Initiative examining sustainable and predictable phosphorus and potassium nutrition of northern farming systems; and Grain and Graze, a project increasing the sustainability and profitability of mixed farming systems.

Chris sees the workshop's theme as directly relevant to his current research interests, as he focuses on nutrient and water use efficiency in agricultural systems under a changing climate. He firmly believes investment in adaptive management of northern farming systems, particularly soil management issues, serves the long-term interests of better food security and a prosperous, sustainable future.

Mr Munir Hanjra

Water and Carbon Policy Analyst, International Centre of Water for Food Security, Charles Sturt University

Munir holds degrees in agricultural economics from Pakistan and a Master of Economics from Australia. He is a development economist with 18 years of work experience in developing countries, particularly in south and south-east Asia. He has worked in multidisciplinary international research teams in the International Water Management Institute to undertake impact evaluation of irrigation infrastructure development and rehabilitation on rural poverty. Under the Challenge Program on Food and Water, he was involved in the development of poverty and vulnerability monitoring indicators in nine river-basins (eg Indo-Gangetic, Mekong and Yellow River). He is currently working on optimisation models for enhancing the productivity of land and water resource management in Australia and internationally, with an emphasis on irrigation infrastructure modernisation.

Munir works on core issues related to rural water management for enhancing the sustainability of agricultural production and livelihoods through water savings and energy savings in major farming systems across Australia. He has developed interests in Australian priority research areas such as water and carbon dynamics, climate change and

public policy, and in developing educational and knowledge products for a wide range of stakeholders on issues of environmental sustainability, rural renewal, and social inclusion. This will be the main contribution to the workshop theme.

Dr Matthew Hipsey

School of Earth and Environment, University of Western Australia

Matthew's research focus is around understanding the hydrological and hydrodynamic interactions with biogeochemical and ecological processing of elements in lakes, rivers, wetlands and estuaries. Interests include assessing impacts of land-use change and hydro-climatological variability on wetland and estuarine biogeochemistry, and using wetlands and lakes as 'barometers of change' by defining quantitative estimates of ecosystem health. Key Australian sites worked on include the lower Murray River (SA), Yarra River (VIC), the Swan River and Peel-Harvey estuaries (WA) and numerous lakes and wetlands. Matthew is also involved in global ecosystem observatory networks for monitoring changes in freshwater systems, and is currently a theme leader in the UWA Terrestrial Ecosystem Research Initiative.

Water quality problems include increases in salinity, turbidity, acidity, in addition to the problems of eutrophication and algal blooms. Such problems have had considerable impact on aquatic ecosystem values such as biodiversity, and in particular to those downstream of agricultural practices. In addition to providing insights into the dynamics of how such systems will respond to land-use changes and shifts in climatic regimes, Matthew also has experience in down-scaling large scale atmospheric circulation models to drive basin-scale ecosystem models for forecasting purposes.

Mr Neil Huth

CSIRO Sustainable Ecosystems

Neil has developed detailed modelling and analytical skills during his career with CSIRO. As a member of the Agricultural Production Systems Research Unit he has provided a lead in the development of detailed plant (phenology, growth, resource use) and soil (water and solute movement, nitrogen and carbon dynamics) models for use within farming systems research. Neil has used these skills in farming systems analysis for dryland agriculture, pastures, horticulture, sugar cane and viticulture. He has also undertaken extension of the modelling frameworks for the simulation of agroforestry systems. Neil's main interest lies in combining detailed experiments, process-based models and farmer knowledge to drive farming systems design.

Neil will bring many insights from his current portfolio of work. He is currently involved in the assessment of climate change impacts on agriculture and forestry in south-east Queensland. This includes engaging with horticultural and pastoral farmer groups, not only to document vulnerability, but to explore and trial adaptive options in the field. His expertise has also been called upon to assist in the choice of best bet management options for long-term studies of carbon, water and greenhouse gas management in northern farming systems.

Dr Tamara Jackson

International Centre of Water for Food Security, Charles Sturt University

Tamara has a background in water and energy trade-offs in the area of irrigated agriculture. She has postgraduate qualifications in applied hydrology, an international internship with UNESCO, and applied research on water and energy management issues in the context of agriculture and food security. Tamara's recently-completed PhD research explored water use efficiency, energy consumption and greenhouse gas emission relationships for different irrigation systems. It also included stochastic modelling to quantify the potential water and energy consumption and carbon equivalent emissions resulting from changes to irrigation systems in terms of environmental and operating inputs. Her current research interests include water management, food security, agricultural development and adaptation in the face of climate change.

Tamara's research carried out as part of her PhD studies regarding the water–energy nexus in irrigated agriculture is pertinent to the theme of this workshop. The opportunity to participate would allow her to both contribute her ideas and learn from others regarding the issues facing irrigated agriculture in Australia, and to explore the potential impacts of climate change on this vital section of the agricultural industry. Ultimately, it would be beneficial if these discussions could lead to options for the continued development of sustainable, vibrant agricultural communities.

Dr Andrew Jacobs

Group Leader, Technology Platforms, Australian Centre for Plant Functional Genomics, University of Adelaide

Andrew's research has focused on the development of grain crops tolerant to environmental stresses through the application of genetic technologies. His group has been responsible for the development of targeted and high throughput gene analysis systems and the isolation of a number of genes and transcription factors important in stress tolerance. Abiotic stresses currently under investigation include salinity, drought and cold/frost. His research perspective is broad, ranging from gene discovery to testing of genetically modified cereals in the field. Andrew works on a range of collaborative academic and commercial projects, has published in various peer reviewed journals and holds a number of patents related to his work.

In addition to presenting research findings as an invited speaker at international conferences, Andrew is engaged in the communication with and education of farmers and the wider community through Grains Research and Development Council research updates and road shows. This gives him insight into the issues and problems farmers face in Australia and has provided opportunities for dialogue regarding technologies which may address these issues. He will be able to use his knowledge to contribute insights into how modern genetic technologies can provide solutions to overcome the challenges grain growers will face as a result of climate change.

Dr Evelyn Krull

Senior Research Scientist, CSIRO Land and Water

Evelyn's expertise lies in the application of stable and radiogenic isotopic analyses to determine organic matter sources and degradation processes that occur in soils and sediments, as well as the effect of vegetation change on soil organic carbon stores. Her approach of combining isotopic and ^{13}C-NMR analyses has enabled us to better determine organic matter sources and transport processes. Her current research is focusing on the degree of urbanisation on carbon cycling in the Logan estuary (south-east QLD), the impact on increased salinisation on the Coorong and Lower Lakes ecosystems (SA), and on the potential of biochar as an agricultural amendment and as a carbon sequestration tool.

Evelyn's expertise relating to the Think Tank theme includes:

- assessment of the effects of land management (fire suppression, grazing pressure) on vegetation change and C stocks;
- evaluation of fire-derived charcoal as a highly stable organic carbon pool in soils as well as estuarine sediments; and
- development and leadership of a national biochar initiative.

Her contribution will draw on her scientific skills, ability to think laterally and endeavour to learn and contribute to society.

Dr Rick Llewellyn

Farming Systems Scientist, CSIRO Sustainable Ecosystems

Rick gained a PhD from the School of Agricultural and Resource Economics at the University of Western Australia for his research into weed management decisions by grain growers. His research bridges farming systems field research and developing research, development and extension strategies for improved technology adoption. He currently leads national projects including the development of the role for perennials in future farming systems, predicting adoptability of new agricultural technologies and a national study of the adoption of conservation tillage practices in Australia. Before joining CSIRO, he spent four years as lecturer in agricultural systems and extension at the University of Western Australia. He has also worked closely with farmer groups.

Rick has a breadth of experience working with farmers and integrates biophysical and socio-economic disciplinary approaches to tackle a range of environmental, production and social pressures facing agriculture. As well as researching and developing new technologies for Australian agriculture, he applies socio-economic research to address the farmer perspective to adaptation and practice change. His research identifying constraints to adoption of complex, information-intensive innovations has led to a keen interest in the development of novel approaches to increasing specialised adoption capacity of farms while still maintaining the opportunity for farm business diversity.

Dr Leo Lymburner

Remote Sensing Applications Specialist, Geoscience Australia

Leo graduated from Macquarie University in 1998 with an honours degree. He worked at CSIRO Land and Water in the Environmental Remote Sensing Group from 1998 to 2001. He completed his PhD on remote sensing of riparian zones through the University of Melbourne in 2005, and from 2006 to 2008 worked for the Australian Centre for Tropical Freshwater Research at James Cook University in Townsville. At the beginning of 2008 Leo returned to Canberra to form part of a new land cover remote sensing team at Geoscience Australia. His main interests are object-oriented image processing and multi-temporal land-cover/land-use mapping techniques with a particular interest in developing tailored image processing techniques to identify cropping and land management practices.

For the past year Leo has been working on a project that characterises the cropping and food production areas of Australia at both national and regional scales. The map products that he has developed in conjunction with the land cover team at Geoscience Australia could form a fundamental talking point for the dialogue around adapting food and fibre production systems to a changing climate.

Dr Nadine Marshall

Social Scientist, CSIRO Sustainable Ecosystems

Nadine has worked within the commercial fishing industry in Queensland for over eight years and with Australian cattle graziers and farmers for over three years. Most of her work focuses on issues pertaining to climate adaptation and vulnerability with particular emphasis on recognising the need for, and influences on, transformative change. Nadine has two degrees in the biophysical sciences; an honours degree and Masters from the Universities of Melbourne and Monash respectively, and completed her PhD in the social and environmental sciences at James Cook University in 2006, and has since been with the Climate Adaptation Flagship and CSIRO Sustainable Ecosystems, based in Townsville.

Nadine's interdisciplinary background equips her with a systems approach to examining natural resource problems. Her research currently addresses how resource users are vulnerable to climate change and how their vulnerability can be minimised. She has seen the variety in the circumstances of resources users, and their dependency on the resource, and has correlated these with the strategies they have chosen to manage their enterprises. Nadine believes that agricultural Australians are generally not sufficiently equipped with the necessary skills to meet the challenges of climate change. The Think Tank would provide the opportunity to discuss potential adaptation strategies.

Dr Darryn McEvoy

Principal Researcher, Climate Change Adaptation, RMIT University

Darryn is a geographer with an interest in interdisciplinary solutions-oriented action research. His most recent research activity has focused on issues relating to climate change impacts and adaptation, with consideration of the implications for sustainable development. This has included managing two large scale projects in the UK (2002 to 2006), and post 2006 he was based in the Netherlands acting as a senior researcher on the EU consortium project Adaptation and Mitigation Strategies: Supporting European Climate Policy (ADAM). His research expertise covers climate risk assessment and adaptation, innovative adaptation practice in different contextual settings (eg climate change and cities; land and water management under a changing climate).

Darryn has analysed adaptation to climate change across a wide range of hazards, sectors, landscape types, and issues for the ADAM project, of particular relevance to this workshop being: Guadiana, Spain and Portugal (drought); the Tisza river basin, Hungary (flooding); and Inner Mongolia, China (desertification and sustainable livelihoods). In addition to this international experience, he is also leader of the climate change adaptation programme for the Global Cities Institute, RMIT University, and the Deputy Director of the newly-established Victorian Institute for Climate Change Adaptation Research.

Mr Mark P McHenry

School of Engineering and Energy, Murdoch University

Mark's research is focused on integrating agricultural production systems with climate change mitigation, adaptation, renewable energy and biosequestration options. He has authored several peer reviewed journal articles, conference proceedings and a book chapter. Mark is due to finish his PhD in February 2010. He has research and consulting experience with Main Roads WA, Brierty Ltd, Maunsell AECOM, the Department of Defence, Transfield Services, WA Department of Fisheries, the Research Institute for Sustainable Energy, and the WA Legislative Assembly. Mark is also a member of the Department of Agriculture, Forestry and Fisheries' Rural Research and Development Council (RRDC).

As Mark's research is focused directly on the contemporary challenges facing Australian agriculture, and his RRDC work on agricultural technology, productivity and food security, he is particularly suited to contribute to this workshop. Mark's PhD research specialises on the integration of mitigation and adaptation technological options for agricultural production systems, and particularly on cost-effective opportunities deriving from climate change projections and competitive advantages of Australia's landscape. As a fourth generation farmer he appreciates the social, cultural, environmental and institutional components of rural Australia and hopes he can make more of his work accessible through this opportunity.

Dr Andrew Moore

Principal Research Scientist, CSIRO Plant Industry

After training as a vegetation ecologist at the University of Adelaide and the Australian National University, Andrew joined CSIRO in 1989 where he works on predictive modelling of pasture growth and quality, the management of grazing systems and the application of agricultural simulation models in decision making. Recently he extended his scientific interests to the linking of crop and livestock simulation models, using them to study risk and integration in mixed farming systems. He currently leads a project studying adaptation to climate change by the southern Australian livestock industries.

Andrew will be able to contribute to the workshop's theme in a number of ways. As an agro-ecosystem ecologist and modeller, he integrates a broad understanding of how weather and climate drive processes in agriculture at scales from the plant to the whole farm. Through conducting his research within a number of programs of participatory research, development and extension he has developed a broad view of the economic, environmental and social drivers of changes in practice on Australian broadacre farms. He has a particular appreciation of the role of climatic variability as a factor that constrains farming practice, including adaptation to climate change.

Dr Saffron O'Neill

Research Fellow, Department of Resource Management and Geography, University of Melbourne

Saffron is a Research Fellow at the University of Melbourne and a Visiting Fellow at the Tyndall Centre for Climate Change Research, UK. Her research interests focus on the interactions between society, policy and climate science. She is particularly interested in the roles of cognition, affect and behaviour in individuals' engagement with climate change adaptation and mitigation. Her ongoing projects include a co-edited book (Engaging communities with climate change and energy demand reduction: Earthscan), exploring the role of the arts in climate change, and investigating how carbon off-setting behaviours may act to promote green identity and behaviour spillover.

Compared to research on the reduction of greenhouse gas emissions and climate change impacts, there has been relatively little research on social responses to climate change. Identifying mitigation and adaptation strategies that acknowledge and address the psychological and sociological aspects of climate change in future agricultural productivity and consumption is a challenge. Saffron can contribute expertise in the social science aspects of the workshop theme. Indeed, she has been interested in developing research to address this challenge for some time, and the workshop would provide an ideal opportunity to develop this further.

Dr Sarah Park

CSIRO Sustainable Ecosystems

Sarah's work draws on an extensive background in development studies and agricultural sciences. She has approached the assessment of climate change impact, adaptive capacity and development of response strategies in crop production using both quantitative biophysical modelling and qualitative stakeholder engagement methodologies. The systems approach she has used recognises the need for effective and appropriate response strategies to be developed in collaboration with decision makers throughout the value chain and at all levels of governance. More recently, Sarah has applied theoretical and applied science in crop production and climate change adaptation applied in Australia, to the issue of climate change adaptation and food security in the Pacific and south-east Asia.

In addition to a systems perspective and innovative approach to problem solving, Sarah will contribute knowledge and skills on:

- engagement of both stakeholders and policy makers to promote evidence-based decision making at all levels;
- multifunctional agricultural landscapes with the potential to support agricultural production and biodiversity conservation;

- crop physiology, agronomic production practices and industry institutional operations; and
- quantification of the impact of climate change on crop yield and the potential of adaptation response strategies under scenarios of future climate change.

Dr Eric Peterson

Lecturer, Architectural Engineering, School of Engineering and Science Faculty of Health, Engineering and Science, Victoria University

Eric's expertise includes solar desalination systems, building services design, as well as modelling dynamic of coral reefs. He is a licensed professional engineer, having ten years industry experience in modelling thermal dynamics of the built environment, followed by ten years of water engineering. He has a PhD from James Cook University for modelling marine pond dynamics and the impacts of aquaculture effluent, with three years of postdoctoral work on the topic. He now balances his time between research and training architects and engineers in ecologically sustainable development and ocean engineering.

Eric believes he can make a contribution to the workshop through his work and experience, such as analysis of meteorological data to determine energy and water efficient building design parameters throughout Australia; using supercomputer facilities to model coral atoll hydrodynamics, validated with fieldwork in the Marshall Islands to inform sustainable resettlement of nuclear weapons testing victims at Rongelap Atoll in the face of sea level rise; evaluation of a pilot 'green powered desalination' solar desalination plant at Mt Coot-tha Botanic Gardens (Brisbane) with marine plants brine treatment; and advising design professionals with location-specific data for rainwater harvesting.

Dr James Petrie

Metabolic Engineering of New Plant Products, CSIRO Plant Industry

James graduated from University of Wollongong with honours, after which he joined the CSIRO Metabolic Engineering team as a PhD student. He is now part of the CSIRO Food Futures Flagship and is working in the Omega-3 Land Plants project, which aims to deliver a sustainable source of long-chain polyunsaturated fatty acids such as eicosapentaenoic acid and docosahexaenoic acid in order to reduce pressure on fish stocks and increase the intake of beneficial omega-3 oils by the Australian population. James is now involved in both the core scientific pursuits and the business development activities in the project.

James believes that the goals of CSIRO's Food Futures Flagship are highly relevant to the Think Tank's theme of agricultural productivity. One of the key aims of the flagship is to develop frontier science and technologies to transform the Australian agrifood sector. A clear example of this is found in the Omega-3 Land Plants project with the aim to add value and increase the productivity of the Australian oilseeds market by making substantial qualitative changes to the product itself, allowing Australian farmers to produce a distinct, high-value oil.

Dr Libby Pinkard

CSIRO Sustainable Ecosystems

Libby has a broad background, encompassing trees in the rural landscape, through her past roles as Greening Australia Tasmania state president and as a farm trees project officer with Forestry Tasmania; trees in the natural environment, as a project officer for the Tasmanian National Parks and Wildlife Service; and through her current role with CSIRO understanding how tree functioning affects forest management. Her involvement in the steering committees of a National Association of Forest Industries project examining industry adaptation to climate change, and a national assessment of forest vulnerability, provide her with a broad perspective of the implications of climate change for Australia and the role of forests in Australia's response to climate change.

Addressing national challenges such as greenhouse gas mitigation, water security or biodiversity conservation will require landscape level solutions that integrate agriculture, production forests and conservation. Forests span these elements. Libby can contribute an understanding and analysis of the contribution of trees within these landscapes and trade-offs with other land-uses, the extent to which forests will be affected by climate change, and how we may build resilience into forest systems to enhance the long-term sustainability of our agricultural environment.

Dr Simon Reid

Veterinary Epidemiologist, School of Veterinary and Biomedical Sciences, Murdoch University

Simon's goal is to make a significant contribution to national and international programs for surveillance and control

of major infectious and zoonotic diseases of livestock. He obtained his veterinary degree from Murdoch University in 1989 and PhD from James Cook University in 2000. In 2008 Simon accepted a posting in Indonesia to provide technical support to the Indonesian National Control program for avian influenza (HPAI), and is currently working in Vietnam for the Food and Agriculture Organization of the United Nations providing expertise in a research project to enable the government of Vietnam to modify its HPAI control program in 2011.

Simon has been a willing and articulate participant in many workshops designed to evaluate issues related to livestock diseases and develop strategies to ameliorate their effects. He has a deep understanding of the need to develop multidisciplinary approaches to tackle some of the more complex problems facing the agricultural sector in Australia. Research programs to address the future impact of climate change on the impact of infectious diseases on livestock production and trade will need to be complex and interdisciplinary. He believes that his contribution to the Think Tank will enable informed discussion of these issues.

Dr Michael (Saam) Renton

Assistant Professor and Modeller, School of Plant Biology, Faculty of Natural and Agricultural Science, University of Western Australia (UWA) and Agricultural Landscapes

Michael completed his honours at UWA in maths and his PhD at the University of Queensland, looking at approaches to modelling the interactions between plant form, function and environment. His postdoctoral position in Montpellier, France, married stochastic models with structural models to create virtual apple trees. He returned to Perth to teach applied maths at UWA, before spending a couple of years creating the Weed Seed Wizard (a model of seed bank dynamics) at the Department of Agriculture and Food. In 2007 he took up a lectureship in computational agro-ecology in the School of Plant Biology. His current projects include modelling of weeds, seed bank population dynamics and evolution of resistance to herbicides and pesticides, competition and interaction between plants in natural and managed systems, the role of new options (such as perennial pastures) in farming systems, and optimal land-use in agricultural systems.

Michael will be able to contribute to the workshop's theme based on his work in modelling agro-ecological systems. Of most relevance is his modelling work on optimising land-use in agricultural systems and mixed-use landscapes across time (land-use sequencing) and space (optimal land-use allocation), while taking into account risk due to climate variability and other factors and carbon sequestration possibilities.

Dr Dean Revell

CSIRO Livestock Industries

Dean's research has focused on interactions between livestock and land management. He completed his undergraduate degree and PhD in agricultural science at the University of Western Australia and since then has worked at the Rowett Research Institute in Scotland, the University of Western Australia, Massey University in New Zealand, the University of Adelaide and, for nearly 4 years, CSIRO Livestock Industries in Perth. Dean currently leads a national, multi-disciplinary project, Enrich, which aims to increase options for landholders to develop new, more resilient and sustainable grazing systems by incorporating Australian native shrubs. He leads a research group in CSIRO whose work covers a broad range of issues relating to interactions between plants, animals, people and the environment.

Dean would bring to the Think Tank specific expertise in nutrition and grazing behaviour of herbivores and, importantly, knowledge on how these disciplines relate to land management, farming systems, and emerging market demands and consumer expectations. Current research is exploring multi-purpose grazing systems that consider the imperative of boosting profitability of farming systems whilst simultaneously dealing with a changing climate and emerging market and consumer demands. Multiple benefits are achievable through beneficial interactions between plants, the behaviour of grazing herbivores, and innovative management.

Dr Carol Richards

Sociology Postdoctoral Research Fellow, School of Social Science, University of Queensland

Carol specialises in agriculture and food. She has extensively researched the issue of environmental sustainability of grazing and agriculture within the context of the global political economy, highlighting why in many instances, it is 'unthinkable' for Australian primary producers to alter their land management practices to align with broader sustainability goals. Recently, Carol has shifted focus to the retail end of the supply chain, and is examining the impact that powerful supermarkets have on the food supply chain. This includes an international comparison of agri-environmental labelling, and the quasi-governance of primary production through a market concentrated retail sector. Carol also coordinates and lectures sociology of the environment.

As a social scientist, Carol brings a perspective that analyses the complex relationships between primary production and the global political economy. It is important to understand how current market structures lock Australian producers into a program of productivism and the necessity to constantly increase supply, often from a diminishing resource base. Her comparative work in this area has shown how other production modalities, such as those found in Europe, and broadly described as multifunctional, have been more attuned to the non-tradable concerns of agriculture, such as the environment.

Dr Randall Robinson

Course Coordinator and Lecturer, Ecology and Environmental Management, School of Engineering and Science Faculty of Health, Engineering and Science, Victoria University

Randall teaches botany, fundamentals of ecology, geographic information systems, environmental impacts and monitoring, and conservation genetics at Victoria University. His research interests focus mainly on recruitment and population dynamics of plants, sexual and clonal (asexual) reproduction in plants, introduced pest plant species and overall ecosystem management. He is a member of several committees and panels focusing on environmental management and has published widely on a range of topics including the conservation of orchids, population dynamics of wetland plants, and weeds and restoration of grassy ecosystems.

Randall's work, particularly that relating to plant germination and establishment, introduced pest plants and the use of GIS, allows him to have an understanding of some of the fundamental issues facing agriculture and the management of resources. His work on recruitment and population dynamics in plants, especially those aspects that deal with the effects of climatic variables and how they affect plant growth, place him in a position to understand what is presently happening in the environment and to predict possible impacts of a changing environment on the growth of desired species and also what impacts climate change may have on introduced pest plant species.

Dr Douglas Rowell

Research Fellow, Department of Resource Management and Geography, University of Melbourne

Douglas is a Research Fellow at the University of Melbourne, working in greenhouse gas emissions from agricultural systems. His current research interest is the measurement of greenhouse gases and ammonia from beef cattle feedlots using open-path spectroscopy and micrometeorology.

His future research will explore a number of management strategies for the mitigation of greenhouse gas emissions from beef cattle feedlots, and it is in discussion of this that he believes he can contribute to the Think Tank's theme.

Dr Katinka Ruthrof

Senior Research Fellow, State Centre of Excellence of Climate Change and Forest and Woodland Health, Murdoch University

Katinka has expertise in invasive and native plant ecology, restoration of degraded ecosystems, as well as experience with resource management issues. She has planned and written environmental management plans for major resources, and has significantly contributed to the field of weed ecology and restoration ecology. Katinka has assisted in winning two major research grants: ARC Linkage and State Centre of Excellence of Climate Change, and Forest and Woodland Health (more than $10 million). As part of the Centre of Excellence, she researches methods of increasing the resilience and success of restoration of declining woodland ecosystems.

Katinka will contribute to the workshop theme through her experience in a broad range of disciplines, including weed ecology, degraded forest and mine site restoration, community engagement and natural resource management. She will add to discussions about the challenges and opportunities Australian agriculture will face to operate in a carbon-constrained economy and in a future of climate change. If climate change adaptation and mitigation strategies become embedded in natural resource management, agricultural techniques and policy, Australia can become resilient and take advantage of global demand for food security and carbon sequestration through productive agriculture, large-scale forestry and diversification.

Dr Saman Seneweera

Research Fellow, Melbourne School of Land and Environment, University of Melbourne

Saman completed his PhD in 1996 at the University of Western Sydney and currently works as a plant physiologist at the University of Melbourne. His research interest is on understanding the mechanisms of how plants respond to global climate change and abiotic stresses like drought and temperature. This will enhance understanding of how

climate change impacts on biodiversity, productivity and global food supply. Molecular, biochemical, physiological and ecological tools are used to assess plant performance under manipulative field and controlled environment chamber experiments. Saman's long-term research focus has been on crop plant responses to climate change, particularly how elevated CO2, temperature and drought modify the various physiological processes, such as growth, respiration, source sink interaction, mineral nutrition and grain quality.

In the workshop, he will discuss how these key individual physiological processes respond to climate change, and then identify possible targets for crop breeding for future climate change which will ensure food security globally. His experience working in free air carbon dioxide enrichment facilities will provide the workshop with a greater insight into plant response to climate change at ecosystem levels.

Dr Sandra Savocchia

National Wine and Grape Industry Centre School of Agricultural and Wine Sciences, Charles Sturt University

In 2002 Sandra was awarded a PhD in plant pathology and fungicide resistance from the University of Adelaide. She is currently employed as a Senior Lecturer at Charles Sturt University in the discipline of viticulture, where she teaches and coordinates various undergraduate subjects. Her research interests are in the area of plant pathology, epidemiology and molecular diversity of plant pathogens, in particular fungal pathogens of grapevine. She also has an interest in how environmental changes will impact on plant diseases of importance to agriculture.

The future of sustainable agriculture is dependent on the management of biotic factors such as pests and diseases. The development of new crop varieties that are tolerant to these biotic factors, high yielding and environmentally adapted will be crucial. Future production of such crops may occur through genetic modification, either via traditional breeding or genetic manipulation. For the latter, the community must be informed of the technology for an acceptance of these crops to occur. Socially, Sandra believes there is an increase in demand for low pesticide use in agriculture and food production. The urban sprawl is also encroaching on farm land and in order to maintain global food security this must be considered.

Associate Professor Susanne Schmidt

School of Biological Sciences, University of Queensland

Susanne graduated in1992 with a German Masters degree in agricultural biology, and a PhD in 1996 from the University of Queensland. In 2004 she became a Senior Lecturer in Plant Ecology and Ecophysiology, and more recently an Acting Professor. Her research interests are in plants and plant-based systems in the context of genetics, soil, management and climate in the sub/tropics, with a focus on plant–soil–microbe interactions as drivers of nutrient and carbon cycles in natural ecosystems and agricultural systems. Her research aims to develop management and plant selection tools to inform strategies for sustainable production, use of bio-resources and adaptation to change.

Susanne will bring knowledge of plant systems to the Think Tank with a view of natural resources and rural industries, agricultural and sustainability science, and ecology, as well as in-depth knowledge of sustainability issues and advances in the sugarcane industry. Networking with national research leaders would allow sharing this knowledge and contributing to strategies for a national agenda to safeguard agricultural productivity. Such agenda is a high priority and concepts proposed in the Millennium Assessment have to be adapted to Australian bioproduction systems, developed with and communicated to the Australian people.

Dr Ronald Smernik

School of Earth and Environmental Sciences, University of Adelaide

Ron is a recognised leader in the field of soil organic matter research, for which he was awarded the Frederick White Prize by the Australian Academy of Science in 2008. He was a QEII Fellow from 2004 to 2009 in the School of Earth and Environmental Sciences, University of Adelaide, where he is now employed as a Senior Lecturer. His research interests cover several aspects of soil organic matter, including its roles in pollutant fate and transport, soil fertility, and global carbon cycling. He has published widely and is also an associate editor of the European Journal of Soil Science *and a regular reviewer for numerous journals, the ARC and international research agencies.*

Ron's expertise in soil organic carbon (SOC) will be a valuable contribution to the themes of the workshop. SOC plays key roles in both agricultural productivity and climate change mitigation. Enhancing SOC levels in soils through

reduced tillage, crop residue retention and the addition of organic amendments (such as biochar) is an important recent advance in agricultural land management that has increased soil fertility, agricultural productivity and resilience to drought. Ron will be able to address important issues on how we can manage soils to mitigate elevated CO_2 levels.

Dr Jonathan Sobels

School of Geography, Population and Environmental Management, Flinders University

From 1981 to 1987 Jonathan developed broadacre markets for Roundup herbicide and conservation farming and was R&D manager for Seedco, managing contracts for international seed production, agronomy and plant breeding and selection of pasture and crop varieties until 1997. From 1998, doctoral studies at Charles Sturt University were interspersed with 18 months consultancy to RMIT University in an attempt to commercialise real-time satellite remote sensing for broad acre crops. Following his PhD in 2007 he completed a number of consultancies in the organisation and role of Landcare. His research interests include:

- *social change resulting from land-use changes brought about by drought, climate change and new rules for irrigation water supply; and*
- *use of GIS and Web 2.0 technologies in a new survey methodology, initially designed around calculating carbon pollution from commuting behaviours.*

Jonathan can contribute to the workshop in a variety of ways, such as: extensive geographic and practical knowledge of the innovations and systems that created and drive modern Australian agriculture; and knowledge of social parameters of change that influence rural and regional people, including local organisation, social learning, mobilisation of community assets and adoption and adaptation or risk management and information flows.

Dr Alison Southwell

Lecturer, Agricultural Systems and Extension, School of Agricultural and Wine Sciences, Charles Sturt University

After completing her honours degree in rural science at the University of New England in 2001, Alison began a PhD investigating the hydrology of native pasture communities in the high rainfall zone of south-eastern Australia. Whilst completing her PhD, she began lecturing in agricultural systems and extension, and this new role has moved her away from eco-physiology to a systems level of research. She has since worked on an ACIAR project looking to improve extension practices to increase buffalo milk production in Pakistan, and with Riverina communities looking to improve resilience in farming systems. Her research interests now lie in improving farming systems in southern Australia. She also co-manages the family sheep and wool property near Canberra.

Australian agriculture needs to adopt innovations and management strategies in an environment of increased climatic and economic risk. Increased labour and economic efficiencies are required to cope with the 'knowledge and skills drain' that is occurring as a result of decline in population, government services and interest amongst youth. New ideas for farming systems and land-use choices need to be examined. Alison is in touch with what's happening in agriculture and has good connections with many sectors of the agricultural industry and rural communities.

Mr Hayden Sprigg

Curtin University of Technology

Hayden completed an honours degree in agribusiness in farm management at Curtin University of Technology in 2005, which provided him with a very solid and broad understanding of agriculture. In 2007 Hayden commenced his doctorate titled Adaptation to wheat production in a drying climate *aimed at increasing wheat yield stability in water scarce environments in light of climate change. In 2008 he was invited to attend the 'Wheat Production in the Western Region in Water Limited (drought-prone) Environments – Where to next?' workshop aimed at shaping the future of wheat research in Western Australia.*

Climate change is likely to lead to less rainfall in most dryland agricultural regions and less freshwater allocation to food and fibre production. The reality is we need to produce more food and fibre from less water. Hayden believes he has the necessary skills set to contribute to this forum as his PhD is directly aimed at finding solutions to this problem. Also his rural upbringing provides him with an insight into social aspects of the issue and his background as a producer and broad understanding of agriculture, means he understands practical barriers to adaptation and mitigation strategies.

Dr Chris Stokes

Senior Research Scientist, CSIRO Sustainable Ecosystems

Chris' research in the rangelands of Africa, North America and Australia has looked at how these ecosystems are impacted by human disturbances such as grazing, land fragmentation and climate change. This ecological understanding has been integrated in multidisciplinary teams to better inform decisions about complex long-term natural resource management issues at paddock to regional scales. His work in the OzFACE experiment, the world's first field CO_2 experiment in the tropics, has demonstrated the importance of tropical grasses (C4 plants) to global ecosystem responses to rising atmospheric CO_2 levels. His current work has involved reviewing climate change impacts and adaptation options in Australian agriculture.

Chris' research has involved assessing climate change impacts and adaptation options in Australian rangelands and developing broad systems approaches that seek to balance policy, social, economic and environmental outcomes in developing adaptation options that will prepare agriculture for future while dealing with the uncertainties in the available science. These approaches draw on simulation models that incorporate process standing of the impacts of climate change on biological systems, integrated with other disciplines to explore adaptation options and the limits of adaptive capacity. This experience should provide a strong basis to contribute to Think Tank discussions.

Dr Christine Storer

Senior Lecturer, Agribusiness, School of Agriculture and Environment, Curtin University of Technology

Christine has been working in her current position since 1991. Previously she worked as an information system analyst and chartered accountant internationally. Her PhD looked at communication between organisations in food chains. Subsequent work has been looking at coordination in the food chain including catalysts, problems and critical success factors. Currently Christine is looking at farmers and rural community responses to climate change and the role of government and scientists. In addition she is developing tracking and tracing systems for small business to address biosecurity issues in food chains.

Research interests include: complex problem solving; information communication systems and management; on-farm quality assurance adoption; traceability systems; use of price risk management tools; and consumer and buyer behaviour and attitudes.

Christine's broad range of research interests and considerable experience in research in rural communities will enable her to engage with a broad range of people at the Think Tank. Much of her work is based on working in multi-discipline teams nationally and internationally. With this background she expects to be able contribute across different topics and consider others points of view.

Dr Kirrilly Thompson

Research Fellow, Human Factors Group, Centre for Sleep Research, University of South Australia

Kirrilly is an applied cultural anthropologist working on mixed-methods research projects at the University of South Australia. Her research interests include: humans, society and the environment; human–animal relations; social and cultural aspects of risk and safety; environmental sustainability; community participation, sports and volunteering; social justice and equity; qualitative and social research techniques; and cross-cultural research. Kirrilly works successfully with industry partners to achieve solutions to multi-faceted problems. She is deputy leader of Operations and Safety in the CRC for Rail Innovation and has won a grant to research the socio-cultural drivers to wasteful food behaviours in Australia.

Kirrilly's anthropological approach equips her with the ability to understand community perspectives and mediate them to a general audience to reconcile difference. She uses ethnographic methods to identify the socio-cultural and psychological drivers that underpin, facilitate and perpetuate behaviours. This understanding is essential for sustainable behaviour change. Her current research portfolio includes an environmental sustainability project to understand and reduce food waste behaviours, and a public service improvement project to understand customer experiences of crowding in the rail industry. Kirrilly can contribute a critical social science understanding of the ways in which climate change is perceived.

Dr Ernesto Valenzuela

Lecturer and Research Fellow, School of Economics, University of Adelaide

Ernesto obtained his PhD from Purdue and was a Fulbright scholar during his Masters studies. His research interests include quantitative economics and economy-wide modelling, and he is currently involved in developing a framework to assess demand and global climate changes in the wine industry. Prior to his current position at the University of Adelaide, Ernesto worked for the World Bank's Development Research Group in Washington DC and was involved as a moderator for WBI courses on trade policy and growth and as consultant for the World Bank's trade policy support program.

Human-induced accelerated climate change poses a great challenge to current agricultural production patterns. It is understood that extreme climate events would exacerbate productivity variations increasing food prices, thus disrupting consumption patterns. Increasing awareness of this substantial risk has not been met with a production-climate adaptation framework of how best to respond. This workshop represents an opportunity to delineate a formulation of climate change agricultural adaptation, which would serve to generate informed policy design and analysis.

Based on his experience in economy-wide modelling, and in particular with his understanding of agricultural markets, Ernesto is able to contribute in devising interlinks between climate change volatility and productivity variation measurement.

Dr Todor Vasiljevic

Senior Lecturer and Postgraduate Program Coordinator, School of Biomedical and Health Sciences, Faculty of Health, Engineering and Science, Victoria University

For the past six years Todor has been associated with Victoria University in the area of nutrition, food and health sciences. His research interests focus on sustainable utilisation of aqua- and agricultural resources and implementation of novel technologies in water and energy recovery. Specifically, he is interested in extending a number of fish species utilised for human food but processed in ways which will improve overall health whilst at the same time enhance the biodiversity of our marine ecosystem by decreasing the economic pressure on existing species. His other focus is on development and implementation of membrane technologies for achieving energy and water savings in major dairy processing, in order to reduce the consumption of potable water in the dairy industry in a carbon neutral way.

Over the next several decades, significant progress can and will be made towards more profitable, resource conserving, and environmentally sound aqua- and agricultural systems. Agriculture could, as a result, become a more rewarding profession, both economically and through stewardship of national land and water resources. With his involvement in this workshop, Todor will try to provide a valuable input to make these changes possible, based on new scientific knowledge, novel agricultural management tools and approaches, and economic necessity.

Dr Michelle Watt

Senior Research Scientist, CSIRO Plant Industry

Since joining CSIRO as a Postdoctoral Fellow in 2001, Michelle has worked on six projects with the Australian Grains Research and Development Corporation to improve wheat roots. Wheat is Australia's most important crop, and the world's most important temperate crop. She and her team apply new molecular and imaging techniques to 'see' how roots function and grow in farmer's fields, and use that information to improve roots with genetics or new land management practices. She has presented widely and has been recognised internationally with six keynote speaker invitations since 2006, and by CSIRO with a Julius Award for leading early- to mid-career researchers. Michelle leads projects with the US Department of Agriculture's Agricultural Research Service and the Indian Centre for Agricultural Research with ACIAR.

Michelle will share her experiences with research to increase agricultural productivity- identifying priorities, linking laboratory to field research and validation, applying new genetic models to crops, working within multidisciplinary teams, and communicating to growers, industry and scientific peers. She will discuss the benefits and challenges of working within large international projects, including with India. Michelle who currently supervises PhD students from Australia, China, Iran and India, is strongly committed to training the next generation of agricultural scientists.

THE ROYAL SOCIETY

The 2009 Think Tank is supported by the Royal Society – the national academy of science of the UK and the Commonwealth – through the Theo Murphy (Australia) Fund.