CONFERENCE HANDBOOK

The CCRSPI CONFERENCE

15–17 February 2011

Melbourne Cricket Ground, Melbourne, Victoria

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CCRSPI CLIMATE CHANGE RESEARCH STRATEGY FOR PRIMARY INDUSTRIES

The CCRSPI CONFERENCE

15–17 February 2011
Melbourne Cricket Ground
Melbourne, Victoria

The CCRSPI Conference is convened by the Climate Change Research Strategy for Primary Industries and its partners

Conference Secretariat

Alison Turnbull
National Program Manager – CCRSPI
University of Melbourne
Level 1, 221 Bouverie Street
Parkville, Victoria 3010
T: 03 9035 8270
E: alison.turnbull@unimelb.edu.au

Conference Managers

Esther Price Promotions
Box 341
Mundijong, Western Australia 6123
T: 08 9525 9222
E: esther@estherprice.com.au

FOREWORD

Australia's primary producers face what is both a significant challenge and major opportunity in coming decades – to make a substantial contribution to feeding almost twice the world's current population. To meet this challenge, our producers and policy makers must be supported by smart, effective and collaborative research. The Climate Change Research Strategy for Primary Industries (CCRSPI) is an integral part of that smarter research effort. It is an important joint initiative under the National Research, Development and Extension (RDE) Framework supported by all research and development corporations, CSIRO, the states and territories, and the Commonwealth.

CCRSPI's aim is to provide a national RDE roadmap for primary industries to respond to the challenges and opportunities of climate change. It will provide a strategy for delivering a more efficient and effective national research effort.

This unique event – the country's only dedicated primary industries and climate change conference – is an important opportunity to exchange knowledge, ideas and innovations amongst scientists, policy makers, industry representatives and producers.

The conference program has been designed to ensure that all delegates are exposed to a range of perspectives and disciplines. For example, the program does not separate mitigation from adaptation, nor allocate sessions by industry. More than a dozen case studies delivered by producers will provide an 'on-the-ground' viewpoint on managing climate change. Professor M.S. Swaminathan, leader of India's green revolution, will offer a global perspective; a panel of politicians will debate the impact of their climate policies on producers; and leaders from across sectors will consider the question 'How do we feed and clothe the world in 2050?'. All these things combined, the conference promises to be a strategic, holistic, pragmatic and cross-disciplinary forum for all sectors of the primary industries.

On behalf of the organising committee, I am delighted to share this conference with you and I thank the scientists, policy makers, industry representatives and producers for their support. With so many high quality presenters, it will feed our thinking for years to come. I commend this event to you.

Dr Michael Robinson

Executive Director, Climate Change Research Strategy for Primary Industries
Director, Primary Industries and Climate Challenges Centre
University of Melbourne and Department of Primary Industries Victoria

CONFERENCE ORGANISING COMMITTEE

Dr Michael Robinson
Climate Change Research Strategy for Primary Industries
Primary Industries Climate Challenges Centre

Ms Alison Turnbull
Climate Change Research Strategy for Primary Industries

Professor Snow Barlow
University of Melbourne

Ms Sara Hely
Grains Research and Development Corporation

Dr Sam Nelson
National Farmers' Federation

Dr Ron Prestidge
Department of Primary Industries Victoria

Dr Rob Young
Industry & Investment NSW

CONFERENCE EDITORIAL COMMITTEE

Dr Michael Robinson
Climate Change Research Strategy for Primary Industries
Primary Industries Climate Challenges Centre

Ms Alison Turnbull
Climate Change Research Strategy for Primary Industries

Professor Snow Barlow
University of Melbourne

Dr Rob Young
Industry & Investment NSW

Dr Richard Eckard
University of Melbourne

Dr Michael Battaglia
CSIRO

Mr Steven McMaugh
Department of Agriculture, Fisheries and Forestry

Professor Tim Reeves
Private Consultant

Mr Chris Stokes
CSIRO

CONFERENCE SPONSORS

CCRSPI would like to acknowledge the following sponsors whom, in addition to their partnering roles at CCRSPI, have made a specific contribution to this event.

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Tasmania Explore the possibilities

CONFERENCE LOGISTICS

Esther Price Promotions
Conference Managers

Site contact:
Ms Esther Price 0418 931 938
Email: esther@estherprice.com.au

CONFERENCE DINNER

The CCRSPI Conference dinner takes place on Tuesday 15 February at Zinc, Federation Square, a short walk from the Melbourne Cricket Ground. Pre-dinner drinks start at 6.30pm and dress is smart casual.

PUBLIC FORUM: HOW DO WE FEED AND CLOTHE THE WORLD IN 2050?

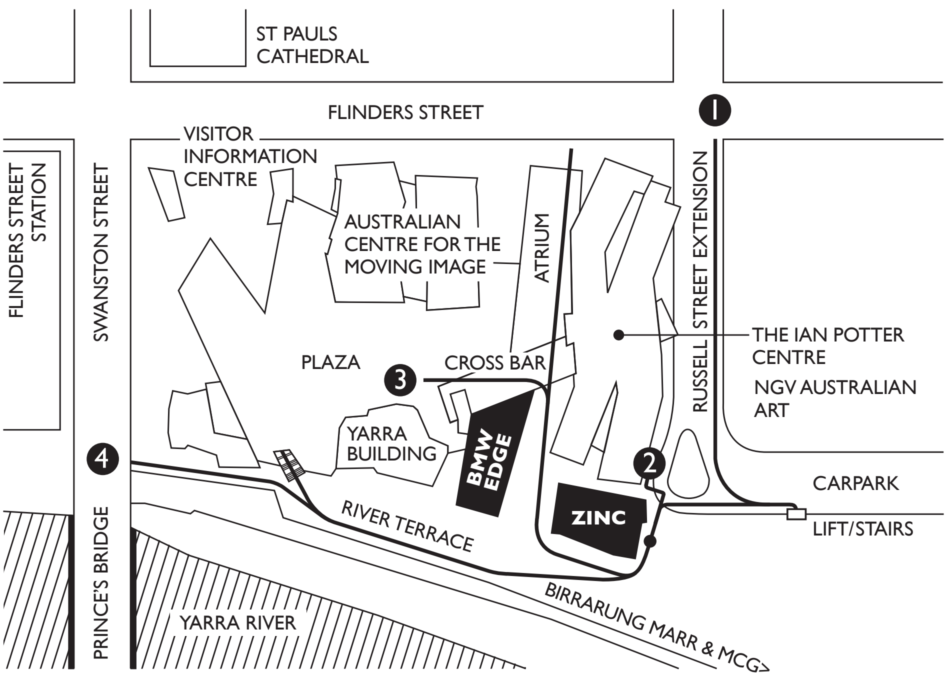
The CCRSPI Conference is pleased to convene a free public forum at 5.30pm Wednesday 16 February at the BMW Edge amphitheatre in Federation Square. The forum will be facilitated by ABC journalist Fran Kelly and feature a panel of leaders from the science, agriculture, community and policy sectors including international keynote speaker Professor M.S. Swaminathan. The forum is open to conference delegates and members of the public alike.

The forum is sponsored by the Primary Industries Climate Challenges Centre and co-hosted by the Sustainable Living Foundation.

OFFICIAL LAUNCH OF THE PRIMARY INDUSTRIES CLIMATE CHALLENGES CENTRE

The official launch of the Primary Industries Climate Challenges Centre (PICCC), a new collaborative research and development venture between the University of Melbourne and the Department of Primary Industries Victoria, will take place at the conclusion of the public forum, at approximately 7pm on Wednesday 16 February.

GETTING TO ZINC AND BMW EDGE AT FEDERATION SQUARE



1

BY CAR
ENTER FEDERATION SQURE VIA THE RUSSELL STREET EXTENSION TURNING LEFT INTO CAR PARK.

PROCEED TO LIFTS AND TAKE LIFTS TO LEVEL 3

WHEN EXITING THE LIFTS TURN LEFT AND PROCEED TO THE END OF CAR PARK

TAKE THE STAIRS TO THE ZINC ENTRANCE AT RIVER LEVEL

2

DROP OFF / ON FOOT
PROCEED TO END OF RUSSELL STREET EXTENSION

TAKE STAIRS ON RIGHT DOWN TO ZINC ENTRANCE AT RIVER LEVEL

3

ON FOOT
FROM THE MAIN PLAZA HEAD TOWARDS BMW EDGE AT THE END OF THE ATRIUM

PROCEED THROUGH THE SLIDING DOORS & DOWN STAIRS TO ZINC

4

ON FOOT
FROM THE PRINCE'S BRIDGE HEAD DOWN THE YARRA ALONG RIVER TERRACE UNTIL YOU REACH ZINC

5

ON FOOT
FROM THE MCG CROSS THE FOOTBRIDGE HEADING TOWARDS THE CITY. PROCEED THROUGH BIRRARUNG MARR AND ALONG THE RIVER UNTIL YOU REACH ZINC

INDEX OF THEMES AND PAPERS

This conference hand book carries extended abstracts from nearly all presentations, which appear by theme order and then by speaking order.

PROGRAM

DAY 1 TUESDAY 15TH FEBRUARY

From 9.00am – Registrations, poster viewing and arrival hospitality		
10.15am	**Opening and formalities**	***Dr Michael Robinson*** *Executive Director, Climate Change Research Strategy for Primary Industries*
10.25am	**Ministerial Welcome**	***Dr Mike Kelly*** *Parliamentary Secretary to Minister Joe Ludwig, Minister for Agriculture, Fisheries & Forestry*
10.45am	**International Keynote: The global challenge to feed and clothe the world's population in a changing climate**	***Professor MS Swaminathan*** *MS Swaminathan Research Foundation, India*
11.30am	**Where does agriculture need to be in 2030/50? Setting a vision for our primary producers in a changing climate**	***Peter Reading*** *Retiring Managing Director, Grains Research and Development Corporation*
12.10pm	**The role of RDE and the Climate Change Research Strategy for Primary Industries**	***Dr Michael Robinson*** *Executive Director, Climate Change Research Strategy for Primary Industries*

12.30pm to 1.30pm	**LUNCH**	
	Plenary session: Theme Synthesis Papers	CHAIR: **Professor Rick Roush**
1.30pm	**Plants**	***Dr Scott Chapman*** *CSIRO*
2.00pm	**Animals**	***Associate Professor Beverley Henry*** *Queensland University of Technology*
2.30pm	**Farming Systems**	***Dr Peter Hayman*** *South Australian Research Development Institute*

AFTERNOON TEA			
3.30pm to 5.00pm	Concurrent Session 1	Concurrent Session 2	Concurrent Session 3
	Plants CHAIR: **Dr Scott Chapman**	**Animals** CHAIR: **Associate Professor Beverley Henry**	**Farming Systems** CHAIR: **Dr Peter Hayman**
	Glenn Fitzgerald Department of Primary Industries Victoria *Elevated atmospheric CO_2 and wheat production in Australia*	**Rob Herd** Industry & Investment NSW *Breeding cattle for lower greenhouse gas emissions in an Australian carbon trading environment*	**Richard Eckard** University of Melbourne *Can we achieve net reductions in greenhouse gas emissions?*
	Rick Roush University of Melbourne. *GM crops for reducing greenhouse gas emissions*	**Zoey Durmic** University of Western Australia *Antimethanogenic plants for grazing systems*	**Melissa Rebbeck** South Australian Research and Development Corporation *Livestock and pasture adaptations for southern Australia*
	Victor Sadras South Australia Research and Development Institute. *Early maturing of grapevines in south eastern Australia*	**Peter Moate** Department of Primary Industries Victoria *Methane emissions unaffected when DHA fed to cows*	**Mike Ewing** Future Farm Industries CRC *Novel perennial based farming systems are a key tool in adaptation*
	Peter Stephens Northern Territory Department of Resources. *Mango yield in relation to predicted climate*	**Malcolm McPhee** Industry & Investment NSW *Preliminary results of estimating on-farm methane*	**Matthew Harrison** CSIRO *Robust pasture management adaptation strategies for Australian farming systems in a changing climate*
	Farmer Case Study *Peter Whip, Longreach, QLD*	**Farmer Case Study** *Ian Litchfield, Mayrung, NSW*	**Farmer Case Study** *Barry Mudge, Port Germein, SA*

CONFERENCE DINNER	
6.30pm	**Zinc, Federation Square**

DAY 2 WEDNESDAY 16TH FEBRUARY

COFFEE/TEA		
8.30am to 10.00am	**Plenary session: theme synthesis papers**	CHAIR: **Rob Young**
8.30am	**Water**	***Professor John Langford*** *University of Melbourne*
9.00am	**Socio-economic**	***Professor Margaret Alston OAM*** *Monash University*
9.30am	**Landscapes**	***Jason Alexandra*** *Murray Darling Basin Authority*

MORNING TEA			
10.30am to 12.00pm	Concurrent Session 1	Concurrent Session 2	Concurrent Session 3
	Water & Landscapes CHAIR: **Jason Alexandra**	**Socio-economic** CHAIR: **Prof Margaret Alston**	**Communications** CHAIR: **Alison Turnbull**
	Craig Clifton Sinclair Knight Merz *What future for Riverina irrigation communities?*	**David Pearson** University of Canberra *Opportunities emerging from consumer led changes*	**Susan McNair** Currie Communications *"Message Received" not "Message Sent"*
	Craig Barton Industry & Investment NSW *Effects of rising CO_2 concentration on water use*	**Kerry Bridle** Tasmanian Institute of Agricultural Research *Closing the loop by using adaptive capacity workshops*	**Graeme Anderson** Department of Primary Industries Victoria *Don't forget the E lessons from 10,000 farmers*
	Richard Harper Murdoch University *Lessons from recurrent droughts in plantations*	**Harm van Rees** Cropfacts *Consequences and lessons from farming with change*	**Neil Cliffe** Department of Employment, Economic Development & Innovation Qld *The climate change risk management matrix*
	Shahadat Chowdhury NSW Office of Water *The role of climate variability and climate change in NSW water sharing arrangements*	**Chris Sounness** Department of Primary Industries Victoria *The Five Big Questions*	**Marion Titterton** Tasmanian Institute of Agricultural Research *A knowledge partnership approach*
	Farmer Case Study ***Steve Mathews**, Victoria*	**Farmer Case Study** ***Lynne Strong**, Cloverhill Dairies, Jamberoo, NSW*	**Lauren Rickards** University of Melbourne *Implications of climate change adaptation for agricultural extension: a preliminary analysis*

LUNCH		
1.00pm to 2.30pm	**Politicians' Panel:** **Under which climate policy will our farmers, fishers and foresters thrive?**	CHAIR: **Bruce Kefford** ***Facilitated by Fran Kelly, with Senator Christine Milne, Hon Greg Hunt MP, NFF President Jock Laurie and others***

AFTERNOON TEA		
	Plenary: RD&E for primary industries in Australia	CHAIR: **Dr Michael Robinson**
3:00pm	**The RDCs delivering the goods, for the past twenty years, and the next twenty years**	***Dennis Mutton*** *Chair, Council of Rural Research Development Corporations*
3.20pm	**Smarter science through the national RDE framework – delivering a more efficient, effective and collaborative innovation system for Australia's primary producers**	***Dr Bruce Kefford*** *Department of Primary Industries Victoria*
3.40pm	**To be advised**	***TBC***
4.00pm	**The Global Research Alliance**	***Laura Hogg*** *New Zealand Ministry of Agriculture and Forestry*
4.20pm	**Panel**	
4.30pm	**Rural Industries Research and Development Corporation Presentation**	***Simon Winter***
4.40pm	**Close and reconvene at BMW Edge**	

PUBLIC FORUM - BMW Edge, Federation Square		
5.30pm	**How do we feed and clothe the world in 2050?**	***Facilitated by Fran Kelly with guests MS Swaminathan, Dr Brian Keating, Renata Brooks, Matthew Wright & Sam Archer***
7.00pm	**Minister's address**	***Hon. Peter Walsh*** *Minister for Agriculture & Food Security*
7.10pm	**University of Melbourne address**	***Vice Chancellor Glyn Davis*** *University of Melbourne*
7.20pm	**The Primary Industries Climate Challenges Centre**	***Dr Michael Robinson*** *Director, Primary Industries Climate Challenges Centre*

DAY 3 THURSDAY 17TH FEBRUARY

COFFEE/TEA		
8.30am to 10.00am	**Plenary: Theme Synthesis Papers**	CHAIR: **Andrew Ash**
8.30am	**Farming and food systems for a carbon, water, energy and nutrient constrained world**	***Andrew Campbell*** *Research Institute for Environment and Livelihoods*
9.00am	**Transformational Adaptation**	***Dr Mark Howden****, CSIRO* ***Professor Snow Barlow****, University of Melbourne*
9.30am	**Greenhouse Gas Accounting**	***Dr Annette Cowie*** *National Centre For Rural Greenhouse Gas Research*
10.00am	**Soils**	***Dr Jeff Baldock*** *CSIRO*

MORNING TEA			
10.30am to 12.30pm	Concurrent Session 1	Concurrent Session 2	Concurrent Session 3
	Transformational Adaptation CHAIR: **Professor Snow Barlow**	**Greenhouse Gas Accounting** CHAIR: **Dr Annette Cowie**	**Soils** CHAIR: **Dr Jeff Baldock**
	Peter Thorburn CSIRO *Can Australia's peanut value chains transform?*	**Louise Barton** University of Western Australia *Greenhouse gas emissions from food and biofuel*	**Peter Grace** Queensland University of Technology *The Nitrous Oxide Research Program*
	Richard Bennett Future Farm Industries CRC *Transformational adaptation for the wheatbelt*	**Karen Christie** Tasmanian Institute of Agricultural Research *Whole farm system analysis of the GHG emissions of Australian dairy farms*	**Graeme Schwenke** Industry & Investment NSW *Emission of nitrous oxide from a cracking clay soil*
	Ros Prinsley *New rural industries for future climates*	**Weijin Wang** Department of Environment & Resource Management Qld *Assessing the greenhouse impact of differing farming systems*	**Kevin Kelly** Department of Primary Industries Victoria *Can we reduce nitrous oxide emissions from animals?*
	Sarah Park CSIRO *Understanding transformational processes*	**Fabiano Ximenes** Industry & Investment NSW *The greenhouse footprint of wood production in NSW*	**Deli Chen** University of Melbourne *Modelling N_2O emissions from agriculture*
	Farmer Case Study ***Laurie Arthur****, WA The Ord*	**Farmer Case Study** ***Mark McKew****, Ararat, VIC*	**Farmer Case Study** ***David Marsh****, Boorowa, NSW*

LUNCH			
1.30pm to 3.00pm	Concurrent Session 1	Concurrent Session 2	Concurrent Session 3
	Farming Systems CHAIR: **Dr Ron Prestidge**	**Impacts and Forecasting** CHAIR: **Col Creighton**	**Socio and Economic** CHAIR: **Dr Rob Young**
	Alistair Hobday CSIRO *Seasonal forecasting to support management decisions*	**Brendan Cullen** University of Melbourne *Resilience surfaces for pasture production under climate change scenarios*	**Bob Farquharson** Future Farm Industries CRC *Future Farm Industries cooperative research into profitable societies*
	Ross Kingwell Department of Agriculture & Food WA *Regional impacts of climate change on dryland farms*	**Jan Edwards** Industry & Investment NSW *Adapting to climate change in Southern NSW*	**Thilak Mallawaarachichi** University of Queensland *Agricultural adaptation during times of change*
	Andrew Moore CSIRO *Will managing for climate variability also manage for climate change?*	**Richard Rawnsley** Tasmanian Institute of Agricultural Research *An historical analysis of the changes in pasture production, growing season and the number of wet and dry days in three dairy regions of South East Australia*	**Jonathan Moss** University of New England *An integrated assessment of land use change*
	Jeff Clewett Agroclim Australia *Grains best management practise for managing climate*	**Peter McIntosh** CSIRO *Practical management of climate variability in a changing climate*	**Practitioner Case Study** ***Rohena Duncombe*** *NSW Health*
	Farmer Case Study ***David Cattanach****, Darlington Point, NSW*	**Farmer Case Study** ***TBC***	**Panel**

AFTERNOON TEA			
3.30pm to 5.00pm	Concurrent Session 1	Concurrent Session 2	Concurrent Session 3
	Farming Systems CHAIR: **Dr Sam Nelson**	**Plants** CHAIR: **Martin Blumenthal**	**Soils** CHAIR: **Michael Crawford**
	Steven Crimp CSIRO *Managing future agricultural production in a variable climate*	**Michael Tausz** University of Melbourne *Wheat performance under elevated CO2*	**Bhupinder Pal Singh** Industry & Investment NSW *The mean residence time of biochar carbon in soil*
	Darshan Sharma Department of Agriculture & Food WA *Can flexibility be built into cropping systems?*	**De Li Liu** Industry & Investment NSW *Impact of climate change on wheat phenology in the NSW wheat belt*	**Helen Suter** University of Melbourne *Impact of DMPP on N2O emissions from pasture*
	Gregory Holz University of Tasmania *Changes in agricultural climate indices in Tasmania*	**David Stephens** Department of Agriculture and Food, WA *How has a changing climate affected Australia's capacity to increase crop productivity: 1990-2009?*	**Roger Armstrong** Department of Primary Industries Victoria *How will the impact of elevated CO2 on grain production vary with different soils?*
	Jean-Francois Rochecouste University of Queensland *Managing crop production uncertainties*	**Ros Gleadow** Monash University *Nutrient supply, below ground processes and elevation*	**Timothy Huggins** University of Melbourne *Is dicyandiamide economically viable on dairy farms?*
	Peter Thorburn CSIRO *Will climate change negate better farm management?*	**Rebecca Ford** University of Melbourne *Securing pulses under changed environments*	**Sally Officer** Department of Primary industries Victoria *Can we reduce nitrous oxide emissions from crops?*
CLOSE 5.00pm			

BIOGRAPHIES

This conference handbook contains the biographies of our invited and plenary speakers, and the extended abstracts of our presenters in theme order. Conference proceedings containing the full papers of our synthesis authors will be published following the event.

OPENING AND KEYNOTE SPEAKERS

Dr Michael Robinson, Climate Change Research Strategy for Primary Industries

Michael Robinson is the Executive Director of CCRSPI – the Climate Change Research Strategy for Primary Industries. He is also Centre Director for the newly established Primary Industries Climate Challenges Centre, a joint research and development venture between the University of Melbourne and the Department of Primary Industries Victoria.

Michael has extensive experience in climate change research management through his roles as the Executive Director of Land & Water Australia and the Chief Executive Officer of the CRC for Greenhouse Accounting. He is a member of the Primary Industries Standing Committee Research and Development Subcommittee. He has worked in research, communication, business development and policy in Australia and New Zealand, and is passionate about research informing sustainable and productive landscape management.

Michael has also worked with CSIRO in business development, management and communication roles, focusing on environmentally sustainable forestry. 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.

Professor Monkombu Sambasivan Swaminathan, M.S. Swaminathan Research Foundation, India

Monkombu Sambasivan Swaminathan is an Indian agriculture scientist, and founder and chairman of the M.S. Swaminathan Research Foundation. He is widely recognised as one of the leaders of the Green Revolution in India for his success in introducing and further developing high-yielding varieties of wheat, fertilisers and irrigation in India.

A plant geneticist by training, M.S. Swaminathan is an advocate of moving India to sustainable development through environmentally sustainable agriculture, sustainable food security and the preservation of biodiversity. In 1999, he was listed by Time magazine as one of the 20 most influential Asian people of the 20th century.

In 1988 he established the M.S. Swaminathan Research Foundation in Chennai, India, to realise his goals in sustainable development. The Foundation is a non-profit research organisation committed developing and promoting strategies for economic growth that directly target increased employment of poor women in rural areas. It carries out research and development in areas such as biotechnology, food security and biodiversity.

Peter Reading, Grains Research and Development Corporation

Peter Reading has been Managing Director of the Grains Research and Development Corporation since February 2004.

Peter graduated from the University of Sydney with an honours degree in agricultural science. He commenced postgraduate studies in agronomy before leaving the university to work for American Cyanamid in Australia, Asia and the United States; Incitec in Australia; and British Oxygen Group in Australia and Asia and the Grain Pool in Western Australia.

Dennis Mutton, Council of Rural Research and Development Corporations

Dennis Mutton is an Adelaide-based independent consultant in resource planning and development, strategic management, sustainability, natural resource management, leadership and regional development. He is Chair of the Council of Rural Research and Development Corporations, BioInnovation SA and the Native Vegetation Council. He is also a Member of the Premier's Science and Research Council and a Director of Operation Flinders Foundation.

Dennis has had a distinguished career in the South Australian Public Service and industry including as Chief Executive of Primary Industries and Resources SA, the Department of Environment and Natural Resources and the Woods and Forests Department. He held the positions of Deputy President and Commissioner of the Murray Darling Basin Commission. He is currently leading a range of development projects in East Timor.

Dr Bruce Kefford, Department of Primary Industries Victoria

Bruce Kefford is the Deputy Secretary of Agriculture Research and Development at the Department of Primary Industries Victoria. As part of this role he oversees the Office of Science, Technology and Commercialisation, the Future Farming Systems Research and the Biosciences Research divisions.

At a national level, Bruce leads the National Primary Industries Research, Development and Extension Committee, reporting to the Standing Committee and Ministerial Council. Bruce is Director of the Agriculture Victoria Services Pty Ltd, the Dairy Futures Cooperative Research Centre and the Biosciences Research Centre Pty Ltd.

Bruce's previous experience has been in research and development, regulation, technology transfer and science management in agriculture, particularly the dairy industry. He has a passionate interest in management of science and science based organisations, program evaluation and the processes of improved community engagement. Bruce lives with his wife and two sons on a small farm near Warragul.

Laura Hogg, New Zealand Ministry of Agriculture and Forestry

Laura Hogg is a Senior Advisor with the New Zealand Ministry of Agriculture and Forestry. She is part of the team leading the establishment of the Global Research Alliance on Agricultural Greenhouse Gases. Laura also works on agricultural issues within the UN climate change negotiations and is involved in the development of international standards for greenhouse gas footprinting agricultural products.

Laura has previously worked on climate change and sustainability issues at the New Zealand Ministry of Foreign Affairs and Trade, and in the private sector in the United Kingdom where her clients included adidas, Marks & Spencer and Cadbury Schweppes.

PUBLIC FORUM PANELLISTS

Sam Archer, livestock and cereal farmer, Gundagai, NSW

Sam Archer runs a livestock and cereal property with his wife, Sabrina, based on native pastures at Gundagai. He was awarded an Australian Nuffield Farming Scholarship in 2008 and travelled throughout the Americas, Europe and India researching private sector funded environmental stewardship schemes broadly based around carbon, water and biodiversity.

The farm has been a research site for the CSIRO's Sustainable Ecosystems program and the Australian National University's Centre for Resource and Environmental Studies. Sam is Chair of Murrumbidgee Landcare, a member of the Australian Farm Institute's Research Advisory Committee and the BioBanking Ministerial Reference Group, a Board Director of the NSW Farmers Association and Chair of the Association's Business, Economics and Trade Committee.

Sam has worked with aboriginal resource agencies delivering socio-economic programs to remote communities in WA, as well as a corporate trouble-shooter within the logistics, utilities and environmental sectors. He holds Commerce and Arts degrees from Deakin University and the Australian National University respectively.

Dr Renata Brooks, Industry & Investment NSW

Renata Brooks is an Executive Director with Industry & Investment NSW, leading the Science and Research Division within Primary Industries. As Executive Director with responsibility for the Orange Head Office based functions of the agency, she represents the Director-General and provides leadership and coordination of cross divisional activities.

Renata was a member of the NSW Department of Primary Industries Executive Board from its creation in 2004, leading a number of divisions including as Deputy Director-General, Agriculture, Biosecurity and Mine Safety (from March 2008), Deputy-Director General, Agriculture and Fisheries (from November 2005) and, with the formation of the Department of Primary Industries in 2004, as the inaugural Executive Director, Biosecurity, Compliance and Mine Safety. In NSW Agriculture, Renata was Chief, Division of Animal Industries. She was also the Program Manager of Meat, Dairy and Intensive Livestock Products with NSW Agriculture for three years.

Renata holds a Veterinary Science degree from the University of Sydney, a Graduate Certificate in Bioethics from the University of Technology Sydney, and is a graduate of the Australian Institute of Company Directors.

Dr Brian Keating, CSIRO Sustainable Agriculture Flagship

Brian Keating is the inaugural Director of the CSIRO Sustainable Agriculture Flagship, which focuses on productivity, greenhouse gas abatement and sustainability challenges in Australian agriculture, forestry and land-use systems.

Brian has 35 years experience in agricultural and natural resource management research and development. He has been engaged in many research activities and leadership roles over this period, including Deputy Chief and then Chief of the Division of Sustainable Ecosystems (2004–2008) and Board member of Sugar, Rainforest Ecology and Management and Tropical Savannas Cooperative Research Centres. A graduate of the University of Queensland (B Agr Sc 1976 and PhD 1981), his research career has focused on sustainable management of farming systems, with deep experience in Australia's grain and sugar industries and smallholder mixed farming systems in Africa.

Brian has authored over 200 scientific papers on soil and water management, plant nutrition, soil carbon and nitrogen cycling, crop physiology, farming systems analysis and design, bioenergy, simulation modelling, climatic risk management and food security. He is a member of the Editorial Board of the international journal, Agricultural Systems and a member of the Australian Government's Domestic Offsets Integrity Committee for the Carbon Farming Initiative.

Professor Monkombu Sambasivan Swaminathan, M.S. Swaminathan Research Foundation, India

Monkombu Sambasivan Swaminathan is an Indian agriculture scientist, and founder and chairman of the M.S. Swaminathan Research Foundation. He is widely recognised as one of the leaders of the Green Revolution in India for his success in introducing and further developing high-yielding varieties of wheat, fertilisers and irrigation in India.

A plant geneticist by training, M.S. Swaminathan is an advocate of moving India to sustainable development through environmentally sustainable agriculture, sustainable food security and the preservation of biodiversity. In 1999, he was listed by Time magazine as one of the 20 most influential Asian people of the 20th century.

In 1988 he established the M.S. Swaminathan Research Foundation in Chennai, India, to realise his goals in sustainable development. The Foundation is a non-profit research organisation committed developing and promoting strategies for economic growth that directly target increased employment of poor women in rural areas. It carries out research and development in areas such as biotechnology, food security and biodiversity.

Matthew Wright, Beyond Zero Emissions

Matthew Wright is the Executive Director of climate solutions think tank Beyond Zero Emissions (BZE) and the current Environment Minister's Young Environmentalist of the Year.

BZE is an organisation focused decarbonising the Australian economy. The organisation has a strategic research collaboration with the University of Melbourne's Energy Research Institute and their work has won the 2010 Mercedes Benz Environmental Research Award.

Matthew started a renewable energy awareness organisation in 2003 called Future Energy. In 2006 the scope of this organisation was broadened to cover all sectors of the economy and he co-founded Beyond Zero Emissions. Prior to his role at Beyond Zero Emissions Matthew worked in the provision of financial information and news to corporate organisations, energy and commodity markets, banks and other financial institutions.

THEME SESSIONS

PLANTS

Dr Scott Chapman, CSIRO Plant Industry

Scott Chapman is a Senior Principal Research Scientist in Crop Adaptation at CSIRO Plant Industry in Brisbane. Following studies at the University of Queensland (UQ), he undertook postdoctoral research at CIMMYT – the International Maize and Wheat Improvement Centre – in Mexico (home of the 'Green Revolution') before returning to work with UQ and then with CSIRO from 1996.

Scott currently leads international research projects in developing tools and methods in breeding for drought stress, and national projects to develop genetic resources to help breeders create 'climate-ready' wheat and sorghum varieties. He has 20 years of broad experience 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 under conditions of drought and heat stress.

In the area of climate change research, Scott's recent projects engage staff in CSIRO, UQ and the Department of Employment, Economic Development and Innovation in understanding how different wheat and sorghum varieties perform under 'climate-change' conditions, so that new germplasm and technologies can be developed to assist plant breeders to deliver new varieties with good adaptation to potential future climates in the Australia.

Peter Whip, beef farmer, Longreach, Qld

Peter Whip runs an 18,000 acre beef grazing property in western Queensland with his wife, Raeleen, and sons, Toby and Sam. He approaches his grazing business from a performance-driven perspective while improving overall health of the landscape in which he operates. He operates his business in a native pasture rangelands grazing environment and his focus over the past 10 years has been of improving ground cover to increase landscape health as well as maintaining and improving profitability.

The low and varied rainfall environment means that decision making is linked closely to seasonal conditions, with animals bred for high feed efficiency and low feed maintenance traits.

He is passionate about fixing the landscape and has trialled and adopted both new and old techniques to address water runoff, poor infiltration, soil loss and degraded pasture levels. He sees significant potential for increasing soil carbon levels through restoring and maintaining pasture health and is keen to be involved in the necessary research to address some of the knowledge gaps in this area.

ANIMALS

Dr Beverley Henry, Queensland University of Technology

Beverley Henry is a Principal Research Fellow in the Institute for Sustainable Resources at the Queensland University of Technology. She also works part time with Meat and Livestock Australia where, until August 2010, she was the Manager for Environment, Sustainability and Climate Change. Her research and industry interests include climate change mitigation and adaptation, environmental stewardship, sustainable and profitable agricultural production and global food security.

Beverley has a background in biological sciences with a PhD from the University of Queensland in Plant Physiology. She has more than 15 years experience in the areas of climate change and greenhouse gas accounting, including having held positions in the Queensland Government and the Australian National University.

She is a member of several national and international technical groups and advisory panels, particularly in areas of climate change research, and greenhouse gas accounting and standard development. She enjoys working with a wide range of colleagues in science, policy, agricultural industries and farming, and applying science-based information to economic, social and environmental sustainability challenges, particularly for the livestock industries.

Ian Litchfield, dairy farmer, Mayrung, NSW

Ian Litchfield and his wife Karen are dairy farmers from Mayrung, near Deniliquin, NSW. They moved to the completely pastured-based property 10 years ago with 170 cows. They immediately installed grain feeding system to lift production and are now milking 500 head.

In their first year at the property they had full allocation of water, however subsequent years of drought and reduced water allocations made it uneconomical to continue watering summer pastures. This created a feeding issue for their growing herd over the summer. On hot days cows would wait at gate to go to sprinklers instead of eating. Old infrastructure meant that not all cows could fit under the sprinklers – many missed out, resulting in heat stress and reduced milk production, as well as mastitis infections due to the confined area.

In 2007 the Litchfields moved into newly constructed, larger dairy which provided ample space for cooling cows. Following a farm tour of the dry climate areas of California and Arizona, they constructed a dry lot system of shelter sheds. Although it has been a significant cash outlay in difficult times, the Litchfields consider the investment well worth it for the resultant reduction in heat stress. Their cows now continue to feed on hot days as they move back to sheds after feeding; milk production loss and mastitis have been reduced, and fertility has improved.

FARMING SYSTEMS I

Dr Peter Hayman, South Australian Research and Development Institute

Peter Hayman is the Principal Scientist in Climate Applications at the South Australian Research and Development Institute, a position he has held since May 2004. Prior to moving to Adelaide he was coordinator of climate applications for NSW Agriculture.

Peter is an agricultural scientist with an interest in applying climate information to dryland and irrigated farming systems. His work has had a recent focus on impacts and adaptation to climate change in the irrigated wine grape and low rainfall grains industries. From 2007 to 2009 he led a World Meteorological Organisation Expert Team on the communication and use of agro-climatic information. He is co-leader of the farming systems theme of the Primary Industries Adaptation Research Network.

In 1999 Peter was awarded the inaugural Seed of Light Award by the Grains Research and Development Corporation for research communication in the northern grain region. After moving to South Australia, he was awarded the 2006 Seed of Light for research communication on climate change in the southern grains region.

Barry Mudge, cropping and livestock farmer, Port Germein, SA

Barry Mudge is a fourth generation farmer from Port Germein, on the lower rainfall edge of the northern South Australian wheat belt. He manages a cropping / livestock family farming business which still includes the original land taken up by his great grandfather under closer settlement in 1878.

Barry has an Agricultural Economics tertiary background and worked as a Rural Officer in the Commonwealth Development Bank for several years. Since returning to the property in 1990, he has focused on developing innovative methods to manage climate risk in a highly variable environment. He believes that climate variability provides an opportunity rather than a threat, and sees an improved approach to managing climate risk as a vital part of developing more robust businesses capable of thriving under a changing climate.

Barry currently undertakes a part time role with Rural Solutions SA specialising in developing and delivering risk management programs to other farmers.

WATER

Professor John Langford, Uniwater

John Langford is the Director of Uniwater, a joint initiative of Monash University and the University of Melbourne. He is internationally recognised for his expertise and leadership in urban and rural water management reform, and plays a prominent role in the national and international water debate.

From 1994 to 2003 John was inaugural Executive Director of the Water Services Association of Australia, the peak body of the Australian urban water industry, and was Managing Director of Victoria's Rural Water Corporation from 1989 to 1994. He chaired the boards of the Cooperative Research Centre (CRC) for Catchment Hydrology, the CRC for Freshwater Ecology and the Advisory Board of Sydney University's Special Research Centre on the Environmental Impact of Coastal Cities. Currently he is chair of the Murray-Darling Freshwater Research Centre.

John is a Churchill Fellow, a Fellow of the Australian Academy of Technological Sciences and Engineering, and a recipient of the Centenary Medal (2003), the Order of Australia (2005) and the Peter Hughes Award for his contribution to the Australian water industry. In 2004 he was listed as one of Australia's 100 most influential engineers by Engineers Australia.

Steve Matthews, land owner and manager, Victoria

Steve Matthews is a consultant ecologist with Ecology Australia Pty Ltd. He has worked in the environmental field in Victoria in various capacities since undertaking studies in forest and environmental sciences. He also owns and manages 5000 hectares of land in Victoria, in 13 different properties, ranging from the South Australian border to the far north east. Each property was purchased based on the ecological values, price, and ease of ecological management, and all are managed to protect and enhance their natural, cultural and aesthetic value. Steve generates income from the properties through a range of land uses, including grazing, sale of biodiversity and carbon credits, and landscape-based tourism.

Steve has been active in assisting a number of community organisations in the landscape and environmental field over the last 15 years, including the Landscape Committee of the National Trust, the Australian Environmental Grantmakers Network, the Invasive Species Council, and as a trustee of the Mullum Trust, a small environmental foundation. Recently he has worked on the design of an ecologically sensitive plan for the development for a property on Melbourne's urban fringe, balancing ecological, water and landscape management outcomes with residential yield.

Steve has a particular interest in seeing land management move towards a more integrated approach, where of primary production, biodiversity conservation, management of water and soil resources, and protection and enhancement of aesthetic and other cultural values are balanced.

LANDSCAPES

Jason Alexandra, Murray Darling Basin Authority

Jason Alexandra is the senior executive at the Murray Darling Basin Authority responsible for Basin-scale natural resource management programs. Jason has had a long term involvement in sustainability policy, adaptive management, the governance of natural resources and use of applied research for solving environmental problems. He has over 30 years experience in agriculture, environmental research and policy, sustainable land use and natural resources management.

Prior to joining the former Murray Darling Basin Commission, Jason was the Executive Director of the Earthwatch Institute Australia, an international non-government organisation delivering environmental research and sustainability education. Between 1996 and 2006 he was the managing director and principal of Alexandra and Associates, a specialist research and consulting business. Over the decade he delivered over 80 research and consulting projects including evaluations of government programs such as the National Heritage Trust, and the scoping and establishment of the National Vegetation and Biodiversity Research and Development Program.

He has also published reviews of state of the environment reporting, regional sustainability reporting, Australian water policy, climate change adaptation, farm forestry policy, environmental management systems, and indigenous enterprise development. Jason was a Director of Land and Water Australia and Greening Australia and has held numerous advisory roles. He has owned and managed a reafforestation nursery, a salvage sawmill and organic orchards, and has continuing interests in several rural businesses.

SOCIO-ECONOMIC I

Professor Margaret Alston, Monash University

Margaret Alston is Professor of Social Work and Head of Department at Monash University, where she has established the Gender, Leadership and Social Sustainability research unit. She is also an Honorary Professor at Sydney University and Charles Sturt University, and the current Chair of the Australian Heads of Schools of Social Work. Prior to commencing at Monash, Margaret was at Charles Sturt University for 21 years, most recently as Professor of Social Work.

In 2010 Margaret was awarded the Medal of the Order of Australia for services to the community, social work and to rural women. She was appointed as an NGO representative to the Australian delegation for the UN's Commission for the Status of Women meeting in New York in 2008. She has been a member of numerous boards and working groups including the Foundation for Australian Agricultural Women and the NSW Farmers' Mental Health Working group.

In her capacity as a UN gender expert in the Gender Division of the UN's Food and Agriculture Organisation, Margaret has been studying gender and climate. She has published widely in the field of rural gender and social issues and in social work including her most recent book Innovative Human Services Practice: Changing Landscapes published in 2009. Her most recent research is on the social and gendered impacts of climate change.

Lynne Strong, dairy farmer, Jamberoo, NSW

Lynne, Michael and Nicolas Strong own Clover Hill Dairies, a seventh generation family-operated business located at Jamberoo on the NSW South Coast. They milk 400 cows three times daily on two farms to produce five million litres of milk per year. The Strongs moved to three milkings per day in 2005, resulting in a 25% increase in milk production. Improvements in farm efficiency and productivity of pastures in the past 10 years have enabled them to fence off 50% of this farm for conversation purposes.

The family's climate change strategy is to produce more milk, using fewer resources and generate less waste – allowing them to adapt, minimise their footprint and mitigate the impact on their business of climate change legislation and any associated costs.

The family is passionate about introducing young Australians to careers in agriculture. Over the past five years Lynne has sourced funds, managed and delivered several projects on behalf Dairy Youth Australia Inc, including Picasso Cows, Cream of the Crop and the Archibull Prize projects. These projects use art and multimedia to engage school-aged children to explore agricultural sustainability issues and show them that responsible agricultural production is a legitimate use of land, water and other resources.

Rohena Duncombe, NSW Health

Rohena Duncombe has been working for NSW Health as a Social Worker in rural settings for 30 years, first in Albury and later in Byron Bay. Her practice includes individual counselling and therapy for issues such as depression, anxiety, grief, relationship breakdown, and stress related to family, finances and ill health or ageing.

Rohena's other areas of practice are community development, group work, research and education. Community development activities have included training unemployed youth to run New Games and running the games for school aged children in rural towns. She is presently involved in developing 'place-based servicing' for a community of homeless people in conjunction with small businesses, volunteers and government agencies.

She has delivered group work activities in parenting, recovering from divorce and separation, assertiveness, women's health and anxiety management. Rohena teaches Social Work for Charles Sturt University and is researching in the area of delivery systems and access to services in rural areas.

COMMUNICATIONS

Susan McNair, Currie Communications

Susan McNair is the Director of Client Services at Currie Communications in Melbourne. She specialises in communicating complex, yet concise messages to people and communities confronted with change.

At Currie Communications Susan works with several national clients in the environment, climate change and agricultural spheres and has developed and implemented several significant national campaigns targeting farmers. These include a Future Farm Industries Cooperative Research Centre campaign to raise farmer and community awareness of real options in adapting to climate change; and Meat and Livestock Australia's communications to manage perceptions of livestock's environmental impact.

Susan has extensive experience in rural journalism in both Australia and New Zealand. She has more than eight years' experience as a journalist, editor and managing editor with Australia's largest rural and regional publisher, Rural Press Limited. She edited Victoria's leading livestock newspaper Stock & Land, as well as New Zealand's largest national farming publication, Straight Furrow. Susan is Honorary Secretary and a former President of the Rural Press Club of Victoria.

FARMING SYSTEMS II

Andrew Campbell, Research Institute for Environment and Livelihoods

Andrew Campbell is the newly-appointed Director of the Research Institute for Environment and Livelihoods at Charles Darwin University in Darwin. The Institute encompasses terrestrial, aquatic and marine issues, and is strongly interdisciplinary across the natural and social sciences.

Until late 2010, Andrew managed Triple Helix Consulting Pty Ltd, a consultancy firm specialising in the business of sustainability, working at the interface between science and policy around climate, water, energy, biodiversity and food systems. Previously, he was the Executive Director of Land and Water Australia, leading the corporation through a period of considerable growth and innovation. Prior to 2000 he was a senior executive in the Australian Government, responsible for the Bushcare program. Andrew managed the Potter Farmland Plan project in western Victoria from 1984-88, was instrumental in the development of Landcare and has written widely on sustainability issues.

Andrew studied forestry at the University of Melbourne and rural sociology at Wageningen Agricultural University in The Netherlands. He chairs the Terrestrial Ecosystem Research Network, is a Fellow of the Australian Institute for Company Directors, an independent director of the Cooperative Research Centre for Future Farm Industries and a Visiting Fellow at the Fenner School at the Australian National University. Andrew's family has been farming in western Victoria since the 1860s. He has been managing the family farm with the help of a neighbour since 1987.

David Cattanach, grain farmer, Darlington Point, NSW

David Cattanach manages his family's farm at Darlington Point near Griffith in southern New South Wales. The property is 600 hectares in size and is irrigated with groundwater. David currently produces soft wheat and malting barley in the winter and corn in the summer.

David was the first farmer to attempt an emissions audit of an Australian farm. He views emissions as a waste of inputs and as such saw this process as a management tool to flag areas of inefficiency for improvement. Economics was the key driver at that time. He believes that the focus for managing emissions should be on improved use efficiency of inputs and not on creative accounting schemes or carbon trading. He sees improved use efficiency as economically viable and sustainable over the long term and not governed by the greed and whim of investors in the stock markets.

In 2004 David was awarded a Nuffield Scholarship sponsored by Rabobank to travel overseas to study greenhouse gas emissions from agriculture and the potential impact of climate change on agricultural production. He is currently part of the Climate and Primary Industries working group in New South Wales and a participant in the Climate Champions program. David believes that if we manage climate variability well we will manage climate change.

TRANSFORMATIONAL ADAPTATION

Professor Snow Barlow, University of Melbourne

Snow Barlow is Foundation Professor of Horticulture and Viticulture at the University of Melbourne and Associate Dean (Strategic Relationships) of the Melbourne School of Land and Environment. He is a plant physiologist and agricultural scientist whose research encompasses plant water use efficiency, viticulture and impacts of climate change on agriculture, water management and global food security.

Snow currently chairs the Expert Assessment Panel of the Department of Agriculture, Fisheries and Forestry climate change research and development program, convenes the Primary Industries Research Adaptation Network of the National Climate Change Adaptation Research Facility and is a member of the Prime Minister's Non-Government Organisation Roundtable on Climate Change. He is Chair of the Victoria Endowment for Science, Knowledge and Innovation, and a member of the Australian Landcare Council, the research advisory committee of the Australian Farm Institute and the science advisory committee of the Australian Science Media Centre.

Snow is a Fellow of the Australian Academy of Technological Sciences and Engineering, the Australian Institute of Agricultural Science and Technology and in 2009 was awarded the 'Australian Medal of Agricultural Science'. He graduated with honours in Rural Science from the University of New England prior to completing a PhD at Oregon State University. Together with his partner Winsome McCaughey, he operates a commercial farm incorporating vineyards, grazing and farm forestry enterprises in the Strathbogie Ranges in north eastern Victoria and markets wine under the Baddaginnie Run label.

Dr Mark Howden, CSIRO Ecosystems Science

Mark Howden is a Chief Research Scientist with CSIRO Ecosystem Sciences. He is also the Theme Leader of the 'Adaptive primary industries, enterprises and communities' theme in the CSIRO Climate Adaptation Flagship and is an Honorary Professor at University of Melbourne's School of Land and Environment.

Mark's work has focused on the impacts of climate on Australian ecosystems and urban systems, dealing with issues such as the dynamics of grazed and cropped ecosystems; development of innovative and sustainable farming systems; biodiversity; energy systems; and water use. He has also developed the national and international greenhouse gas inventories for the agricultural sector and assessed sustainable methods of reducing greenhouse emissions from agriculture.

Mark has worked on climate change issues for over 22 years in partnership with farmers, farmer groups, catchment groups, industry bodies, agribusiness, urban utilities and various policy agencies. He was a major contributor to the Intergovernmental Panel on Climate Change (IPCC) Second, Third, Fourth and Fifth Assessment reports, the IPCC Regional Impacts Report and the IPCC Special Report on 'Land use, land use change and forestry' that addressed issues of carbon sequestration and the Kyoto Protocol. In 2007 Mark shared the Nobel Peace Prize with other IPCC authors and Al Gore.

GREENHOUSE GAS ACCOUNTING

Professor Annette Cowie, National Centre for Rural Greenhouse Gas Research

Annette Cowie is Director of the National Centre for Rural Greenhouse Gas Research in the Primary Industries Innovation Centre, a joint venture between the University of New England and Industry & Investment NSW. She has a background in plant nutrition and soil science, with particular interest in sustainable resource management.

Previously Annette led the New Forests research program in the NSW Department of Primary Industries, and also the Applications and Outreach program in the Cooperative Research Centre for Greenhouse Accounting. She was coordinating lead author for the United Nations Convention to Combat Desertification White Papers 'Understanding Desertification and Land Degradation Trends'.

Annette has over ten years experience in greenhouse gas (GHG) accounting and carbon cycle research. She contributes to development of policy for GHG abatement, including GHG accounting for emissions trading at state, national and international levels. Annette is one of the six members of the Domestic Offsets Integrity Committee, an independent expert committee established to assess offset methodologies proposed under the Carbon Farming Initiative. She is a member of the International Standards Organisation working group developing the standard for quantifying and communicating the carbon footprint of products. She has authored more than 40 peer reviewed publications, largely focused on carbon cycle and climate change policy for the land sector.

SOILS

Dr Jeff Baldock, CSIRO Land and Water

Jeff Baldock leads the Soil Carbon and Nitrogen Balance in Agricultural Lands stream of CSIRO Land and Water. He has been studying soil organic matter chemistry, dynamics and its contribution to soil productivity for more than 25 years.

Jeff is currently leading a national research program aimed at defining the influence of agricultural management practices on the quantity and composition of soil organic carbon. Other projects include improving the capability of the computer simulation modelling framework used by the Department of Climate Change and Energy Efficiency to assess the impact of land use on national greenhouse gas accounts including CO2, N2O and CH4 emissions.

Jeff's current work with the Grain and Research Development Corporation, the Department of Agriculture, Fisheries and Forestry and the Department of Climate Change is providing a national framework for soil carbon and greenhouse gas emissions research across Australia in terms of measurement and modelling. He has active collaborations at both national and international levels and is regularly invited to contribute to workshops and meetings.

David Marsh, livestock farmer, Boorowa, NSW

David Marsh has been farming at Boorowa, in the south west slopes of NSW, since 1971. Recognising box gum woodland decline as a problem for the landscape, David and his wife Mary have established approximately 60,000 trees on their property 'Allendale' since the late 1970s. Woody vegetation has increased from approximately 3% to almost 20%. Existing remnants have been managed to allow natural regeneration.

Since 1999 Allendale has changed from a mixed farming operation to running livestock only. Matching stocking rate to carrying capacity and managing to allow the biotic community to regenerate itself are cornerstones of farm decision-making. Improving landscape function has led to a very low cost farming operation.

David undertook a Masters Degree in Sustainable Agriculture (University of Sydney) and a course in holistic management in 1999. In recent years David has addressed farmer groups in four states, hosted many tours of the farm and been asked to speak at regional conferences on healthy soils, people in the landscape, exploring issues on soil carbon, biodiversity, salinity and managing for improved landscape function. He has been a member of the NSW Native Vegetation Advisory Council, and of local and regional Landcare bodies, and is currently a board member of the Lachlan Catchment Management Authority. David and Mary and their four children won the Central West Conservation Farmer of the Year award in 2004.

THEME

PLANTS

SYNTHESIS PAPER

TITLE PLANT ADAPTATION TO CLIMATE CHANGE – OPPORTUNITIES IN BREEDING

Theme Plants
Primary Author Dr Scott Chapman
Institution CSIRO
Email scott.chapman@csiro.au
Co-Authors Fernanda Dreccer, Sukumar Chakraborty, Mark Howden
Key search words Varieties, water use efficiency,

Climate change in Australia is expected to influence weather through direct increases in average growing temperature in many regions, and through increases in the variability of climate with potential to increase the occurrence of the stresses like heat, drought and waterlogging. Associated effects of climate change and higher CO2 concentrations are influences on the water use efficiency of dryland and irrigated crop production, and potential effects on biosecurity via impacts on natural and introduced pests and diseases. Direct adaptation to these changes can occur through changes in crop, farm and value-chain management and via economically-driven geographic shifts in where different farming systems operate. Within specific crops, a longer-term adaptation is the breeding of new varieties that have an improved performance in 'future' growing conditions. This paper considers some of the ways in which breeding technologies can deliver improved adaptation.

Climate change and the associated increases in atmospheric carbon dioxide levels will provide novel challenges and opportunities for many crop species. Plant breeding has long contributed to improvement in the yield and quality of crops. It is an incremental and cyclic process of selecting and crossing the most elite performing cultivars, and evaluating to find the best progeny. Where novel traits are needed in the released cultivars, breeding may take many 10 to 30 years while traits are identified, found in wild accessions of the species, and then introduced into released cultivars. In recent years, this traditional breeding process has been accelerated by the use of genetic markers for traits, by integration with simulation modelling and also by the advent of genetic engineering approaches.

Plant products can be categorised into those which are based on biomass production (pastures, sugarcane, forestry), and those based on the production of reproductive or specialised organs (grains, vegetables, fruits). For both types of products, catastrophic events (cyclones, flooding, long-term drought, extreme heat-waves, massive insect infestations) are virtually impossible to breed for, and can only be partially controlled via crop or farm management. Biomass-based products are generally more tolerant of the milder impacts of climate change (increased temperature), but are generally more difficult to breed due to their long cycle times and often perennial nature. Organ-based products are typically more susceptible to stress at particular parts of their life-cycle, in most cases the stages related to the flowering period. An increased incidence of high temperature 'heat shock' events would impact greatly on the reproductive potential of crops to maintain their yield. In many species, both types of products can benefit from slight increases in CO2 level, due to the 'CO2 fertilisation effect' which increases the water use efficiency of the crop, particularly when there is drought stress. Both types of products can be bred for resistance to pest and disease; however due to their potentially devastating impacts, these threats need to be anticipated many years in advance.

For Australian farmers, continued access to germplasm banks and international breeding programs for crops like wheat are important to meet these new challenges. These efforts will need to consider interactions with changing management due to climate change itself (climate adaptation and mitigation) and also anticipated alterations in technologies, social preferences (e.g. environmental regulation or subsidization) and input and output prices. This paper will provide a context to explain the process of modern plant breeding, how the explosion of understanding about plant genomes contributes to this research and how this research may contribute to efforts to adapt to climate and other changes and hence to global food security.

TITLE ELEVATED ATMOSPHERIC CO_2 AND WHEAT PRODUCTION IN AUSTRALIA

Theme Plants
Primary Author Dr Glenn Fitzgerald
Institution Department of Primary Industries
Email glenn.fitzgerald@dpi.vic.gov.au
Co-Authors Michael Tausz, Robert Norton, Garry O'Leary, Jo Luck, Roger Armstrong, Mahabubur Mollah, Saman Seneweera, Jason Brand, Cassandra Walker, Sabine Posch, Nicole Mathers, Piotr Trebicki, James Nuttall
Key search words FACE, AGFACE, CO_2, wheat, Australia, Horsham, climate change

Adaptation to climate change by the agricultural industry requires knowledge about the responses of crops to the factors that define climate change: elevated CO_2, changes in precipitation and increasing mean temperature. The Australian Grains Free Air CO_2 Enrichment (AGFACE) experiment in Victoria, Australia strategically integrates field and laboratory experimental methods together with simulation modelling and communication activities to deliver to industry and policymakers tools to make more informed decisions for climate adaptation policy across Australia. It was designed to study the response of wheat to elevated atmospheric $[CO_2]$ (eCO_2) levels expected to occur in 2050 by creating a range of environments (temperature X soil moisture X nitrogen inputs).

One main objective is to validate and improve crop model response to eCO_2 under relatively low water inputs (230-460 mm). These results will help inform industry to develop adaptation policies for climate change. Between 2007-2009 there were 3 physical facilities: (1) a core site at Horsham where measurements were collected on the impacts of irrigation (2 levels), different temperatures at heading (2 times of sowing), nitrogen inputs (2 levels) and cultivar (2-8 varieties) on wheat production under ambient (370 ppm) and eCO_2 (550 ppm) levels; (2) Walpeup, where CO_2 by time of sowing was investigated in a warmer, drier climate, and (3) in a SoilFACE experiment at Horsham where a CO_2 (2 levels) by soil type (3 types) by rotation (wheat and field pea) experiment commenced in 2009.

Results indicate mean increased biomass and yield of 27% with a range of 17% to 50% due to eCO_2, depending on year, location and treatment. The drier Walpeup site showed the greatest relative increases, consistent with the hypothesis that drier climates lead to greater gains in WUE than wetter climates and concomitant increases in growth and yield. Grain and leaf N concentrations were both reduced but total N uptake increased by 20-60%, again depending on environmental conditions. Grain micronutrient Fe and Zn concentrations were reduced by about 10% each under eCO_2. Changes in human nutritional qualities would impact people most severely in developing nations where much of the food consumed is plant-based. Pests and diseases responded differentially to eCO_2, with crown rot (*Fusarium pseudograminerarum*) showing significantly increased fungal biomass but there was no significant effect of eCO_2 on stripe rust (*Puccinia striiformis*). In 2009, 8 varieties of wheat were sown that incorporated a range of traits expected to respond to eCO_2 including sink strength, transpiration efficiency and early vigor. Results indicate that medium tillering types had greater yield response to eCO_2. Soil type was a factor influencing wheat biomass and nitrogen fixation in field peas. In 2010, a field pea - wheat rotation was begun at the main Horsham site to study the interacting effects of above- and belowground C and N dynamics in the rotation system, including agronomic production, cultivar response and N fixation. Early results show increased pea biomass (dry) of 20 to over 40% at anthesis.

The field-generated results were used to independently validate a crop simulation model. This model was linked to a landscape (Catchment Assessement Tool, CAT) model and the CSIRO Mark III down-scaled climate model. When applied to Victoria, this regional and future climate analysis showed that drier regions may experience a 10-20% decrease in yield by 2050, despite the increased growth and yield due to the CO_2 "fertilization" effect. Wetter areas, further south may improve yields by up to 20%. Generation of different scenarios showed that adaptation is possible with later sowing and careful selection of longer season cultivars.

Future adaptation will be possible through a combination of breeding for traits responsive to eCO_2 and changes in management.

TITLE GM CROPS FOR REDUCING GREENHOUSE EMISSIONS

Theme Plants
Primary Author Professor Rick Roush
Institution School of Land and Environment, University of Melbourne
Email rroush@unimelb.edu.au
Key search words CO_2 emissions, nitrous oxide, fossil fuel use

Key issues for the sustainability of agriculture include conservation of soil, water and energy, and reduction of the use of fertilizers and so-called "bad actor" pesticides. Reduction of fossil fuel use, tillage and nitrogen fertilizers are especially important for reducing greenhouse gasses such as nitrous oxide, which is about 300 times as potent by weight as CO_2 in climate warming over a 100 year period (2007 IPCC Fourth Assessment Report (AR4) by Working Group 1).

Genetically modified crops already commercialized or in field trials have helped to address all of these needs. GM crops are now grown by at least 12 million farmers across more than 130 million hectares in at least 26 countries, including in Europe (www.isaaa.org). GM cops have reduced the use of pesticides by at least 352 million kg since 1996, with a reduction in environmental impact of about 16% compared to conventional cultivars (Brookes and Barfoot 2008, www.agbioforum.org/v13n1/v13n1a06-brookes.htm) across a range of crops (Fernandez-Cornejo and McBride 2002, http://www.ers.usda.gov/publications/aer810/; Fernandez-Cornejo and Caswell 2006, http://www.ers.usda.gov/publications/eib11/). Much of the reduced environmental impact has been from the substitution of glyphosate, a relatively safe herbicide (even allowed for use by homeowners) for more toxic and persistent chemicals such as atrazine.

At least as importantly, by substituting relative safe herbicide applications for ploughing in weed management, herbicide resistant crops have dropped CO2 emissions by cutting fuel use in tilling operations, and by encouraging reduced tillage, storing carbon more efficiently in the soil. Reduced fuel use has saved about 9 million tonnes of CO2 emissions since 1996, and reduced tillage about 100 million tonnes, a total equivalent of removing some 6.9 million cars from use (Brookes and Barfoot 2008, as above).

Some GM crops already in trials are more water efficient and nitrogen use efficient. Nitrogen Use Efficient (NUE) crops are especially important in offering the opportunity to further reduce greenhouse gas emissions in the energy used for the production and distribution of nitrogen fertilizer, and reducing subsequent gas emissions because some of fertilizer volatizes into the atmosphere as nitrous oxide. The latter is hugely important; it is estimated that nitrogen fertilizer accounts for one-third of the greenhouse gasses produced by agriculture (e.g., the Stern Review, 2006).

NUE canola, rice, barley, maize, wheat varieties that overexpress alanine aminotransferase in their roots to generate increased nitrogen uptake efficiency are now being tested. In field trials, the NUE canola yielded the same as the conventional variety (about 3.2 tones/ha) on one-third of the nitrogen fertilizer application (56 kg/ha rather than 168 kg/ha) (Good, AG. et al. 2007, Can J. Bot. 85, 1-11; see also www.arcadiabio.com). If NUE crops could reduce by even half the amount of nitrogen that needed to be applied to crops, this could significantly reduce greenhouse gas emissions both of nitrous oxide and the fossil fuel emissions required to produce and deliver the fertilizers to crops. Further, this is a key "no regrets" strategy for greenhouse gas reductions; the cost savings to growers alone will justify adoption.

Although there remains public opposition to GM crops, it is important to note that GM crops are being increasingly accepted. Europe imports and grows millions of tonnes per year of GM crops, mostly for animal feed, without any requirement to label the animal products. Japan also imports millions of tonnes per year, similarly for feed, but also GM canola from Canada for human consumption as canola oil. The environmental (not to mention economic) advantages of nitrogen and water use efficient crops, as well as the current crops used for pest and weed management, are too great to ignore as we consider the challenges of an uncertain world climate.

TITLE EARLY MATURITY OF GRAPEVINES IN SOUTH-EASTERN AUSTRALIA BETWEEN 1995 AND 2009 WAS ASSOCIATED WITH EARLY ONSET RATHER THAN FASTER RIPENING

Theme Plants

Primary Author Victor Sadras
Institution South Australian Research and Development Institute
Email victor.sadras@sa.gov.au
Co-author Paul Petrie, Treasury Wine Estates Ltd

Key words berry development, vapour pressure deficit, modelling, temperature, phenology

The shift in phenological development of plants and poikilotherm animals is the most conspicuous biological effect of recent warming. In association with realised warming over the last few decades, early maturity of grapevines has been reported for Europe, North America and Australia. Between 1993 and 2006, maturity of grapevines in Australia advanced 0.5 to 3 d y^{-1} or 9.3 ± 2.67 d $°C^{-1}$ [(1)]. Shifts in maturity of grapevine are well documented but the underlying processes are poorly understood. Here we ask the question: is early maturity associated with early onset of ripening or with increased rate of sugar accumulation?

We used records of total soluble solids (TSS) for Chardonnay, Shiraz and Cabernet Sauvignon collected in commercial vineyards of Coonawarra, Barossa Valley and Riverland between 1995 and 2009 ($2,395 \leq n \leq 24,196$). The combination of 15 vintages and three regions yielded a range of average seasonal temperature between 15.5 and 20.5 °C. Using boundary functions of TSS vs time, we derived the onset and rate of increase in TSS, and the time of maturity set at 12 °Bé. Across varieties, the rate of change in maturity was -9.8 ± 0.94 d $°C^{-1}$. Shifts in onset accounted for 86% of the variation in time of maturity, and rate of ripening for the remaining variation[(2)].

Gap analysis revealed a quantitatively significant effect of vapour pressure deficit on grapevine ripening[(3)].

Conclusions

Warming is a complex syndrome including biologically relevant factors such as higher vapour pressure deficit with direct consequences for grapevine ripening[(3)].

Early ripening associated with the warming syndrome over recent decades has been primarily related to shifts in onset rather than increase in rate of ripening[(2)].

A simple onset-rate model can be coupled with (i) short-term temperature forecasts to predict the trajectory of TSS for management purposes, and (ii) long-term records of temperature to produce probabilistic profiles of maturity date[(3)].

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(1) PR Petrie, VO Sadras 2008 Advancement of grapevine maturity…Austr J Grape Wine Res 14, 33-45
(2) VO Sadras, PR Petrie 2011 Climate shifts in south-eastern Australia…Austr J Grape Wine Res, in press
(3) VO Sadras, PR Petrie 2011 Quantifying the onset, rate and duration…Austr J Grape Wine Res, in press

MANGO YIELD IN RELATION TO PREDICTED TEMPERATURE INCREASES DUE TO CLIMATE CHANGE IN NORTHERN AUSTRALIA.

Theme Plant

Primary Author Dr Peter Stephens
Institution Plant Industry Division, Department of Resources, Northern Territory, GPO Box 3000, NT 0801, Australia.
Email peter.stephens@nt.gov.au
Co-Authors Nick Hartley

Key search words Mango, climate change, temperature, yield

The Intergovernmental Panel on Climate Change (2007) predicts that by 2030 each of the major mango growing regions in Australia will experience approximately a 1°C increase in temperature in the event of a continuing mid-range greenhouse emissions scenario. To assess the possible impact of this predicted temperature increase on mango production in northern Australia, nine years of yield data from a block of 5760 Kensington Pride mango trees in Outer Darwin, Northern Territory was correlated with a variety of temperature variables (Bureau of Meteorology Weather Station, Middle Point). These measurements were collected before, during and just after anthesis (full flowering). Trees had been planted in 1992 and maintained under a relatively constant management regime, with flowering typically occurring between late May and early July each year. Yields (2002-2010) varied between 3 and 13 trays per tree, which was below the regional average. There was a significant ($P<0.01$) negative correlation between mango yield and the percentage of days ≥ 32°C in July. Using linear regression models, this predictor explained 88% of the variation in mango yield over this nine year period. When the maximum temperature on each day in July was increased by one degree for the two highest mango yielding seasons (2004 and 2006), the model predicted a 17 to 25% reduction in mango yield.

To further evaluate this relationship between mango yield and maximum daily temperature in July, evaporative cooling (using overhead irrigation) was applied to mango trees [in a fully replicated (n=12) and blocked trial] in the same orchard, between the hours of 13:00 and 17:00 in July 2010. Results were compared to 'control" (no additional water applied, other that provided by the grower) and 'under-tree irrigation' (same amount of additional water applied under the tree canopy, as that applied with overhead irrigation). Thirty, out of thirty-one days in July had a temperature ≥32°C. Maximum daily temperature of trees subject to evaporative cooling was reduced on average by 4.9°C±0.3°C(SE). There was a significant treatment effect of irrigation regime on both total fruit number ($P<0.005$) and total fruit weight ($P<0.005$). Trees subject to evaporative cooling had a significant 52% and 48% increase in mean fruit number and fruit weight compared to the control. The additional water per se had no significant effect on these parameters.

While these limited results suggest that a small increase in temperature due to climate change may have a significant detrimental impact on mango production in this orchard, further research is required to define the geographical regions, management practices and mango varieties for which this relationship is valid.

TITLE VARIABILITY OF WHEAT PERFORMANCE UNDER ELEVATED CO_2 IN DRYLAND AGRICULTURE EVALUATED IN THE AGFACE FACILITY

Theme Plants
Primary Author Michael Tausz
Institution University of Melbourne, Victorian Dept of Primary Industries, International Plant Nutrition Institute
Email Michael.tausz@unimelb.edu.au
Co-Authors Sabine Posch, Robert Norton, Glenn Fitzgerald, Saman Seneweera
Key search words Wheat, elevated CO_2, traits, photosynthesis

It is a virtual certainty that atmospheric CO_2 levels will continue to rise during this century. Whilst causing climate perturbations linked to increasing global temperatures and changing regional rainfall patterns, elevated CO_2 (eCO_2) is the substrate for photosynthesis and therefore has a potential direct positive impact on crop production. Breeding of wheat (Triticum aestivum) for superior performance under increasingly dry conditions is an ongoing aim, with growth traits such as tillering and grain filling patterns or physiological traits such as improved water use efficiency being used to select promising lines and developing superior cultivars. However, much less effort is made to ensure that potential direct gains from eCO_2 are maximised, although there is some evidence that past breeding efforts may have even reduced responsiveness to elevated CO_2.

Within the Australian Grains Free Air Carbon dioxide Exposure (AGFACE) facility in Horsham, Victoria, we grew a range of wheat cultivars characterised by traits that are hypothesised to govern eCO_2 responsiveness. We compared the relative growth and yield performance of cultivars under ambient and elevated CO_2 to address the variability of eCO_2 responses across wheat cultivars.

In addition to growth and yield, we measured in situ leaf gas exchange and chlorophyll fluorescence to investigate whether eCO_2 changes the comparative performance of the investigated varieties in terms of stomatal behaviour, leaf level carbon assimilation, light use and photoprotection characteristics, key physiological variables determining water use efficiency, growth and yield, and stress tolerance. Such information is important to guide future cultivar selection and breeding programmes.

Apart from the collaborating organisations named in the address line, the presented research received funding from the Commonwealth Department of Agriculture, Fisheries and Forestry (DAFF) and the Grains Research and Development Corporation (GRDC).

TITLE IMPACT OF CLIMATE CHANGE ON WHEAT PHENOLOGY IN THE NSW WHEAT BELT

Theme Plants
Primary Author Dr De Li Liu
Institution Industry & Investment NSW, Wagga Wagga Agricultural Institute, PMB, Wagga Wagga 2650, Australia
Email de.li.liu@industry.nsw.gov.au
Co-Authors Professor Bob Martin
Key search words Wheat phenology, vernalization, winter genotype wheat, spring genotype wheat, forest risk, heat stress

Abstract

Temperature is one of the man drivers of the wheat developmental processes. Under global warming conditions, higher temperatures are expected to speed up wheat flowering and lead to earlier switching from the vegetative to reproductive stage. On the other hand, as winter varieties require cool temperatures for vernalization, higher winter temperature would delay the time of flowering. Therefore, it is anticipated that impacts of climate change on winter and spring genotypes would have different consequences. Early study showed that spring wheat genotypes in NSW will become predominant, while the winter genotype will only be viable in clearly defined areas where sufficient days of cool temperature exist for completion of vernalisation in a future warmer climate (Liu et al., 2011). However, the results were based on a single sowing date for each genotype. It is not clear if a change in sowing date could mitigate the impact of climate change on wheat over the state. The aim of the current study was to extend the previous study to all possible sowing dates. The ultimate goal of this study was to examine if shifting our current sowing dates can be an adaptive strategy for mitigation of the impact of climate change on the NSW wheat industry. In this study, both winter and spring genotypes were sown at intervals of 4 days from 15 February to 1 August to establish the relationship between the impacts of climate change on wheat flowering and sowing dates. Indices analysed included days to flowering, frost days at flowering, hot days at flowering and grain filling for both winter and spring wheat. Days to completion of vernalization for winter wheat was also analysed. Results showed that shortened days to flowering for spring wheat would occur at all sowing dates, while days to flowering for winter wheat in the next two decades would change little. Further warming would cause the delaying in flowering due to delayed completion of vernalization. The impact of climate change on wheat production in NSW is mitigate-able in a number of future decades by optimizing sowing dates. Change to spring genotype varieties would be an adaptive strategy for future higher warming conditions.

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TITLE HOW HAS A CHANGING CLIMATE AFFECTED AUSTRALIA'S CAPACITY TO INCREASE CROP PRODUCTIVITY: 1990-2009?

Theme Plants
Primary Author Dr David Stephens
Institution Department of Agriculture and Food, Western Australia (DAFWA)
Email david.stephens@agric.wa.gov.au
Co-Authors
Key search words Climate, productivity, yield trends, technology,

Method

In response to a Productivity Commission review of rural research and development agencies, the Grains Research and Development Corporation (GRDC) commissioned an update of the crop productivity analysis of Stephens (2002). The DAFWA regional crop forecasting system STIN was utilized to calculate technological increases in yields and changes in water use efficiencies in recent decades. Changes in climate were taken into account with the calculation of a moisture stress index (SI) at a shire and statistical sub-division level. Multiple regression equations were then developed to calculate State yields as a function of moisture stress (SI), technological improvements with time (T), and an interaction term between moisture stress and technology (SI *T), i.e.

$$Yield = b_0 + b_1*(SI) + b_2*(T) + b_3*(SI * T) \quad (1)$$

where b_0, b_1, b_2 and b_3 are the population regression coefficients estimated by the method of least squares. We also calculated the rate of change in yield trends in time using:

$$Yield = b_0 + b_1*(T) + b2*(T)^2 \quad (2)$$

where the coefficients b_0, b_1, and b_2 represent the initial level of yield in time, the rate of yield increase and changes in this rate over time, respectively. A positive b_2 coefficient is an indicator of compatibility between climate and technology.

Results

At a State level wheat yield trends over the last twenty years dropped off dramatically across the four States of Western Australia, South Australia, Victoria and New South Wales. In these regions the rate of change in the yield trend over a 30-year window reached an all-time minimum in 2008. The climate-technology interaction term was minimal through the 1980s and 1990s, but jumped considerably in the 2000s with a large jump in yield variability. In equation 2, b_2 changed rapidly in magnitude and sign indicating the presence of abnormal weather impacts and an abrupt change to a more negative climate in the 2000s. Climate resources were therefore shown to meet the requirements of the technology in the 1990s, whereas the recent climate has imposed severe constraints on technology which has limited the rate of yield increases. In Queensland, these results were reversed with a recent reduction in yield variability after the severe droughts in the early 1990s.

Preliminary analysis at a regional scale show that the largest decrease in yield trends has been where there has been a large increase in yield variability and a decrease in nitrogen fertiliser application. Late sowing, dry finishes, and an increased frost occurrence also appear to have affected recent productivity gains. These results have large ramifications for the whole direction of crop research which has tried to maximize yields with an associated reliance on higher inputs in better seasons. It should also warn that there is a danger in reducing agricultural R&D in such a critical time of rapid climate change.

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TITLE NUTRIENT SUPPLY, BELOW GROUND PROCESSES AND ELEVATED CO_2 CHANGE THE NUTRITIONAL QUALITY OF CYANOGENIC *TRIFOLIUM REPENS* L.

Theme Plants
Primary Author Associate Professor Ros Gleadow
Institution Monash University
Email ros.gleadow@monash.edu
Co-Authors Siobhan Isherwood, Tim Cavagnaro, Saman Seneweera, Rebecca Miller
Key search words Cyanogenic glycosides, food security, plant defence, clover, nitrogen, phosphorus

Background

The challenge for Victorian agriculture in the 21st century is to increase productivity in the face of rising global concentrations of atmospheric CO_2, higher temperatures, reduced water availability, and possibly in conjunction with more expensive fertilisers. Our focus is on the changing balance between plant growth and resource allocation with climate change and its impact on food security. Previous work by us (and others) has shown that C3 plants grown experimentally at elevated CO_2 have lower leaf nitrogen and allocate less of that N to protein and photosynthesis but more to N-based secondary metabolites such as cyanogenic glycosides. Concentrations of C-based secondary metabolites, such as phenolics, also increase. The decrease in protein relative to anti-nutritional compounds could lead to a decrease in the nutritional quality of temperate pastures in the future.

We are developing *Trifolium repens* L. (white clover) as a model species suitable for high throughput experiments in temperate Australia as a companion to our work on the tropical crops, sorghum and cassava. Clover in one of over 2000 species (including many crops) that produce cyanogenic glycosides, which break down to release hydrogen cyanide (HCN) when plant tissues are damaged (cyanogenesis). HCN is highly toxic and its release from stable endogenous glycosides is thought to primarily function as a defence against herbivores, although cyanogenic glycosides may also be important in N turnover in some species. Clover is polymorphic for cyanogenic glycosides and represents an ideal system to strengthen knowledge of defence chemistry, allocation and resource trade-offs under different environmental conditions. It forms symbiotic associations with mycorrhizae as well as *Rhizopus*, both of which enhance nutrient uptake. Previous contained-environment experiments showed that clover allocates more N to endogenous cyanogenic glycosides when grown at elevated CO_2 but only when supplied with additional phosphate.

Methods

We grew clover (cv Haifa) plants for 5 months at ambient and elevated CO_2 under field conditions in the AGFACE facility at Horsham. Half the plants received supplemental water. In a parallel experiment we grew cyanogenic and non-cyanogenic clover in the same agricultural soil in a glasshouse and supplied them with fertiliser containing different proportions of N and P. Plant growth and colonisation rates were determined and leaves analysed for cyanogenic glycosides, nitrogen, phosphorus and micronutrients. Ratios of stable isotopes of N were used to indicate the proportion of N in the plant taken up through N fixation, and C isotopes were used to measure the degree of water stress.

Results and Conclusions

The role of roots and soil microbes in the uptake macronutrients and their allocation to N-based defence *in planta* at elevated CO_2 was examined. We found that changes in relative proportions of carbon, nitrogen and phosphorus affect the allocation of resources to defence. We were, however, unable to detect any cost to the plants (in terms of growth sacrifice) in the production of cyanogenic glycosides. FACE studies were broadly consistent with earlier work. The absolute availability resources, their stoichiometric relationship and possibly the source of those nutrients appear to affect the nutritional quality of clover. Understanding what drives changes to resource allocation in plants will be important in determining successful management of agriculture and animal health into the future.

TITLE SECURING PULSES UNDER CHANGED CLIMATES

Theme Plants
Primary Author Associate Professor Rebecca Ford
Institution The University of Melbourne
Email rebeccaf@unimelb.edu.au
Co-Authors Kurt Lindbeck
Key search words Pulse, Grain Legume, Pathogen, Ascochyta, Fungus

Food security and disease impact

Food security is defined as the "physical and economic access, at all times, to sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life" (WHO). A major and often under-considered cause of insufficient food production is plant disease. This affects the quantity produced, on amounts available for consumption or the ability for larger enterprises to meet export market demand. Quality of the product to meet rigid market requirements, for premium financial return is also affected. Plant pathogens survive in the environment in a delicate balance with requirement for both susceptible host and correct environmental conditions to cause disease. Favourable shifts in environmental conditions, either at the macro- (weather) or micro- (plant canopy, rhizoplane, phyloplane) climate, may select for increases in greater numbers and/or more pathogenic individuals within a pathogen population.

Pulse crops and their importance in the Australian farming system

Pulses are a group of high protein content temperate legumes including field pea, chickpea, lentil and faba bean, grown in Australia for human and animal consumption and sold as high value export commodities. Their popularity as a cereal or oilseed break crop is driven by premium cash returns in favourable seasons, nitrogen fixing capability and the recent release of varieties adapted to diverse ecogeographical regions. However, farmer confidence in these crops is historically unstable due to inconsistent and poor performance caused by several major diseases. Consequently, collaborative programs pioneered by GRDC and PBA have developed disease-specific management plans based on region adapted cultivar responses and pathogen population structure and response to control measures. Within these plans, the control of disease is a careful balance of cultural (i.e. time of sowing, spacing, and rotation) and chemical (i.e. fungicide) methods aimed at maximum yield from minimal environmental impact. This, together with the use of novel pre-breeding screening tools and the search for broad resistance sources is expected to produce stable resistant cultivars. However, predicted changes in the Australian climate have not been incorporated into these plans.

Impacts of climate variation on plant disease and management

Having struggled for over a decade with extremely low residual soil moisture, large, intense rainfall events in the latter half of the 2010 season destroyed much of the chickpea crop in northern NSW. This was caused by unprecedented fungal disease epidemics followed by water logging. Newly released and supposed moderately resistant chickpea varieties to the ascochyta blight fungus experienced up to 100% yield loss. Similarly, lentil grown on the South Australia York Peninsula was affected, with previously resistant varieties appearing to breakdown under the increased disease pressure. At the microclimate level, impacts of the elevated CO2 and temperatures predicted in the coming decades, on the major pathosystems that are currently affecting the pulse industry, are unknown. Increased carbon availability may cause changes in foliar physiology, which may lead to changes in canopy density and microclimate. Warmer temperatures earlier in the season may increase humidity at the plant surface, which may directly impact on the fitness and pathogenicity of foliar-associated fungal pathogens. The net affect of these changes may result in the development of plant disease epidemics earlier and at a more intense level than current management strategies allow for. Therefore, knowledge of impacts of changes in foliar microclimate on risk of disease epidemic is urgently required to formulate preparedness into current management plans. This presentation will discuss the biological and pathological implications of pulse plant and pathogen responses to predicted climate changes, and the potential downstream impacts on food and feed security in pulse and associated farming systems.

TITLE ADAPTING TO INCREASES IN MEAN DAILY TEMPERATURE BY INCREASING THE HEAT TOLERANCE OF PERENNIAL RYEGRASS

Theme Plants
Primary Author Richard Rawnsley
Institution Tasmanian Institute of Agricultural Research
Email Richard.Rawnsley@utas.edu.au
Co-Authors Karen Christie, Brendan Cullen and Richard Eckard
Key search words Dairy, Perennial ryegrass, Adaptation, Heat tolerance

Abstract

Climate projections for Australia suggest that there will be a general increase in daily temperatures of 0.4 to 1.8°C by 2030 and 2.2 to 5°C by 2070 (CSIRO and BoM, 2007). Climate change impact modelling based on future climate scenarios, created by direct scaling of historical climate data, can be used to examine the effect of increased temperature on pasture production and potential adaptation approaches, while maintaining the inherent climate variability. The biophysical model DairyMod (Johnson et al. 2008) was used to simulate mean annual pasture yields for the three Australian dairying regions of Elliott (North West Tasmania), Ellinbank (South East Victoria) and Terang (South West Victoria), which heavily rely on perennial ryegrass (Lolium perenne L.) to support dairy production.

Five climate files for each region were created by direct scaling the historical baseline climate file (1971 to 2008) by 0, 1, 2, 3, 4 and 5°C with corresponding atmospheric CO_2 concentrations of 380, 435, 535, 640, 750 and 870 ppm, respectively. The highest mean annual yield for Elliott, Ellinbank and Terang resulted from scaling to 3°C/640 ppm (a 27.2% increase above the baseline climate data), 1°C/435 ppm (1.7% increase) and 2°C/535 ppm (10.1% increase), respectively. At Elliott, increases in temperature with corresponding increases in atmospheric CO_2 concentration increased annual pasture yields. At Ellinbank and Terang, increasing temperature and CO_2 concentrations to and above 2°C/535 ppm and 4°C/750 ppm respectively, resulted in lower annual yields than those produced using the baseline climate data.

The effect of exposure to periods of extreme high temperatures on the growth of perennial ryegrass was then explored using nine variations of high temperature tolerance, in conjunction with the scaled increases in temperature and atmospheric CO_2 concentrations described above. Three onset and full temperature combinations (28/35°C, 29/36°C and 30/37°C) were examined across three critical T-sums (20, 35 and 50°C). The onset temperature represents the temperature at which a reduction in plant function commences due to heat stress, the full temperature represents the upper temperature at which plant function ceases, and the critical T-sum represents the recovery period required following exposure to heat stress. Increasing the high temperature tolerance of perennial ryegrass was able to alleviate the negative effects on annual pasture production up to 5°C of warming at Terang and up to 4°C warming at Ellinbank. This highlights the relative benefit of selecting and introducing more heat tolerant perennial ryegrass cultivars to the regions used in this study.

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TITLE EFFECT OF DEFICIT RAINFALL AND ROOTING DEPTH OF PERENNIAL RYEGRASS ON PASTURE PRODUCTION IN SOUTH EAST AUSTRALIA

Theme Plants

Primary Author Richard Rawnsley
Institution Tasmanian Institute of Agricultural Research
Email Richard.Rawnsley@utas.edu.au
Co-Authors Karen Christie, Brendan Cullen and Richard Eckard

Key search words Dairy, Perennial ryegrass, Rooting depth, Adaptation

Abstract

The biophysical model DairyMod (Johnson et al. 2008) was used to simulate the annual and seasonal production of perennial ryegrass (*Lolium perenne* L.) pastures for the three dairying regions of Elliott (North West Tasmania), Ellinbank (South East Victoria) and Terang (South West Victoria). Five rooting depth treatments were assessed; a baseline rooting depth of 30 cm, and then increments of 10 cm to a maximum of 70 cm. Six differing rainfall scenarios were implemented; a baseline rainfall scenario (current rainfall pattern for the period 1971 to 2008) and five deficit increments between 0.5 and 0.9 of the baseline rainfall. Mean annual and seasonal pasture production (kg DM/ha) figures for each rooting depth/rainfall treatment were calculated for the period 1971 to 2008.

There was a positive linear relationship between rooting depth (cm) and annual pasture production (kg DM/ha.year) for each rainfall scenario. The greatest benefit of increasing rooting depth was observed over the spring period, and to a lesser extent summer, at all sites. This would indicate that management practices should be tailored towards maximising rooting depth during spring. There was very little benefit of increased rooting depth in autumn and winter when the winter-dominant rainfall patterns of these regions was sufficient for maintaining growth, especially were rainfall deficits were minimal. Increasing the rooting depth from 30cm to 50cm was able to alleviate the impact of a 20% decline in rainfall on mean annual pasture production at Ellinbank. However, this increase in rooting depth was not able to overcome a 20% rainfall deficit at the other two sites, with an 8.8 and 0.9% decline in mean annual pasture production for Terang and Elliott, respectively. At all three sites, when the rainfall deficit exceeded 20%, a doubling of the rooting depth to 60cm was not able to alleviate the effects on mean annual pasture production. This indicates that although the adaptation of increasing rooting depth may be considered a very favourable adaptation strategy for adapting to a drier future climate, the ability to alleviate the impacts under significant rainfall decline is limited. Shallow rooted perennial temperate pastures, such as perennial ryegrass, are currently considered the main forage source for dairy cattle in temperate regions of SE Australia. However, a changing and variable climate may lead to alterations to the current the forage base in favour of deeper rooted species. Further work is required to analyse the adoption of these forage combinations at whole of farm system level and under agreed climate projection scenarios for the differing regions.

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THEME

ANIMALS

SYNTHESIS PAPER

TITLE LIVESTOCK PRODUCTION IN A CHANGING CLIMATE

Theme Animals
Primary Author Beverley Henry
Institution Queensland University of Technology
Email beverley.henry@qut.edu.au
Co-Authors Ed Charmley, Richard Eckard, John Gaughan, Roger Hegarty

Animal agriculture is important to Australia's economy, but also through its roles in providing the major land management activity on almost half of the land mass and underpinning rural and regional communities. Globally livestock provide multiple benefits to developing as well as developed societies. Future climate change will have direct impacts on livestock production systems. These systems will also be affected by policy and community responses to the threat of dangerous climate change as livestock are estimated to contribute approximately 10% of Australia's total greenhouse gas emissions and in the order of 8 – 11% of global emissions. This paper discusses the challenges facing livestock industries in Australia in adapting to and mitigating climate change, against the background of an exporting sector in a world where the demand for food and fibre, and particularly for livestock products, is forecast to grow by 70% as the human population increases to an estimated 9.2 billion by the middle of this century.

With projections of future climate, especially rainfall, remaining uncertain, especially on a regional scale, climate change impacts on livestock production also remains uncertain. However, that animal agriculture will be affected is clear, occurring through impacts on pastures and forage crop quantity and quality, feed-grain production and price, disease and pest distributions, and importantly on animal health, growth and reproduction, including through heat stress. Climate change also affects broader landscape functionality directly and, particularly in rangelands, adaptive responses will also be guided by efforts to mitigate risks of land degradation in productive ecosystems.

The degree of uncertainty in projected climate and regional impacts is a factor in rate of adoption of adaptation strategies by farmers. However, the management changes adopted by northern Victorian dairy farmers during the recent extended drought with associated heatwaves, (trends consistent with long-term predicted climate patterns) provide some insights into their capacity for practical adaptation. Our Case Study further illustrates one farmer's innovative response to manage water use and heat stress.

One of the more certain impacts of climate change is potential for increased incidence of heat stress affecting normal animal behavioural, immunological and physiological functions. Adaptive approaches to minimise effects of high heat load through (a) adjusting the environment; (b) nutritional manipulation; and (c) selection for thermal tolerance are developing. A second important impact for animals is a likely increase in exposure and susceptibility to parasites and disease, as vectors and pathogens respond to changing climate conditions. These impacts are discussed with associated animal health and welfare challenges.

Climate change also affects livestock production through international and domestic policies to reduce greenhouse gas emissions. Livestock industries can contribute to greenhouse gas mitigation through managing emissions from production systems and through the significant potential for sequestration in vegetation and soils managed for animal agriculture. Current mitigation targets are directed towards reducing the quantity of net emissions. However, with the meeting future demand for food and fibre a major objective, the metric for mitigation of agricultural emissions must be emissions intensity.

Abatement practices and research needs to achieve a reduction in the emissions per unit of livestock product including:

- For non-ruminants, managing waste emissions with potential renewable energy production from methane;
- For ruminants, reducing enteric methane production through improved feed quality and supplementation, genetic selection for lower methane phenotypes; and more efficient herd management;
- Abatement of emissions of nitrous oxide from grazing systems as a result of cultivation, legumes, N fertilisers and animal excreta; and
- Increasing biosequestration through sustainable and productive grazing land management.

Significant current 'best-bet' mitigation options for enteric methane include feeding supplements with high levels of lipids is an option that achieves reduction in emissions intensity and increases animal productivity in dairies and feedlots. This strategy is not available on extensive grazing systems, much of which is in the northern tropical and subtropical regions. For the northern cattle herd, major reductions in methane emissions intensity can be achieved through increasing the productivity of the breeder. Mitigation of nitrous oxide loss is more relevant for intensive livestock systems where options include improving efficiency of N fertiliser use and reducing N losses from urine.

Research needs to increase practical options to reduce the emissions intensity of livestock products and to enhance adaptation opportunities for Australian livestock production systems are identified to support the role of livestock industries in Australia's economy and regional communities and in addressing global food security in a changing climate.

TITLE BREEDING CATTLE FOR LOWER GREENHOUSE GAS EMISSIONS IN AN AUSTRALIAN CARBON TRADING ENVIRONMENT

Theme Animals
Primary Author Dr Robert Herd
Institution Industry & Investment NSW
Email robert.herd@industry.nsw.gov.au
Co-Authors Dr Paul Arthur, Prof Roger Hegarty, Dr Simon Bird and Dr Kath Donoghue
Key search words Methane, feed efficiency, residual feed intake, genetics, selection, cattle

Cattle emit methane, a potent greenhouse gas (GHG), as part of the fermentation process in their stomach. This paper highlights the scientific information underpinning the use of animal breeding to reduce GHG emissions and a strategy for developing quantification protocols for an Australian emissions trading/offset scheme.

Residual feed intake (RFI) is a measure of feed efficiency in beef cattle and is moderately heritable (Arthur et al. 2001). Research in Australia and Canada (Nkrumah et al. 2006; Hegarty et al. 2007) has shown that:

- Low RFI cattle emit less methane than high RFI cattle in experiments where methane production was estimated (15% - 21%), and also where actual methane emission was measured (25-30%).
- The reduction in methane emissions by low RFI cattle is through reduction of feed intake.
- The reduction in methane production by low RFI cattle is achieved with no major impact on the growth of the cattle.
- Preliminary results showing natural variation between animals in methane yield (methane produced per unit of feed intake) is, in part, under genetic control.

It has been estimated that, for a representative 100-cow Australian herd, the reduction in GHG emission through selection for low RFI over a 25-year period is in the order of 24.5 t CO_2 e, representing a 7.4 % cumulative reduction over the simulation period, and resulting in a 15.9 % annual saving over an unimproved herd by year 25 (Alford et al. 2006).

The National genetic improvement scheme for beef cattle, BREEDPLAN, started producing trial EBV (genetic merit) for RFI in 2002. Breeding values for methane yield could also be developed through the BREEDPLAN system to enable breeding for reduced GHG emissions.

For a GHG reduction protocol to be acceptable in a carbon trading/offset environment, it needs to follow UN IPCC guidelines, be based on science, be quantifiable and be auditable. The beef industry already has quality assurance systems in place for EBV which can be fine tuned to meet these criteria. Additional funding and research is required to deliver accredited protocols for GHG emission reduction by animal breeding to our cattle farmers.

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TITLE ANTIMETHANOGENIC PLANTS FOR GRAZING SYSTEMS

Theme Animals
Primary Author Dr Zoey Durmic
Institution The University of Western Australia
Email zoey.durmic@uwa.edu.au
Co-Authors D. Revell, C. A. Ramírez-Restrepo, P. Moate, K. Ghamkhar, P. Vercoe
Key search words Rumen, methane, plant secondary compounds

Ruminants (cattle, sheep and goats) are a major source of methane, accounting for nearly half of total methane emissions from the agricultural sector. Methane is formed in the rumen and hindgut as a product of microbial fermentation of plant material. The amount of methane produced by ruminants is directly related to the type and composition of the consumed forage (Waghorn *et al*. 2002). Apart from the nutritive profile and digestibility of the forage, plant secondary compounds may also affect microbial activity in the gut, and therefore alter the activities of microbes that produce methane in the rumen (Woodward *et al*. 2004; Bodas *et al.* 2008). Grazing or browsing forage plants that contain these 'bioactive' compounds may therefore provide opportunities for reducing methane emissions from livestock (Ramírez-Restrepo and Barry 2005).

A collaborative project involving leading Australian research organizations and funded by the Department of Agriculture, Fisheries and Forestry and Meat and Livestock Australia is investigating the variability in methanogenic potential of forage species. To date, over 200 plant species have been screened, targeting a range of livestock systems, from sheep production in arid zones of Western and South Australia, dairy cattle in Victoria, to beef in tropical zones of North Queensland. Methane production from microbial digestion of plant material was determined in a laboratory-based (*in vitro*) system designed to mimic rumen fermentation. Our results indicate that methanogenic potential amongst different forage species is highly variable, with some plant species (i.e. Acacia spp., *Eremophila* spp. and some annual legume pastures) producing five times less methane (around 10 mL per g of dry matter incubated) compared to, for example, lucerne (50 mL per g of dry matter incubated) when fermented in our system. Our findings also indicated that methanogenic potential of plants may be influenced by the environment where a plant was grown, season and plant maturity. Differences also occurred between individual plants grown at the same location and sampled at the same time.

In conclusion, there is opportunity to select forage plants that can alter methane production in the rumen. The next step will involve *in vivo* experimentation of the top ranked plants and optimizing their dietary inclusion in livestock production systems. Changing the ruminant diet based on these results may offer a sustainable practice for reducing the contribution of ruminants to greenhouse gas emissions.

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TITLE METHANE EMISSIONS UNAFFECTED WHEN DHA FED TO COWS

Theme Animals
Primary Author Dr Peter Moate
Institution Ellinbank Centre, DPI, Victoria
Email peter.moate@dpi.vic.gov.au
Co-Authors Richard Williams, Murray Hannah, Richard Eckard, Joe Jacobs
Key search words DHA, algae, methane, rumen, dairy cows

Background

Previous in vitro research from Europe indicated that docosahexanoic acid (DHA) reduced methane (CH_4) emissions by up to 80%.

Methods

In this present study, 32 Holstein cows in mid lactation were allocated to four treatment groups. Cows within a group were offered algae meal containing 20% DHA at one of 0 (D0), 125 (D25), 250 (D50) or 375 (D75) g/cow/day. Cows in all groups were offered 5.9 kg DM/day of concentrates (68.3 % cracked wheat, 25% cold-pressed canola, 4.6% granulated dried molasses, 2.1% mineral mix) and ad *libitum* lucerne hay. The algae meal was added to the concentrate and offered to each cow during the morning and afternoon milking, while the lucerne hay was fed individually in pens post milking. Cows were gradually introduced to their diets over seven days then offered their treatment diets for a further 23 days. Dry matter intake (DMI) and milk yield were measured daily. Milk composition was measured on representative samples collected on one day of each week. During the last two days of the experiment, cows were individually housed in calorimeters where their individual DMI, milk yields, milk fatty acid profiles and CH_4 emissions were measured.

Results

Regression analysis showed mean intakes of lucerne decreased ($P<0.05$) with increasing dose of DHA, (from 16.2 to 16.4, 15.1 and 14.3 kg DM/day). Milk yield during days 8 – 21, averaged 22.8 kg/cow/day and was not affected by DHA dose. Addition of DHA to the diet, at any dose, reduced ($P<0.01$) milk fat concentration relative to D0 (49.7, 37.8, 37.0, 38.3 g/kg for D0, D25, D50, D75 respectively) and consequently milk fat yields (1.08, 0.90, 0.83, 0.85 kg/d). The feeding of DHA substantially altered milk fatty acid profiles. As the dose of DHA increased, concentrations of DHA in milk increased ($P<0.01$) (from 0.04 to 0.36, 0.60 and 0.91 g/100g milk fatty acids) and cis-9 trans-11 conjugated linoleic acid (CLA) increased ($P<0.01$) (from 0.36 to 1.09, 1.79 and 1.87 g/100g milk fatty acids). Total emissions (average 545 g CH_4/cow/day) and emissions intensity (average 23.7 g CH_4/kg milk) were not affected by dose of DHA but emissions with respect to DMI increased with DHA dose (from 22.6 to 23.5, 24.5, and 24.4 g/kg DM).

Conclusion

Feeding algae meal containing high concentrations of DHA to dairy cows did not decrease CH_4 emissions, but milk concentrations of the nutritionally beneficial CLA and DHA were markedly elevated.

TITLE PRELIMINARY RESULTS OF ESTIMATING ON-FARM METHANE EMISSIONS FOR SHEEP PRODUCTION ON THE NORTHERN TABLELANDS OF AUSTRALIA

Theme Animals

Primary Author Dr Malcolm McPhee
Institution Industry & Investment NSW
Email malcolm.mcphee@industry.nsw.gov.au
Co-Authors Clare Edwards, Jim Meckiff, Niel Ballie, Derek Schneider, and Roger Hegarty

Key search words decision support tools, greenhouse gas, high fertility, low fertility, pasture production

Abstract. A 36 hectare site at the University of New England, Armidale on the Northern Tablelands of NSW has been established to demonstrate the magnitude of carbon fluxes, especially methane (CH_4), associated with crossbred lamb production. This is a joint project with Meat and Livestock Australia and the Australian Government's Climate Change Research Program. Field days for livestock producers will be conducted to demonstrate the results of this study and the techniques employed to measure CH_4 (e.g., open-path Fourier-transform infrared spectrometer technology). A soil map and 7 soil samples have been used to characterize the site: it contains soil and topographical diversity typical of the region (pH 4.8 – 5.1 (1:5 CaCl2); soil organic carbon 1.2 – 3.8 (%); cation exchange capacity 3 - 41(meq/100g)). The replicated study over 2 years will compare animal productivity and emissions of low stocking rate enterprises on a low fertile landscape (hills) (16 ewes/ha) versus a high fertile landscape (flats) (32 ewes/ha) (Figure 1) at 3.7 and 6.7 dry sheep equivalents (DSE)/ha, for hills and flats respectively. Data will be analysed in terms of methane (g) produced/kg lean meat and kg of wool produced. Pasture biomass, botanical composition, image analysis of pasture, water holding capacity, nitrous oxide (N_2O) and animal production data (live weight gain, fat score, fecundity, wool and lamb carcass weights at slaughter) will be collected. Decision support tools (e.g. EcoMod and AusFarm®) will be used to estimate total on-farm CH_4 and the collated data will be used in life cycle and economic analyses. Preliminary results (Table 1) of estimating CH_4 on the low and high fertility landscapes will be reported.

(a)

(b)

Figure 1. Supplementary feeding during lambing on (a) the hills (low fertility) and (b) the flats (high fertility) (Photo J Meckiff 2010)

Table 1. Preliminary results of methane produced/kg live weight (LW) over a 24 hour period from a single paddock on both the hills and flats using GrazFeedTM based on data collected on 18th Oct 2010

Land	Green (t DM/ha)	Dead (t DM/ha)	DMI (kg)		Wt gain (g)		Methane (g/kg LW)	
			Ewes	Lambs	Ewes	Lambs	Ewes	Lambs
Hills	0.48	5.55	1.86	0.34	-47	223	0.96	0.58
Flats	2.08	0.06	2.21	0.29	80	305	1.0	0.43

TITLE BY-PRODUCTS FED TO COWS REDUCE METHANE EMISSIONS

Theme Animals

Primary Author Dr Peter Moate
Institution Ellinbank Centre, DPI, Victoria
Email peter.moate@dpi.vic.gov.au
Co-Authors Richard Williams, Chris Grainger, Murray Hannah, Richard Eckard

Key search words Brewers grains, hominy, canola, methane, rumen, dairy cows

Background

There are few studies in the scientific literature concerning the comparative effectiveness of by-products as dietary supplements for reducing methane (CH4) emissions from lactating dairy cows.

Methods

This experiment evaluated four dietary treatments designated control (CON), brewers grains (BG), hominy meal and cold-pressed canola (HCC) and hominy meal only (HM) for their effects on CH4 emissions (measured in respiration chambers) and milk production. Sixteen late-lactation Holstein cows were used in pairs, in a double 4 × 4 Latin square experiment with the four dietary treatments fed as total mixed rations over 24 day treatment periods. On a daily basis, the forage component of the diet consisted of approximately 5 kg DM of lucerne hay and 7 kg DM of perennial ryegrass silage. The CON diet contained 303 g/kg DM of cracked wheat and 70 g/kg DM of solvent extracted canola meal and the CON diet was formulated to contain approximately 26 g total fat/kg DM. For the BG, HCC and HM diets, part of the cracked wheat and solvent extracted canola meal was substituted with the designated fat supplement so that the resulting experimental diets contained 51, 52 and 65 g total fat/kg DM respectively.

Results

Fat supplementation did not influence total dry matter intake (DMI), and there were only small ($P < 0.05$), positive effects on milk yield and negative effects on concentrations of milk fat and milk protein. The HM diet resulted in a reduction ($P < 0.05$) in CH_4 emissions when expressed either in g CH_4/cow/day, g CH_4/kg DMI, or g CH_4/L milk. The BG diet also ($P < 0.05$) reduced CH_4 emissions when expressed as g CH_4/cow/day or g CH_4/L milk, while the HCC diet decreased CH_4 emissions in terms of g CH_4/L milk. Combining data from all of the fat supplemented diets (FAT) revealed that CH_4 emissions were reduced ($P < 0.05$) from 500 g CH_4/cow/day (CON) to 462 g CH_4/cow/day (FAT); and similarly from 25.0 to 23.2 g CH_4/kg DMI and from 23.3 to 20.5 g CH_4/L milk.

Summary

Regardless of the type of by-product fed, for each one percentage increase in dietary lipid concentration, emissions were reduced by 0.79 g CH_4/kg DMI or by approximately 3.5 percent. These findings allow estimation of the magnitude of CH_4 abatement based on dietary fat supplementation.

TITLE DIETARY NITRATE REDUCES ENTERIC METHANE PRODUCTION IN SHEEP

Theme Animals
Primary Author Ms., Wiam, Diani
Institution Industry and Investment NSW, University of New England
Email rhegart3@une.edu.au
Co-Authors Roger Hegarty, Bruce McCorkell, John Nolan
Key search words Nitrate methane

The chemical reduction of nitrate to ammonia in the rumen of livestock is thermodynamically more favourable than is reduction of carbon dioxide to methane, so nitrate supplementation may provide a means of decreasing enteric methane production from ruminants. The level of abatement achieved by providing dietary nitrate was evaluated in sheep using open circuit respiration chambers. Four (4) Merino sheep (59kg LW) were acclimated to a basal ration of 1kg/d of lucerne chaff fed in 8 equal portions at 3 hour intervals. The basal ration had been sprayed with 10g nitrate-N/kg DM, provided as hydrated calcium nitrate. After 10d of acclimation, sheep were placed in respiration chambers (n=4) and each sheep received 4 feeds/d of the basal ration interspersed with 4 feeds/d of a test ration containing 0.3, 0.5 or 0.7% added nitrate-N. The interspersing of test ration with basal ration minimised risk to the animals from nitrite toxicity and provided within-day replication of methane mitigation. On any test day, each sheep received only the basal plus one test ration, but each sheep was in the respiration chamber for 4 days so that all sheep received each test ration over the 4 days of respiration chamber studies. Methane production by sheep in each respiration chamber was monitored at 15 min intervals. The level of methane abatement achieved from nitrate inclusion was derived by comparing methane production in the 3h following the test ration with methane production in the 3h following the basal ration. A crossover statistical model including a 2 level factor (test v basal) and its interaction with the dietary nitrate treatment, a spline and individual sheep was used.

There was a linear decline in methane production with increasing nitrate inclusion in the ration (L/d abatement = 0.65 – 7.7 x nitrate-N%; r^2 = 0.999), Graphing of methane production rate over time showed that while animals fed the basal ration increased methane production in the hour post-feeding, additional nitrate caused methane production rate to fall within the first hour post-feeding. The decrease in methane production from nitrate in test rations was approximately 70% of that predicted stoichiometrically, indicating that not all nitrate was fully reduced to ammonia within 3h of feeding. The data confirm that dietary nitrate is an effective feed additive to reduce enteric methane output but mitigation is less than expected and this may be due to both absorption and wash-out of nitrate and nitrite from the rumen.

TITLE FEASIBILITY OF SELECTING SHEEP FOR REDUCED ENTERIC METHANE EMISSIONS

Theme Animals
Primary Author Dr. John Goopy
Institution Industry and Investment NSW,
Email John.goopy@industry.nsw.gov.au
Co-Authors Roger Hegarty, Dorothy Robinson, Johan Greeff, Philip Vercoe
Key search words Gentics, methane, breeding, selection

Due to the extensive nature of Australia's ruminant industries, potential strategies for mitigating enteric methane which rely on regular access to animals (such as dietary change or nutritional supplements) have limited scope to reduce industry emissions. Selective breeding leading to genetic change in animal populations is one technique of modifying livestock production that has proved highly effective in improving a range of production and production efficiency traits, and is being considered as an approach to reduce enteric emissions from ruminants.

A project has been established to obtain initial estimates of genetic parameters for methane production by sheep, including the heritability of methane production and the genetic correlations it has with wool and growth traits. Methane production is being estimated from a short term (1 h) measure of methane production which has a moderate correlation with daily methane production (Goopy et al. 2010). Initial measurements on 708 sheep representing progeny from 20 sires showed significant sire effects for methane production per hour, and a heritability for this trait of 0.29 or 0.13 if adjusted for sheep bodyweight (Robinson et al. 2010). This study did not obtain measures of feed intake so it was not possible to estimate methane/kg DM intake. More recent studies have indicated that the association between 1h methane production and emission/d is greater if the 1h measurement is made with sheep taken from pasture in the morning rather than fasted overnight. It is intended to apply the measurement procedure to approximately 2000 mature sheep in the Information Nucleus Flocks of the Sheep Industry CRC to obtain improved estimates of methane heritability and also its correlation with productivity traits.

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THEME

FARMING SYSTEMS

SYNTHESIS PAPER

TITLE CLIMATE CHANGE AND AUSTRALIAN FARMING SYSTEMS – THE R,D&E IMPERATIVE

Theme Farming Systems
Primary Author Dr Peter Hayman
Institution South Australian Research and Development Institute
Email Peter.Hayman@sa.gov.au
Co-Authors Professor Deirdre Lemerle, Charles Sturt University.
Key search words Climate change adaptation and mitigation, Farming Systems

The term "farming systems" is widely used. In a recent review of RD&E for the grains industry (GRDC 2010), the term farming systems appears 94 times (more than once per page). A challenge of combining farming systems with the topic of climate change is that both terms encompass many complex issues, are relatively elastic, and tend to mean different things to different people. We use a framework of nested hierarchies from Passioura (1979) to highlight the need for R&D on climate change at the farming systems to build on more fundamental plant soil and animal science and to link into higher themes of landscape science, rural communities and product value chains.

The link between climate and farming systems is strong. Farming systems evolve to manage a variable but stationary climate. The notion of agro-climatic zones shifting in a changing climate has grabbed attention of industry and policy makers. Many of the adaptation options to a warmer, drier climate such as ratio of livestock to cropping, adjusting crop area and crop choice make sense at the farm level. Likewise options to reduce GHG need to be considered at a farm level.

This paper uses five questions commonly asked at a farming systems level to consider emerging issues for RD&E on climate change for farming systems.

1) What are the climate change projections for my farming region? 2) What are the impacts of these changes? 3) What can be done to adapt? 4) What are the risks and opportunities for my farm from policies to reduce emissions? 5) How can I measure and manage emissions on my farm?

Some of the emerging issues discussed include a changed emphasis on climate change projections leading to an understanding that while useful, projections are not essential for action on adaptation. While there has been a lot of work on the direct impacts of climate change on crop production there is an increasing recognition of less direct impacts on weeds, pests and disease and the influence that changed crop rotations such as continuous cereals are likely to have on the spectrum of weeds, pests and disease.

Australian farming systems are recognised to have a high adaptive capacity due in part to managing the variable climate. R&D programs such as the Managing Climate Variability Program have increased the tools and skills of researchers and farmers in linking climate science to farming systems, these skills need to be built on as we manage a variable and changing climate, indeed demand for these skills and tools will increase internationally. Farming systems also need to adapt to reduce emissions, to cope with costs of policies to reduce emissions and to find ways to benefit as a sink for carbon. The understanding of integration in farming systems will be valuable in finding the appropriate balance between these 5 questions.

TITLE CAN WE ACHIEVE NET REDUCTIONS IN GREENHOUSE GAS EMISSIONS AND MEET GLOBAL FOOD DEMAND?

Theme Farming Systems

Primary Author Associate Professor Richard Eckard
Institution The University of Melbourne and Dept of Primary Industries, Victoria
Email Richard.Eckard@unimelb.edu.au
Co-Authors Prof. Snow Barlow

Key search words Population growth, methane, nitrous oxide, abatement

The world's population is predicted to increase from an estimated 6.1 B in 2000 to 9.1 B by 2050 (mid scenario). However this growth is predicted to occur predominantly in the developing world (54%) while the developed world is predicted to only grow by 7%, over the same time period. While sub-Saharan Africa is predicted to grow by the largest percentage, South and East Asia will be the largest population centres in 2050. In order to feed this additional 3 B people, global food production will need to increase by 70% by 2050. As developed countries produce mostly high value food, the additional food required will need to be produced locally in developing countries, where access to relevant research has historically not kept pace with developed countries.

Global greenhouse gas (GHG) emissions from agriculture were estimated at 6.1 $GtCO_2e$/yr in 2005 with 54% as methane (CH_4) and 46% nitrous oxide (N_2O). Global agricultural emissions have increased by nearly 17% from 1990 to 2005 (average of 60 Mt CO_2e/yr). Agricultural N_2O emissions are projected to increase by 35 to 60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production. Likewise livestock-related CH4 emissions are likely to increase in direct proportion to livestock numbers, predicted to increase by 60% up to 2030.

On farm non- CO_2 emissions averaged 0.95 t CO_2e per person between 1990 and 2010. However, this ratio varies between countries with Australia averaging 4.1 t CO_2e per person, USA 1.5 t CO_2e, India 0.38 t CO_2e, Brazil 3.3 t CO_2e and China 0.9 t CO_2e. If we assume that the developing world will grow by 54%, at an average of 0.85 t CO_2e/person, and the developed world by 7%, at an average of 1.65 t CO_2e/person, then emissions from agriculture are likely to increase to 8.8 Gt CO_2e by 2050. This represents a 54% increase in GHG emissions from agriculture by 2050 over 2000.

Estimates of abatement from currently technology range from 15 to 56% for CH_4 and 9 to 26% for N_2O. However, many of these technologies are yet to be adopted in developed countries, let alone developing countries. Even if we assume policies in developed countries can drive a 20% abatement in on-farm GHG, and assume no abatement in developing countries, the net result will still be around 7.0 Gt CO_2e or a 23% increase in global GHG from agriculture by 2050 over 2000.

Demand for livestock products is predicted to grow as a small proportion of the global population growth become more affluent. However, the majority of the increased global population will need to rely on locally grow crops and perhaps mono-gastric meat sources as they are unlikely to afford red meat and dairy products. Thus strategies to reduce agricultural emissions through reducing red meat and dairy consumption are unlikely to have a major impact on projected increases in global GHG from agriculture by 2050.

It is clear that net global CO_2e from agricultural production will increase by 2050. Intensification has and can continue to reduce emissions per unit of product, when compared to using more land. Therefore future research should focus on emissions intensity (GHG/unit product and perhaps GHG/unit energy and protein), as this is the only way in which already challenging global food production targets can be met, but with fewer emissions than would have otherwise occurred.

TITLE LIVESTOCK AND PASTURE ADAPTATIONS FOR SOUTHERN AUSTRALIAN LIVESTOCK BY 2030

Theme Farming Systems

Primary Author Ms Melissa Rebbeck
Institution South Australian Research and Development Institute – Climate Applications
Email Melissa.rebbeck@sa.gov.au

Acknowledgements Russell Pattinson (Miracle Dog) Phil Graham (NSW DPI)
Key search words Climate adaptations, livestock enterprises.

Introduction

Livestock managers across southern Australia have been able to examine some profitable and sustainable changes to their enterprises under future climate scenarios by viewing outputs from the Grass Gro model (Moore et al, 1997). The Meat & Livestock Australia (MLA) and Department of Agriculture Forestry and Fisheries (DAFF) funded project 'Adaptation to Climate Change in Southern Australian Livestock Industries' has allowed NSW, SA, Victoria, Tasmania and WA Departmental staff to work closely with livestock managers in order to analyse and test the most viable farm management adaptation options to meet a range of climate scenarios in 2030. This paper discusses the adaptations tested so far in the south east of South Australia.

Methods

Climate change projections were made using four Global Circulation Models (GCM's). Rainfall and temperature data was downscaled using the "Weather Maker, 2009 Simulations were run within Grass Gro for the period 2016-2045 (for 2030) and for the periods 1970-2000, 2001-2009 and 1995- 2005 for comparative purposes. We assumed 450ppm carbon dioxide across the 2030 time period. Locations were selected in the high, medium and low rainfall areas of the south east of SA to look at the impact of climate change and climate variability on pasture and livestock production and then analysed the effects on supplementary feed requirements, gross margins, ground cover and animal sale weight.

Various climate change projections and comparative time periods were used in order to promote discussion about alternative management options and adaptations for their livestock enterprises by 2030. During workshops producers were shown these outputs and then asked to suggest adaptation options for testing within Grass Gro.

Adaptations options most commonly suggested for an optimum 2030 system in the south east of SA included a trading or breeding scheme, a pasture production focus, optimum calving or lambing times, optimum stocking rates and optimum pasture species mixes.

Results/discussion

To date, tests using the Grass Gro model have shown that by 2030 the main impact of climate change to South Australian livestock managers is likely to be increased climate variability and a shortened growing season This has flow on affects to livestock systems such as more variable gross margins. Other affects of climate change suggest that perennials will be less viable in the higher rainfall areas of the south east of SA. It also appears that more flexible systems such as cattle trading systems will be more profitable than breeding enterprises in may areas.

To alleviate some of these impacts producers suggested they would use the tested optimised calving and lambing times and optimal stocking rates and improve pasture utilisation.

Further Work

Adaptations suggested and tested will vary across locations within a State and between States . Further tests will be performed across SA and other southern livestock areas until the project concludes in 2012. Papers will be published and listed on project partner websites.

We used both projections and a temporal approach to supporting adaptation to climate change. Further tests could be done with a sensitivity approach (for example simulating a drier season finish.

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TITLE NOVEL PERENNIAL BASED FARMING SYSTEMS ARE A KEY TOOL IN ADAPTATION TO CLIMATE CHANGE

Theme Farming Systems

Primary Author Dr Michael Ewing
Institution Future farm Industries Cooperative Research Centre
Email mike.ewing@futurefarmcrc.com.au
Co-Authors John McGrath, Kevin Goss

Key search words cropping, dryland, farming systems, grazing, perennials,

In southern Australia current dryland cropping and grazing systems face significant challenges from climate change with predictions of higher temperatures, increased seasonal variation in rainfall and increasing frequency of drought. Wider use of perennial plants in partial replacement of the currently dominant annual crop and pasture species has been advanced as one opportunity to deliver a more resilient production system while at the same time maintaining or increasing productivity and profitability.

Wider use of perennials has been proposed because as a group they have characteristics likely to be increasing important under emerging climatic scenarios. Characteristics likely to confer greater resilience to farming systems are the:

1. Capacity to use water efficiently
2. Ability to fully utilize the available water
3. Ability to convert water into products of high value
4. Capacity to remain productive or persist under drought conditions through drought avoidance and or drought tolerance
5. Capacity to productively utilize areas and resources that are unfavourable for traditional annual pasture and crop systems

The wide range of circumstances that apply across southern Australia requires a diverse array of plants and approaches to match the needs of particular regions and industries. While major changes in agricultural technologies and practices are realistically measured in decades, progress so far with new perennial plant technologies provide the opportunity to deliver insights into future opportunities and directions.

The perennial systems being developed to provide adaptation to drought, NRM benefits and to improve productivity and profit that will be highlighted are:

- Perennial pasture and livestock systems in grazing dominant areas (Evergraze), using a range of perennials to fully utilize the available resources and optimise feed availability across the year.
- Fodder shrubs in mixed crop/livestock farming systems(Enrich), which evaluate a range of native perennials for their grazing potential and their capacity to persist under harsh climatic and soil conditions.
- Perennials that improve productivity in crop dominant systems (Evercrop), where the productivity and drought tolerance of a range of perennial grasses and legumes (e.g. Tedera - Bituminaria bituminosa) have shown considerable promise.
- Woody perennials in farming systems (New Woody Crop Industries) using drought tolerant Australian eucalypt species integrated with existing agricultural systems to produce bioenergy and to utilize stored water and reduce recharge.

The aim of these initiatives is to produce plants and systems to improve the profitability and reduce risks in dryland agriculture while at the same time providing environmental benefits.

TITLE ADAPTATION STRATEGIES TO SHORTER GROWING SEASONS FOR LAMB FARMING ENTERPRISES IN SOUTHERN AUSTRALIA

Theme Farming Systems

Primary Author Dr Matthew Harrison
Institution CSIRO Climate Adaptation National Research Flagship
Email Matthew.Harrison@csiro.au
Co-Authors Dr Andrew Moore

Key search words Climate change, CO_2, growing season, lambs, rainfall, temperature

Global circulation models forecast future climates with increased temperatures, greater atmospheric CO_2 concentrations [CO_2] and more erratic rainfall distributions in many regions of southern Australia. Such weather changes are likely to cause greater pasture growth rates in winter and shorter growing seasons (SGS), altering the extent and distribution of livestock forage supply. The purpose of this study was to identify management adaptation strategies for lamb farming enterprises that mitigated or reversed the effects of SGS in two diverse grazing regions of southern Australia.

Historical weather records from 1970-99 for Hamilton (Vic) and Wagga Wagga (NSW) were used in the GrassGro decision support tool to identify the distribution of growing season breaks and ends. Daily sequences of rainfall and clearness index data were produced by mapping the baseline growing season break and end dates to later and earlier periods, respectively, to contract the growing season length by 10% from the baseline of each site. At both sites this contraction equated to approximately 22 d. Average daily temperatures at both sites were increased uniformly by 2°C above baseline weather and [CO_2] was set to 450 ppm, allowing the SGS weather to cause greater winter growth. Adaptation strategies examined included renovating pastures with a perennial grass or with annual grasses that had more rapid phenological development, increasing pasture fertility by 10%, confinement feeding of livestock between 1 November and 1 August when total dry matter was less than 800, 1600 or 2400 kg ha^{-1}, or changing lambing time or ewe age at first mating from baselines of late April and 1-2 yrs old, respectively.

At Hamilton the baseline and SGS weather produced similar average annual net profits (NP, \$ ha^{-1}) of 477 ± 116 and 437 ± 102 respectively. At Wagga the SGS had a greater effect, decreasing the baseline NPs from 102 ± 70 to 79 ± 57 \$ ha^{-1}. At Hamilton increasing pasture fertility or confinement feeding of livestock at high turn-off levels of total dry matter (1600, 2400 kg ha^{-1}) were the best options, increasing NP by around 10% relative to no adaptation. At Wagga, renovating existing pastures with annual grass that had rapid phenological development increased NP by more than 70% relative to no adaptation, whilst sowing pastures with phalaris boosted NPs by over 20%. Shifting (1) the mating time from December to November or January, or (2) ewe age at first joining from two years old to one or three years old reduced NPs by up to 19% at Hamilton and 38% at Wagga, relative to no management changes.

The investigation showed that the most profitable adaptation strategies under SGS differed between locations: favourable adaptation strategies for farms in cooler regions include better fertiliser management or confinement feeding of livestock when ground cover is lower than a viable threshold. At relatively warmer sites with growing seasons that are already short, renovation of pastures with annual grasses that develop faster will be a beneficial adaptation option since it allows greater stocking rates and reduces the requirement for maintenance supplement in winter. The analysis revealed that the most favourable adaptation strategies under present conditions were generally consistent with those that were most favourable under SGS conditions, suggesting that management changes which enhance NPs under current conditions in southern Australia should also increase NPs under future climates that shorten growing seasons.

TITLE SEASONAL FORECASTING TO SUPPORT MANAGEMENT DECISIONS IN MARINE SALMON AQUACULTURE

Theme Farming Systems (Day 3 Thurday 17th February; Concurrent Session after lunch)

Primary Author Alistair Hobday
Institution CSIRO
Email Alistair.Hobday@csiro.au
Co-Authors Vincent Lyne, Donna Hayes, Roger Scott, Ron Thresher, Claire Spillman, Ana Norman-Lopez

Key search words Climate change, seasonal forecasting, salmon farming, aquaculture, management, decision support

Abstract

Marine primary industries include both wild fisheries and aquaculture; these industries face many of the same climate-related challenges as the terrestrial sector, namely: increased environmental variability at a range of space-time scales, and directional environment change. Marine waters in south-east Australia have been identified as a climate change hotspot, with rates of ocean warming up to four times the global average. Southward range expansion has been reported in a number of wild marine species, of both commercial and conservation value. Marine farms in this region, particularly south-east Tasmania are also reporting changes in the performance of farmed Atlantic salmon. This species is grown in water temperatures that are close to its thermal limit at some months in some years. While adaptation to long-term change is seen as important by the sector, dealing with climate variability exacerbated by ongoing climate change is a more immediate need.

Warm summers can significantly impact farm production via an increase in operational expenses and impacts on fish condition, mortality and recovery potential, while cool winters slow salmonid growth. In response to requests from the salmon industry, we are exploring several forecasting approaches to provide short-term ocean forecasts for several sites at lead times of up to four months. Both statistical and dynamical methods are being developed and compared. The first forecasts were delivered to industry in September 2010, and will continue on a monthly interval. Validation using historical data and updates from the farms suggest that offshore sites may be more predictable while inshore sites may be under the influence of local factors (such as freshwater flow, tides, mixing) that increase the variability in water temperatures. By knowing which farm sites are more predictable, and by focussing future effort on improving forecasting skill for the more difficult sites, we enable farm managers to gain confidence in using the predictions to assist their operations. These efforts allow management to consider a number of responses that will help maintain industry profitability in an uncertain environment, and are likely to help this valuable industry come to terms with long-term climate change, and to begin longer term adaptation planning.

TITLE IMPACTS OF CLIMATE CHANGE ON FARM BUSINESS RISK IN THREE REGIONS OF WESTERN AUSTRALIA

Theme Farming Systems
Primary Author A/Prof Ross Kingwell
Institution Department of Agriculture and Food (WA) & University of Western Australia
Email rkingwell@agric.wa.gov.au
Co-Authors Brent Payne
Key search words Business risk, farming systems, climate change

A farm simulation model known as STEP (Simulated Transitional Economic Planning) is used to examine the financial performance of farms under current and projected climate in three regions of Western Australia. A range of different farm types is examined.

In two of the regions climate change is expected to cause more unfavourable production years, whilst in the other region more favourable production years are projected. Farms in regions where more adverse climate is projected are shown to experience increased business risk, in contrast to the findings for the other region.

Characteristics of farms that increase their risk of business failure, in the presence of projected climate change, are small farm size, initial low equity and an enterprise mix that favours wool production. For all types of farms, as would be expected, a favourable trend in the terms of trade increases farm business resilience.

In regions where adverse climate change is projected, crop dominant farms that currently have high equity appear capable of withstanding the projected adverse climate change whilst farms with similar characteristics in the other region are likely to prosper further, given their projected favourable change in climate.

Recently gathered farm survey data confirm the findings of this simulation study that farm size, farm indebtedness and frequency of poor yields play major roles in affecting farm viability.

TITLE WILL MANAGING FOR CLIMATE VARIABILITY ALSO MANAGE FOR CLIMATE CHANGE? A SOUTHERN AUSTRALIAN GRAZING SYSTEM AS AN EXAMPLE

Theme Farming systems
Primary Author Dr Andrew D. Moore
Institution CSIRO Climate Adaptation National Research Flagship
Email Andrew.Moore@csiro.au
Co-Authors
Key search words

It has been suggested that farmers faced with a changing climate will successfully adapt their systems by means of successive small, short-term changes in management practice. In livestock production, however, decisions on key profit drivers such as stocking rate and joining date will have consequences that persist beyond the year in which they are made. Large management changes have transaction costs associated with them (such as lower reproduction rates if the period between matings is shortened), and must be made in the face of significant production and price risk.

The GRAZPLAN soil water, pasture and ruminant production models were used to simulate the behaviour of a sheep production system (Merino ewes producing first-cross lambs) grazing annual grass-clover pastures at Lucindale in south-eastern South Australia. The behaviour of this grazing system under changing climate was modelled over the period 2010-2099 using daily weather data downscaled from multiple realizations of the NCAR-CCSM3 and MPI-ECHAM5 global circulation models under the SRES A1B scenario. Price variability was taken into account using a Markovian model of prices for wool, sheepmeat and grain for supplementary feed. Overstocking was penalized via a requirement for confinement feeding in order to preserve ground cover. Costs of trading livestock were taken into account.

Four approaches to setting stocking rates and the date of joining were examined:

- "Traditionalist" policy: maintain the optimal stocking rate and joining date from the 1970-2009 period.
- "Incremental" policy: make a small change in either stocking rate or joining date each year, based on relative profitability over the last 5 years.
- "Step-change" policy: every 15 years, choose the stocking rate & joining time that optimized net cash flow over the previous 15 years
- "Forecast" policy: set stocking rate & joining time each year as functions of an accurate forecast of long-term expected pasture production

The relative advantages and disadvantages of these policies in terms of long-term cash flow, year-to-year variability and natural resource management outcomes (deep drainage and methane production) are compared.

TITLE GRAINS BEST MANAGEMENT PRACTICE FOR MANAGING CLIMATE OPPORTUNITIES AND THREATS

Theme Farming Systems
Primary Author Dr Jeff Clewett
Institution Agroclim Australia, Toowoomba, Qld 4350
Email jeffclewett@agroclim.com.au
Co-Authors Nina Murray (Agforce Qld), Rod Collins (DEEDI) and Dan Hickey (Morgan Rural Tech)
Key search words Climate risk, climate change, farm management practice, Australian grain industry

Grains BMP

The Grains 'Best Management Practice' (BMP) program for Australia's Northern Grains Region is a voluntary, industry led process which builds capacity for broad acre grain growers to improve farm production practices. The program has eight modules to cover property design, managing climate risk, making the most of rainfall, crop nutrition, pest management, irrigation and grain storage. Each module identifies about 20 management topics (e.g. land preparation, crop choice or assessing climate forecasts) and within each of these topics the module identifies which practices meet a minimum standard defined by industry. Practices that are not aligned with the minimum standard are described as either at a level that is below the standard, or at a level that is potentially desirable but above the minimum industry standard. The modules can be completed on-line or in one-day workshop environments, use a self-assessment process and focus on the actions needed to implement management plans. This paper firstly describes the climate risk module that has been developed for managing climate variability and climate change in Australia's Northern Grains Region, and secondly describes the process that will be used to roll-out and review the module in 2011 and 2012. Module content and results from the initial one-day action planning workshops with grain growers are discussed.

Key areas of Climate Risk Module and Priority Issues

Climate risk is set in the wider context of risk management using the methodology defined in the Australian Standard on risk management (AS/NZS ISO 31000: 2009). The four key areas of the module are: (1) linking climate and crop performance which covers practices for monitoring the current situation, analysing historical data and evaluating short-term, seasonal and climate change forecasts, (2) risk management principles, framework and process including risk assessment (likelihood, consequence and treatment priority), communication, monitoring and review, (3) review of strategies for managing climate risks (opportunities and threats) such as the "perfect" season for grain production, low and variable rainfall, catastrophic events, extended and severe drought, excessive rain and high intensity storms, cool weather, frost, and hot-dry weather, and (4) managerial skills for strategic and tactical management of climate risks at paddock, whole-farm and off-farm levels. The module provides an effective mechanism for growers to review their management and thus to consider actions that may be needed to implement research findings from climate variability and climate change programs. The action plans developed for individual farming enterprises will contribute to district analyses and will provide a valuable cross section of current management practices used by industry.

While "best management practice" varies with location, enterprise and land capability, the management practices to emerge as high priority concern: (a) structural adjustments to the enterprise such as enterprise mix, machinery selection and adaptation of land use to on-going reviews of land capability particularly for high-risk marginal lands, (b) adjustments in seasonal tactics such as land preparation, crop selection, cropping intensity, planting methods, weed control, livestock management and marketing, and (c) development of managerial skill, adaptive capacity and off-farm investment. In general, those practices which deal effectively with the climate risks (opportunities and threats) evident in historical records would be at the minimum industry standard, while practices that are designed to also deal with future climate risks projected from climate change scenarios would be assessed as desirable but above the minimum industry standard.

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TITLE MANAGING FUTURE AGRICULTURAL PRODUCTION IN A VARIABLE AND CHANGING CLIMATE

Theme Farming Systems
Primary Author Steven Crimp
Institution CSIRO Climate Adaptation Flagship and Division of Ecosystem Science
Email Steven.Crimp@csiro.au
Co-Authors Alison Laing, Bronya Alexander, Phil Bowden, Kerry Bridle, Peter Brown, Howard Cox, Peter deVoil, Jan Edwards, Alex Gartmann, Peter Hayman, Mark Howden, Philip Kokic, Shaun Lisson, Neil McLeod, Jim Meckif, Barry Mudge, Uday Nidumolu, David Parsons, Brendan Power, Michael Robertson, Daniel Rodriguez, Janet Walker, Michael Wurst
Key search words Agriculture, adaptation options, climate change

There is growing evidence that current changes in climate are linked to both human activities and natural variability and that these patterns of change in Australia (particularly temperature but also rainfall) are consistent with future projections. History has demonstrated that natural resource based industries, such as agriculture, are particularly sensitive to climate with productivity highly responsive to climate variations. The current farming environment is complex, characterised by market risk and variation in resource conditions and technologies. Climate change, particularly changes in climate variability and in extremes, will further add to this complexity. There are many potential incremental adaptation options available to offset projected impacts. These incremental adaptation options often involve modification of current practices to offset risk associated with past climate variability.

Understanding which adaptation options to pursue in response to climate change remains a difficult and problematic exercise. This is largely due to the uncertainty associated with regional projections of climate change as well as the limited scope (i.e. largely simulation studies) for assessing the effectiveness of adaptation.

We have adopted a participatory approach to assessing adaptation options: working with farmers, integrating their knowledge and including their estimates of costs, benefits, practicalities and constraints. This approach has been successfully implemented across three broad grain growing regions in New South Wales and is currently being undertaken nationally, via support from DAFF and GRDC, to identify practical management responses to climate change options and assess their value in terms of productivity and profitability.

The results from the pilot study show how some adaptation options provide resilience to both modest and more extensive climate change across much of NSW. These adaptation options include the implementation of additional "fallow" or "pasture" components in the rotation and the enhancement of current residue retention practices, splitting nitrogen applications and, to lesser degrees, changing cultivars, planting densities and irrigation scheduling.

The research to date shows that the effectiveness of any adaptation option will depend on the complex interaction of many factors including soil types, field layout, farm technology and machinery, the extent of future projected climate change, labour cost and availability, and investment capacity and external markets. Results from across the three disparate regions and different farming systems of the NSW pilot study and, more recently, from the national assessment, show that attempts to conserve moisture in the soil through practices such as fallowing, increasing pasture in the rotation and residue retention serve to offset likely yield losses in a warmer and drier future.

TITLE CAN FLEXIBILITY BE BUILT INTO CROPPING SYSTEMS FOR MITIGATING THE IMPACT OF UNCERTAINTY COMPONENT OF CLIMATE CHANGE?

Theme Farming Systems
Primary Author Darshan Sharma
Institution Department of Agriculture and Food, Western Australia
Email darshan.sharma@agric.wa.gov.au
Co-Authors David Bowran
Key search words Phenotypic plasticity, variety mixture, population density, stability, cropping system

An important component of climate change (CC) is the increased uncertainty of forecasting seasonal weather. Farmers generally lock in most of their inputs by an early stage in the crop development – when seasonal forecast and price outlook accuracy is low. A mechanism is therefore required to change cropping commitments during the season or to reduce yield losses and realise yield potential. In this presentation, we aim to discuss an evidence-based argument that the risk due to uncertainty component of CC can be mitigated by building flexibility in cropping system through strategic pre-season planning. The hypothesis is that useful flexibility can be generated through at least three approaches: i) growing a variety that exhibits desirable plasticity of yield components, ii) tactical population control where farmers could kill a part of the crop under water deficient conditions, and iii) strategically structured plant populations to maximise crop buffering.

These hypothesised strategies are based on a review of previous agronomy research in Western Australia (WA) and relevant literature. A) Plasticity: Plasticity of yield components seems to underpin the yield stability of most predominant wheat varieties in WA (Sharma et al 2008 Variability of optimum sowing time for wheat yield in Western Australia. Aust J Agric Res 59: 958-970). For example, Wyalkatchem and Carnamah, the two highly predominant varieties of WA, showed remarkably high plasticity for mean kernel weight. Apparently, this plasticity enables maximising the capture of resource-limited (e.g. rainfall) potential irrespective of the sink status. B) Population control: High seed rates have been advocated as an integrated weed management practice but we have some experimental data that shows a disadvantage of high plant populations under rapidly warming conditions. This highlights the need to optimise plant population in areas where climate is changing towards consistently drier and warmer winter growing conditions. Growing mixtures of varieties with- and without- imidazolinone tolerance genes is one tactic that we intend to test in 2011 for a need based reduction of plant population. C) Population structure: Based on the concept of population buffering (Allard and Bradshaw 1964 Implications of genotype-environmental interactions in applied plant breeding. Crop Science 4: 503-508), we believe varietal mixtures can reduce yield losses associated with the uncertainties of seasonal weather forecasts (e.g. forecasts of drought, late rains, frost, and high temperature). For example, varieties differing for phenology and growth pattern may be mixed. Some new phenology models (such as, Sharma and D'Antuono 2011 Predicting flowering dates in wheat with a new statistical phenology model. Agronomy Journal 103, 221-229) can distinguish varieties for flowering date response to warmer or colder season types. A hypothetical estimate shows that the yield benefit from post-frost water use can be up to three times for an appropriate mixture in comparison to a monoculture crop of a frost damaged variety. We recognise there will be issues with yield penalty due to late maturity but suitable varieties for such shandying need to be carefully identified. Experimental data on the optimum composition of such variety mixtures is however scant.

We suggest that future CC adaptation research should test these hypotheses through direct comparisons of the suggested populations with the most stable varieties and if found useful, devise decision tools that farmers could use to select components and proportions of mixtures to match their specific conditions..

Acknowledgements

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TITLE CHANGES IN AGRICULTURAL CLIMATE INDICES IN TASMANIA USING DYNAMICALLY DOWNSCALED FINE-RESOLUTION CLIMATE PROJECTIONS

Theme Farming systems

Primary Author Greg Holz
Institution Antarctic Climate and Ecosystems CRC
Email gholz@utas.edu.au
Co-Authors Michael Grose, Stuart Corney, James Bennett, Chris White, Nathan Bindoff

Key search words Climate change, chill, growing degree days, drought

Projected changes to the climate of Tasmania resulting from global climate change will have profound impacts on agricultural enterprises at farm, industry and regional scales. This will lead to substantial changes in farm management, choice of crops and land use and underlying biological capital.

Projections of climate variables from the Climate Futures for Tasmania project have been used to assess the impacts of a changing climate on aspects of agriculture in Tasmania. The fine resolution (0.1° grid) of the dynamically downscaled model outputs has allowed for changes in climate, and therefore impacts, to be differentiated across the agricultural regions of Tasmania over the period 1961-2100.

Frost incidence is projected to reduce by around half by the end of century under the A2 emissions scenario. The period of frost risk is projected to contract from March-December to May-October for many areas in Tasmania but there may still be damaging late winter and spring frosts, especially since bud burst is likely to occur earlier.

Indices of meteorological and agricultural drought indicate the episodic and regional nature of drought events will continue. There is considerable inter-model variability indicating uncertainty, but general trends suggest a reduction in the proportion of time subject to meteorological drought in the south-east, north-east and south-west of the state and an increase in the central to north-west regions.

Chill hours are projected to decrease at sites below 400-500 m and increase at higher elevation sites. There is projected to be adequate chilling to satisfy the vernalisation requirements of most crops except for high chill varieties along the east and north coasts and Bass Strait islands.

Projected increases in Growing Degree Days (GDD) are likely to lead to changes in crop types, varieties and management. A crop requiring 1000 (10 °C base) GDD will mature approximately 1 month earlier than the baseline period of 1961-1990 by 2030 and two months earlier by the end of the century. Wine varieties such as Cabernet Sauvignon will ripen reliably by the middle of the century in current grape growing regions. By 2085, varieties such as Pinot Noir will be harvested around mid-February, more than two months earlier than the baseline period of 1961-1990. These changes are likely to have significant implications for wine quality and optimum vineyard locations.

TITLE MANAGING CROP PRODUCTION UNCERTAINTIES AND CLIMATE VARIABILITY THOUGH A MAP-BASED SYSTEM – WA CASE STUDY

Theme Farming Systems
Primary Author Mr Jean-Francois Rochecouste,
Institution University of Queensland
Email rochecouste@iinet.net.au
Co-Authors Mr Brad Jones, Mr James Betti
Key search words Climate change, GNSS, farm mapping, variable rate, fertiliser efficiency

Bungulla Farming Pty Ltd operates a 7,200 hectare property to the East of Tammin in Western Australia's cereal belt, with an average 320mm predominantly winter rainfall. The soils are shallow sandy loams with low fertility, highly dependent on *reliable winter rainfall and fertiliser inputs* for production. The owners are aware of the significant risk scenario presented by a changing climate that would decrease the reliability of rainfall in addition to the ongoing rising costs of fuel and fertiliser. With limited investment resources, it was necessary to clearly identify risks in terms of likelihood plus impact, and management options for investment priorities.

This presentation starts by identifying critical points of production failure and demonstrates the use of a map based system using spatial data as a tool to collate and analyse production variables across paddock zones. Each critical operation such as planting, weed control or harvest, seeks to have relevant spatial layers from remote and proximal sensors that allow managers to analyse issues for discussion with advisors. The layers are used to implement prescriptive farming systems using such tools as *'variable rate controllers'* to apply the required fertiliser where it is most needed. This means efficiency is based not only on demonstrated reduce inputs (e.g. fertiliser, chemicals) but faster operation, so as to allow for timing efficiency such as fertiliser application on a Bureau of Meteorology predicted rain front, rather then a preset seasonal operation.

The risk analysis of critical points of failure asks; what information layer is needed for specific management decision? This brings the focus on to the needs of the farm operation rather then get ovewhelmed with farm data collection per se. Planting operation is used as an example where fertiliser is a key input for the light soils of WA and is generally applied before planting on the assumption of rain, but in 2010 the rains did not appear at the right time. The scenario of changing climatic conditions (dry years) allows the farm manager to invest resources on better performing paddocks. Those farmers that had applied too early were gradually losing expensive nitrogen. Applying on an incoming rainfront to maximise plant uptake requires critical timing. Soil maps, moisture content, combined with cropping history and historical yield data helps to target high performing investment areas. Variable rate application of fertiliser is set to speed up operations by skipping unproductive areas and allows for more timely application. Yield data at harvest and paddock input costs give gross margin maps for various paddocks. Other operations such as weed control, harvest and environmental management all require diferrent map layers.

An extension of this type of operational analysis is personal on-farm research, where sections of a paddok can test crop type, varieties, weed control option or the addition of soil ammendments such as livestock manure. These trial blocks are compared via yield data, all other things been equal. Such trials can be informal or more sophisticated employing replicated plots with analysable sample data points. The use of Global Navigation Satellite Systems (GNSS) can precisely place treatments for follow up analysis, with results usually available within a season.

Some digital data layers are still being developed as the sophistication and range of proximal sensors keep growing. Some current problems include layers not being interactive on one platform, nevertheless the investment in this process has demonstrated substantial savings for Bungulla farming in terms of fertiliser/fuel inputs but more significantly it has reduced the risk profile to manage inputs away from unreliable mid-term forecast. It allows operation to operate more effectively on more reliable short term forecast, as expensive inputs can be held back longer towards critical timing points.

TITLE WILL CLIMATE CHANGE NEGATE BETTER FARM MANAGEMENT FOR IMPROVING WATER QUALITY IN THE MACKAY-WHITSUNDAY REGION?

Theme Farming Systems

Primary Author Dr Peter J Thorburn
Institution CSIRO Ecosystem Sciences and Climate Adaptation Flagship
Email peter.thorburn@csiro.au
Co-Authors Jody S. Biggs, Steve Crimp and Will Higham

Key search words Great Barrier Reef; Sugarcane; Reef Rescue; Farming systems; APSIM; CO2 fertilisation.

Abstract

Nitrogen (N) lost from cropping is one of the major threats to the health of the Great Barrier Reef (GBR) in northern Australia. Sugarcane is the dominant crop in most catchments draining into the GBR lagoon, especially those of the Mackay-Whitsunday region (8,400 km^2) where sugarcane represents > 99% of cropping in the catchments. Currently, there are substantial efforts supported by incentives from the Federal Government's Reef Rescue program and Queensland Government regulations to change farming practices and reduce N losses from sugarcane farms. As farmers and farming systems adapt to a future requiring lower environmental impact, the question arises whether climate change may 'undo' these improvements. This is a question rarely considered in water quality studies.

To address the question, we used the APSIM farming-systems model to investigate the complex interactions between the range of potential sugarcane management systems, soil types and sub-regional climates under different climate change scenarios. These scenarios covered wetter and drier, and modest to extensive warming for 2030, extracted from the OZCLIM scenario generator. Tillage, fallow management and N inputs in sugarcane production were categorized according to the local systems defining the resultant level of water quality improvement, from 'A' (cutting-edge) to 'D' (outdated). Importantly, this study allows the representation of controlled traffic systems which are an important component of 'A-Class' management in GBR regions, but yet to be represented in simulation studies.

Climate change scenarios predicted median annual rainfall would be reduced by up to 19%, and maximum and minimum temperatures increased by up to 0.5°C and 0.6°C, respectively, across all four sub-regional climates. The study predicted that the improvement in farm management needed to meet water quality improvement goals will not be greatly affected by climate change. However, the frequency of years with very high N losses, and hence extreme ecological risk, was predicted to increase by up to 10-15%. Improved management practices were predicted to reduce N losses during these years, compared with traditional practices, by up to 66%. The results support continued adoption of improved management practices to achieve proposed water quality targets in both the current and a range of potential future climates.

However, the predictions are substantially influenced by assumptions about CO_2 fertilisation of sugarcane growth. If CO_2 fertilisation effects are not as great as assumed and so sugarcane production (and crop N uptake) lower than predicted, water quality outcomes maybe worse than predicted. These issues require further study.

TITLE MODELLING PASTURE BASED DAIRY SYSTEMS TO A CHANGING CLIMATE IN A CARBON CONSTRAINED WORLD

Theme Farming Systems
Primary Author Richard Rawnsley
Institution Tasmanian Institute of Agricultural Research
Email Richard.Rawnsley@utas.edu.au
Co-Authors Richard Eckard, Brendan Cullen and Karen Christie
Key search words Dairy, Adaptation, Greenhouse Gas Emissions, Farm Systems

Abstract

Tasmanian dairy farms are characterised by being predominantly pasture based and modelling the pasture production under future climate scenarios has shown that pasture production is likely to increase (Holz *et al*. 2010) in this region. As such the Tasmanian dairy industry will continue to focus on milk production per ha and pasture consumption per ha as key profit drivers. However, there appears to be an emerging conflict between the most profitable approaches to adapting to a warming climate and that of mitigation of greenhouse gases (GHG). Using the dairy simulation model DairyMod (Johnson *et al*. 2008), the current study modelled a typical pasture based dairy farm system in North West Tasmania under a baseline climate scenario (1979/80 to 2008/09) and a future climate scenario. The future climate scenario was created by scaling the baseline climate by 2°C (with atmospheric CO_2 concentrations of 535 ppm) and a rainfall deficit of 10%. The baseline farming systems was a 300 cow, August calving herd, on a milking area of 100ha. This farming system resulted in a simulated mean annual milk production of 14,671 litres/ha, a mean annual pasture consumption of 11.9 t DM/ha and a mean annual on farm GHG emissions of 6.0 t CO_2-e/ha. Under the future climate scenario an array of within farm system adaptations were simulated including increases in stocking rate and removal of concentrate feeding. The mean pasture consumption under the future climate scenario was 14.6t DM/ha. All within farm system adaptations were found to increase the estimated mean annual on farm profit margin but there was also an associated increase in on farm GHG emissions per ha and GHG emissions per litre of milk.

While warming of the climate and associated increases in atmospheric CO_2 appear likely in the future, there is less confidence in predicting rainfall changes. This modelling analysis has shown that the cool temperate dairy regions of Tasmania are well buffered against predicted climate changes and that within farm system adaptations appear most likely. As pasture production in these regions is most likely to increase under climate change, Tasmanian dairy farmers will continue to focus on pasture consumption and milk production per ha as key drivers of farm business success. While within farming system adaptations such as increased stocking rates and reductions in concentrate feeding are likely to increase profit margins these adaptations are also likely to result in higher total emissions and higher emissions per unit of product. For these pasture based dairy systems there is an urgent need to develop and adopt GHG abatement strategies that enable farmers to fully utilise their comparative advantage of growing high quality temperate pastures while not diminishing their competitive advantage of producing milk at a low cost.

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TITLE VEGETABLE PROJECT TO GUIDE PRODUCTION UNDER CURRENT AND FUTURE CLIMATES.

Theme Farming Systems
Primary Author Associate Professor Colin Birch
Institution Tasmanian Institute of Agricultural Research
Email colin.birch@utas.edu.au
Co-Authors Dr Richard Doyle, Dr Leigh Sparrow, Mr Laurie Bonney, Mr Jimmy Maro, Mr Michael Atuai
Key search words Climate change, vegetables, population, value chain analysis, land suitability

Production of vegetables and other foods in Papua New Guinea (PNG) needs to increase substantially to meet the food needs of a rapidly increasing population, with an emerging middle class and increasing expatriate population associated with resource development projects (natural gas, mining) leading to expectations of greater diversity in food availability. Vegetables are a traditional food source, however, heavy reliance on carbohydrate-rich sweet potato and banana as staple foods has resulted in some malnutrition. We have recently commenced a research project designed to increase vegetable supplies, specifically for Port Moresby. However it is expected that technologies and practices that emerge from the project will be applicabile in PNG and nearby Island States, as commercial food production increases to meet the needs of urban populations. Pressure on land resources is also increasing, meaning sustainable production practices are required to address land degradation while meeting the needs of intensification of production. PNG has a wide range of agro ecological zones, from temperate highland regions with reliable near year round rainfall, to seasonally dry tropical lowlands, providing the opportunity for continuity of supply of a diversity of temperate and tropical crops. Climate change is expected to result in temperature changes of around 2° C in tropical areas by the mid to late 21st century, increased frequency of severe weather effects, and in the islands of the south west Pacific, variable effects on total and seasonality of rainfall (Bates et al. 2008, Nurse and Sem 2001). Thus, agro ecological zones in PNG could change, but with complex orographic influences of highly variable topography, local changes in temperature and rainfall are likely to be highly variable.

Our project addresses vegetable production in lowland, mid-elevation and highland agro ecological zones with a range of temperature and rainfall conditions, and will therefore increase understanding of food production in PNG under current and future climates with warmer temperatures requiring greater care in selection of production sites. We are undertaking a broad scale assessment of land suitability and infrastructure availability using PNGIS data. Our next step will be to undertake a more detailed regional study of candidate areas for vegetable production in Central Province to provide the basis for detailed production oriented research. We are using a Value Chain Analysis approach to identify vegetables to be used in the project, and through the systems analysis approach embedded in it, identify key constraints and researchable topics. Findings to date indicate that the focus of ongoing research will be the adaptation of existing socio-cultural, production and marketing practices to improve low input production and achieve a critical mass of coordinated supply based on retailer/consumer value attributes. The project will complement the development of climate change adaptation strategies in Australia, which has a wider range of agro-ecological zones, albeit largely due to latitude rather than, as in PNG, elevation. Thus, while addressing the immediate challenge of meeting food needs of current and anticipated populations in PNG, our project will provide information that will be useful in adapting to future climates. Future, warmer climates may constrain areas in which production of some crops e.g., temperate vegetables, and/or result in changes in production practices e.g., time of planting, cultivars used, irrigation frequency in response to shifts in seasonal characteristics and water supplies being needed.

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TITLE	DIRECT FARM ENERGY USE OF TWO DAIRY SYSTEMS IN SOUTH WEST VICTORIA
Theme	Farming Systems
Primary Author	Ms Seyda Özkan
Institution	The University of Melbourne
Email	sozkan@unimelb.edu.au
Co-Authors	Julian Hill, Bill Malcolm, Bob Farquharson
Key search words	Dairy cow, energy use, feeding

The dairy industry in Australia faces challenges to increase productivity and maintain profitability when confronted by drought, reductions of irrigation water and high water and supplementary feed prices, and at times, high exchange rates. The dairy industry in South West Victoria is seasonal and based on pasture. Feeding is predominantly supplied from perennial ryegrass pasture. The supply of grazed pasture means that these pasture-based systems are one of the most efficient feeding systems in the world and in particular Australia. However, there is a limit to how much milk solids can be produced by cows at pasture only, and perennial and annual ryegrass pastures or fodder crops are not available throughout the whole production period. Extra feed has to be purchased to increase milk solids produced, to supplement feed gaps when the pasture is in limited supply. Managing feed costs in the Australian dairy industry has become the key to dairy farmers remaining competitive. Output can be increased, and the cost of production can be reduced, in seasonal production systems, such as in South West Victoria, by providing high-quality pasture at key times of the year. Management practices to increase pasture production and utilisation are required.

Conversion of pasture energy in farm systems to milk solids can potentially be increased by modifying dairy cow feeding systems. A five year of dairy farmlet study was conducted in South East Australia, evaluating two different feeding systems. The two different feeding systems were Ryegrass Max (RM) in which feed supply consisted of pasture and supplementary conserved pasture and concentrate feed; and Complementary Forages (CF), in which total feed supply included summer forage crops in summer and cereal silage in winter when the pasture availability was lower. The systems were stocked at different stocking rates. The energy use was calculated as direct energy used on the farmlets, which consisted of diesel and electricity use. Diesel fuel was used for the application of fertiliser and other field operations e.g. herbicide use and silage cut. Electricity was mainly used for milking, heating water and cooling milk. The indirect energy used associated with the production of imported resources was not included. These two feeding systems were compared on the basis of typical-sized dairy farms running the RM and CF systems. In this comparison the pasture system (RM) had higher energy use per kilogram of MS produced than the CF system. This reflected a greater reliance on silage production, low utilisation of complementary forage crops and lower yield of milk solids produced per hectare in the RM system. The ultimate judgement about the merit of these systems is based on the relative profitability and economic efficiency of the two systems after charging the cost of carbon against the profits.

THEME

WATER & LANDSCAPES

SYNTHESIS PAPER

TITLE AUSTRALIA'S FUTURE LANDSCAPES – CAUTION, HOPE, INSPIRATION AND TRANSFORMATION

Theme Landscapes
Primary Author Jason Alexandra
Institution Murray Darling Basin Authority
Email jason.alexandra@mdba.gov.au
Key search words landscape management, climate adaptation, integrated planning and assessment, inspiration, consequence, future scenarios

Australia's future landscapes will be shaped by global and Australian climatic, economic, policy drivers and cultural and demographic trends. Landscapes are not designed in architectural sense, but evolve as the long term product of the interplay of many natural and cultural factors. They are manifestations of complex "negotiations" between nature and culture: emergent characteristics or expressions of complex social-ecological system.

This paper outlines how landscape design and management capacity could be critical for reducing risk and realising opportunities in an era of accelerated climate change responses. By building on the experience and policy experiments of the past two decades (NRM, landcare, water reform, bio-banking and bush tender etc) Australia could develop comparative advantages in integrated and adaptive management of ecosystems at local and bioregional scales and in large scale ecological restoration. A scenario of global consensus on the urgency and resourcing of climate change responses is used to illustrate the potentially productive interplay between research, policies and social innovations.

Climate change adds complexity and uncertainty to the future trajectories of Australia's diverse bioregional ecosystems, adding to existing stressors and drivers of change, and providing new challenges for integrated assessment and planning. Australia's technical capacity and NRM policy settings are assessed as providing useful foundations, but further commitments to comprehensive reform, innovation and practice change are called for. Capacity constraints include insufficient knowledge to predict and respond to thresholds or tipping points in complex socio-ecological (landscape) systems.

Due to the complexity and unpredictability of ecological and climatic systems, Australia needs to invest in building further capacity in the large scale ecosystem science to support more integrated assessment and planning and to underpin systematic, adaptive management and governance. Furthermore the cultural and governance aspects of responding to climate change need to be central components of national adaptation strategies, because responsibility for landscape management is spread across a great diversity of public agencies and private sector actors, and because the consequences of poor governance can be profound, in ecological and economic terms.

SYNTHESIS PAPER

TITLE WATER – FUTURES FOR IRRIGATED AGRICULTURE

Theme Water
Primary Authors John Langford[1, 2] and Snow Barlow [2]
Institution 1. Uniwater; 2 University of Melbourne
Email s.barlow@unimelb.edu..au

Irrigated agriculture in Australia, particularly the Murray Darling Basin (MDB) is currently undergoing its most comprehensive redevelopment since the development of irrigation more than 120 years ago. The Murray Darling Basin legislation passed by 2 governments to establish the Murray Darling Basin Authority(MDBA) has dramatically changed the policy environment of water allocation as well as state/federal balance .The subsequent draft Murray Darling Basin management plan has stimulated a comprehensive and very 'vigorous' discussion of not only the balance of water allocation between agriculture and the environment but also the potential to change water allocations between primary industries.

Climate change and its possible involvement in the 1997-2009 drought has been an important driver of the current comprehensive reorganisation of water management within the MDB..Climate change considerations have also led to more direct competition between urban and rural demands for water as Australia's cities to secure water supplies for current and future population growth. This has resulted in the building of the North/South pipeline in Victoria connecting the city of Melbourne to the MDB. These water shortages in Southern Australia have also led to a comprehensive reconsideration of the potential for irrigation in Northern Australia.

The adaptation of primary industries to future hotter and drier climates within the Southern MDB is already under occurring as a result of the experiences of the recent drought. The annual water availability in the latter part of this drought was in the order of the 2040-50 projections of future climate change. Under these conditions it is clear that water trading offered considerable advantages in enabling annual irrigation allocations to be traded to higher value users for the mutual benefit of irrigators and local communities. The higher cost and lower availability of water under these conditions has led to changes in some production systems such as dairy and irrigated cereals.

The RDE needs of irrigated agriculture in the face of reduced allocations and higher costs of water are considerable. The large investments in irrigation delivery infrastructure in many irrigation areas will decrease water losses off farm. However to capture the full benefits of reduced delivery losses concomitant efficiency gains will have to be made on farm. This may require incentives to persuade irrigators to adopt new and emerging technologies to improve on-farm water use efficiency. In future climate and policy environments ,the potential system efficiency gains necessary to maintain profitability and productivity with decreasing water supply will are only achievable if both on-farm and off-farm water use efficiency is improved. Such whole of system improvements would allow systems operation to become more sophisticated delivering higher efficiency and better service.

TITLE WHAT FUTURE FOR RIVERINA IRRIGATION COMMUNITIES?

Theme Water and landscapes

Primary Author Mr Craig Clifton
Institution Sinclair Knight Merz
Email cclifton@skm.com.au
Co-Authors Dhakshy Sooriyakumaran, Nick Schofield, Stephen Joyce

Key search words Irrigation, Murray-Darling Basin Plan, Climate risks, Futures planning, Resilience

Introduction

The Carrathool, Griffith, Leeton, Murrumbidgee and Narrandera Councils, representing Riverina Irrigation communities, are undertaking a project to help them plan for a 'future with less water'. The project seeks to understand the key factors driving change in the region, consider how they may shape it in future, identify risks and opportunities and plan for adaptation to these. This paper reports on work with the five Councils and their stakeholders to explore how their region may change and to identify key risks and opportunities this may present.

Regional overview

The five local government areas (LGAs) are located in the NSW Riverina region. Four of the five include significant irrigation holdings. About 9% of land in the region is irrigated, with the actual area varying with annual allocations. Water is sourced from the Murrumbidgee and Lachlan Rivers and associated alluvial aquifer systems. About half of the region's over $800 million in gross value of agricultural production (2005-06) is generated through irrigation. The region's 'agricultural' economy (including farming, food and beverage production, water and services to agriculture) accounts for about 38% of the total regional value added production and 34% of employment (2009-10).

Drivers of change

The region's reliance on its farming and food production sectors means that it is highly exposed to influences that affect its capacity for agricultural production, the demand and price for its farm and food products and the costs of production. The key drivers of change therefore include: climate variability and climate change; the global economy and its influence on interest and currency exchange rates and agricultural commodity and energy prices; and policies that influence irrigation water allocations and trade.

Future risks and opportunities

Critical future risks for the region, identified by local stakeholders, are associated with climate and/or policy influenced step changes in water availability: the latter including those through the proposed Murray-Darling Basin Plan (MDBP). Such changes would significantly affect economic activity and, as evidenced by the recent drought, lead to the loss of people, employment, wealth and investment.

A variety of opportunities exist for the region's future, including generating increased value from water. While non-agricultural economic development opportunities exist experience indicates that these take considerable time to bring to fruition and are unlikely to offset expected losses associated the MDBP or recurrence of the recent drought.

TITLE EFFECTS OF RISING CO_2 CONCENTRATION ON WATER USE EFFICIENCY OF *EUCALYPTUS SALIGNA*.

Theme Landscapes and Water
Primary Author Dr Craig Barton
Institution Industry and Investment NSW
Email Craig.Barton@Industry.nsw.gov.au
Co-Authors M. Adams, J. Conroy, R. Duursma, D. Eamus, D. Ellsworth, S. Linder, B. Medlyn, D. Tissue, R. McMurtrie
Key search words Elevated CO_2, Climate change, Water Use Efficiency

The Hawkesbury Forest Experiment in Sydney has investigated the effects of elevated [CO_2] on young *E. saligna* trees growing in large environmentally controlled whole tree chambers (WTC). Temperature and humidity in the 12 WTCs were regulated to follow ambient conditions at the site. The [CO_2] in six chambers tracked the outside ambient [CO_2] while [CO_2] in the other six chambers was elevated by 240 ppm. The WTCs monitored the CO_2 and water exchange of the whole tree canopy and provided measurements of CO_2 and water fluxes every 14 minutes (see Barton et al 2010). A single *E. saligna* seedling was planted into the centre of each WTC and grown from seedling to 9 m tall tree over two years.

Results from whole tree gas exchange show that whole tree instantaneous transpiration use efficiency, the ratio of carbon assimilated to water lost through transpiration, increased under elevated [CO_2]. The increased water use efficiency results from a combination of a reduction in water used and a small increase in carbon fixed per unit leaf area. The relative contribution of these two components depends on the temperature. A large down-regulation of photosynthetic capacity was observed along with stomatal closure in response to elevated [CO_2]. The results are consistent with theoretical predictions in that the increase in instantaneous transpiration efficiency under elevated CO_2 was proportional to the increase in the CO_2 concentration. Potential implications of the results for forest productivity and hydrology will be discussed.

Craig V.M. Barton, David S. Ellsworth, Belinda E. Medlyn, Remko A. Duursma, David T. Tissue,
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TITLE DRAWING LESSONS FOR CLIMATE CHANGE ADAPTATION FROM RECURRENT DROUGHTS IN AUSTRALIAN PLANTATION FORESTS

Theme Water and Landscapes

Primary Author Prof. Richard Harper
Institution Murdoch University
Email r.harper@murdoch.edu.au
Co-Authors John McGrath (CRC FFI), Keith Smettem (UWA), Don McGuire (ForestrySA), Tom Baker (Univ. Melbourne), Brad Evans (Murdoch)

Key search words Eucalyptus, Pinus, plantation, water balance

Australia has 2 million ha of predominantly Pinus and Eucalyptus plantations, with these producing sawlogs or pulpwood. Many of these plantations are in areas with >700 mm annual rainfall in southern Australia and were developed in two phases. Softwood plantations expanded between 1950 and 1980 and eucalypt plantations between 1990 and 2005. There has been some recent plantation expansion into drier areas for new industries such as carbon sequestration and biodiversity conservation

It is predicted that the climate of southern Australia will become drier as a result of climate change and consequently forest managers will need to adapt management systems to accommodate a drier climate. Australia's plantations have been subject to both regional reductions in rainfall and recurrent droughts. The droughts in particular have affected both tree growth and survival, with total stand collapse in extreme circumstances.

In this paper we test the concept that the knowledge developed in response to both extended dry periods and recurrent droughts by Australia's forest managers will provide insights for future climate change adaptation. We draw on specific examples from plantations across southern Australia, and in particular examine the response of managers, and the role of ongoing research and development in enabling adaptation.

Adaptation to recurrent droughts has occurred both as a result of research into specific issues or through adaptive management particularly during phases of rapid plantation expansion into new growing environments. The main adaptive responses have included:

(a) *Modification of site selection procedures*. While it has been recognised that climate provides the overall limitation to plantation potential certain soils, and particularly those with poor overall water holding capacity are inappropriate for plantations.

(b) *Species selection*. Different species have different optimum distributions and there are examples of species with a greater capacity to tolerate water stress being substituted. Attempts have been made to select drought tolerance in various species, with different degrees of success.

(c) *Restricting tree water use*. This is achieved by reducing leaf area through reducing initial stocking and subsequently thinning and pruning plantations, limiting leaf growth by reducing fertilizer inputs. In drier areas strips of trees have been promoted, with these drawing on water from the adjacent farmland,

The approach of using previous droughts as an analogue of future change may have some limitations. Climate change may result in new interactions (e.g. between rising CO_2 concentrations and water use efficiency) or in the emergence of new pests and diseases. Nonetheless, we suggest that previous periods of drought in Australian plantations may provide some lessons for future climate change adaptation for the plantation industry.

TITLE THE ROLE OF CLIMATE VARIABILITY AND CLIMATE CHANGE IN NSW WATER SHARING ARRANGEMENTS

Theme Water and Landscapes
Primary Author Richard Beecham
Institution NSW Office of Water
Email Richard.Beecham@water.nsw.gov.au
Co-Authors Shahadat Chowdhury and Mark Harris
Key search words NSW, inflows, planning, water-sharing

Climate variability has long been a core consideration in developing water sharing arrangements for rural catchments in NSW. The increased attention to climate change as well as the recent long drought in south-east Australia has resulted in calls to include projections of changes to climate in this process. There are technical as well as planning challenges in doing this, and the NSW government is identifying and assessing options.

The NSW Government advocates an adaptive approach to water planning and management, with the objective of achieving an equitable balance between water for environmental purposes and for consumptive use. Decadal water sharing plans are developed in consultation with stakeholders, with temporal distribution of water availability and use informed by climatically driven water resource management computer models. Once a water sharing plan is set in place, water use and environmental flows for the remaining decade are ultimately determined by the weather.

Subject to the rules in these plans, irrigators use a higher percentage of inflows during drier years, and a lower percentage during wetter years. Examples of this include the Namoi Valley, which uses 55% of inflows over the ten driest years, 20% during the wettest ten years, and 35% for the whole period of record. The corresponding figures for the Lachlan Valley are 60%, 25%, 35%. This characteristic is reflected in the sensitivity analysis of GCM derived climate projections in the CSIRO Sustainable Yields Project.

The decadal plans allow an adaptive approach, to varying degrees. Whilst some existing plan rules self adjust as new information becomes available, other rules can be amended. Our experience with the first round of plans is that they need to be more flexible to allow for their continued operation during a greater range of water availability and climate scenarios.

What these climate scenarios should be and how they should be used in water planning is an evolving science, especially as there is still considerable uncertainty in GCM based precipitation projections. The Guide to the Draft Basin Plan includes a proposal that requires maintaining ratios of consumptive water use to water availability across the full spectrum of dry and wet periods. Basing water sharing arrangements solely on a conservatively dry climate scenario would result in surplus water returning to the environment than would be otherwise required as well as greater impacts for consumptive water users, whereas basing it on an optimistically wetter scenario could lead to overinvestment and lower environmental flows than required.

The approach advocated in the recent NWC discussion paper has merit, where a series of plausible climate scenarios are used to identify weakness in water management systems, so as to develop appropriate management responses. NSW Office of Water is investigating different options to develop these climate scenarios. The natural variability in the historical record is still an appropriate starting point. Some palaeological information may also help to better understand the natural variability of droughts. GCM results contain useful information, and different downscaling techniques are of interest, including the daily scaled work proposed by MDBA, recently completed statistically downscaled results, and proposals to develop high resolution dynamically down scaled results from regional climate models. However GCM projections lack adequate length of realisations required to ascertain the probability and the corresponding impact of extreme drought within the decadal planning time window.

TITLE RESPONDING TO CLIMATE CHANGE ON THE EYRE PENINSULA

Theme Water and Landscapes
Primary Author Mr Mark Stanley
Institution Eyre Peninsula Natural Resources Management Board
Email Mark.stanley@epnrm.com.au
Co-Authors Mr Peter R Day
Key search words Climate change, communities, research

Introduction

Communities, primary producers and natural resource managers on the Eyre Peninsula all confront the risks, uncertainties and opportunities of a changing climate. The Eyre Peninsula Natural Resources Management Board has encouraged local research into climate change to help people manage these risks and to plan for a more sustainable and productive future. This research has been in partnership with a range of organisations including the CSIRO, SARDI at Minnipa Agricultural Centre, the Universities of Adelaide and South Australia, Flinders University, Rural Solutions SA and Greening Australia.

Climate change predictions

The Earth's atmosphere is changing. Greenhouse gas levels are rising and climatologists believe this is trapping heat in our atmosphere and causing changes to our climate and oceans. Predicting climate change is not an exact science, but there is a high degree of confidence among climate researchers that the planet will continue to heat up as more greenhouse gases are emitted. Computerised climate change models predict that over the coming decades, Eyre Peninsula will experience:

- higher temperatures;
- less rainfall (with longer and more frequent droughts, but possibly more heavy rain events); and
- increased evaporation.

Global warming will cause sea levels to continue rising and increased carbon dioxide (CO_2) in the atmosphere will result in increased CO_2 concentrations in the oceans, causing them to become more acidic.

If the Eyre Peninsula's climate changes as predicted, it will affect the environment, communities and regional economy:

- crucial groundwater resources may become stressed and require special management;
- changes may be necessary in the biggest land use - agriculture;
- natural ecosystems and native species will come under increased pressure; and
- a rise in sea levels and changes in the ocean will affect coastal developments and townships, marine life, and the aquaculture and fishing industries.

Risks and opportunities

All change brings both risks and opportunities. The Eyre Peninsula Natural Resources Management Board has encouraged local research into climate change so the community can understand the potential risks and the opportunities that may emerge. Research helps identify what to monitor so that we can better gauge the direction and rate of any future change. This will allow people in the region to make informed decisions about how they manage risk and capitalise on opportunities. Communities on Eyre Peninsula have long experience in coping with drought and climate variability and in managing scarce water supplies, which places them at an advantage in dealing with climate change. Understanding the possible nature of climate change is central to planning for a sustainable and productive future - for individuals, businesses, industries, communities and the region.

TITLE MAINTAINING "WRIGGLE ROOM" IN CONTESTED SPACE: THE MISSING SPATIAL DIMENSION IN ADAPTATION STRATEGIES FOR AGRICULTURE

Theme Landscapes
Primary Author Mr Peter Houston
Institution Department of Primary Industries and Resources, South Australia
Email peter.houston@sa.gov.au
Co-Authors Mr Gerry Davies
Key search words land use policy, land use planning, peri-urban, amenity landscapes

Introduction

A feature of adaptation strategies in the agriculture sector is the absence of references to either the spatial implications of changing regional circumstances, or to land use policy. Whereas strategies for the NRM sector propose corridors for biodiversity migration, and those for sea-level rise anticipate special measures for low-lying coastal areas, strategies in the agriculture sector are different. With few exceptions, they seem to assume adaptation occuring *in situ*; a continuation of "pole position" in regard to access to land, water and infrastructure assets; and unfettered scope for adoption of new technologies in local settings.

Such assumptions may well hold in the more remote parts of Australia. However, in environmentally favoured regions where population is concentrated, and especially in peri-urban regions and so-called amenity landscapes, they will likely be challenged. These regions are where the effects of projected national population growth will be most evident, even allowing for heroic assumptions about more compact urban form. Furthermore, as illustrated in the Adelaide & Mt Lofty Ranges NRM region, agriculture is not alone in this space: the demands of biodiversity protection, environmental flows and water catchment functions also have to be considered (Bardsley and Sweeney, 2010).

Despite the challenges, negotiating secure space for agriculture in such circumstances is important. These regions generate a disproportionately large share of production value nationally (Houston 2005). They also appear to hold some strategic opportunities for adapting to anticipated climate change. Besides providing a generally cooler, wetter buffer to projected hotter, drier conditions, opportunities include: 1) access to the reclaimed waste streams of urban areas, in particular treated wastewater; and 2) scope for minimizing transport costs and CO_2 emissions in the face of an uncertain energy and carbon future.

However, emerging evidence provides cause for concern. Using examples at three distinct scales in the Greater Adelaide region – a region which generates 25% of South Australia's gross value of agricultural production – this paper illustrates circumstances that seem likely to jeopardize current adaptation efforts and investment. Case studies include: rural dwelling construction activity on land zoned for agriculture across the Outer Metropolitan region; urban encroachment into one of SA's major vegetable production areas; and the increasing use of Environmental Covers intended to protect horticultural crops in high amenity areas.

The paper concludes with a proposal that the evolving greenhouse strategies and agri-food policies of government include more explicit attention to: 1) policy governing the asset base for agricultural production; and 2) the local regulatory environment for food, wine and fibre businesses in these increasingly contested settings.

TITLE DESIGNING AUSTRALIAN LANDSCAPES FOR CLIMATE CHANGE WITHIN NATURAL, ECONOMIC AND INSTITUTIONAL RESOURCE CONSTRAINTS

Theme Landscapes
Primary Author Prof Wayne Meyer
Institution University of Adelaide
Email Wayne.meyer@adelaide.edu.au
Co-Authors Brett Bryan, Bart Kellett, Dave Summers, Greg Lyle
Key search words Landscape Futures analysis, Transformational land use change

Farming significantly changes many landscape characteristics; particularly those associated with water balance, water distribution, vegetation and soil properties. Developing renewable agriculture requires that flows of water, carbon, nutrients and energy in the production ecosystem be well matched to the flows that have occurred in the landscape as a consequence of its evolution through geological time (Williams, 1991). Significant perturbations of these flows will likely result in production systems that are poorly adapted to the immediate environment and hence will require large, energy intensive interventions to maintain the system. With the coincidence of effects from a warming and possibly drying climate, the imminent costs of peak oil and peak phosphate and the legacy of agricultural practices that have fundamentally changed the landscape we are faced with unprecedented challenges. Adaptation to these challenges will need more than ongoing incremental change. Transformational interventions will almost certainly be needed.

The recent recognition of regional natural resource management (NRM) regions in Australia correctly identifies the vested interest that regional populations should have in the condition of the natural resources of their immediate environment. Given the rapidly emerging challenges it seems important to develop capability that can identify the management options to assist adaptation. This capability will need to incorporate bio-physical and socio-economic process understanding into descriptions of multi-functional landscapes. The aim is to identify the options for future mixing and matching of land uses that will give both agricultural production and biodiversity conservation for the region with the best chance of adapting to changing climate and market conditions and community expectations.

It is possible to define a system of land use that is close to reaching critical component balances within natural resource constraints. In irrigated areas for example very well controlled water and nutrient additions together with careful placement and intensity of irrigation around the landscape can be shown to meet water and nutrient balances (Khan et al., 2003). However the chance that these changes will be implemented is low because of economic, social and institutional impediments. As Walker et al. (2009) concluded, only with transformational attitude and institutional change will this be possible. In another social ecological system study of rain fed agriculture (Bryan et al., 2007) it was demonstrated that many land use distribution options exist that would meet the natural resource conservation and community expectations.

We identify the constraints and opportunities that several NRM regions are working with and show how landscape futures analysis can help define options for multi objective land use. Increasing the awareness of and influencing the decision makers is the next challenge.

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THEME

SOCIO-ECONOMIC

SYNTHESIS PAPER

TITLE SOCIO-ECONOMIC FACTORS RELATING TO AGRICULTURE AND COMMUNITY DEVELOPMENT

Theme Socio Economic

Primary Author Professor Margaret Alston
Institution Monash University
Email Margaret.Alston@med.monash.edu.au

Introduction

For much of the 2000s the environmental and economic impacts of climate change have dominated discussions and commentary relating to agriculture and rural communities. Most recently this has centred on the Water Act and the federal government's Murray-Darling Basin Authority plan to withdraw water from irrigators in the Murray-Darling Basin (MDB) area and return it to the environment. Understandably this has resulted in considerable tensions amongst critical stakeholders with conflicting views on the priority to be given to the socio-economic impacts for the affected areas.

The anger expressed by rural people in the MDB illustrates that social outcomes of climate variability in rural areas have been given inadequate policy consideration by governments and policy makers. This indicates institutional miscreancy (or lazy politics) and benign neglect and an unspoken expectation that less populated rural areas will bear the burden of climate change actions (Molnar 2010: 12). This paper outlines both the reasons why the lack of consideration of the socio-economic factors is derelict and a vision of policy for rural people and places. It gives substance to ongoing social changes in agriculture and rural Australia and indicates strategies for governments, policy makers, agricultural leaders, farming families, community groups and individuals to ensure that Australians living and working in rural areas are not carrying an unfair burden of climate change action and can be assisted to adapt to a more viable and positive future.

Of note is that, regardless of climate change events, significant restructuring has been occurring in agriculture and rural communities over at least the last half century. This restructuring has been linked to a number of factors unrelated to climate variability including technological developments, new production techniques, rising fuel prices, changing industry developments, capital intensive agriculture replacing labour intensive practices, farm workforce decline, population out-migration, significant changes in rural demographics and declining service delivery. As a consequence, rural areas have been in a state of seemingly constant change despite agriculture underpinning much of the industry base of rural and remote Australia. It would be wrong to assume therefore that climate change / variability has been the overarching catalyst for change in agriculture and rural communities. Rather, it is one of a number of forces shaping our inland communities, albeit a very significant and largely unpredictable one.

The critical point I want to make in this paper is that agriculture and rural policy responses must acknowledge and attend to long-standing socio-economic changes as well as those emerging as a result of climate variability. Unpredictability and uncertainty does not excuse inaction on the part of policy makers and politicians to the social condition of rural people and places.

Why should social issues affecting rural people and communities be prioritised? There are several reasons why the socio-economic issues relating to agriculture and rural communities must be prioritised. These include:

- environmental stewardship is dependent on rural Australians acting responsibly in the national interest;
- rural Australians are at the pointy end of climate impacts and must be supported to address these challenges;
- our biosecurity is dependent on adequate attention to rural people and places;
- citizenship rights of rural people carry as much weight in our constitution although perhaps not so much in our ballot box;
- rural people are being held back from achieving their potential because of constraints on their access to services; and
- rural people need certainty to allay their anxieties.

A diverse agricultural base – protecting our environment

Environmental stewardship and protection of our landscape are dependent on our rural people. While the environmental movement has been highly successful in alerting the community to the need for environmental action, it is rural people who will implement and absorb much of the change. The problem for rural people is that the environmental movement has captured the attention of the community and, by contrast, rural people are unfairly portrayed as environmental vandals. There is room for movement on both sides for the good of rural people and places - farming organisations to acknowledge the significant messages of environmental organisations and for these organisations in turn to respect the lives, work and circumstances of rural people.

Before discussing the socio-economic impact of change, it is important that we acknowledge the complexity and diversity of rural Australia. The inland areas are home to approximately 16% of Australians in a vast, sparsely populated area. Differential forces are shaping development in more remote areas as opposed to those close to regional centres and capital cities. In more remote areas and the further one moves from a capital city, there is an increasing tendency for farms to be becoming larger and therefore for traditional farming families and farm workers to be leaving in large numbers from what were once closely settled areas. As a result these remoter areas are experiencing significant population decline and a changing demographic profile.

Communities which serve these areas are under pressure because of the decline in the numbers of farm families, farm workers and their families, and supporting professionals such as teachers and health professionals. Those communities most likely to be negatively affected are towns with populations of less than 10 000 (particularly those with less than 4000) and communities more distant from regional service centres. These communities are struggling with a declining and aging population base and a loss of service infrastructure.

In stark contrast, areas on the edge of regional centres and capital cities are experiencing a growth of peri-urban development, as well-resourced and skilled tree-changers move in and settle on small acreages at the edge of large well-serviced communities. Many of these families bring resources, are dependent on off-farm income and view farming as secondary to lifestyle. These regional areas are growing more rapidly, attracting expertise and resources and moving beyond a dependence on agricultural production. They are also experiencing a growth in services that provide a further attraction for new people with skills and ideas. Nonetheless there is evidence in these communities of a clash of cultural expectations in relation to farming practices that does cause division and divided expectations. Cultural clashes are also evident within and between groups – for example, long term residents who have a long history of familial settlement in these areas and those newcomers who have no familial ties to an area and no long-standing place-based connection.

Lynne Strong's case study paper details the issues facing farm families who are committed to farming in these peri-urban areas. She details cultural clashes between lifestyle dwellers and farmers but also the opportunities for families like hers to lease vast areas of under-producing but high quality land from these families. This has given her family a significant and bountiful area of land. Her message is to adopt 'smart farming' techniques – for them this has also meant improving pastures and improving the genetic merit of their dairy herd in order to increase production in an area where expansion is limited,

In summary there are significant and diverse trends evident in agriculture and rural communities dependent largely on place-based amenity, lifestyle factors and access to services and shaped by growing diversity in populations. More remote communities are changing, contracting and experiencing significant decline in services and are marked by poverty and social exclusion. Larger communities and those closer to cities are expanding, diversifying their income base and becoming lifestyle retreats. These trends have been underway for some time and the impacts of climate change overlay this unstoppable and ongoing restructuring.

Climate change impacts

Climate variability is adding significant uncertainty to changes already underway. Globally climate change impacts are creating major social problems. Rising temperatures on land and sea, unseasonable climate variability, widespread droughts, heavy rains and more intense cyclones, heat waves, changing cropping cycles, changes in rainfall patterns, greater erosion and more bushfires are just some of the predicted outcomes of the build up greenhouse gas emissions in the atmosphere. The potential impacts on food supply and a secure agricultural base are evident. These impacts are compounded by predictions that the world's population will rise to 9 billion by 2050 placing even greater pressure on already stretched resources.

Australia has experienced both incremental climate variability as a consequence of drought, and catastrophic climate events typified by extreme weather events such as floods and bushfires. Catastrophic events have also resulted in significant loss of life in many areas including the Victorian bushfire areas. Over our 2010/2011 summer many areas of Australia experienced unseasonal and significant flooding events, events that have placed extraordinary pressure on communities and people and led to major loss of property, crops, homes and businesses. These unpredictable events are changing the face of rural areas as they reduce the resilience of people and community to address what is often catastrophic change. They also add tension to the ongoing process of change and reduce the economic viability of areas and the social cohesion of its members. Businesses are destroyed, jobs are lost, services are reduced or inaccessible and people may be in crisis accommodation for significant periods of time.

Climate impacts are of major concern for Indigenous people whose see their country and significant sites destroyed or diminished. Writing this I am conscious that the small, town of Goodooga in northern NSW, with a predominantly Indigenous population is about to be cut off by flood waters for up to six weeks. Attachment to place is strong, people are very reluctant to leave and yet, ensuring supplies into the area will be problematic. The impact of climate events on Indigenous Australians is an under-researched area.

Socio-economic factors – agriculture and rural communities

As agriculture adapts to changing circumstances, so too do the social relations that govern this dominant Australian industry. Over 90% of farms are still run by farm families making this the main mode of production. As farms become bigger in rural and remote areas, these larger-than-family farms are run by families with assistance from hired labour or by large corporate entities run by managers with assistance from a small poorly paid workforce. This point is worth making as the families of isolated workers may not have the same access to education in remote areas. In the past educational access has been highly dependent on financial access to boarding schools and tertiary institutions and the unacknowledged efforts of mothers who have found the time and resources to home school their children. Our research suggests that some children are slipping through the net because their parents may not have the time and capacity to ensure that regular lessons are conducted - often because both partners, as well as the children, may be working regularly on properties. Children may also be denied access to high school and tertiary education because of a lack of financial means to send them to boarding school (Alston and Kent 2006).

The growing size of remote area farms has several additional social consequences including, as farm families leave, a decline in numbers of children at small schools, small school closures, closure of school bus routes, decline of small communities, high numbers of empty farm houses, reduced road maintenance, low levels of telecommunications access, greater likelihood that women may move away for work and so their children can access education and greater social isolation for those remaining.

By contrast the peri-urban fringe lifestyle farms are becoming smaller and are usually run with support of off-farm income. There is a high level of diversification evident in these peri-urban areas as newcomers introduce new crops, animals and/ or value-added product.

In between the two extremes are the bulk of farms run by families with little or no farm labour and reliant on family to undertake the critical tasks associated with running a working, productive farm. These families are critical to social capital in their communities as they contribute a great deal of unpaid work to their communities in a voluntary capacity and in a number of organisations and services. More recently this additional contribution to community is under stress as these family farms are increasingly dependent on off-farm income. This is usually provided by the female partner working in the local town, regional centre or capital city.

During the past decade of drought, this off-farm income has become critical for families to survive in agriculture but is not often acknowledged as key to a viable agricultural industry. It may not be too far from the truth to say that the profitability of Australian agriculture rests heavily on the shoulders of women. What is also of note is that volunteer work is declining because of time pressures experienced by these family members. Nonetheless our research reveals that women in small communities take these voluntary duties seriously and time-poor women are conflicted by competing priorities. These time conflicts create trauma for families trying to juggle the needs of their communities with their family's need for income. Elsewhere I have argued there is a case for critical community work to be paid and for public and private sector organisations to negotiate with workers to ensure essential voluntary community work is incorporated into workforce wages.

The Australian Bureau of Statistics (ABS) Socio-Economic Indexes for Areas (SEIFA) are locality-based measures of social disadvantage. Australia's rural areas are significantly over-represented amongst the lowest bands of SEIFA. A brief and generalised assessment of socio-economic indicators for rural and remote communities reveals the extent to which citizenship rights of rural people and places have been eroded. There are increasing levels of poverty, significant out-migration of young people for work and education, and of workers and their families displaced by drought. There are static or declining populations in more remote communities, a gendered trend in out-migration is resulting in more remote communities becoming masculinised, higher levels of unemployment or precarious attachment to the labour force, poorer health on a number of indicators, higher morbidity including from road accidents and suicide, lower life expectancy, lower levels of education, a higher proportion of aged citizens and lower levels of service delivery. Women are working at much the same rates as their city cousins, but there are fewer aged, child and disability care services. There are also fewer public transport options, telecommunications are patchy and services are more costly.

More remote communities have a growing proportion of Indigenous people and an in-migration drift of welfare dependent people seeking cheap housing. These communities are experiencing increasing levels of poverty and higher levels of violence as the numbers of socially excluded people with few job opportunities and reduced services grow. Remote inland communities are sites for growing disaffection and alienation as poor services and poverty compound reduced expectations.

Many small community hospitals have closed or offer only basic services, often excluding essential services such as birthing care. Mental health has been identified as a significant factor in rural areas and particularly amongst rural men by the National Beyond Blue organisation and yet mental health servicing is at best poor. Where high schools are available they may offer fewer subjects and /or subjects by distance education and, as numbers decline, so too do teacher numbers. The numbers of rural young people accessing higher education has been declining markedly during the drought period as financial pressures reduce a family's ability to support one or more young people away from home and access to Youth Allowance is unfairly limited for rural young people. Thus it is little wonder that the proportion of the population with a post-school qualification declines as remoteness increases (references for these factors can be found in Alston 2009).

Farm workers leaving with their families have created significant and dramatic declines in the numbers of students in schools. Blackall, for instance saw a reduction of 100 students from their central school in a twelve month period – from 350 to 250. This has major implications for staffing as teacher numbers are dependent on student numbers. Many teachers lose their positions, subject offerings are reduced, some students are forced to take their subjects by distance education, and many students lose close friends – all within a short period of time. These social impacts experienced by children are under-researched. What we do know from our research (and here I'm not referring to Blackall) is that teachers are expressing increased concern for the mental well-being of children in their schools because they are absorbing the impacts of significant change within their families, schools and communities with little formal support and a perception that their life chances are being reduced by climate events (Alston and Kent 2006).

Nonetheless, there is no doubt that agriculture and rural people and communities have been significantly destabilised by climate variability and climate events and this adds to the uncertainty and social complexities in rural life. Over the last decade this has taken the form of a major drought as well as catastrophic events such as fires, floods, cyclones, and dust storms. The recent events in response to the Murray-Darling Basin Authority's guide to its water plan suggest that this has become a focal point for those who are disaffected by long years of government inaction to significant hardship, a lack of planning for the future and a lack of direction from governments on ways communities and people in affected areas might be supported to a more positive future. The unpredictability of the extent of change and the lack of certainty in climate science confounds people reliant on agriculture and the communities that support them, rendering them somewhat helpless to make determined decisions about their futures. Thus the resilience of rural people and communities is significantly eroded and they are searching for support and guidance to move through what are major change processes.

Human Service providers

Rural Australia is serviced by an army of human service providers working in health, education, emergency services and welfare support. These workers often carry high caseloads, work with limited resources, cover vast areas, have few colleagues, may be supervised from distant regional centres and often must determine how to provide services to highly stressed populations. It is not unusual to find farm family members, often the female partner, working in health and education areas. These women speak of carrying the burden of their personal situation and of hearing similar issues from their clients / patients in their workplace. Supervisors are aware of this additional stress on workers and assist where possible to allow women to juggle the burdens of their busy lives (Alston and Kent 2004; Alston and Whittenbury 2010).

Rohena Duncombe's case study paper reveals her long years of experience working as a rural health professional in rural Australia. She notes that climate events have added significant stress to farm family members because of the uncertainty and unpredictability of climate variability. The rise in suicides is well documented. What is not so well understood is that the low mood of primary producers adds significant stress to family members. In recent times as the drought and other climate events have further destabilised these areas and the mental health of rural people is further compromised, the work of human service providers has become much more complex. The impacts on children are under-researched and the use of self-medication in the form of drugs and alcohol be farm family members is well understood by health workers. Attracting and retaining service workers is an issue and accessing specialist care is a significant problem for rural people.

Our research also reveals that rural human services are often under-funded or that the barriers to service delivery are misunderstood by regional administrators. For workers at the coal-face, a limited resource base makes it difficult to prioritise services. Nonetheless rural Australia is home to significant innovative human service practice and it is not unusual for service workers to work together in creative ways to assist people in their areas. Yet funding is a constant barrier to providing optimal service. Our research also reveals that charities bear an unfair burden of service provision in rural areas and it is not unusual for organisations such as the Salvation Army and St Vincent de Paul to be providing basic services. Among the most trusted workers are the financial counsellors who work with families to develop future plans (Alston and Kent 2004; Alston and Whitney-Soanes 2008). Adding to the complexity of service support is the lack of comprehensive rural social policy.

Policy shortcomings

The community response to the MDBA guide to the Basin Plan demonstrates that communities are feeling alienated and disaffected and that policy development and implementation is flawed. While it is important to note that anger at the lack of attention to long-standing social issues in rural areas has been simmering, there is a real sense that informed consultation has not taken place and that policy has been imposed from above. There is also a widespread feeling that governments and policymakers do not understand the culture of farming life and rural communities. There is an unrelenting sense that what passes for process is a one way giving of information rather than an informed exchange and consultation.

Policy relating to agriculture and rural communities has been at best haphazard and marked by short term programs and policies and a lack of determined commitment to vision a future for agriculture that is embedded in viable rural communities. For example, there has been an historical trend to view rural policy as indivisible from agricultural policy and this has resulted in a lack of attention to the social needs of people engaged in, or supporting, agricultural industries. These policies demonstrate a benign neglect and active exploitation of rural people and places (Molnar 2010). What is lacking is an engagement with place – or what Shucksmith (2009) calls place-shaping. Policy must be constructed on a territorial rather than sectoral basis, and acknowledge the multifunctional nature of our rural areas. These are places that are essential to our national environmental well-being, to our food security and national wealth, to our sense of who we are as a people. Ignoring their place in our national policy vision is derelict at best.

Resilience is defined by Eckersley (2009) as the ability of people to respond positively to adversity. Positive adaptation to change is critical to the ability of people and places to manage resilience with intent (Gooch and Warburton 2009). What is needed is policy that is grounded in rural experience, and which enhances rather than erodes resilience. A failure of metagovernance, or the governance of government (Bell and Quiggin 2008), has restricted our nation's ability to transform to more desirable futures in rural areas because positive futures are highly dependent on governments being deeply engaged. What is needed is to 'bring government back in' to the policy process, having an overarching role in goal setting, coordination, information exchange, risk management and resourcing (Bell and Quiggin 2008: 74). Such a role would assist in the building of resilience, helping people and communities to adapt, aid the transformability of communities to positive futures and provide knowledge and resources to build trust between stakeholders. This role would includes fostering inclusive partnerships (Shucksmith 2009) between government, non-government and voluntary sectors, a factor that would assist these communities to move through very difficult times and to adjust in a supportive environment. In other words - there is a need for governments to do more 'heavy lifting' (Bell and Quiggin 2008: 727).

Adaptation to climate change

Globally two divergent policy responses to climate change include mitigation strategies – or reducing as much as possible the effects of climate change – and adaptation strategies - which include strategies to assist people to respond to inevitable change. In the context of rural Australia, mitigation strategies might include reducing water for irrigation, introducing efficiency measures, growing different crops and monitoring extreme weather events. Adaptation strategies might include targeting particular irrigation areas to be dryland farming only, changing cropping and livestock patterns, reducing farming in marginal areas and rewarding famers for environmental stewardship work.

Social adaptations being adopted by farming families and communities in the short term include:

- generating income off-farm to ensure the family can remain in farming;
- men working in isolation while their families live and work away;
- reduced attention to health care;
- rising levels of mental health and stress but a lack of help-seeking behaviour;
- alcohol and drugs being used for self-medication for stress;
- young people leaving for a future elsewhere;
- young people dropping out of school;
- small business closures or reduction / casualisation of employees;
- small businesses operating as quasi-banks; and
- gender implications leading to differential experiences for men and women.

These adaptations are occurring incrementally and with limited purposeful policy to develop sustainable futures for families and communities.

Further, there are significant resistances to exit packages and to moving away from farming which should be understood in a social and cultural sense. Farming land has often been passed to sons through patrilineal inheritance practices and there is a strong sense of masculine identity being located in the male farming occupational status. To exit is to lose far more than land and occupation. It also involves a loss if identity and a fear of the future that must be acknowledged in policy parameters. At the same time our research indicates that women are more likely to want to receive funding from the water buyback scheme and from exit based grants. For them, this means a retreat from an unending working life and a future that looks much easier for themselves and their children. Understanding gendered experiences is a critical part of policy development.

A vision for rural Australia

What is needed to achieve our objectives of a viable rural Australia where climate impacts are addressed responsibly, where citizenship rights are recognised, where people have access to services to achieve their potential, is a visionary rural social policy development process.

There are obvious policy gaps relating to social imperatives in rural Australia that should be addressed immediately. These include making Youth Allowance available to any young person from a rural area who must leave home to complete their studies; ensuring that health services are adequate and include antenatal and birthing care provided by midwives; health and welfare service support in the form of funding, adequate staffing and staff supervision and making use of technological advances to provide further expert advice; state of the art telecommunications and telecommunications hubs in small towns; accessible and affordable public transport.

In the medium term, local governments should be funded to auspice social inclusion committees that employ community development workers. The role of these workers would be to assist communities to develop plans for their regions that assist growth and development, and build human and social capital. Their role would also encompass writing grants for competitive government funding for community programs and alternative industry development.

In the long term federal and state governments must work to develop a future vision for rural areas that addresses the socio-economic needs of people in these communities, and environmental protection for our damaged landscapes. Part of the government's 'heavy lifting' requires development of a rural plan detailing:

- a vision for rural and remote areas in the light of climate change, ongoing social change and reduced water availability;
- a vision that acknowledges diversity in agriculture, small business and rural communities;
- a vision that prioritises people;
- a vision that enhances resilience, family well-being and community capacity;
- social inclusion strategies;
- new models of governance characterised by inclusive partnerships between governments, non-government organisations and the private sector;
- greater community participation in policy and place shaping, more transparent community consultation and information exchange, and an acknowledgement that rural people are experts in their own lives;
- thick and comprehensive human services and supported environments for human service workers;

- a commitment to rural people and communities through a vision for change and the supports that will be provided to people in these communities to achieve this change;
- the supports - financial, services and infrastructure - that will be needed to assist people to informed choices about their futures;
- a plan for the future of rural and remote areas;
- an acknowledgement that the people in these communities cannot address the future unaided while there is such uncertainty over their industries, communities and people;
- an investment in human capital so that people in rural areas can achieve their potential and access education / retraining to achieve their ambitions;
- a fund that provides investment funding to rural communities to establish new directions for change;
- a social taskforce to be established to oversee the vision, the investment in rural people and communities and the change management process; and
- the establishment of a new, well-funded model of Human Services practice that values and builds rural community capacity and acknowledges and values voluntary contributions through workforce practices.

However this is not just the role for governments. There is a need for agricultural and rural community organisations and women's groups to advocate for rural areas and their members; there is a need for businesses and private enterprise to address and resource rural needs; there is a need for farming families and rural community members to work together to determine their immediate social requirements and to develop future strategies and there is a need for individuals to provide leadership and vision for their communities.

A positive future for rural people and communities

There is no doubt that rural and remote communities are going through a rapid period of change. While this process has been ongoing, the impact of climate events and the uncertainty this creates, has eroded the resilience and well-being of rural people and communities and degraded our landscapes. There is a sense amongst rural people that their views have been ignored, that they are somehow responsible for the environmental concerns of the community and that they are being asked to bear the brunt of government policies to address climate change adaptation. This has led to a growing sense of alienation from governments and from the rest of the community and a growing sense of distrust of governments and institutional mechanisms. Rural and remote people feel disenfranchised. This paper has outlined socio-economic factors that indicate rural Australians are slipping behind on a number of indicators of well-being. Previous government policies have focused on letting the market decide the future of rural areas and advocating self-reliance and a 'do it yourself' mantra for rural people. Climate change is exposing the need for governments to be much more engaged in assisting communities under threat of major social dislocation to re-vision their futures.

What farm families and those living and working in rural communities expect from governments is a commitment to fearless and visionary rural policy development. Ideally this should be based on current conditions but also draw on the precautionary principle that it is better to be prepared for potential future scenarios than to hope for the best. It must also be responsive to ongoing and constant change and it requires careful planning to ensure that the quality of life and citizenship rights of rural people are not compromised. In developing appropriate policy, governments must ensure they are sensitive to governance practices that are inclusive, partnership-based, supportive and attentive to emerging and ongoing trends. This requires cooperation and respect from farmer organisations, women's groups, environmental bodies and private enterprise to name a few. Without this agriculture and rural communities will change in ways that may be defeatist and divisive and adaptation may be negative and unsustainable.

In attending to rural people and places it is important that diversity is acknowledged and that there is recognition of area variations dependent on industry base, size of farms, where one lives, how close the area is to a centre of regional population growth, demographic variations, income levels and service infrastructure. Resilient people and places are dependent on innovations and adaptations that create sustainable practices and social sustainability. Creating and maintaining a vibrant agriculture is dependent on vibrant communities, well-resourced people, adequate industry and business support, optimal service infrastructure and attention to sensitive policy development that rewards and supports people who live and work in these areas and who have the same citizenship rights as people in the cities.

TITLE OPPORTUNITIES EMERGING FROM CONSUMER LED CHANGES TOWARDS A MORE 'CLIMATE FRIENDLY' DIET

Theme Socio-economic
Primary Author Associate Professor David Pearson
Institution University of Canberra
Email david.pearson@canberra.edu.au
Co-Authors
Key search words Sustainable consumption, consumer, behaviour change, diets

Primary industries in Australia are world class producers of a range of food, fibre, fuel and pharmaceutical products. Organisations and individuals in this industry are able to benefit from new opportunities that will emerge as household food buyer's change their behaviour towards a diet that is more sustainable for the natural environment.

The research presented in this paper is a proof of concept study. Empirical results are from focus group discussions and an online survey with 163 consumers in Canberra. These examined household food buyers understanding of a sustainable diet through investigating factors motivating their food choices and the importance of environmental issues in these decisions. As such they contribute to the emerging literature on sustainable consumption.

The results indicate that consumers have a wide range of perceptions about a sustainable diet as well as specific views about sustainable behaviours in relation to how food is produced, the context and types of food purchases as well as food consumption.

The four highest priority areas identified are:

- reducing consumption of meat,
- reducing consumption of dairy products,
- reducing consumption of low nutritional value products, and
- reducing food waste.

The other, lower priority, behavioural change areas identified are:

- reducing consumption of out-of-season fresh fruits and vegetables,
- reducing consumption of non-sustainable fish,
- reducing consumption of non-organic food,
- reducing energy use associated with food purchases and preparation, and finally,
- reducing consumption of bottled water.

The results indicate that most consumers would like to lead a more environmentally friendly lifestyle but do not know what to do to make their diet more sustainable. Whilst only a very small number of

consumers are proactively engaging in activities to reduce the environmental impact of their diet. This suggests that demand may shift relatively rapidly as information on sustainable diet becomes more widely available. This will impact on all organisations involved in the supply chain for the products associated with these behavioural changes.

In those situations where the trend is towards reducing consumption, the opportunity requires developing a niche marketing strategy which may incorporate premium branded high-value with low-volume products. This could also include demand management via reducing sales through de-marketing and hence targeting only high value customers. Successful examples from other industries include personal banking and social marketing in areas such as reducing domestic water consumption. In addition, the reputation of an industry, as well as an organisation, could be enhanced through proactive engagement in these areas as a form of corporate social responsibility.

In addition, an increase in demand for an alternative product is likely to be associated with the reduction in consumption in the areas previously mentioned. Thus, identification of these substitute products is an important area of opportunity for increasing sales.

In conclusion, research is required to quantify the actual climate change impact of the nine behavioural change areas identified. Combining this with Australia wide market research that profiles current consumer knowledge, and their willingness to change in these areas, will enable determination of the priority areas for climate change adaptation. In addition, undertaking industry based case studies will help to highlight the opportunities for specific organisations in both profiting from a reduction in demand with their existing products and developing supply to meet the increase in demand for substitute products.

TITLE CLOSING THE LOOP – USING ADAPTIVE CAPACITY WORKSHOPS TO PLAN CHANGES TO FARMING ENTERPRISES UNDER PROJECTED CLIMATE CHANGE

Theme Socio-economic
Primary Author Dr Kerry Bridle
Institution Tasmanian Institute of Agricultural Research/CSIRO Ecosystem Sciences
Email Kerry@utas.edu.au
Co-Authors Peter Brown (CSIRO), Shaun Lisson (CSIRO), David Parsons (UTAS), Neil MacLeod (CSIRO)
Key search words Participatory research, adaptive capacity, mixed farming systems, Tasmania

Overview

The Climate Futures Tasmania project is unique in Australia in that it has modelled projected changes in climate at a scale of 14 km grid cells across Tasmania from 1960 to 2100 (Corney et al. 2010) . This allows for detailed climate projections that can account for strong environmental gradients within the topographically and climatically diverse agricultural regions. Projections were used to provide inputs to model the production of crops and pastures commonly found in mixed farming enterprises for five agricultural regions around the State. Outputs were communicated to existing farmer network groups at participatory workshops. Discussions at the workshops centred on presentations of climate projections for the region and potential impacts on crops and pastures. Participants were then invited to use this information to discuss: 1) their current adaptation strategies; 2) adaptation strategies that they would consider in the future; and, 3) identification of potential barriers to adoption. In addition, two regional adaptive capacity workshops were held in Hobart and Launceston in conjunction with farmers, local catchment management agencies, and agricultural extension personnel. Workshop participants were asked to use the five capitals of sustainable livelihoods analysis (see Brown et al. 2009) to identify key indicators for climate change adaptation strategies. The findings from both approaches provide an overview of current adaptive strategies and can place them in the context of transformational changes (Howden et al. 2010) at local and regional scales, thus providing inputs into policy development to facilitate adaptation strategies on farms.

Results

Tasmanian farm enterprises face both potential opportunities and challenges under regional climate change projections. Opportunities largely arise out of the projected small changes to rainfall in many regions, increased temperatures and reduced frost risk. Most participating farmers stated that they had or were in the process of diversifying their enterprise mix as a result of fluctuating climatic conditions, in addition to other external factors, particularly commodity prices. Regional differences were strongly represented in responses. For example farmers in the northern regions had difficulty managing waterlogged soils, whereas farmers in the drought-affected south-east had limited access to water for irrigation, which they felt restricted enterprise diversification strategies. Most adaptation options that were identified were incremental in nature, with few transformational changes listed.

Using the 'five capitals' of sustainable livelihoods analysis, these opportunities were generally centred on natural and physical capital. Perceived challenges included both internal and external factors, particularly those relating to human, social and financial capitals. These challenges were closely aligned with the barriers to adoption given at the farmer group workshops. The cost and availability of skilled labour, costs of production and government legislation were most commonly cited as potentially impacting on adaptation strategies.

Discussion

The use of an adaptive capacity framework is valuable for highlighting potential needs of farmers to become 'climate ready'. Results from workshops at the farm group level and at the regional governance level were used to inform local communities, and regional and state governance agencies of the support needed to allow farm operators to transform their agricultural enterprises for successful food and fibre production into the future. We demonstrated a process by which links to local and state level governance need to be developed to 'close the loop' better enabling farm enterprises to adapt to climate change.

TITLE FARMERS ADAPTING TO CLIMATE CHANGE

Theme Socio-economic
Primary Author Dr Harm van Rees
Institution BCG (Birchip Cropping Group)
Email harm@cropfacts.com.au
Co-Authors Alexandra Gartmann, Brooke White, James Laidlaw
Key search words climate change; farm viability; adaptation

From 1997 to 2009 there was a marked reduction in both annual and growing season rainfall in the Mallee region of Victoria. This reduction, in combination with higher temperatures during spring made it more difficult for farmers to grow profitable grain crops and, in some years, to grow feed for sheep or even to maintain groundcover. After more than a decade of these conditions, farmers are questioning their long term financial and agronomic viability, should these conditions become 'the norm' in the future. In 2010 BCG investigated the long term relationships between rainfall, production and financial performance for three 'typical' farms in the region. The resilience of the farms to continued climate variability was assessed. This paper discusses the findings of one case study farm.

When considering farm viability, the bio-physical constraints to crop and livestock production are as important as outside influences such as the price of commodities. The farm is located in the southern Mallee on soils with moderate to severe subsoil limitations (soils high in chloride which restricts root growth). This limits: (i) the option for break crops, such as lentils and canola, which are intolerant to subsoil constraints, and (ii) the ability of the cereals to access soil water required during grain filling period in spring.

Prior to 1997, the farm grew cereals (45% of the farm), pulses and canola (15%) and pasture/fallow (40%). Currently the farm only grows cereals (65%) and pasture/fallow (35%), pulses and canola are regarded as high risk crops and are only grown occasionally. Average cereal yield before the start of the drought was 2.4t/ha, by 2009 the average cereal yield was 1.0t/ha (Figure 1). The impact on the farm financial performance has been severe (Figure 2). Note the financial analysis includes all income achieved from grains and livestock, and costs include operating, machinery, financial and labour.

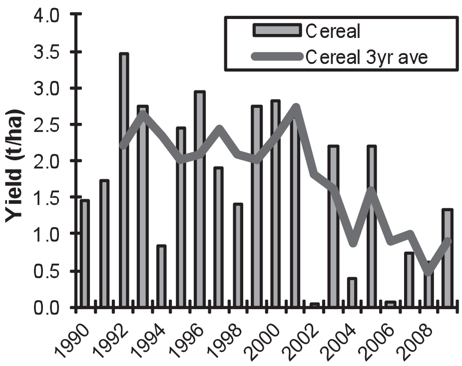


Figure 1. Cereal production from 1990.

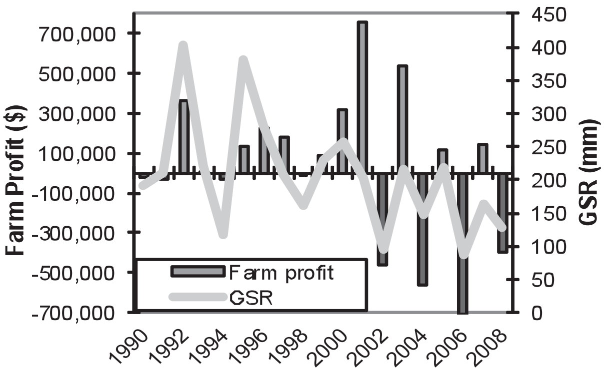


Figure 2. Whole farm profit from 1990.

The farm has managed to maintain costs per hectare at around $250. The largest component increase in costs has been in servicing debt, and interest now comprises 35% of total costs. This is not sustainable and debt repayment is a priority for this farm. Since 2000 the three year rolling average cumulative farm profit has gone from an annual average profit of $600K to a debt of $50K at the end of the 2008 financial year.

To improve the resilience to changing climatic conditions, the farm increased its emphasis on livestock production in 2006 with the establishment of a feed-lot. This enabled the stocking rate to be increased, without additional environmental cost. Together with the current high price for sheep products (wool and meat) this adaptation has been successful – in drought years the income received from livestock buffers the farm's income and provides cash flow, reducing the need for further borrowings.

TITLE FIVE BIG QUESTIONS: ASSISTING BROADACRE AGRICULTURE TO FACE THE NEED FOR TRANSFORMATIONAL CHANGE

Theme Socio economic theme
Primary Author Mr Chris Sounness
Institution DPI - Victoria
Email Chris.sounness@dpi.vic.gov.au
Co-Authors Graeme Anderson, Lucy Stott, Danielle Park
Key search words

Australian broad-acre farmers have a history of innovation and making incremental changes to their farming systems in order to adapt to the many challenges they face. Under a climate change scenario, there is a concern that incremental adaptation will not be sufficient for farmers to maintain profitability and increase productivity. Together with the finding that half of Victorian farmers do not believe that climate change is affecting their local climate (DPI climate change survey 2009) this makes the communication of this need for transformational change a challenge.

In order to engage farmers about the possible need for transformational change, the Victorian Department of Primary Industries has developed a framework to outline future options and adaptation pathways for farming families, for use in group discussions. The framework is called the "Five Big Questions" and has been developed to assist tackle the issue of transformational change (Barr 2011 pers. comm.). The framework enables discussion about both incremental and transformational change and helps farmers determine which option may best suit their farm family.

The framework is based around the five change pathways available to most farm businesses:

1. Improve profitability - Incremental change
2. Change the business structure - Incremental/transformational change
3. Change enterprise - Transformational change
4. Change the capital base Transformational/Incremental change
5. Exit - Transformational change

To encourage the audience to think about the pathways available a series of questions are presented to the audience. The questions are

- Are you enjoying what you are doing?
- Can you sustain the effort?
- Is your family supporting what you are doing?
- Are you living a lifestyle that you are happy with?
- Have you enough to retire on?

Each of these questions is quite personal and there is no right or wrong answer. However if someone answer no to one or more of them it suggests the person needs to make a change. This change is determined by the individual and is expected to be one of the five change pathways identified above. The challenge being is an incremental change pathway going to lead to transformational outcomes needed for a large number of farming business under a climate change scenario.

The "Five Big Questions" framework has been piloted with Victorian broad-acre farmers. Preliminary evaluation indicates that the program has prompted farming families to consider an increased range of options for their future. The full impact of this pilot program and its correlation with both incremental and transformational change will be monitored.

Australian agriculture has a bright future, but not necessarily for every individual currently in farming today – that's why we need to have an improved approach to empower farming families to identify and choose the pathway which unlocks the doors to a brighter future for them as individuals which will also have a flow on effect for Australian agriculture.

One point to keep in mind is the role technical data plays in contextualising the presentation. Discussing climate information helps set the scene. An interesting observation so far is when farmers are asked to consider their historic experiences of climate and think about the value of integrating climate information into decision making processes. When farmers have been asked what decision they would change over the last 10 years if they had access to perfect climate data many have said they would not change any decisions. This highlights the fact that climate is only one component in the many drivers for change. These drivers include the age of the farmers, farm size and location and industry. Climate is very rarely the primary driver of change

TITLE FUTURE FARM INDUSTRIES COOPERATIVE RESEARCH INTO PROFITABLE PERENNIALS: ECONOMIC IMPACTS AND POTENTIAL PAYOFFS IN A VARIABLE CLIMATE

Theme Socio-economic Policy analysis
Primary Author Dr Bob Farquharson
Institution Melbourne School of Land & Environment
Email bob.farquharson@unimelb.edu.au
Co-Authors Amir Abadi, Claire Lewis, Ralph Behrendt, John McGrath and Kevin Goss
Key search words

The Future Farm Industries Cooperative Research Centre (FFI CRC) aims to develop 'Profitable Perennials' that will change the nature of farming, create new industries and inform the management of catchments in southern Australia. This in the context of typical (historic) climatic variability and potential future climate change. FFI CRC's activities include research and development, education and training, and commercialization and utilisation. Headline farming systems are EverGraze (pasture and livestock systems for high rainfall zone), Enrich (fodder shrubs in mixed crop/livestock farming systems, EverCrop (perennial use in crop dominated agricultural systems), New Woody Crop Industries (woody perennials from saltland in mixed farming systems), Saltland Systems (production from saltland in mixed farming systems), and Environment (perennials and their environmental footprint in dryland agricultural landscapes).

Recently an Impact Assessment was made of the value of the FFI CRC's research along a chain from inputs to impacts. The CRC articulated how, and by what mechanisms, activities are linked to intended impacts. The net benefit from FFI CRC activity to the Australian economy is the discounted value of impacts less the costs of usage and research expenses which are also discounted. The Assessment found that adoption of the scientific outputs of the FFI CRC could achieve the CRC goal of substantial improvements in profitability and significantly increased sustainability. Accounting for research costs up to 2016, usage costs up to 2018 and impacts up to 2022 the most likely scenario for net benefits provides a value of $1 billion up to 2022, and $2.4 billion up to 2030. When the benefits were estimated under more conservative assumptions, net benefits were about $0.7 billion up to 2022.

An example from FFI CRC project analysis is by Lewis *et al*. (2011) of pasture investment decisions by farmers in western Victoria, based on EverGraze trial results at Hamilton. Two new perennial pasture systems were trialled and the results assessed using a whole-farm management analysis of the merit of investing in these pasture systems compared to current practice. The analyses accounted for likely increases in carrying capacity, expected return on extra capital invested, financial implications, effects on the farm balance sheet and other whole-farm implications of the change over time including risk. Climatic risk (seasonal variation in pasture production) was included to assess the investment decision under the (realistic) expectation that future livestock benefits are uncertain. The results showed that investing in these new perennial pasture systems can be an attractive option for farmers in the study region, even with substantial climatic variability.

AGRICULTURAL ADAPTATION DURING TIMES OF CHANGE: SOME OBSERVATIONS FROM AUSTRALIA'S EXPERIENCE DURING 2000-2010

TITLE

Theme Socio-economic Policy analysis

Primary Author Thilak Mallawaarachchi , David Adamson, John Quiggin and Peggy Schrobback
Institution Risk and Sustainable Management Group, The University of Queensland, Brisbane 4067
Email t.mallawaarachchi@uq.edu.au

Abstract

Adaptation to a changing climate has become a mainstream policy issue over the past decade. The National Agriculture and Climate Change Action Plan 2006-2009 (NACCAP) provided a policy platform to launch agricultural policy responses in Australia. Numerous adaptation responses have followed across jurisdictions with multimillion dollar investment since 2006. A combination of drought conditions and widespread water shortages for irrigation in the Murray Darling Basin has helped maintaining the policy thrust with a focus on building resilience in the long run. As NACCAP reaches maturity, this paper analyses how Australian agriculture has responded by expanding its output in taking advantage of growing conditions, market incentives and policy stimuli. Drawing on an analysis of the composition of state level agricultural output and its value over past ten years, the paper raises questions about best ways to tackle global food security and improve the resilience of farming systems that support economic opportunities as operating conditions continue to change.

In meeting the adaptation challenge for Australian agriculture, understanding how agricultural sustainability—the ability to feed a growing world population without degrading the environmental and natural resource base—will change and be affected by climate change is critical. Because uncertainty plays a key role in developing this understanding and as uncertainty will influence the expected benefits of adaptation and the capacity of farmers to chose appropriate responses, broadening the range of options available for farmers to suit emerging conditions will be a key to successful adaptation.

The recent experience under an expanding global market and improving global per capita income suggests that farmers will choose practices that will provide greater opportunities for income generation in the short run, while adjusting the enterprise mix to changing conditions. As the states of nature alternate between favourable and unfavourable under local conditions, success at a global scale will be determined by the net impacts on supply and demand as influenced by the level of global food trade and earning profiles of global communities. As success cannot be guaranteed at local scales, agricultural adaptations would require improving prospects for resource-conserving technological options to boost agricultural productivity under changing natural conditions as well as measures to improve broader social resilience to provide for disaster management and recovery under extreme conditions.

This concept of resilience embedded change may mean that the profile of Australian agriculture could change from a land-extensive system to a knowledge intensive system to survive into the future.

TITLE AN INTEGRATED ASSESSMENT OF LAND-USE CHANGE IN THE BORDER RIVERS-GWYDIR CATCHMENT

Theme Socio-economic
Primary Author Mr Jonathan Moss
Institution University of New England
Email jonathan.moss@une.edu.au
Co-Authors Professor Oscar Cacho, Dr Stuart Mounter
Key search words land-use change, carbon sequestration, adaptation

Recent times have seen a shift from solely attempting to mitigate greenhouse gases to prevent climate change towards a more realistic approach which also includes the preparation and adaption of industries for the unavoidable impacts of climate change. For landholders in rural Australia, the adoption of different management practices or land uses may provide additional greenhouse gas mitigation along with increased resilience to further changes in climate though their participation in emerging carbon markets.

Landholders' decisions to change current land uses or management strategies are based on a number of factors, including economic, social and technical aspects. This paper investigates the potential for landholders in a northern NSW catchment to change from their current land uses to one of four different land-use strategies which both sequesters additional carbon and may provide additional income security in a changing climate. The four proposed land uses investigated were: 1. *Pinus radiata* plantations; 2. mixed species environmental plantings; 3. *Eucalyptus globulus* plantations; and E. cladocalyx plantations.

Carbon sequestration potential for both the current and proposed land uses was calculated spatially over a 60-year period using the FullCAM model developed by the Australian Greenhouse Office. It was found that, on average, the *P. radiata* and mixed species environmental plantings options provide the highest additional carbon sequestration potential across the region. An economic optimisation model was developed to determine the locations and the agricultural industries with the lowest cost of adopting alternative land-use systems. The optimal land-use strategy was found to be dependent on the current land use and biophysical characteristics of each farm. In addition, it was found that no single proposed land use provides the minimum-cost strategy across the entire catchment.

Supply curves for the quantity of additional carbon that can be sequestered were also generated. These supply curves will allow further investigation of how incentive structures and policy instruments may be developed to encourage landholders to adapt to increased variance in the climate and emerging carbon markets.

TITLE SUPPORTING INTEGRATION: KNOWLEDGE CO-DEVELOPMENT FOR INTEGRATED CATCHMENT MANAGEMENT UNDER A VARIABLE CLIMATE

Theme Socio Economic

Primary Author Dr. Margaret Ayre
Institution The University of Melbourne
Email mayre@unimelb.edu.au
Co-Authors Dr. Ruth Nettle and Sonya Love

Key search words sustainable catchment management; communities of practice; interdisciplinary research; knowledge co-development; variable climate

After a period of extended drought in southern Australia and likely continued impacts of climate variability on natural resource and agricultural systems, national efforts at reforming water policy and management provide the context for a large interdisciplinary project called Farms Rivers and Markets (FRM). The FRM Project aims to create opportunities to 'do more with less water' and acknowledges 'the key challenge [of research and policy for integrated catchment management[i]] is to coordinate change' (The University of Melbourne, 2009).

This poster describes how the FRM Project is working with communities and other stakeholders in producing new knowledge for sustainable development of water and agricultural production in the Goulburn-Broken catchment Victoria through the FRM research project. Our research asks: how do diverse groups co-develop new knowledge and options for sustainable catchment management under a variable climate? We introduce a design framework for the engagement of FRM knowledge communities and argue that supporting processes of knowledge co-development enables integration of both disciplinary and community knowledges in developing new options for sustainable catchment management.

Reference

THE UNIVERSITY OF MELBOURNE 2009. Farms, Rivers and Markets. THE UNIVERSITY OF MELBOURNE, UNIWATER, THE VICTORIAN WATER TRUST, DOOKIE TRUST (ed.). Melbourne.

TITLE INCREASED RESEARCH, DEVELOPMENT AND EXTENSION CAPACITY ESSENTIAL TO AGRICULTURAL ADAPTATION TO CLIMATE CHANGE

Theme Socio-Economic

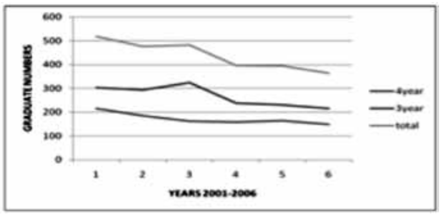
Primary Author Associate Professor Colin Birch
Institution Tasmanian Institute of Agricultural Research
Email colin.birch@utas.edu.au
Co-Authors Dr Richard Doyle, Mr Warren Hunt

Key search words Agricultural research, Agricultural extension, Environmental management, human capacity

The effectiveness of the research, development and extension to agricultural and community responses to climate change requires proactive strategies to address existing and anticipated shortages in professional capacity across numerous disciplines eg. environmental science and management, agricultural science, hydrology, information technology, engineering, communications, economics, extension and rural sociology for optimum solutions to complex problems under future climates to emerge.

Adapted and perhaps transformed resilient production systems, industries and communities will require multidimensional solutions and ongoing commitment to support them through changes that will be essential to long term viability. Thus, they will depend on the support and involvement of appropriately trained and adequately resourced professionals who can integrate across multiple disciplines. Foremost among these are agronomists, extension specialists, animal production specialists and environmental scientists and agricultural and environmental managers. However, long term declines in University graduations from most of these and several cognate disciplines limit current and near term capacity – the Australian Council of Deans of Agriculture has identified a severe shortfall in agricultural graduation, with annual graduations of around 800 while demand is around 6000 (ACDA 2009).

Figure 1. Graduations in agriculture from Australian Universities 2001-2006 (ACDA 2010)



Some disciplines e.g. extension have been downgraded or disappeared, and agricultural science has been widely subsumed into other Faculties, thus losing visibility and presence. Increasing demand for expertise to deliver under complex, challenging situations will not met from current enrolments. Also, increasing average age and impending retirements of relevant practising professionals will intensify the human capacity constraint.

Enhancement of capacity will require public and private investment and strong institutional responses. Increasing enrolments will require proactive strategies, as the time lag to initial graduation and subsequently the gaining of sufficient postgraduate training and experience will exacerbate the capacity constraint. Government , Industry and University responses could include agricultural and environmental sciences and management and cognate disciplines being given priority status with reductions in student contributions, enhanced educational and research infrastructure, industry investment through funding of academic positions and infrastructure, development of clear attractive career pathways, enhanced undergraduate and postgraduate scholarships and salary packages, and program redesign to include greater flexibility, more experiential learning and greater retraining opportunities.

Necessary adaptation by agricultural industries and communities to climate change will depend on availability of appropriate professional support. Proactive strategies by all stakeholders to enhance University enrolments and develop rewarding and attractive career pathways in appropriate disciplines are required so industries and communities are not constrained by inadequate professional support.

ACDA (Australian Council of Deans of Agriculture) (2010) Capacity -The educated workforce in agriculture in Australia. March 2010

TITLE RURAL SOCIAL WORK, CLIMATE CHANGE AND PRIMARY INDUSTRY

Theme Socio Economic
Primary Author Rohena Duncombe
Institution NSW Health, NCAHS
Email rduncombe@csu.edu.au

Introduction

To provide you with a little context, I am a social worker with NSW Health on the far north coast of NSW and before that in Albury. I grew up in northern Victoria and although I have lived most of my life in rural areas, I am a 'townie' not a farm person per se.

The north coast is a rural coastal area where primary industry was first characterised by 'timber getting' as it is referred to locally (the harvesting of cedar and other tropical rainforest trees) and whaling, and dairy farming. There is a remnant of the dairy industry, remnants of rainforest, and the whaling industry is now about tourism and research (not the Japanese type of whale research but monitoring numbers and research into communication between whales).

Sugar cane, bananas, and beef are a continuing part of the local primary industry, and from the 1970's on, tropical stonefruit, custard apples, macadamias, and avocados.

Climate change on the north coast has brought more adverse weather events including: hail which has negatively affected stonefruit growers; changes in the amount and distribution of rain; and higher temperatures. These have increased crop vulnerability to new pests, and to pests over longer periods of the production cycle. Changes in temperature and rain are also affecting what strains of crop are successful.

The other major climate issue in northern NSW is coastal erosion.

I will address a couple of themes: the paucity of rural health services, mental health, the lack of primary producer targeted health services, and the need to address structural issues.

Health in general

Rural and remote Australians receive less health funding per head than urban Australians: we have less primary health visits (dentists, GP's, physiotherapists) less diagnostic tests (pathology), less visits to specialists, less PBS scripts and less non-acute hospital admissions. The only thing we have more of is acute hospital admissions, which not surprisingly because we have less health care! (National Rural Health Alliance (2011). An overview of the

shortage of primary care services in rural and remote areas, Canberra) If it was our goal to receive the same pro-rata funding for health as urban Australians we would still be receiving fewer services because we are more expensive to service.

In respect of our children, early intervention for speech therapy for example has waiting times of a year and more. This is really disturbing. We know that delay in treating these deficits has lifelong implications for the children, and therefore for their communities and the economy of those communities. If these children aren't brought in before school age by their parents they will wait considerably longer and receive fewer services. Given the cost to the child, the child's family and the child's community I see this as gross neglect.

Mental Health

There are some factors that particularly affect primary producers:

- isolation
- income variations
- weather

The famous UK Whitehall studies have shown that we experience stress significantly more when circumstances are outside our control. While an effective primary producer will limit his or her exposure to these, income variations and weather are beyond the control of the individual. The UK research found that stress, and this was borne out in physical conditions such as back pain and heart disease, increased when the individual had less control. They found a clear health gradient with the healthiest and least stressed being those in executive positions who had most control and increasing stress and illness at each level down the hierarchy as control diminished. Primary producers, on the positive side, can be their own bosses having some discretion over daily activities, what to produce and when, and this would be expected to be a protective factor.

On the other hand, weather is beyond our control and can reasonably be expected to increase stress. And climate change is a multiplying factor, amplifying the unpredictability of weather, increasing adverse weather events.

In regard to recent droughts and floods, you will understand that these will be 'last straw' events for some people. The suicide risk of primary producers is well documented.

- suicide rates are 33% higher in rural areas
- 189% higher in very remote areas (Australian Institute of Health and Welfare, 2010).
- agricultural workers are over twice as likely to die by suicide
- farm managers comprise 2/3rds of farm suicides (Suicide Prevention Australia 2008 reviewed 2010)

Low mood, anxiety and depression, let alone suicide, have a significant impact on the mental wellbeing of close friends and family. These are the people I tend to meet in my practice, less often the primary producer him or herself.

My contact with primary producers has been about:

- problems of negotiating between aging family members with a shared interest in a property,
- low mood,
- stress related to issues in addition to primary production itself (eg a disabled child)
- and, when a family member has become inactive due to illness or injury.

In general the community health service I provide is not much accessed directly by primary producers.

This is an issue for the health service that NSW hasn't adequately addressed. We don't usually design our services to make them accessible and relevant to primary producers. The workers most likely to hear about producer distress are the agricultural outreach workers and district agronomists. They have pre-existing relationships based in agriculture, and practical support. They link to financial support during hardship, and will refer to Health Services but in my experience there has been very little relationship between the agricultural outreach workers and Health Service staff. I am told that NSW is the last State to have maintained this role and it too will phase out agricultural extention in favour of industry representatives. It cannot reasonably be expected that industry representatives would take the same interest in farmer welfare when there cannot be a financial or business incentive.

(As an aside, it is also difficult to see the commercial advantage for private representatives in pursuing the development of biological pest management being undertaken by the Department of Industry in response to the pest problems arising from climate changes).

Youth Mental Health

Young people are affected by the emotional status of the adults in their family, and by the more general mental health issues for their age/stage. The late teens and early 20's are characterised by early onset psychoses (for a minority), anxiety and shyness, depression and low mood and the use of drugs including alcohol to manage these. There is also the risk taking behaviour, more prominent in young men, that can contribute to motor vehicle accidents. Rural areas also have problems with binge drinking and its associated violence, and in my observation, and that of our mental health team, an increasing incidence of secondary problems; Post Traumatic Stress Disorder and closed head injuries as a result of assaults associated with binge drinking, again usually in young men.

- Male youth suicide in rural areas is estimated to be double that of metropolitan areas
- Rural inland towns with populations of less than 4,000 have experienced the most significant increases in male youth suicide (Suicide Prevention Australia 2008 reviewed 2010)

Management of anxiety, depression and stress

Management of anxiety, stress and depression have improved significantly in recent years. For most people useful change can be achieved in a small number of sessions. I am using a combination of cognitive and behavioural therapy (strategies to alter thinking and behaviour patterns), solution focussed therapy, and a strengths approach.

What needs to be acknowledged though is that the stress, anxiety and depression of primary producers can be structural, not psychological. Structural problems require structural responses. Margaret Alston in her keynote address called for 'visionary rural policy development'. Such policy, says Professor Alston, needs to include strategies that support and develop rural communities, infrastructure and financial supports for primary producers, and investment in rural people, communities and in change management.

Not every farm will succeed and not every farmer can be protected from the exigencies of nature and the market, but overall, we, as a society need to be better at supporting our primary producers, not least in the face of increasing concerns for food security. We will certainly not improve rural health and reduce suicide rates unless we do.

Service Planning

There is a continuing issue with attraction and retention of professional health staff in rural areas. Wagga Wagga, a city of 65,000 souls has not one locally based psychiatrist, but relies on local psychiatric nurses, psychologists, occupational therapist's and social workers, and a 'fly in' psychiatric service. By comparison my coastal town of 9,000 residents has 1 full time and 4 part time psychiatrists. The inability of market forces to operate to meet demand highlights the need for government planning and action and community planning and action as described by Professor Alston.

Increased centralisation, most obvious in the closure of small country hospitals - decreases employment, and decreases commitment to rural towns - the opposite of the 1970's investment in rural areas and communities through the AAP and Regional Councils for social Development- and is based on a rise in popularity of a belief in the so called 'free market':

Supporting and encouraging rural development has been replaced with leaving us to our own devices. Contrary to the example of the Albury Wodonga Development Corporation, coastal rural growth centres are left to manage as best they can, for increasing population without the planning, co-ordination and co-operation characterised by the 1970's. My own Shire Council actually retrenched it's community development worker and deleted the position as part of cost cutting.

Summary

In rural Australia we have poorer health, less health expenditure per head, and health services not reaching or designed to reach primary producers. We need to deal with structural issues that contribute to stress, anxiety, depression and suicide in primary producers. And we need Professor Alston's visionary governmental response to rural development and service provision as the 'free market' is not capable of responding adequately.

THEME

COMMUNICATIONS

CASE STUDY

TITLE 'MESSAGE RECEIVED' NOT 'MESSAGE SENT'

Theme Communications
Primary Author Ms Susan McNair
Institution Currie Communications
Email susan@curriecom.com.au

The communications environment for Australian primary producers is cluttered. RDCs, industry bodies, industry programs, DPIs, CMAs, processors, consultants, suppliers and mainstream media compete vigorously for their attention.

Information about improved farming practices and technology is plentiful, yet peak industry bodies estimate that only 5% of primary producers are early adopters of technology.

Another third are more cautious followers, with approximately 40% not proactive and one quarter classified as recalcitrant (Australia's Farming Future market research – Final Report 2009).

While the same research shows knowledge and understanding of farming practices that adapt to or mitigate climate change is relatively strong amongst farmers, the desire to act - as yet - is not.

Generally, farmers are motivated by the possibility of improved profit and productivity. They also have a strong sense of pride in their land.

Convincing farmers to take up mitigation and adaption practices that move towards future-ready farming is an ongoing challenge which must link to their particular drivers.

The test is not only to provide information in a meaningful and accessible way, but to ensure that it is listened to, understood, and acted upon. 'Message sent' does not always mean 'Message received'.

TITLE DON'T FORGET THE "E" – LESSONS FROM COMMUNICATING CLIMATE & CARBON INFORMATION TO 10,000 FARMERS

Theme Communication
Primary Author Mr Graeme Anderson
Institution Department of Primary Industries – Farm Services Victoria
Email graeme.anderson@dpi.vic.gov.au
Co-Authors Chris Sounness, Chris Gerbing
Key search words Climate change, extension, seasonal variability, carbon farming

Want to test your science communication skills? Then jump in a car, drive 3 hours from a capital city and drop by the nearest local community hall and spend a few hours talking climate change and emissions in agriculture with a group of farmers……….Come and hear some lessons from our experiences delivering 480 sessions to over 12,000 people in the last 2 years. Take home some simple tips on what works, and what sinks like a lead balloon.

Victoria's Future Farming Strategy kick-started our first climate change extension program which in 2 years has:

- Established a cross industry extension team that's working to convert the climate/emissions story into the right industry context
- Undertaken a survey of 1500 farmers and better details their understanding of climate and carbon issues and avenues for communication
- Tested a popular "Upscaling" technique which links a farmers local weather and seasons with larger scale climate drivers and projections
- Developed some 60 second animations to get across complex science – the "Climate dogs" story
- Merged the often separate worlds of seasonal variability and climate change in a way that farmers prefer
- Crafted techniques and language that improves how receptive farmers are to climate and emissions messages
- Developing a range of products and services designed to be a conduit for emerging climate information (policy, science and practices)
- Commenced the fast tracking of capability development for extension staff & service providers
- Expanded production of climate risk farmer e-newsletters such as "The Break"
- www.dpi.vic.gov.au/climaterisk to see the range of products and approaches.

The key is to "tell a new and powerful tale, one so persuasive that it sweeps away the old myths and becomes the preferred story, one so inclusive that it gathers all the bits of our past and our present into a coherent whole, one that even shines some light into our future so that we can take the next step……." – " If you want to change a society, then you have to tell an alternative story" - Austrian philosopher Ivan Illich

Substantial information failures exist in the area of climate and emissions in agriculture. If we wish to address these in the coming decade then we'll need to do things differently. So, are we allocating enough attention to getting what we already know out there? Is the significant work from CCRSPI getting to all users? If not, why?.... and what can we do differently to ensure that it does?

TITLE THE CLIMATE CHANGE RISK MANAGEMENT MATRIX – FROM THEORY TO PRACTICE THROUGH A PROCESS OF STAKEHOLDER ENGAGEMENT

Theme Communication
Primary Author Mr Neil Cliffe
Institution Queensland Department of Employment Economic Development and Innovation
Email neil.cliffe@deedi.qld.gov.au
Co-Authors Mr David Cobon, Mr Grant Stone
Key search words Risk Matrix; Risk Management; Climate Change Adaptation; Stakeholder Engagement; Evaluation

The Climate Change Risk Management Matrix or 'risk matrix' is a process adapted from the Australian and New Zealand Risk Management Standard AS/NZS 4360, that can assist primary industries at a range of levels and scales plan responses that help adapt to the changing climate. The 'risk matrix' is a simple but structured risk assessment process that can analyse the complexity of climate change impacts and identify key areas of vulnerability.

In a collaborative project between the Queensland Climate Change Centre of Excellence and Department of Employment Economic Development and Innovation in Queensland, current climate change projections and impact information was coupled with extension, engagement and evaluation processes. Through a series of briefings, our objective was to raise awareness and build capacity within peak primary industry and stakeholder groups in Queensland to use the 'risk matrix' as a tool to identify the impacts, risks and opportunities, adaptation responses and vulnerability associated with a changing climate.

During the briefings a process of facilitated engagement helped participants determine the value of the 'risk matrix' process for their industry or situation. Five peak industry body briefings were conducted targeting the Horticulture, Fishing and Aquaculture, Cropping, Intensive and Grazing Industries, with over 70 participants from 26 stakeholder organisations represented. Each briefing was evaluated and the data analysed by an external evaluation consultant.

Evaluation of the briefings showed that participants valued highly the quality and usefulness of the 'risk matrix' process and they gained a high level of understanding in its use. They also expressed a high likelihood of undertaking relevant 'risk matrix' activities, sharing what learning they had gained with others and promoting its use for their situation. Although responses were positive, some differences existed between industries. For example, the Grazing & Feedlot Industry rated the value of the information lower than other industries, while the Horticulture Industry valued the information the highest.

The 'risk matrix' and stakeholder engagement processes together have provided peak industry bodies with a tool to identify and analyse climate change impact risks and opportunities, possible adaptation responses and vulnerability. Armed with the 'risk matrix' process, industry groups can be better prepared for the changing climate by planning and prioritising adaptive responses relevant to their situation.

More briefings are planned across regional Queensland to further engage with regional primary industry and natural resource management stakeholder groups to build their capacity in order to use the 'risk matrix' with regional communities.

TITLE A KNOWLEDGE PARTNERSHIP APPROACH TO CLIMATE CHANGE ADAPTATION EXTENSION PROGRAMMES

Theme Communications
Primary Author Dr Marion Titterton
Institution Tasmanian Institute of Agricultural Research
Email Marion.Titterton@utas.edu.au
Co-Authors Robyn Eversole and Joanna Lyall
Key search words Knowledge partnership, extension, climate change adaptation

The challenge of communication with the agricultural industry in adaptation to climate variability

From surveys carried out in the agricultural industry, it is widely known that farmers are ambivalent about climate change, with some accepting that climate change is happening and is at least partly driven by man-made activities, while others believe that changes in the climate, even those that they have observed, are cyclical and to be borne as an occupational hazard. Information and knowledge are essential skills for adaptation but there have been few attempts to address the challenge of communication that would be effective in building capacity of farmers to adopt strategies of climate change adaptation and mitigation. Traditional extension has been based on technology transfer but we argue that this does not totally fit with the complex and volatile environment in which one of the few certainties is constant change. Capacity building should be designed to assist farmers not just through learning but through sharing knowledge and building on it. We termed this approach "knowledge partnering" in the development of an extension programme to assist Tasmanian dairy farmers to develop coping strategies for climate adaptation.

The knowledge partnering methodology

Intensive face-to-face semi-structured interviews were carried out with thirty dairy farmers across six dairy regions of Tasmania. Farmers were asked to recall any changes in weather patterns they may have observed in the time they were living and farming in the area. Based on these observations, they were asked to identify any changes in management practice they had undertaken in response to these changes and what issues had emerged on which they needed more information and knowledge. These issues could be discussed in a focus group meeting in their region. The data from the interviews in each region were collated and the observed changes and management issues recorded in "theme grids". The major themes which emerged from these grids were taken to focus groups in each region and discussed as themes for a regional extension programme. Verification of priority themes was sought from the wider dairy farming community before the final programme was formulated.

Conclusion

The knowledge partnership approach to the extension programme on adaptation to climate change has been considered to be successful in that rather than try and convince farmers that climate change is a reality and attempt to assist them through technology transfer alone, whereupon it was not likely that an extension programme would have attracted much interest from farmers, it engaged farmers in acknowledging changes in weather patterns they have noticed over time for themselves and which could impact on their farm business. It encouraged farmers to drive the agenda for the extension programme in which they could be assisted to build capacity for informed decision making on risk management and resilience in the face of climate variability.

TITLE IMPLICATIONS OF CLIMATE CHANGE ADAPTATION FOR AGRICULTURAL EXTENSION: A PRELIMINARY ANALYSIS

Theme Communications
Primary Author Dr Lauren Rickards
Institution University of Melbourne
Email Lauren.rickards@unimelb.edu.au
Co-Authors
Key search words Adaptation, extension

Climate change adaptation refers to all of the ways in which we are changing in response to climate change. It incorporates how we are altering our worldviews and practices in response to the very idea of climate change, 'precautionary' methods like climate change mitigation, and second order changes in response to adaptive (and maladaptive) efforts. Understood in this way, climate change adaptation is a broad social force changing the context in which we live. Like changes in the atmosphere, climate change adaptation is impossible for sectors to avoid or to not be part of. This includes agricultural extension as well as agriculture.

The unique industry of extension has the potential to play a key role in assisting agriculture to adapt to climate change. Yet, it too needs to adapt to the profound and diverse challenges posed by climate change and the adaptation imperative in agriculture. To date, climate change adaptation seems to have been mainly tackled within extension as simply another topic area. However, the preliminary analysis conducted for this paper suggests that it will be or needs to be something far more influential, especially if the growing warnings of the need for transformational adaptation in agriculture (eg Ash et al 2009) are taken on board. Compared to what Howden and Stokes (2009) call incremental or system-level change, transformational change – whether understood as coordinated large-scale change, a rapid degree of change along a pre-existing trajectory, or 'deep change' (eg a shift in goal posts and identity as well as practice) – is relatively new territory for most elements of agricultural extension. And yet it is just this sort of adaptation that some commentators (eg Pannell 2010) assert that agricultural extension of the future should be focused upon.

Based in the Australian context, this paper provides a high level and preliminary examination of four central aspects of agricultural extension which, it is asserted, climate change adaptation (particularly transformational adaptation) calls into question. These aspects – the rationale, focus, philosophy and structure of extension – correspond to the following important questions:

- What is the goal of extension – what is it trying to achieve?
- What are its focal topic areas? How do its main topic areas inter-relate? How are tensions between them handled?
- What are the guiding principles of extension? What approaches are dominant and why?
- How is extension structured, internally and in relation to broader systems?
- For all of the above we also need to ask: How have they changed over time? Why? And with what result?

By addressing these questions, we can develop a better handle on how extension is currently situated. We can then tackle the crucial issue of what climate change adaptation means for each of these areas and identify what challenges and opportunities extension faces in relation to climate change adaptation.

Such a task is particularly timely in Australia for numerous reasons: the growing urgency of adaptation (including the need to adapt agriculture to the crucial mitigation imperative); current government interest in how best to facilitate adaptation to climate change among agriculturalists, guided by the recent National Adaptation Research Plan for agriculture; and ongoing debate about how agricultural research, development and extension can and should be justified, structured and funded. Exploration of agricultural extension in relation to adaptation also provides insights of value to, and opportunities to learn from, the rapidly expanding literature that exists on climate change adaptation in general. In highlighting this potential for cross-fertilisation, this paper helps to address one of the existing weaknesses of extension, which is an unhelpful disengagement from the adaptation literature and other related sources of knowledge; something which will no longer be tenable in the face of the immense, interdisciplinary learning needs that adaptation poses. To end, the paper identifies key areas for further research.

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TITLE A PRACTICAL COMMUNICATION TOOL TO FACILITATE DISCUSSION ON CLIMATE CHANGE ADAPTATION IN SOUTHERN NSW FARMING SYSTEMS

Theme Communication
Primary Author Mr John Smith
Institution Industry and Investment NSW – Primary Industries
Email john.smith@industry.nsw.gov.au
Co-Authors Mr Michael Cashen
Key search words Communication tool, climate change adaptation, soil water

Abstract

Climate change research is an active area of research however, from an adaptation point-of-view it is important that these results are applied to enable farmers to have a clear understanding of the practical impacts of research findings on the farming systems.

This paper critiques a simple methodology that has been used successfully with farmers in the NSW Murray Valley during 2008-2009 to highlight the implications of historic changes in rainfall patterns and plant water use (ETc) on winter cropping programs.

A graphical comparison of mean rainfall was made for the periods 1961-1990 and 1991-2008 which highlighted the reduction in autumn rainfall that has occurred between the two periods. Monthly plant water use was overlaid on top of the rainfall figures for each month using crop water use figures from ETo and CSIRO derived crop factors.

This methodology highlighted to farm managers a shortening of the crop growing season and reduction in the plant available water carried through to the spring period. The initial findings from the South Eastern Climate Initiative have suggested that the observed autumn rainfall decline in south eastern Australia during the 1991-2008 period is associated with the intensification of the subtropical ridge most likely driven by increasing global temperatures.

In an irrigated environment the management implications of autumn rainfall decline are of greater reliance on autumn irrigation for timely plant establishment and considerations of plant maturity to reduce the reliance on spring conditions to finish crops and provide production returns. In a dryland environment the methodology highlights the importance of fallow management and maximising the storage of soil water for plant production within the season.

THEME

TRANSFORMATIONAL ADAPTATION

SYNTHESIS PAPER

TITLE BEYOND INCREMENTAL ADAPTATION: DRIVERS, PROCESSES AND RDE NEEDS OF TRANSFORMATIONAL ADAPTATION

Theme	Transformational Adaptation
Primary Authors	Mark Howden[1, 2] and Snow Barlow[2]
Institution	1. CSIRO; 2 University of Melbourne
Email	s.barlow@unimelb.edu..au

Australia's primary industries have been shaped by variable climates, access to global markets and continued innovation for the past 2 centuries. Climate change has become a major driver of our primary industries development through its influence on production climates, the availability of irrigation water and its indirect effect on global markets. Extreme events within the emerging climates can also be a powerful driver of transformation adaptation. In the policy sense global and national emissions mitigation responses to anthropogenic climate change can also influence development and sustainability of primary industries.

In this paper we shall briefly consider the drivers, processes and RDE needs of Transformational Adaptation within Australia's primary industries and regional communities that support these industries. As defined by Howden in 2009, Transformation Adaptation within primary industries involves a change in the nature of the primary industry enterprise mix at any given location , the relocation of the enterprise or industry to a different more climatically suitable region , better resourced region or a change in the nature of the product produced by a given industry

While most of Australia's primary industries are already undertaking adaptive management responses to climate change and some are undertaking production system changes there is little experience of transformational change. As many transformational changes will involve unknown and unpredictable risks to the personal and financial well-being of the people and communities directly involved, and to investment in land development, production infrastructure and public infrastructure the information demand are increasingly more diverse. Understanding these risks will be important for all individual and communities potentially directly affected by transformational changes, those involved in related industries and governments at all levels.

Although more than 50 new primary industries have emerged in Australia in the past 50 years the processes of transformational change, information requirements and the role of regional community capacity to support these changes are not well documented or understood. Therefore there are challenges in developing industry and government policies to support such change.

Transformational adaptation often involves a change of enterprise or industry or moving an industry to a new area. Consequently the RDE needs to support this change are frequently not well served industry R & D plans developed in conjunction with those already in the industry in existing production areas. The RDE priorities of to support transformational adaptation are inherently cross sectoral and multidisciplinary as well technological in nature because an understanding of the capacity of regional industries and communities to undergo transformation is essential. The support of this cross sectoral research with strong with strong social and economic as well as scientific components is therefore the responsibility of governments as well as industry.

TITLE CAN AUSTRALIA'S PEANUT VALUE CHAINS TRANSFORM TO ADAPT TO FUTURE CLIMATES?

Theme Transformational Adaption
Primary Author Dr Peter J Thorburn
Institution CSIRO Ecosystem Sciences and Climate Adaptation Flagship
Email peter.thorburn@csiro.au
Co-Authors Nadine Marshall, Yash Chauhan, Felix Bianchi, Emma Jakku, Emily Mendham, Nancy Schellhorn, Tony Webster and Graeme Wright
Key search words Biosecurity risks; Social science; Katherine, Northern Territory; Nitrogen leaching; Cropping systems; APSIM.

Abstract

Agriculture in Australia has developed in response to a variable, but relatively stable climate. Under projected climate change, one adaptation strategy for farmers and/or industries is to move from areas of decreasingly favourable climates, to regions becoming more suitable for crop production. Such a transformation may underpin future food production and food security. Examples of this change are currently happening in Australia: One is the efforts by the peanut industry to establish a 'greenfield' production base in Katherine, Northern Territory, to protect against climate-driven poor production in the Burnett region, south-eastern Queensland, the traditional home of Australian peanut production. However, 'transition' raises many questions, both biophysical and social, that are beyond current experience of those involved in agricultural industries. To better assess the issues facing industries contemplating or undertaking transformation, we are asking questions such as: What will be the impact of this cropping system on the environment in the new region? What are the pest, disease and biosecurity risks? How will the cropping system, and its impact, change with further climate change? Within the social domain, what key characteristics of the planning and reorganisation phases, and what are the 'preconditions' for a successful transformation?

We are monitoring the transformation process in both the 'new' and 'old' peanut regions to identify the main influences on, and magnitude of the impacts of transformation. Our simulation results are currently suggesting that there is potential for mal-adaptation in the biophysical dimensions of this transformation. One is potential for substantial nitrogen leaching from peanut production systems to groundwaters, which sustain dry season flows and valuable ecosystems in the regions' rivers, unless nitrogen fertiliser inputs are carefully managed. Also, future climates in the Katherine region may be less favourable to agricultural production than they are now, so the advantages being sought through transformation by the peanut industry may diminish. Conversely, biosecurity risks of establishing a peanut production industry in the Northern Territory are small, and landscape modelling suggests there is scope for reducing pest and disease pressures on future crops through maintaining native vegetation cover of >20%, an achievable target given the mosaic nature of agricultural development occurring. Social data are suggesting that Queensland peanut farmers are unlikely to support the transformation by relocating because of their high level of dependency on 'what they do now', including having high levels of attachment to their place and occupation. Key concerns amongst these farmers include knowledge of how to farm in Katherine, research and development support, and availability of experienced labour. Thus, it is not yet clear whether Australia's peanut industry can successfully transform to adapt to future climates. Work is continuing to better resolve these issues, and consider economic aspects of transformation.

TITLE TRANSFORMATIONAL ADAPTATION FOR THE WHEATBELT: ENERGY TREE CROPPING

Theme Transformational Adaptation
Primary Author Mr Richard Bennett
Institution FFI CRC/CSIRO
Email Richard.Bennett@csiro.au
Co-Authors Amir Abadi, Kevin Goss
Key search words Energy; Biomass; Sustainable; Adaptation

The nascent 'mallee industry' in Southern Australia will be a major player in the region's transformational adaptation in response to climate change. This paper describes emerging R&D and regional scenario analyses for energy tree cropping of mallees, a system in harmony with the dominant grain, meat and wool enterprises that offsets greenhouse gas emissions from energy generation.

Development of the mallee tree industry is supported by market-driven economic research and financial assessment of viability of all stakeholders along the supply chain. After two decades of research and farmer engagement, this path to a new regional industry for farmers is now supported by an R&D plan to address harvesting, processing and transport limitations and to ensure the sustainability of production through harvest interval, water and nutrient management.

Assessment of a sustainable mallee tree crop industry included considerations of: concentrations of mallee farming in biomass supply hubs the size of which is reflected in the economics of electricity supply and biomass transport costs which form organically around processing centres; a value at the farm gate for the woody crop that makes it profitable in its own right, thereby exceeding the opportunity cost of annual crops and driving mallee adoption; and a production system where trees are grown in belts to minimise trade-off with food production and water supply, while trees provide environmental services, including habitat resources for native fauna, groundwater control and land cover. Analyses of scenarios with conservative projections suggest that mallee energy tree crops can grow to generate 176MW of electricity, through several regional sites. This bioenergy system will displace emissions from fossil fuels to a cumulative total of 12 million tonnes CO2_e. Electricity from tree crops is base-load energy and valuable to balance and stabilise supplies to a network receiving intermittent power from wind and solar generators.

This analysis is well grounded because of the "bottom-up" approach taken in mallee industry development, including consultation with farmers who grow belts of coppicing, drought tolerant mallee trees, contractors who harvest and transport woody biomass and managers of biomass processing centres that generate multiple products, including renewable energy, fuel, char and oil. Economic analysis of the supply chain has identified where technology breakthroughs are required to achieve a supply cost to the processor of $50-60/green tonne, a price which provides financial incentive for stakeholders and is competitive with other forms of renewable energy, given an assumed initial carbon price of $25/t CO_2 equivalent.

Energy tree crops will facilitate adaptation of farming systems to the challenges of climate change in Australia. Mallee tree crops are highly drought tolerant and can be integrated into rural properties where two-row belts of trees are spaced with wide alleys for existing crops and pastures with little interruption or inconvenience to agricultural production. Energy tree crops on 8 – 10 per cent of the farm area are profitable, taking opportunity costs of cereal cropping and competitive effects into account, thus beneficially transforming rural businesses within supply zones and creating new long term jobs and employment in the rural regions.

TITLE NEW RURAL INDUSTRIES FOR FUTURE CLIMATES

Theme Transformational Adaptation
Primary Author Dr Brendan Cullen
Institution Melbourne School of Land and Environment
University of Melbourne
Email bcullen@unimelb.edu.au
Co-Authors Peter Thorburn, Elizabeth Meier, Snow Barlow and Mark Howden
Key search words New rural industries, climate change

Climate change projections for Australia indicate higher temperatures and evapotranspiration demand, changes to rainfall patterns, increased probabilities of extreme climatic events, and higher atmospheric carbon dioxide concentrations. The 'New rural industries for future climates' project provides the first step in identifying new opportunities for Australia taking these climate projections into account.

New industries adapted to the warmer and drier future climates expected in southern Australia will require plant traits that increase water-use efficiency, heat tolerance, frost tolerance, and have lower chilling requirements. Three specific production opportunities were identified and are outlined below:

- High value irrigated crops – that rely on adequate supplies of high quality irrigation water to ensure production and product quality. Production systems that require a consistently large amount of good quality irrigation water will need to produce a high value product to ensure their financial sustainability as the amount of irrigation water decreases. Crops in this category include traditional horticultural industries such as pomefruit and citrus.
- Resilient irrigated crops – that have lower water requirements and/or can tolerate periods when irrigation cannot be supplied, then rapidly respond when irrigation water becomes available. Resilience to low water availability can be achieved with drought tolerant perennial species, or annual plant based systems where the crop is planted only when water will be available. Salinity-tolerant crops are also considered here. Examples of resilient irrigated crops include: olives, jojoba, pomegranates, capers, Australian native bush foods (such as quandong, bush tomato, desert lime), cacti, dates and annual crops.
- Dryland farming systems – with declining total amounts of irrigation water there will be a conversion to dryland agriculture. Examples of industries considered here include: mustards, crambe, quinoa, tepary bean, Australian native grass crops, industrial crops (guayule, lesquerella, buffalo gourd and grindelia), eucalypts for oil and extensive animal industries (goats and kangaroos).

At a regional scale, increasing agrodiversity is suggested as a means of reducing the risk associated with extreme climatic events by having a range of crops at different stages of their production cycle at any single point in time. In this way an extreme climate event, such as a heatwave or cyclone, will not affect all production from a farm or region.

The challenge for industries and communities is to incorporate the unavoidable impacts of climate change into their planning and decision making. The challenge for policy makers is to aid the transition from existing to new rural industries.

TITLE UNDERSTANDING TRANSFORMATION PROCESSES IN AUSTRALIAN PRIMARY INDUSTRIES AND COMMUNITIES

Theme Transformational Adaption concurrent theme
Primary Author Dr Sarah Park
Institution Climate Adaptation Flagship, CSIRO Ecosystem Sciences
Email sarah.park@csiro.au
Co-Authors Nadine Marshall, Emily Mendham, Emma Jakku, Anne-Maree Dowd, Mark Howden

Abstract

Many primary industries and communities in Australia are undergoing fundamental change in response to climatic, demographic, technological, policy and institutional, economic and cultural drivers. If decision-makers at all levels of these industries are to be supported in their attempts to develop and implement informed and effective response actions, it is necessary to understand both the incremental and transformative adaptation strategies that are being adopted.

From a review of literature relating to theories of transformation and transition in agricultural and land-use research and application, we have developed an a *priori* theory of the dynamics of change management. We are seeking to test this theory over the course of a five-year study being undertaken in collaboration with stakeholders from the wine, peanut and livestock industries, and the communities of Sunraysia and Wimmera. In these five case studies we are particularly focusing on understanding the adaptation strategies that are being implemented, and the decisions being taken by stakeholders in their attempts to undertake fundamental transformation of their livelihoods. The purpose of this research is to develop a blueprint of transformational change to help decision-makers at all levels take more informed and effective actions.

We present results from the first year of this longitudinal study and show how our theory is useful for understanding the dynamics of incremental and transformative adaptation, and importantly, how this understanding is providing insights into the opportunities and limitations experienced by stakeholders. From this we identify some of the information and policy needs of those Australian primary industry stakeholders seeking to undertake transformative change.

THEME

GREENHOUSE GAS ACCOUNTING

SYNTHESIS PAPER

TITLE GREENHOUSE GAS ACCOUNTING FOR INVENTORY, EMISSIONS TRADING AND LIFE CYCLE ASSESSMENT IN THE LAND-BASED SECTOR

Theme Greenhouse Gas Accounting
Primary Author Annette Cowie
Institution National Centre for Rural Greenhouse Gas Research
Email Annette.Cowie@une.edu.au
Co-Authors Richard Eckard, Sandra Eady

Key search words Carbon credits, carbon sequestration, Carbon Farming Initiative, carbon trading

Governments, organisations and individuals have recognised the need to reduce their greenhouse gas (GHG) emissions. To identify where savings can be made, and to track progress in reducing emissions, we need methodologies to quantify GHG emissions and removals through sequestration. Of particular relevance to primary producers is the development of methodologies for the Carbon Farming Initiative (CFI) through which landholders may generate credits for reducing emissions and sequestering carbon. These credits will be tradable on the voluntary carbon market to organisations and individuals wishing to offset their emissions.

National GHG inventories for the United Nations Framework Convention on Climate Change (UNFCCC), and accounting under the Kyoto Protocol use a sectoral approach. For example, fuel use in agriculture is reported in the transport component of the energy sector; energy use in producing herbicide and fertiliser is included in the manufacturing section of the energy sector; sequestration in farm forestry is reported in the land use change and forestry sector, while emissions reported in the agriculture sector include methane from ruminant livestock, nitrous oxide from soils, and non-CO_2 GHGs from stubble and savannah burning. In contrast, project level accounting takes into account agricultural sector emissions using whole farm systems modelling and, until energy and transport inputs are covered by a separate system for pricing carbon, direct inputs such as diesel and electricity. A carbon footprint calculation uses a life cycle approach, in which all the emissions associated with an organisation, activity or product are included. The carbon footprint of a food product includes the upstream emissions from manufacturing fertiliser and other inputs, from fuel used in farming operations, from transport, processing and packaging, distribution to consumers, electricity use in refrigeration and food preparation, and waste disposal.

Methods used to estimate emissions range from simple empirical emissions factors, to complex process-based models. For example, the amount of carbon sequestered by a forest can be estimated from a table of default sequestration rates. Australia's National Carbon Accounting System, in contrast, uses a sophisticated model based on process-level understanding of factors that drive plant growth and turnover of carbon in the soil, to estimate sequestration from data on climate, soil and forest management.

Methods developed for inventory and emissions trading must balance the need for sufficient accuracy to give confidence to the users, with practical aspects such as ease and expense of data collection. Requirements for frequent on-ground monitoring and third party verification of soil carbon or livestock methane estimates, for example, may incur costs that would negate the financial benefit of credits earned, and could generate additional GHG emissions.

Research is required to develop rapid on-farm measures of methane and nitrous oxide, and methods to quantify carbon in environmental plantings, agricultural soils and rangeland ecosystems, to improve models for estimation and prediction of GHG emissions, and enable baseline assessment. There is a need for whole-farm level estimation tools that accommodate regional and management differences in emissions and sequestration, to support landholders in managing net emissions from their farming enterprises. These on farm "bottom up" accounting tools must align with a "top-down" national account. To facilitate assessment of carbon footprints for food and fibre products, Australia also needs to build a comprehensive life cycle inventory database.

It is critical that cost-effective yet credible GHG estimation methods are devised, to encourage participation in voluntary schemes such as CFI, and therefore achieve maximum mitigation in the land-based sector.

TITLE GREENHOUSE GAS EMISSIONS FROM FOOD AND BIOFUEL PRODUCTION: CONTRIBUTION OF SOIL N_2O EMISSIONS

Theme Greenhouse Gas Accounting
Primary Author Associate Professor Louise Barton
Institution University of Western Australia
Email louise.barton@uwa.edu.au
Co-Authors Wahidul Biswas, Klaus Butterbach-Bahl, Ralf Kiese, Daniel Carter and Daniel Murphy

Key search words Canola, IPCC Default Emission Factor, Life Cycle Analysis, Nitrous oxide, Wheat

Correctly accounting for soil nitrous oxide (N_2O) emissions is necessary when assessing the carbon footprint of agricultural and bioenergy cropping systems. Although soil N_2O emissions appear low in relation to N fertiliser inputs [e.g., 1.0% if Intergovernmental Panel on Climate Change (IPCC) default factor employed; IPCC 2006], the high global warming potential of N_2O(298 times greater than CO_2), and the increasing amount and area to which N fertiliser is applied, means accurate estimates are required when calculating net greenhouse gas (GHG) emissions from food and biofuel production.

We measured soil N_2O emissions from a rain-fed, cropped coarse textured soil in a semi-arid region of the Western Australian grainbelt for three years on a sub-daily basis (Barton et al. 2010; Barton et al. 2008). The site included N fertiliser (75–100 kg N ha^{-1} yr^{-1}) and no N fertiliser plots ('control'). Emissions were measured using soil chambers connected to a fully automated system that measured N_2O using gas chromatography. Daily N_2O emissions were low (-1.8–7.3 g N_2O-N ha^{-1} day^{-1}) and culminated in 0.09–0.13 kg N_2O-N ha^{-1} yr^{1} from the N fertiliser soil and 0.07–0.09 kg N_2O-N ha^{-1} yr^{1} from the control. The proportion of N fertiliser emitted as N_2O each year, after correction for the control emission ('background'), was 0.02–0.07%. The N_2O emission factor calculated from this soil was up to 50 times lower than the IPCC default value for the application of synthetic fertilisers to land (1.0%; IPCC, 2006).

Incorporating locally measured N_2O values greatly decreased the carbon-foot print of wheat and biodiesel produced from the Western Australian grainbelt. Greenhouse gas emissions decreased from 487 to 304 kg CO_2-equivalents per tonne of wheat using local N_2O emissions rather than the international default value (Biswas et al. 2008). Furthermore, utilising locally measured soil N_2O fluxes decreased GHG emissions from the production and combustion of one GJ canola based biodiesel from 63 CO_2- to 37 CO_2-equivalents; with GHG emissions up to 2.1-times lower than that from the production and combustion of one GJ mineral diesel (Biswas et al. 2011). Indirect soil N_2O emissions from ammonia volatilisation (9% of total GHG emissions), estimated using an IPCC default value, contributed more than the measured direct soil N_2O emissions (5%) to GHG emissions from the production and combustion of one GJ biodiesel. By contrast, indirect N_2O emissions from N leaching were negligible based on IPCC calculations.

We recommend utilising regionally specific estimates of direct soil N_2O emissions, and include estimates of indirect N_2O emissions, when assessing GHG emissions from food and biodiesel production.

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TITLE WHOLE FARM SYSTEMS ANALYSIS OF THE GREENHOUSE GAS EMISSIONS OF AUSTRALIAN DAIRY FARMS

Theme Greenhouse Gas Accounting

Primary Author Ms Karen Christie
Institution Tasmanian Institute of Agricultural Research
Email Karen.Christie@utas.edu.au
Co-Authors Cameron Gourley and Richard Rawnsley

Key search words Carbon dioxide; DGAS; Methane; Nitrous oxide; Pre-farm embedded

Abstract

The Australian dairy industry contributes approximately 1.6% of the nation's greenhouse gas (GHG) emissions, emitting an estimated 8.9 million tonnes of carbon dioxide equivalents (t CO_2e) per annum (DCC, 2008). This study examined GHG emissions of 41 dairy farms from throughout eight dairying regions of Australia, using the Dairy Greenhouse gas Abatement Strategies calculator (Christie *et al*., 2011), which incorporates International Panel on Climate Change and Australian inventory methodologies, algorithms and emission factors. The sources of GHG emissions included CO_2 associated with the pre-farm embedded emissions of key farm inputs and on-farm emissions of CO_2, methane and nitrous oxide. The mean total dairy farm GHG emission was 2,214 t CO_2e/annum. The estimated milk GHG emission intensity was 1.02 ± 0.17 kg CO_2e/kg of fat and protein corrected milk (mean ± standard deviation; FPCM, IDF (2010)), with a range of 0.74 to 1.65 kg CO_2e/kg of FPCM. The estimated mean cow GHG emission intensity was 6.17 ± 0.73 t CO_2e/cow, with a range of 4.51 to 8.19 t CO_2e/cow. The estimated mean area GHG emission intensity was 7.54 ± 3.71 t CO_2e/ha, with a range of 1.35 to 17.64 t CO_2e/ha.

Farms were grouped according to the farm system intensity (FS) classification defined by Dairy Australia. Farm system 1 farms are characterised as predominantly pasture based with low grain and purchased supplementary feeding (< 1t DM grain/cow.lactation and < 30% purchased supplementary feed), FS2 farms are characterised as pasture based with medium to high levels of grain (> 1 t DM grain/cow.lactation and >30% of purchased supplementary feed) and FS3 farms are characterised as a hybrid between grazed pasture and high purchased supplementary feeding (> 2 t DM grain/cow.lactation and > 40% purchased supplementary feed). This study resulted in 19 FS1, 13 FS2 farms and 9 FS3 farms being assessed. The mean emission intensity of milk production was significantly ($P<0.05$) higher for FS1 farms, at 1.12 kg CO_2e/kg FPCM, compared to FS2 and FS3 farms which were not significantly ($P>0.05$) different to each other, at 0.93 and 0.92 kg CO_2e/kg FPCM, respectively. There was no significant ($P>0.05$) differences in mean milk GHG emissions intensity between the regions, with the exception of Tasmania, which was significantly ($P<0.05$) higher, at 1.28 kg CO_2e/kg FPCM, compared to between 0.93 and 1.04 kg CO_2e/kg FPCM for all other regions. One reason for Tasmania being significantly higher was partially due to one farm having an estimated milk GHG emission intensity that was approximately 50% greater than the next highest farm.

While these results indicate that adopting a more intensive farming system resulted in reducing milk GHG emissions intensity, this will most likely require a greater reliance on imported feeds and/or fertilisers which may result in increased nutrient losses to the environment, could potentially diminish our international competitive advantage of producing milk at a lost cost, in addition to reducing the resilience of the farming system in a changing climate.

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TITLE ASSESSING THE GREENHOUSE IMPACT OF DIFFERENT FARMING PRACTICES USING A WHOLE-SYSTEM APPROACH

Theme Greenhouse gas accounting
Primary Author Dr Weijin Wang
Institution Department of Environment and Resource Management (DERM)
Email weijin.wang@derm.qld.gov.au
Co-Authors Dr Ram Dalal
Key search words Greenhouse gas, agriculture, no-till, CO2, N2O, CH4, LCA

Agriculture affects global greenhouse gas fluxes not only through the on-farm processes and management practices but also indirectly through the off-farm activities along the supply chains and export pathways of farm materials. The long-term (40 years) greenhouse gas inventory under no-till (NT) vs. conventional till (CT), stubble retention (SR) vs. stubble burning (SB), and N fertilisation (NF) vs. no N fertilisation (N0) were assessed for a cereal cropping system in SE Queensland by taking into account all the major sources, sinks and fluxes of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

The experimental site is on a cracking clay soil containing 65% clay. Mean annual temperature at the site is 17.5°C and mean annual rainfall is 685 mm. From 1968 to 2008, wheat (Triticum aestivum L., cv.) was grown generally from June/July to November/December each year except 1982, 1991, 1994 and 2004, when there was insufficient rainfall for sowing. In the present study, eight treatments were examined, which consisted of a 2 × 2 × 2 factorial combination of tillage (CT or NT), stubble management (SR or SB), and N fertilisation (N0 or NF) arranged in a randomised block design with four replications. The treatments under CT generally involved three or four tillage operations during the fallow period each year (approximately December to June), while the plots under NT were sprayed with herbicide to control weeds. Crop residues with the SB practice were burnt shortly after harvest. The treatments with NF received urea at 46 kg N ha^{-1} yr^{-1} during the first eight years, then at 69 kg N ha^{-1} yr^{-1} until 1996 and at 90 kg N ha^{-1} yr^{-1} thereafter. On-site measurements of N_2O and CH_4 fluxes from soil were undertaken over three years from 2005 to 2008 using a combination of automatic and manual gas sampling chambers. Soil organic C stocks in the 0-20 cm layer were measured in 2002.

Averaged across different treatments over the 36 cropping years, annual emissions from on-farm sources including diesel combustion, stubble burning, urea hydrolysis and fertiliser N application were estimated to be 438 kg CO_2-e ha^{-1} yr^{-1} for CT vs 337 kg CO_2-e ha^{-1} yr^{-1} for NT, 489 kg CO_2-e ha^{-1} yr^{-1} for SB vs 286 kg CO_2-e ha^{-1} yr^{-1} for SR, and 187 kg CO_2-e ha^{-1} yr^{-1} for 0N vs 588 kg CO_2-e ha^{-1} yr^{-1} for NF. Pre-farm emissions were 90 kg CO_2-e ha^{-1} yr^{-1} for NT vs 50 kg CO_2-e ha^{-1} yr^{-1} for CT resulting from the manufacture and transport of herbicide, farm machinery and diesel fuel, and 292 kg CO_2-e ha^{-1} yr^{-1} for NF owing to the production and transport of urea. Off site N_2O emissions resulting from the N lost during stubble burning and fertiliser N volatilisation from soil were in the range of 22-55 kg CO_2-e ha-1 yr-1. In comparison to the CT + N0 + SB treatment, significantly higher organic C stocks in soil and crop residues were achieved only under the NT + NF + SR treatment (by 230 kg CO_2-e ha^{-1} yr^{-1}).

This cereal cropping system is a net emitter under all combinations of different tillage, stubble management and N fertilisation practices studied, contributing from 144 kg CO_2-e ha^{-1} yr^{-1} or 63 kg CO_2-e t^{-1} grain under the NT + N0 + SR treatment to 1050 kg CO_2-e ha^{-1} yr^{-1} or 403 kg CO_2-e t^{-1} grain under the CT + NF + SB treatment. Among the fertilised treatments, practising NT + SR resulted in the lowest net emission (576 kg CO_2-e ha^{-1} yr^{-1} or 201 kg CO_2-e t^{-1} grain). Direct emissions associated with manufacture, transport and application of N fertiliser accounted for 83% of the gross emissions under the NT + NF + SR treatment. Therefore, future efforts should be directed to improve fertiliser N use efficiency while practising no-till and stubble retention for conservation agriculture.

TITLE THE GREENHOUSE FOOTPRINT OF WOOD PRODUCTION IN NSW

Theme Greenhouse Gas Accounting
Primary Author Mr Fabiano Ximenes
Institution Industry and Investment NSW
Email fabianox@sf.nsw.gov.au
Key search words Greenhouse; wood products; energy; footprint

Wood products can significantly extend the greenhouse gas mitigation benefits provided by forests. The proper management of wood products is essential to optimise the use of the land devoted to commercial forests. The true greenhouse impact of wood products is measured to a large extent by the energy required in their extraction, manufacture and use and by their disposal strategies, as well as the physical carbon storage in the products.

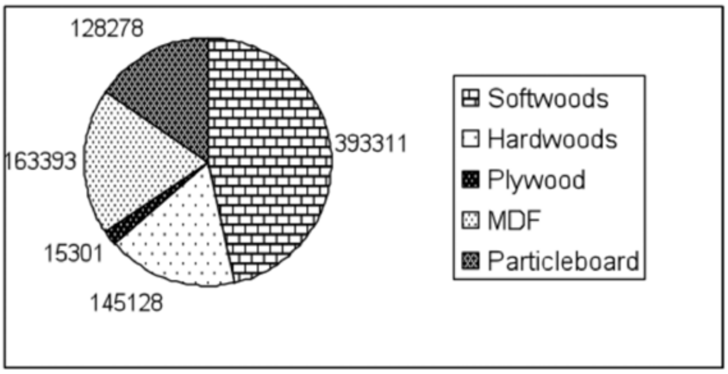
This presentation will detail the results of a three-year project aimed at developing a greenhouse budget for the main types wood products used for building in NSW and determine the greenhouse impact of waste disposal options. The study was conducted with the cooperation of three softwood mills, three hardwood mills, one plywood mill and one truss and frame manufacturer, as well as information on particleboard and medium-density fibreboard production. The results include three main modules: harvest and log transport, manufacture and transport to the market.

In the case of the production of sawn hardwood and sawn softwood where an obvious main finished product was produced, neither by-products (e.g green packing) nor residues were assigned any of the greenhouse emissions produced. The main finished product carried all the greenhouse burden of production, as that product is the primary reason for the existence of the facility.

The mean greenhouse intensity of all operations (including harvest, log transport, manufacture and transport to markets) was low (ranging from 0.13 to 0.63 tonnes CO_2-e / m^3 of finished products) and in agreement with the vast majority of literature. The energy intensity of the operations was also quantified and ranged from 1.67 to 5.37 GJ / m^3 of wood. The energy required for drying is the most significant component of the energy intensity of the manufacture of wood products.

Any extrapolation of the results to the whole of the industry needs to be approached with caution and should be seen as indicative only. Based on the annual volume of production of wood products in NSW, an estimated 845,000 tonnes of carbon dioxide equivalents were emitted due to the annual production of wood products in NSW (Figure 1). The implications of considering the physical storage of carbon in those products will be discussed.

Figure 1. Greenhouse emissions (tonnes CO_2-e) for the annual production of wood products in NSW, considering harvest, log transport, manufacture and transport of products and residues.



THEME

SOILS

SYNTHESIS PAPER

TITLE **SOILS AND CLIMATE CHANGE: POTENTIAL IMPLICATIONS AND FUTURE RESEARCH FOR AUSTRALIAN AGRICULTURE**

Theme Soils
Primary Author Dr. Jeff Baldock
Institution CSIRO
Email Jeff.Baldock@csiro.au
Co-Authors J.A. Baldock1, N. McKenzie2, A. McBrateny3
1 CSIRO Land and Water/Sustainable Agriculture Flagship, PMB 2, Glen Osmond, SA 5064
2CSIRO Land and Water, Canberra, ACT 2601
3University of Sydney, Faculty of Agriculture Food & Natural Resources, Sydney, NSW 2006

Soils contain large stores of organic carbon and nitrogen that are continuously exposed to decomposition and a range of additional biologically mediated transformations that generate or consume all three major greenhouse gases (CO_2, N_2O and CH_4). Globally, soils and their management therefore have the potential to either enhance or reduce atmospheric concentrations of greenhouse gases and the magnitude of climate change. Concern also exists over the potential positive feedbacks that a changing climate may have on rates of greenhouse gas emission from soil.

Climate projections for most of the agricultural regions of Australia suggest a warmer and drier future with greater extremes relative to current climate. Since emissions of greenhouse gases from soil derive from biological processes that are sensitive to soil temperature and water content, climate change may impact significantly on future emissions. In this paper the potential effects of climate change and options for adaptation and mitigations will be considered followed by an assessment of future research requirements.

Carbon dioxide can be removed from the atmosphere by photosynthesis and stored in soil as organic material through the deposition of plant derived materials in and on soil. Soil organic carbon (SOC) is returned to the atmosphere as CO_2 via respiration that occurs during decomposition. SOC exists in many forms that exhibit marked differences in their susceptibility to decomposition. Although measures of total soil organic carbon can suffice for carbon accounting purposes; knowing the allocation of soil carbon to the different forms (particulate, humus and resistant) will allow assessments of the vulnerability of soil carbon to change and facilitate the use of computer models in scenario predictions.

The amount of SOC results from the balance between carbon inputs and losses both of which will be impacted on by climate change. Losses will be accelerated under increased temperature and slowed under drier soil conditions. Some evidence suggests that the relative increase in loss rates with increasing temperature will be greater for the more stable than less stable forms of carbon. Inputs of carbon may be enhanced by warmer temperatures and higher CO_2 concentrations but decreased by a lower availability of water. The final direction of change will be defined by the balance of all these processes.

The positive influence that increased soil carbon content can have on soil water holding capacity may help maintain productivity as drying occurs. Irrespective, the guiding principal to enhance carbon capture in soils under any climate change scenario will be to maximise carbon inputs. Where the ability of a soil to protect organic carbon against decomposition is not saturated and/or where inefficiencies in resource use (water and nutrients) can be improved by altered management to allow plants to capture additional atmospheric CO_2, the potential exists to increase SOC and enhance soil resilience and productivity. This potential will vary from location to location as a function of soil type (clay content, depth, bulk density, etc.), environmental conditions (amount of available water and nutrients, temperature, etc.) and past management regimes (how much carbon has been lost due to past management).

Nitrous oxide is generated in soils as a by-product of two natural biological processes involved in transformations of inorganic nitrogen: 1) nitrification (conversion of ammonium to nitrate) and 2) denitrification (conversion of nitrate to N_2 gas). The key to mitigating emissions of N_2O from agricultural soils is to minimise concentrations of inorganic N particularly during periods of high soil water content. By limiting the amount of inorganic N available for nitrification and denitrification,process rates will be reduced. Lowering concentrations of inorganic Ncan be achieved by reducing the reliance on fertiliser N were possible and/or by better matching fertiliser N applications to plant demand. The use of multiple fertiliser additions at low application rates defined by plant growth stage and seasonal conditions, will likely result in lower N_2O emissions than the use of less frequent larger applications. Under irrigation agriculture, where large rates of N fertiliser addition are common, using smaller and more frequent irrigation or fertigation events that reduced the extent of soil saturation and inorganic N concentrations will help mitigate N_2O emissions. In any consideration of agricultural practices that mitigate N_2O emissions, additional greenhouse gas production (e.g. CO_2 created by burning fossil fuel) must also be considered to accurately define the level of mitigation.

Because nitrification and denitrification are biochemical processes, process rates will increase with increasing temperature provided the appropriate inorganic N substrate is present. However,these processes respond differently to variations in soil water content. Both processes are limited at very low soil water contents with nitrification being optimised under drier conditions than denitrification. If climate change results in a warmer and drier environment across Australia's agricultural region, emissions of N_2O under dryland practices may decrease. However, under irrigated systems, where water content limitations are removed, the higher temperatures associated with projected climate change may enhance N_2O emissions unless soil inorganic N levels are tightly controlled.

Methane can be produced and consumed by soil microorganisms. Most dryland agricultural soils, will provide a net sink for methaneexcept when subjected to prolonged saturation. Increased temperatures and drier conditions would be expected to reduce CH_4 emissions and enhance CH_4 consumption, provided soils do not dry to the extent that the activity of methanotrophs is limited.

Future research will need to focus on developing methodologies capable of quantifying soil carbon stocks and fluxes of greenhouse gases and building a modelling capability that can predict the outcomes of defined management scenarios and policy decisions. Various measurement strategies and modelling approaches for quantifying soil carbon stocks exist, but continued development and in particular building a capability to define the level of the uncertainty associated with measured or modelled soil carbon stocks is required. As Australia enters into carbon trading systems, just measuring or predicting that soil carbon has or is projected to increase by 10 t CO_2-e ha^{-1} over a 5 year period will not be good enough. The uncertainty associated with such values will be required and would include that associated with measurements, modelling (if used) and the spatial variability associated with the variable of interest (e.g. soil carbon content) and all other variables required to complete calculations (e.g. bulk density in the case of soil carbon stocks). Further development of N_2O and CH_4 emission measurement capabilities and simulation modelling, again with associated uncertainties, will be required.

The diversity of climate, soil types and agricultural practices in place across Australia will make it difficult to define generic greenhouse gas emissions scenarios. Development of a robust modelling capability will be required to construct regional and national emission assessments and define the potential outcomes of on farm management decisions and policy decisions. This model development will require comprehensive field data sets to calibrate the models and validate model outputs. Additionally, improved spatial layers of model input variables collected on a regular basis will be required to optimise accountingat regional through to national scales.

TITLE THE AUSTRALIAN NITROUS OXIDE RESEARCH PROGRAM

Theme Soils
Primary Author Professor Peter Grace
Institution Institute for Sustainable Resources, Queensland University of Technology, 2 George St., Brisbane Qld 4000.
Email pr.grace@qut.edu.au
Co-Authors Louise Barton, Deli Chen, Richard Eckard, Kevin Kelly, Sally Officer, Clemens Scheer, Graeme Schwenke, Helen Suter, Weijin Wang
Key search words N_2O, nitrous oxide, mitigation

Full greenhouse gas (GHG) accounting is critical when developing emissions reduction strategies for both irrigated and dryland farming systems. The relatively short duration and episodic emissions of the most potent GHG, nitrous oxide (N_2O) are closely related to water, carbon and nitrogen management and require specific attention. To fully understand the interactions of soil and plant management, biogeochemistry and climate requires the collection of long-term, high spatial and temporal resolution data afforded by automated GHG monitoring systems. An informal network of high (spatial and temporal) resolution GHG sampling systems has existed in Australia since 2005, with the majority of sites using gas chromatography and infra-red CO_2 analysis. Since 2009, the Australian Nitrous Oxide Research Program (NORP) has explicitly linked six experimental sites real-time N_2O and carbon dioxide (CO_2) emissions, and (in some cases) methane (CH_4) consumption data from a broad geographical range of irrigated and dryland, crop and pasture farming systems. Fourier Transform Infrared Spectroscopy (FTIR) and Tuneable Diode Laser (TDL) technologies are also in use.

The objective of NORP is to develop a detailed understanding of the biogeochemical and physical processes influencing N_2O emissions from agricultural systems of Australia. This will provide landholders with management strategies which have a significant impact on reducing N_2O losses whilst maintaining productivity and profitability as well as the base data for the further development and testing of the National Carbon Accounting System (NCAS) and simulation models. The major elements of NORP are an overarching integration and coordination project; six automated GHG sampling and analysis projects with multiple treatments at experimental locations throughout Australia; and a laboratory based project examining the impact of nitrification inhibitors on N_2O production.

The integration project coordinates data acquisition, database development and maintenance, data entry and web-based management, synthesis, analysis and retrieval. The database is totally scalable to ensure addition of new sites as they come on-line. The location of the experimental sites and their specific objectives are:

- Grains/cotton (Qld) – irrigated systems at Kingsthorpe (near Toowoomba), examining the impacts of water and N management on emissions.
- Grains (WA) – rainfed systems at Wongan Hills, examining the emissions of N_2O associated with the substitution of grain legumes for sources of nitrogen, and the liming of cereals.
- Grains (NSW) – rainfed systems at Tamworth, examining the use of legumes as alternate nitrogen sources.
- Sugar cane/grains (Qld) – rainfed systems at Mackay. Treatments include the use of nitrification inhibitors with fertilisers to reduce N_2O emissions and substituting legume sources of nitrogen for fertilisers.
- Dairy (Victoria) – high rainfall pasture systems at Terang, measuring N_2O emissions in response to the application of urine and inhibitors at the DemoDairy site.
- Grains (Victoria) – high rainfall systems at Hamilton, measuring N_2O emissions from direct drilled and conventionally sown legume/wheat rotations, including the use of nitrification inhibitors.

NORP is principally funded by the federal Department of Agriculture, Fisheries and Forestry (DAFF) under its Australia's Farming Future (AFF) initiative (2009-1012), with additional funding from four Research and Development Corporations (RDCs) – Grains (GRDC), Sugar (SRDC), Dairy (SRDC), Cotton (CRDC) as well as Incitec Pivot, with cash and in-kind contributions from state governments and university participants. NORP also provides analytical services for the AFF's National Adaptation and Mitigation Initiative (NAMI).

TITLE EMISSION OF NITROUS OXIDE FROM A CRACKING CLAY SOIL USED TO GROW CANOLA AND CHICKPEA IN THE NORTHERN GRAINS REGION

Theme Soils
Primary Author Dr Graeme Schwenke
Institution Industry and Investment NSW
Email graeme.schwenke@industry.nsw.gov.au
Co-Authors Prof David Herridge, Dr Guy McMullen, Bruce Haigh, Kelly Baker
Key search words nitrous oxide, greenhouse gas emissions, legume, chickpea, canola

Nitrous oxide (N_2O) is emitted from soil as a by-product of nitrification and an end-product of denitrification, both biologically-mediated processes. Neither process has any regard for the original source of the nitrogen (N), be it inorganic (fertiliser) or organic (soil humus, crop residues, manures). Therefore, the potential for loss of N_2O depends on managing the amount and timing of the source N that enters the soil system.

Legume crops utilise both plant-available soil N (nitrate) and biologically fixed N_2. In-crop emissions are likely to be very low, but the post-harvest crop residues will provide an organic source of N that is mineralised during the fallow into nitrate. In contrast, non-legumes generally require added fertiliser N to supplement that mineralised from the soil's organic matter. Some N_2O emissions are expected as a by-product of the conversion of urea/ammonia fertiliser to nitrate in the soil. More emissions may occur if the soil becomes waterlogged in the period between nitrification and crop uptake, leading to losses via denitrification. As with the legume crop, once the non-legume crop has been harvested, the crop residues then constitute an organic N source that slowly feeds mineralised N back into the soil. During the fallow period, the mineralised N (nitrate) is again susceptible to denitrification loss - should waterlogging conditions occur with summer rains.

We measured N_2O emissions from a dryland vertosol (cracking clay soil) in northwest NSW during and after the growth of N-fertilised canola and N_2-fixing chickpea. At sowing in June 2009, canola received 80 kg N/ha as urea. Chickpea received no fertiliser N but was inoculated with effective rhizobia and fixed 41 kg N/ha during its growth. Emissions of N_2O from the soil were monitored 7-8 times per day for a year using an automated system of chambers connected to a gas chromatograph. Over one year, N_2O emissions from the canola plots totalled 627 g N/ha, while the chickpea plots emitted just 134 g N/ha. Several distinct periods of emissions occurred in response to moderate to heavy rainfall, with low or nil emissions in between. Approximately one third of the year's N_2O emissions occurred in two separate week-long waterlogging events during the summer post-harvest fallow.

Emissions monitoring continued during 2010 with wheat or sorghum grown in the same plots following the canola and chickpea. Preliminary results for June–December 2010 will be presented at the conference. We conclude from the first year's results that greater use of N_2-fixing pulses in the cropping systems of Australia's northern grains region should lead to substantially reduced N_2O emissions and contribute to the overall reduction of total greenhouse gas emissions from the broadacre grains industry.

TITLE CAN WE REDUCE NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION SYSTEMS?

Theme Soil
Primary Author Kevin Kelly
Institution Department of Primary Industries (Victoria)
Email kevin.kelly@dpi.vic.gov.au
Co-Authors Graeme Ward, Sally Officer, Tim Huggins, Richard Eckard
Key search words Dicyandiamide, DCD, dairy, urine patches, southern Victoria

The excretion of nitrogenous compounds by livestock to pasture and rangelands makes a significant contribution to Australian nitrous oxide (N_2O) emissions. Recent research in New Zealand has demonstrated the potential for significant reductions in direct N_2O emissions and nitrate leaching (thereby also indirect nitrous oxide) from the surface application to pasture soils of a nitrification inhibitor dicyandiamide (DCD).

Our current research project is investigating the potential of DCD, as a liquid spray, to reduce N_2O emissions from dairy cow urinary deposition in south-western Victoria. The site at Terang (38o14'S, 142o55'E), is on a brown chromosol derived from quaternary basalt and has a long term average annual rainfall of about 780 mm. This project commenced in 2009 and uses an automated chamber system linked to a Fourier Transformed Infrared spectrometer for continuous gaseous measurements to estimate emissions.

To date we have shown a reduction of about 35% in N_2O emissions from urine patches deposited in August and September when DCD was applied in August, and a reduction of 45% in N_2O emissions from urine patches deposited in April and May when DCD was applied in April. We have also studied the impact of DCD application on pasture DM production at six sites across the dairy region in south-western Victoria, where DM production responses have varied from 0 to 15% at the whole urine patch level. Given the amount of a paddock covered by urine patches in a year it is unlikely that these DM responses would be significant at the paddock scale.

We have shown that emission from urine patches can be reduced by the use of DCD, although the emission reductions are lower than those reported in New Zealand, and pasture responses to the application of DCD have been negligible.

TITLE MEASUREMENT AND SIMULATION OF AMMONIA VOLATILIZATION FROM UREA FERTILIZER IN CROPPING AND PASTURE SYSTEM

Theme Soils concurrent theme
Primary Author Professor Deli Chen
Institution The University of Melbourne
Email delichen@unimelb.edu.au
Co-Authors Yong Li, Debra Turner, Helen Suter, Tom Denmead, John Freney, Richard Eckard

Key search words Modelling, WNMM, DNDC, N2O, nitrification, gentrification

Abstract

Ammonia (NH_3) volatilization is an important pathway in soil N cycling and often responsible for the low efficiency of N fertilizer in plant-soil systems. The NH_3 volatilization is strongly influenced by soil and climatic factors and management practices. The quantifying NH_3 volatilization is a technically challenge and costly exercise.

We present the NH_3 volatilization losses from the field experiments after the nitrogen fertilizer application in wheat, maize and pasture systems in Australia and China under different soil and climate conditions and management practices. The NH_3 volatilizations were measured by micrometrological methods of full profile (mass balance), gradient fluxes and the recently developed technique of open path laser/FTIR- Lagrangian model of atmospheric dispersion.

NH3 volatilization accounts up to up to 50% total N applied to alkaline in the North China Plain, up to 20% in the acidic pasture soils in Australia. The fertilizer application and irrigation methods strongly influence the NH_3 volatilization as well as soil and climate conditions. Green urea, a commercial product containing NBPT as a urease inhibitor, was effective in reducing the NH_3 volatilisation (up to 90% less) when applied to wheat crop and pasture by surface broadcasting.

A NH_3 volatilization sub-model was developed under the simulation framework of Water and Nitrogen Management Model (WNMM). A unique feature of this simulation component is the introduction of fertilizer N distribution function in soils for different applying methods, surface broadcasting, surface broadcasting followed by irrigation and deep placement. This sub-model calculates ammonia volatilization from surface and subsurface soil separately. For the surface layer, ammonia volatilization is controlled by soil temperature and wind speed, while for the subsurface soil layer, it is regulated by soil temperature, soil moisture, CEC and depth. The effect of localized pH surrounding urea granules and urine patches due to urea hydrolysis has been simulated, which is the main cause of NH_3 volatilization in acidic soils. The model also incorporate the effect of urease inhibitor.

TITLE QUANTIFYING THE IMPACT OF CONVERSION OF PASTURE LAND TO *PINUS RADIATA* PLANTATION ON SOIL CARBON STOCKS AND DYNAMICS

Theme Soils
Primary Author Dr. Bhupinder Pal Singh
Institution Industry and Investment NSW
Email Bp.singh@sf.nsw.gov.au
Co-Authors Lai Fan Poon, James Quilty, Pushpinder Matta, Annette Cowie, Balwant Singh, Mark Adams
Key search words Afforestation; Land use change; Pasture; Soil carbon; Soil respiration

Abstract

Afforestation is likely to expand across Australia in response to the growing opportunities for forests to earn "carbon credits" under emissions trading. Thus, there is a need to make a detailed assessment of the impact of afforestation on soil organic carbon (C) stocks and dynamics, as well as to resolve any contradictions as to whether soil organic C may decrease or increase when agricultural lands are afforested with pine plantations.

In a preliminary study, soil samples were collected from a chronosequence of 3-yr, 5-yr and 25-yr 'paired' pasture–pine (*Pinus radiata*) plantation sites in central tablelands of New South Wales. Organic C and total nitrogen (N) stocks in the top 30 cm soils were quantified. Microbial biomass-C, heterotrophic respiration, metabolic quotient, and temperature sensitivity (Q10) were determined at incremental soil depths to 30 cm. We found that the difference in the organic C content of soil varied greatly (64 to 104 t/ha) between sites. Compared with adjacent pasture, younger pine plantations (3-yr and 5-yr after establishment of first rotation plantation) had lower soil C stocks (by up to 30%), whereas mature pine plantation (25-yr after establishment of second rotation plantation) had ~15% higher soil organic C. Microbial biomass-C was lower and metabolic quotient greater in the 5-yr plantation compared to adjacent pastures. Rates of heterotrophic respiration were similar for the 3-yr and 5-yr plantation-pasture pairs, but were faster at greater depths (5–10 cm and 10–30 cm) in the 25-yr pine plantation than the adjacent pasture. The temperature sensitivity of heterotrophic respiration was not significantly influenced by the land use change (Q10 =1.9 to 2.5). This study suggests that afforestation with Pinus radiata leads to changes in soil C. Soil C stocks may decrease initially, likely due to decreased input of plant C during early stages of plantation growth. Soil C in mature pine plantations may stabilise at greater concentrations than in pastures. This study does not support the common assumption, which is based on a limited number of Australian studies, of a 15% decline in soil C where pasture is converted to pine; in fact the soil C content was higher in a mature pine plantation than in adjacent pasture. Clearly, in order to determine the net greenhouse gas mitigation potential of plantation forestry, further research is required to accurately quantify and predict soil C stocks and losses following afforestation of agricultural lands.

Currently, we are undertaking a detailed study (funded by the Department of Agriculture, Fisheries and Forestry) that focuses on quantification of soil C and N stocks as well as sources of soil respiration in a replicated (n = 3) chronosequence of first-rotation pine plantations on ex-pastoral lands under contrasting rainfall regimes (700 mm versus 1000 mm). For in-situ separation of soil respiratory components, we have employed girdling (ring-barking) and shading approaches in two 23-yr old pine plantations and adjacent pastures, respectively. Preliminary data will be presented at the conference.

TITLE	A FIELD STUDY ON THE IMPACT OF THE NITRIFICATION INHIBITOR DMPP ON N2O EMISSIONS FROM A PASTURE IN SOUTH WESTERN VICTORIA

Theme Soils
Primary Author Dr Helen Suter
Institution The University of Melbourne
Email helencs@unimelb.edu.au
Co-Authors Humaira Sultana, Rohan Davies, Matthew Mahoney and Deli Chen

Key search words Nitrification inhibitor, DMPP, N2O

Abstract

The nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) has been found to reduce emissions of nitrous oxide (N_2O) in laboratory studies on Australian soils (Chen *et al*. 2010). Field studies have found that another nitrification inhibitor, dicyandiamide (DCD), is capable of reducing N_2O emissions in dairy pasture systems in Australia (Kelly *et al*. 2008), but no studies have been done with DMPP on pasture systems. This paper reports on a field trial that was carried out in south western Victoria on a ryegrass seed crop on an acidic (pH 4.6 ($CaCl_2$)) clay loam where surface applications of urea (40 kg N/ha) ± DMPP were made regularly over an 8 month period (autumn to summer) in 2010 to a randomised small plot trial with 5 replicates per treatment. A control (no fertiliser) treatment was also included. Nitrous oxide (N_2O) emissions were measured using manual chambers (23 cm diam., 25 cm high) inserted into the ground (5 cm) for the entire course of the trial. Nitrous oxide flux measurements were collected at regular intervals over the course of the trial by capping the chambers and collecting gas samples at 0, 30 and 60 minutes. Collected gas samples were analysed by GC. Soil mineral N and pasture dry matter (DM) production were also measured with pasture cuts taken and 50% dry matter return to simulate grazing events.

DMPP was effective in maintaining nitrogen (N) as ammonium (NH_4+) for zero to eight weeks longer than unamended urea, most noticeably over the winter months with 6 times higher net NH4+ measured in the DMPP amended urea (8 versus 49 kg net NH_4+-N/ha measured in August, one month after fertilisation). DMPP reduced net nitrate (NO_3-) production over winter by 86%, to 0.5 kg NO_3--N/ha compared to 3.9 kg NO_3--N/ha for urea. The June pasture cut, 2 months after a fertiliser application, showed a 33% increase in DM production with DMPP (876 to 949 kg DM/ha). The cumulative data (over six months) showed that the DMPP treatment reduced NO_3- and N_2O emissions by more than 55% while maintaining more N in NH_4+ form (by 32%) and increasing DM production and N uptake by 9 and 5% respectively (Table 1).

Table 1. Cumulative net N uptake, N_2O emissions soil mineral N (kg N/ha) and DM production (kg/ha) following 5 fertiliser applications of 40 kg N/ha over 6 months

Treatment	NH_4+-N	NO_3--N	DM	N uptake	N_2O
Urea	173	24	1751	70	0.26
Urea + DMPP	230	10	1907	73	0.07
Difference (%)	+32	-59	+ 9	+ 5	-73

The results showed that DMPP is very effective in reducing N_2O emissions while increasing N efficiency in pasture systems in south west Victoria. DMPP was found to be most effective over the winter months, highlighting the need to target application timing to achieve the greatest benefit from the inhibitor.

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TITLE HOW WILL THE IMPACT OF ELEVATED CARBON DIOXIDE ON GRAIN PRODUCTION VARY WITH DIFFERENT SOILS?

Theme Soils
Primary Author Dr Roger Armstrong
Institution Future Farming Systems Research, Victorian Department of Primary Industries
Email Roger.armstrong@dpi.vic.gov.au
Co-Authors Dr Nicole Mathers, Raymond Lam, Dr Deli Chen, Dr Rob Norton, Jian Jin, Dr Caixian Tang and Dr Peter Sale
Key search words Elevated carbon dioxide, soil nutrients, water, nitrogen fixation

Global atmospheric concentrations of carbon dioxide (CO_2) are expected to reach 500 ppm by 2070 (IPCC), although at current rates this level will be reached much sooner. Overseas studies have shown that 'CO_2 fertilisation' can markedly alter the physiological responses of grain crops including water and nutrient use efficiency. Soils can inherently alter the interactions between plants, water and nutrients. Soils underpinning the Australian grains industry vary markedly so there is speculation about how different soils may influence interactions between rising atmospheric CO_2 concentrations and grain production.

A Free Air Carbon Dioxide Enrichment (SoilFACE) array was established at Horsham in 2009 to specifically investigate interactions between elevated CO_2 (eCO_2) and below-ground processes. SoilFACE comprises bunkers (replicated 4 times), subjected to either elevated (550 ppm) or ambient CO_2 concentrations, that house large intact cores (0.3 m diameter x 1.0 m deep) representing 3 major cropping regions/soil types of Victoria (Wimmera Vertosol; Hamilton Chromosol and Mallee Calcarosol). The cores have been sown in a phase replicated design of wheat (*cv.* Yipti) or fieldpeas (OZP0601). The bunkers have been designed so that auxiliary experiments, such as the nutrient response of crops to CO_2, can be undertaken using smaller cores.

In 2009, the first season of CO_2 fertilisation, there was a significant ($P< 0.01$) effect of soil type on dry matter production, N uptake, grain yield and the amount of N fixed by fieldpeas at peak biomass, but no effect of CO_2 fertilisation. Dry matter production of wheat at maturity was 26% greater under elevated CO_2 but there was no significant effect on grain production. In 2010 soil nitrate prior to sowing varied markedly with soil type; ranging from very high in the Hamilton soil (145.7 kg/ha) to a low of 23.4 kg/ha in the Walpeup soil. There was no effect of CO_2 fertilisation from the previous year although soil nitrate tended to be greater in the surface layer of soil previously sown to wheat but lower at greater depths. Similarly, soil water throughout the profile at sowing in 2010 tended to be higher in cores sown to fieldpeas the previous season (reflecting their lower biomass production) but was unaffected by CO_2 fertilisation. There was a significant interaction ($P = 0.039$) between soil type and CO_2 treatment on the dry matter production of fieldpeas, which appeared to be related to differences in the amount of nitrate present in the different soils at sowing. CO_2 fertilisation increased the total amount of N_2 fixed in the Vertosol but had no significant effect in the other two soil types. The difference in the amount of N fixed concentrations reflected the greater N uptake (ie. increased biomass) under eCO_2 rather than any difference in the proportion of N derived from the atmosphere (%Ndfa).

In an auxiliary experiment conducted in SoilFACE using small cores containing a P deficient Vertosol, the growth of fieldpea and chickpea seedlings was significantly stimulated by both P application and exposure to eCO_2. There was a significant interaction between P and CO_2 treatment with the largest relative response to applied P occurring under eCO_2 at highest rate of P applied, especially for chickpea. Studies are currently in progress to determine whether the effect of CO_2 on P responsiveness of these two pulses reflects changes in either root morphology or a differing ability to mobilise different soil P pools.

TITLE IS IT COMMERCIALLY VIABLE TO USE DICYANDIAMIDE ON A DAIRY FARM IN SOUTH-WESTERN VICTORIA?

Theme Soil

Primary Author Timothy Huggins
Institution University of Melbourne
Email t.huggins@pgrad.unimelb.edu.au
Co-Authors Kevin Kelly, Helen Suter, Richard Eckard

Key search words DCD, nitrous oxide, pasture growth, urine

Nitrous oxide is a powerful greenhouse gas that can be produced from urinary nitrogen deposited onto pastures by dairy cattle. A loss of nitrous oxide to the atmosphere also represents a reduction in nitrogen available for uptake by perennial pasture plants, thereby potentially limiting growth. The use of the nitrification inhibitor, dicyandiamide (DCD), is one abatement strategy that could allow a farmer to reclaim this lost nitrogen. This may result in increased pasture dry matter or reduced nitrogen fertilizer inputs to grow the same amount of pasture (assuming nitrogen fertilizer is not the most limiting nutrient) – both of which should reduce the cost of each tonne of pasture dry matter that is grown. Either of these outcomes are desirable when assessing whether it is commercially viable to use dicyandiamide (at an estimated annual applied cost of $165 per hectare) on a dairyfarm in south-western Victoria.

In this study, small-plot trials were set up on 6 commercial dairyfarms in south-western Victoria and nitrous oxide emissions, soil nitrogen fractions and pasture growth were measured comparing a control with the application of synthetic urine (1000 kg N/ha equivalent) at the start of the experiment or one month later. Each of the treatments were repeated with and without DCD applied at the start of the experiment.

Interim results from Spring 2009 and Autumn 2010 treatments have shown an increase in pasture dry matter within a urine patch of 0-15% as a result of DCD application. At the same time, nitrous oxide levels were reduced by close to 40% for approximately 70 days following each application. These data, along with summary figures from the Dairy 2010 Situation and Outlook Report were put into the Dairy Greenhouse Gas Abatement Strategies calculator.

Based on the simulation with the abatement calculator, the additional pasture growth required to cover the cost of DCD is 420 kg DM/ha/year, which represents an increase of approximately 13.5% across the whole paddock (not just the urine patch) within the treatment period. Reducing the application of nitrogen fertiliser is unlikely to be able to cover much of the cost of the DCD application unless the cost of nitrogen fertiliser increases dramatically. Therefore, while there is potential to reduce the cost of pasture grown by using DCD, the results are likely to be variable and are unlikely to be significant enough to cover the cost of application.

This simulation based on preliminary results would suggest that the use of DCD may not be economically viable in the absence of a substantial carbon price.

TITLE CAN WE REDUCE NITROUS OXIDE EMISSIONS FROM CROPS?

Theme Soils
Primary Author Dr Sally J. Officer
Institution Victoria Department of Primary Industries.
Email sally.officer@dpi.vic.gov.au
Co-Authors Gavin Kearney, Dr Frances Phillips, Dr Roger Armstrong and Kevin Kelly

Nitrous oxide (N_2O) is generated by the biological nitrogen (N) cycle in the soil. More N_2O is produced from soil that has been enriched with N and therefore agricultural soils are a large source of this greenhouse gas.

The application of N fertiliser, which supplies a concentrated source of N to soil, has been shown to further enhance N_2O emissions. The alternative supply of N through leguminous crops creates a dispersed and slowly releasing pool of N in the soil and this may reduce N_2O emissions from agricultural soils. It must also be pointed out that the manufacture of N fertiliser is a significant source of greenhouse gas. Therefore reducing the use of concentrated synthetic N fertiliser may reduce N_2O emissions from crops. In this study, we compared N_2O emissions from winter wheat with N supplied by N fertiliser or legumes crops grown in the previous year.

This study was carried out in the semi-arid southern Australian wheat growing Wimmera region of Victoria at a site that had been in a long-term faba bean and winter wheat rotation. We compared emissions from an alkaline Vertosol soil growing winter wheat in 2007 and 2008, with and without urea fertiliser (50 kg N/ha), following either a legume (Faba beans, peas or medic) or canola crop. N_2O fluxes were measured in automated chambers continuously, with gaseous measurements made using a tuneable diode laser. The effect of agronomic treatment on N_2O flux was identified by linear mixed model analysis that included cubic smoothing splines.

Total N_2O emissions over two consecutive cropping seasons (sowing in June to harvest in mid December) were related to the soil moisture. In 2007 the regional annual rainfall was slightly below (decile 4) the long term average of 444 mm, which was a combination of above average pre-season autumn rainfall and reduced (decile 2) growing season (April to October) rainfall. Rainfall was even less in 2008, with total regional annual rainfall of 315 mm (decile 3) and very poor growing season rainfall (decile 1). Consequently, cumulative emissions from the respective treatments of wheat growing from June to mid-December in 2008 were fewer than half those recorded over the same period in 2007. In both 2007 and 2008, the application of urea fertiliser at sowing consistently increased N_2O emissions. The increase in loss of N_2O-N from the fertilised plots was between 23 and 64% in 2007, and between 84 and 154% in 2008, compared to emissions from plots where no N fertiliser had been applied and N was supplied by legume rotation. Consequently, the apparent loss of the fertilizer N in the form of N_2O in 2007 and 2008 ranged between 40 and 106 g N_2O-N ha^{-1}, with an average of 74 g N_2O-N ha^{-1}, which was equivalent to 0.15% of the added fertilizer.

In this study, N supplied by previous legume crops appeared well matched to the small demand of wheat for N in relatively dry seasons and there was no wheat crop response to N fertiliser in either year. In fact, the application of fertiliser reduced wheat yield in the first year, because of a 'haying off effect' whereby the vegetative growth was stimulated by the fertiliser N and used up all the available soil moisture before the grain formed. The use of previous legume crops to supply N for following crops was therefore a more efficient method of supplying N to wheat in two relatively dry years and also reduced the N_2O emissions, compared to using fertiliser. Unfortunately, leguminous crops are regarded as 'financially risky' compared to cereal crops, especially in drier seasons, and it is this financial consideration that currently drives management decisions by farmers. Legumes can be difficult to establish and may not grow adequately in drier years, while a year of more reliable non leguminous grain crop has been relinquished for the legume. Nevertheless, encouraging farmers to increase their use of legume rotations to substitute for synthetic N fertiliser may be a viable method of reducing greenhouse gas emissions from crops.

TITLE NITRIFICATION INHIBITORS TO REDUCE N_2O EMISSIONS FROM AUSTRALIAN FARMING SYSTEMS

Theme Soils
Primary Author Dr Helen Suter
Institution The University of Melbourne
Email helencs@unimelb.edu.au
Co-Authors Deli Chen, Huilin Li and Charlie Walkerr
Key search words DMPP, DCD, N2O, nitrification inhibitor

Nitrification inhibitors such as Dicyandiamide (DCD) and 3,4-dimethylpyrazole phosphate (DMPP) suppress ammonia oxidizing bacteria and therefore can reduce nitrogen (N) losses, resulting from nitrification and subsequent denitrification (nitrate (NO_3-) leaching, denitrification and also emission of the greenhouse gas nitrous oxide (N_2O)), from applied nitrogen fertilisers. However the benefit achieved from these inhibitors is dependent upon such factors as temperature, moisture and soil type. Studies have shown that the performance of the inhibitors is reduced under higher temperature and in soils with high organic content. This study reports the results of controlled environment laboratory incubation experiments (5-35°C, 40-80% WFPS) carried out on a number of different soil types fertilised with urea (100-160 kg N/ha). The soils used were collected from Queensland and Victoria, to cover a range of local temperatures, which the incubation studies simulated, and to include soils from different agro-industries (sugarcane, cropping, pasture) and with different soil properties. The studies looked primarily at DMPP but also included DCD and N-serve.

The study found that the ability of the nitrification inhibitors to reduce nitrification rates, as measured by NO_3- formation over time, ranged from 0-98% (Table 1) and was dependent upon soil type. However in all soils examined, even when no impact on NO_3- was observed the nitrification inhibitors reduced N_2O emissions from 15 to 99% (Table 1). Temperature had a greater influence on the reduction in N_2O emissions when the nitrification inhibitors were less effective, such as for Mackay and Dookie soils than on the soils where it was more effective (eg. Pin Gin). DMPP performed overall as well as DCD and N-serve at application rates around 1/10th of the other inhibitors.

Table 1. Reduction in nitrate (NO_3-) formation and N_2O emissions (%) measured over 70 days (42 days for Kalkee) from different soils at 60% WFPS.

Soil	Soil type	Temp (°C)	NO_3- reduction		N_2O reduction		
			DMPP	DCD or N-serve	DMPP	DCD	N-serve
Pin Gin	pH 4.5, sugarcane soil, clay loam	25	89	-	94	-	-
		35	85	-	99	-	-
Mackay	pH 4.0, sugarcane soil, sandy loam	25	0	-	64	-	-
		35	0	-	19	-	-
Dookie - topsoil	pH 5.4, organic dairy pasture, fine sandy loam, topsoil	5	0	0	68	83	-
		15	0	0	58	65	-
		25	0	0	36	15	-
Dookie - subsoil	pH 5.5, organic dairy pasture, medium clay subsoil	5	51	81	76	88	-
		15	0	41	74	86	-
		25	0	0	31	44	-
Kalkee	pH 8.3, cropping soil, clay loam	5	70	97	98	-	97
		15	72	98	96	-	98
		25	4	83	96	-	99

In conclusion the nitrification inhibitors DMPP, DCD and N-serve show promise as a means of reducing N_2O emissions from Australian agricultural systems.

TITLE MAKING THE USE OF COMPOST COUNT FOR MITIGATING CLIMATE CHANGE

Theme Soils
Primary Author Mr Johannes Biala
Institution The Organic Force
Email biala@optusnet.com.au
Co-Authors Annie Kavanagh, Dept of Environment, Climate Change and Water NSW
Key search words carbon sequestration, compost, organic soil amendment, National Carbon Accounting System, humus balance toolbox

Climate Change Mitigation through Soil Management

While many agronomic and environmental benefits from using organic soil amendments are well documented, this is not the case when it comes to mitigating climate change. A recent literature review for the NSW Department of Environment, Climate Change and Water collated internationally available information regarding the possibilities of using compost as a means of mitigating climate change. Apart from providing compost related information, the report provides also extensive information about other soil related climate change mitigation measures such as minimum tillage, use of organic soil amendments such as manure and sludge, and organic farming methods.

Compost Use can Deliver Climate Change Mitigation

The use of compost and other organic soil amendments for land management purposes offer the following means of mitigating climate change:(i) diversion of organic materials from landfill, (ii) reduced emissions from properly managed organic residues, including agricultural and food processing residues, (iii) the removal of atmospheric carbon by means of sequestering compost carbon in the soil, (iv) the reduction of GHG emissions by reducing soil emissions (N_2O), (v) enhanced carbon sequestration through improved plant growth due to improved soil properties, and (vi) reduced emissions associated with the manufacturing of mineral fertiliser. Organic residuals are transformed into more stable carbon compounds during both the composting process and also after compost application. Medium-term (7 - 12 yrs) research from Europe demonstrated that 30% to 50% of compost carbon is retained over that period. Consequently, sequestration of carbon applied with compost at rates of 10 t dry matter (DM) per hectare (ha^{-1}) is estimated to sequester carbon that is equivalent to around 5,000 kg CO_2-e over 20 years 3,500 kg CO_2-e over 50 years and 1,000 kg CO_2-e over 100 years. In addition, compost use can replace mineral fertiliser, and hence reduce GHG emissions that are associated with fertiliser production. Based on estimated mineralisation and nutrient up-take rates, use of 10 t DM ha^{-1} of compost can deliver additional climate change benefits worth about 200 kg CO_2-e over all three time frames.

Urgent Need for Determining the Climate Change Benefits of Using Organic Soil Amendments

So far, research activities, the National Carbon Accounting System and carbon trading proposals have largely ignored the effects the annual use of maybe 20 to 25 million tonnes of organic soil amendments for land management purposes have on climate change mitigation. Urgent action, including research, data collection, modelling, and extension is required (i) for including the use of compost and other organic soil amendments (e.g. manure, sludge, food & fibre processing residues) into the National Carbon Accounting System, and (ii) for developing a 'humus balance' toolbox that can be used by farmers for estimating the development of soil carbon levels on their farms and paddocks.

TITLE SOIL INFORMATION FOR AGRICULTURAL LANDSCAPES

Theme Soils
Primary Author Mr Nathan Robinson
Institution Victoria Department of Primary Industries
Email Nathan.Robinson@dpi.vic.gov.au
Co-Authors Richard MacEwan
Key search words Primary Production Landscapes, PPL

Successful farming systems are well-adapted to climate, soils, water availability and terrain. Scenarios for climate change in Victorian agriculture predict limited water availability and uncertain seasonal distribution of rainfall. Soil data are required by modellers of hydrological processes (surface and groundwater, water erosion, plant available water) and by consultants or farmers for use in crop production models such as APSIM and CropSyst. There is also an increasing interest in the interactions between farming systems and soil with respect to potential for soil carbon sequestration. The challenge for soil science is to provide data that are spatially relevant at paddock or land management unit scales, and that can be used by farmers, their advisers and researchers refining or redesigning farming practices to get the most productive outcomes from soil. This is a challenge because soil data are sparse and soils are highly variable. In Victoria a tiered approach to provision of this information and an ongoing process to create a digital soil map for the state is proposed to understand soil resources and Victoria's farming systems. Data provided through this process will incorporate estimates of certainty for values assigned to key soil parameters such as pH, Soil Organic Carbon (SOC), and Plant Available Water Capacity (PAWC).

The 'Primary Production Landscapes' (PPLs) of Victoria have been delineated to distinguish major landscape divisions of Victoria that have marked influence on the development of farming systems (MacEwan et al. 2008). They are essentially agro-ecological divisions based on terrain, soils and climate. They are based on the geomorphic divisions represented in the GMU250 spatial data layer for Victoria, http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/primary_prod_landscapes but with some boundary lines following watershed divisions and aspect rather than geological boundaries. This difference in boundaries reflects the important influence of topography on local climate. There are 6 major PPLs with 22 sub-regions. Major soils occurring in each sub region are described with respect to their major constraints to management. Mapped PPLs and descriptions were reviewed by regional industry experts (grazing – meat and wool, cropping, dairy and forestry) and primary producers to gather information on the dominant land use practices specific to the PPLs, industry pressures and future prognosis under climate scenarios.

The PPLs provide a regional spatial platform from which to evaluate the interrelationships between climate, farming systems, terrain and soil. They are recommended as focus areas for researchers studying climate change in relation to farming practice and land use change in Victoria. PPLs are currently being used to stratify sampling for soil sampling in the Victorian Soil Carbon project, national stratification soil degradation threats as part of the 'Caring for our Country' prioritisation process and to map soil asset values and threats for Victoria to enable targeting and long-term protection of high value NRM assets threatened by soil degradation or dryland salinity.

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TITLE QUANTIFYING THE IMPACT OF CONVERSION OF PASTURE LAND TO PINUS RADIATA PLANTATION ON SOIL CARBON STOCKS AND DYNAMICS

Theme Soils
Primary Author Dr. Bhupinder Pal Singh
Institution Industry and Investment NSW
Email Bp.singh@sf.nsw.gov.au
Co-Authors Lai Fan Poon, James Quilty, Pushpinder Matta, Annette Cowie, Balwant Singh, Mark Adams
Key search words Afforestation; Land use change; Pasture; Soil carbon; Soil respiration

Abstract

Afforestation is likely to expand across Australia in response to the growing opportunities for forests to earn "carbon credits" under emissions trading. Thus, there is a need to make a detailed assessment of the impact of afforestation on soil organic carbon (C) stocks and dynamics, as well as to resolve any contradictions as to whether soil organic C may decrease or increase when agricultural lands are afforested with pine plantations.

In a preliminary study, soil samples were collected from a chronosequence of 3-yr, 5-yr and 25-yr 'paired' pasture–pine (*Pinus radiata*) plantation sites in central tablelands of New South Wales. Organic C and total nitrogen (N) stocks in the top 30 cm soils were quantified. Microbial biomass-C, heterotrophic respiration, metabolic quotient, and temperature sensitivity (Q10) were determined at incremental soil depths to 30 cm. We found that the difference in the organic C content of soil varied greatly (64 to 104 t/ha) between sites. Compared with adjacent pasture, younger pine plantations (3-yr and 5-yr after establishment of first rotation plantation) had lower soil C stocks (by up to 30%), whereas mature pine plantation (25-yr after establishment of second rotation plantation) had ~15% higher soil organic C. Microbial biomass-C was lower and metabolic quotient greater in the 5-yr plantation compared to adjacent pastures. Rates of heterotrophic respiration were similar for the 3-yr and 5-yr plantation-pasture pairs, but were faster at greater depths (5–10 cm and 10–30 cm) in the 25-yr pine plantation than the adjacent pasture. The temperature sensitivity of heterotrophic respiration was not significantly influenced by the land use change (Q10 =1.9 to 2.5). This study suggests that afforestation with *Pinus radiata* leads to changes in soil C. Soil C stocks may decrease initially, likely due to decreased input of plant C during early stages of plantation growth. Soil C in mature pine plantations may stabilise at greater concentrations than in pastures. This study does not support the common assumption, which is based on a limited number of Australian studies, of a 15% decline in soil C where pasture is converted to pine; in fact the soil C content was higher in a mature pine plantation than in adjacent pasture. Clearly, in order to determine the net greenhouse gas mitigation potential of plantation forestry, further research is required to accurately quantify and predict soil C stocks and losses following afforestation of agricultural lands.

Currently, we are undertaking a detailed study (funded by the Department of Agriculture, Fisheries and Forestry) that focuses on quantification of soil C and N stocks as well as sources of soil respiration in a replicated (n = 3) chronosequence of first-rotation pine plantations on ex-pastoral lands under contrasting rainfall regimes (700 mm versus 1000 mm). For *in-situ* separation of soil respiratory components, we have employed girdling (ring-barking) and shading approaches in two 23-yr old pine plantations and adjacent pastures, respectively. Preliminary data will be presented at the conference.

TITLE MEASUREMENT AND SIMULATION OF AMMONIA VOLATILIZATION FROM UREA FERTILIZER IN CROPPING AND PASTURE SYSTEM

Theme Soils concurrent theme

Primary Author Professor Deli Chen
Institution The University of Melbourne
Email delichen@unimelb.edu.au
Co-Authors Yong Li, Debra Turner, Helen Suter, Tom Denmead, John Freney, Richard Eckard

Key search words Modelling, WNMM, DNDC, N_2O, nitrification, gentrification

Abstract

Ammonia (NH_3) volatilization is an important pathway in soil N cycling and often responsible for the low efficiency of N fertilizer in plant-soil systems. The NH_3 volatilization is strongly influenced by soil and climatic factors and management practices. The quantifying NH_3 volatilization is a technically challenge and costly exercise.

We present the NH_3 volatilization losses from the field experiments after the nitrogen fertilizer application in wheat, maize and pasture systems in Australia and China under different soil and climate conditions and management practices. The NH_3 volatilizations were measured by micrometrological methods of full profile (mass balance), gradient fluxes and the recently developed technique of open path laser/FTIR- Lagrangian model of atmospheric dispersion.

NH3 volatilization accounts up to up to 50% total N applied to alkaline in the North China Plain, up to 20% in the acidic pasture soils in Australia. The fertilizer application and irrigation methods strongly influence the NH_3 volatilization as well as soil and climate conditions. Green urea, a commercial product containing NBPT as a urease inhibitor, was effective in reducing the NH_3 volatilisation (up to 90% less) when applied to wheat crop and pasture by surface broadcasting.

A NH_3 volatilization sub-model was developed under the simulation framework of Water and Nitrogen Management Model (WNMM). A unique feature of this simulation component is the introduction of fertilizer N distribution function in soils for different applying methods, surface broadcasting, surface broadcasting followed by irrigation and deep placement. This sub-model calculates ammonia volatilization from surface and subsurface soil separately. For the surface layer, ammonia volatilization is controlled by soil temperature and wind speed, while for the subsurface soil layer, it is regulated by soil temperature, soil moisture, CEC and depth. The effect of localized pH surrounding urea granules and urine patches due to urea hydrolysis has been simulated, which is the main cause of NH_3 volatilization in acidic soils. The model also incorporate the effect of urease inhibitor.

TITLE THE EFFECT OF AGRICULTURAL LAND USE ON THE SOIL CARBON FRACTIONS OF RED FERROSOLS IN NORTH WEST TASMANIA

Theme Soils
Primary Author Jocelyn Parry-Jones
Institution Tasmanian Institute of Agricultural Research
Email Eve.white@utas.edu.au
Co-Authors Garth Oliver, Eve White, Richard Doyle
Key search words Agriculture, Ferrosol, HUM, POC, soil organic carbon

Abstract

Soil organic carbon (SOC) is of importance both due to its association with soil quality and its role in the global carbon cycle. Depending on the nature of management, agricultural practice can either result in the loss or gain of SOC. This research forms a part of a long term study, in which the SOC content of Tasmanian Red Ferrosols was measured to determine the extent of management-related change. Composite sampling was conducted at two depths (0-150 mm and 150-300 mm) over a total of 25 sites in Northern Tasmania, both in 1997 and 2010. In addition to being measured for total organic carbon (TOC), the soil was divided into two size fractions (POC >50μm and HUM <50μm), as these fractions have been found to provide additional information about the effect of agricultural management on SOC. In this study, TOC was presented as a percentage of the sample and the two size fractions were presented as proportions of the TOC. Samples were fractionated with a wet vibratory sieving device and then measured for carbon by means of an automated dry combustion elemental analyser (Perkin Elmer).

The percentage of TOC decreased with increasing years of cultivation. The proportions of POC and HUM decreased at uniform rates to the TOC, suggesting that they are both prone to the same degree of depletion under cultivation. The mean TOC in 2010 was significantly higher for sites classed as predominately pasture than for those sites classed as continuously cropped, at the depth of 0-150 mm. At both depths, there were no significant changes in the percentages of TOC, or proportions of POC and HUM for either land use category between 1997 and 2010. The lack of change in TOC suggests that under each management, soils have received consistent treatment for a length of time such that equilibrium may have been reached. The lack of change in the proportions of POC and HUM indicates that both fractions are affected evenly under both cropping and pasture. The SOC associated with the HUM fraction has typically been found to be far more resistant to depletion than that of the POC. The finding that both HUM and POC are uniformly affected by management suggests that Red Ferrosols may differ from other soil types in regard to carbon storage in the HUM fraction. The properties of these soils which may be responsible for the short term storage of SOC in the HUM fraction are the clay type kaolinite and the high content of iron oxides and aluminium oxides. Alternatively, this behaviour may be attributed to the Tasmanian climate. Further research is required to improve the understanding of the storage mechanisms of SOC Red Ferrosols, particularly in the HUM fraction.

The 2010 component of this project formed part of the Australia-wide SCRP (soil carbon research program) study which is investigating the effects of soil type and land use on soil carbon. The sampling will continue to be conducted at regular intervals.

TITLE SOILS FARMER CASE STUDY

Theme	Soils
Farmer	David Marsh
Region	Boorowa, NSW
Email	dmarsh1@bigpond.net.au
Farm Area	814ha
Soils	Acid volcanic hill tops, brown clay loam duplex soils on slopes grading to duplex, fine white clays in valley floors
Rainfall	625mm average

The Marsh Family of "Allendale"

1850 to1900 - clearing left only about 3% remnants in the form of widely scattered paddock trees and several clumps of less than 5ha. Native understorey absent.

Previous owners had begun using superphosphate and clovers in the 1950s, to restore lost fertility and attempt to increase yields from livestock and crops. This practice was subsidised by a government 'super bounty'.

The Marsh family commenced management of the property in the mid 1960s. Sheep and wool was the main enterprise with some limited cropping for winter feed and cash cropping of wheat.

Changes of management style 1970 to 1999. Mixed farming of sheep for wool and cropping approximately 25% of area for wheat and oats. Oats stored as insurance against drought or in seasonal feed shortages usually in Autumn and Winter. The prevailing attitude was to try and generate maximum yield from the landscape. I would call this an economics-driven style of management.

From 1982 to 1991 annual tree planting program gradually expanded as well as some changes to internal subdivisions to try and have paddock shapes matching up with landscape function and soil capability. 1992 to 2001 direct seeding of trees aimed at enhancing remnants and larger habitat areas, including natural regeneration areas were undertaken. Woody vegetation is now approximately 20% of property area.

1999 I undertook a post graduate Masters degree in Sustainable Agriculture at Sydney University, Orange campus. Also in 1999, I commenced a course in Holistic Management. Since 1999 the property has been run using holistic management principles. Decisions are made towards the future landscape we desire; one able to support increasingly diverse, resilient and regenerative communities of plants, animals and biota. We see ourselves as part of the living community rather than the directors of it. Learning to match our enterprises to the constantly-shifting availability of resources enabled us to manage eight years of drought without spending anything on feeding stock and never losing ground cover. Currently we are breeding cattle (1800dse), trading steers(1600dse), and running the equivalent of 2500 sheep on agistment. Annual cropping was phased out ten years ago.

Managing to allow the living community to maximise solar energy capture and adjusting our own behaviour and attitude has been fundamental to creating the conditions conducive to commencing the restoration of the approximately 70% of soil organic carbon lost from Australian soils since European settlement. This restoration will not happen using the practices that caused the losses in the first place.

THEME

IMPACTS & FORECASTING

TITLE SOUTHERN LIVESTOCK ADAPTATION. 3. RESILIENCE SURFACES FOR PASTURE PRODUCTION UNDER CLIMATE CHANGE SCENARIOS

Theme Impacts and forecasting

Primary Author Dr Brendan Cullen

Institution Department of Agriculture and Food Systems, University of Melbourne

Email bcullen@unimelb.edu.au

Co-Authors Assoc Prof Richard Eckard

Key search words Climate change impacts, SGS Pasture model, perennial ryegrass, kikuyu

Plant production responses to climatic changes will be determined by individual species responses to higher temperatures, altered rainfall patterns and elevated carbon dioxide (CO_2) concentrations. The large variation in climate change projections between global circulation models makes it difficult to determine appropriate climate scenarios for climate change impacts analysis on agricultural systems. This is particularly so for rainfall projections. A sensitivity approach exploring incremental changes in climate can be used to highlight the potential changes in pasture production by creating responses surfaces to temperature, CO_2 concentration and rainfall changes. These responses surfaces can be used to demonstrate the resilience of production systems to climate changes, and the conditions under which alternate production systems are favoured.

In this analysis the sensitivity of a perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*) pasture production to a range of climate changes was modelled at Hamilton in south west Victoria, Australia. A series of climate scenarios were created based on the 1971-2000 baseline climate, using the range of projected changes expected across southern Australian over the next 60 years. Incremental temperature changes of 0, 1, 2, 3 and 4°C (with corresponding atmospheric CO_2 concentrations of 380, 435, 535, 640 and 750 parts per million) were applied in combination with rainfall changes of 0, -10, -20, -30 and +10%, to create 25 climate scenarios. Impacts of the climate scenarios on total annual pasture production (t DM/ha) and monthly average pasture growth rates (kg DM/ha) were simulated using the Sustainable Grazing Systems Pasture model. The production of an alternate forage system, based on the C_4 grass kikuyu (Pennisetum clandestinum) and subterranean clover, was also modelled to explore the conditions under which a more heat tolerant and deeper rooted pasture system would be favoured. In all simulations no soil nutrient limitations were imposed.

In the baseline climate the annual average perennial ryegrass based pasture production was 10.0 t DM/ha. In the future climates, trends in the perennial ryegrass based pasture production indicated that total annual pasture production could be maintained at the historical average with 1°C warming and 10% lower rainfall, or with 2-3°C warming and approximately 15% less rain. Simulations with less climate change indicated increased pasture production compared to the historical baseline (up to 11.6 t DM/ha with 2°C warming and 10% higher rainfall) while simulations with higher imposed climatic changes reduced annual pasture production. In addition to changes in total annual pasture production, an altered seasonal pattern of pasture growth was predicted. In warmer and drier conditions the modelling indicated a trend towards increased winter and early spring growth rates, with a contraction of the spring growing season.

Average annual production of the kikuyu based pasture in the baseline climate (7.4 t DM/ha) was lower than the perennial ryegrass pasture under the same climate conditions, however the kikuyu pasture increased production in the warmer climate scenarios so that its production was higher than the perennial ryegrass pasture with +2°C or more. This indicates an increasing role for C_4 species in grazing systems adapted to warmer climates, but other factors including forage digestibility and protein content are likely to be lower.

While there are some limitations to the scaling approach used to develop the climate scenarios, for example they do not take into account projected changes in precipitation intensity, it does demonstrate the range of possible climate change impacts and allows investigation of the conditions under which alternate pasture systems may become more productive and dominant. In particular, the contours of similar pasture production provide information on the 'resilience surface' of a species for a location.

TITLE ADAPTING TO CLIMATE CHANGE IN SOUTHERN NSW

Theme Impacts and forecasting
Primary Author Ms Jan Edwards
Institution Industry & Investment NSW
Email jan.edwards@industry.nsw.gov.au
Co-Authors Greg Meaker, Phillip Bowden and Janet Walker
Key search words farming systems – adaptation – impact – climate change

Background

As part of a national initiative, Industry & Investment NSW is investigating the impact of climate change and identifying adaptation strategies for mixed farms in southern NSW.

The project is a combination of research and farmer participation. The Agricultural Production Systems Simulator (APSIM) and GrassGro pasture growth model are being used to model case study farms. Farmer groups have identified the base line scenarios and the adaptation options. Farmer attitudes to climate change are also being benchmarked.

This paper will describe the participatory methodology and the preliminary findings from the attitudinal surveys.

Attitudes to climate change

To date, 547 people have attended climate change workshops. The results from the workshop evaluation indicated that the majority of farmers benefited from the workshop and would attend another day.

The baseline survey showed that 48% of the farmers identified that they believed in climate change. However, a large percentage of respondents remain unsure of what that means. While 37% of respondents agreed with the statement that in the future there would be less rainfall in autumn and spring, 50% were unsure and 13% disagreed. A similar trend was seen in the responses to the statements that the climate would be more variable, the incidence of droughts would increase, and temperatures would increase by 1 to 2 degrees Celsius.

Feedback also indicated that famers view the public debate as polarised with a selective use of data. Presentation of results from four global circulation models gave famers confidence that they were not receiving a slanted view of the potential outcomes.

Findings

Key findings for Southern NSW are that all sites experienced a significant reduction in growing season length, pasture growth, crop yield and summer/autumn ground cover. Further modelling work is continuing to identify the adaptation options improve resilience.

Farmers indicated that the potential outcomes were not as bad as they thought it would be. The use of the 2000 to 2009 data is critical to put the 2030 results into a context that they can understand.

TITLE AN HISTORICAL ANALYSIS OF THE CHANGES IN PASTURE PRODUCTION AND GROWING SEASON IN THREE DAIRY REGIONS OF SOUTH EAST AUSTRALIA

Theme Impact Modelling
Primary Author Richard Rawnsley
Institution Tasmanian Institute of Agricultural Research
Email Richard.Rawnsley@utas.edu.au
Co-Authors Brendan Cullen, Karen Christie and Richard Eckard
Key search words Dairy, Wet, Dry, Growing Season, Climate, Historical

Abstract

The production of high quality perennial ryegrass (*Lolium perenne* L.) is a strong determinant of business success for pasture-based dairy systems in Australia (Beca, 2005; Chapman *et al*., 2008). There is concern regarding the influence of a changing and variable climate on these systems, with evidence that the global climate has changed over the past century and that the risk of extreme events and abrupt changes in climatic patterns is increasing (NRMMC 2006). It is important to quantify these changes and their effects in order to identify and explore potential system adaptations. For pasture-based dairy systems in South East Australia, seasonal and annual pasture production, the commencement, length and reliability of the growing season and the duration of wet and dry periods are all significant factors that influence management decisions and profitability. Using the biophysical pasture simulation model DairyMod (Johnson et al. 2008), the current study quantified the changes and variability of these factors, by undertaking an historical analysis (1960 -2009) across three dairy regions in South East Australia: Terang (South West Victoria, Mediterranean climate); Ellinbank (Gippsland, Victoria, temperate climate), and Elliott (North West Tasmania, cool-temperate climate).

A significant linear relationship between year and commencement date of the growing period at Elliott (P = 0.04) and Terang (P = 0.01) indicated that for every 10 year period, between 1960 and 2009, the commencement date of the growing period for these regions was 1.5 days earlier. There was no evidence that the commencement date of the wet and dry periods has changed over the last 50 years. However, during the last 4 to 5 years, all three sites have experienced an unusually low number of days in the year when soil moisture content has exceeded field capacity, and an unusually high number of days when the readily available water in the root profile has been exhausted. Although unpredictable to date (i.e. there was no significant (P > 0.05) linear relationship between year and the number of days for the wet and dry periods at any of the sites over the last 50 years), the observation that in recent years the number of dry days has been unusually high has important implications for farm management decisions.

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TITLE PRACTICAL MANAGEMENT OF CLIMATE VARIABILITY IN A CHANGING CLIMATE

Theme Impacts and Forecasting
Primary Author Dr Peter McIntosh
Institution CSIRO
Email peter.mcintosh@csiro.au
Co-Authors Senthold Asseng, Dean Thomas, Guomin Wang and Nirav Khimashia
Key search words Seasonal rainfall forecast, management decision, payoff time, POAMA

Seasonal climate variability will remain a primary consideration for farmers regardless of how the climate changes. For example, grain yields vary widely from year to year in rain-fed agriculture due to natural climate variability. Seasonal rainfall forecasts can be used to adjust fertiliser inputs to increase returns in high rainfall years and reduce losses due to over-fertilisation in low-rainfall years. Effective strategies to manage climate variability may also help mitigate the negative consequences of climate change.

Australia's dynamical seasonal climate forecast system, POAMA, incorporates the important physical processes that drive seasonal climate variability and long-term climate change. POAMA has been used to forecast growing season (May-Oct) rainfall in the southern wheat-growing region of Western Australia. Forecasts starting on 1 May correctly predict above or below median rainfall in 70% of the years from 1980 to 2006. Such a forecast appears to have little value if the management response is to apply fertiliser to maximise income. However, using a more realistic risk-averse strategy, where $1 of fertiliser is applied only if the expected return is $2, can lead to a substantial benefit of about $50/ha. This value varies depending on location, soil type, initial soil moisture, wheat price and fertiliser price.

Similar benefits from a seasonal forecast are possible in mixed wheat-sheep farming systems. In years forecast to have above median rainfall, the effective stocking rate is increased by planting some of the pasture with wheat. In forecast dry years, the additional wheat paddocks are returned to pasture. The fertiliser strategy remains the same as for a wheat-only enterprise. Returns of more than $60/ha are possible.

While a viable farming operation must ensure high returns in good years, it must also avoid losses, particularly over consecutive years. This is likely to become even more important as the climate changes. Farmers use a risk-averse strategy to reduce the chance of enterprise failure. The "break-even time" is the number of years a farm takes to start making a profit. In south-west Western Australia, a risk-averse fertiliser strategy has a 95% chance of reaching this point after 3 years. In contrast, a strategy that aims to maximise long-term profit will take 6 years to break even at the same level of confidence.

POAMA seasonal forecasts can be used to reduce the risk associated with a string of dry years while still allowing increased income in the long run. Additional profit almost equivalent to the maximisation strategy can be achieved with a reduction in the break-even time from 6 years to 4 years.

The "payoff time" is the number of years a forecast must be used in order to achieve a high probability of benefit. A farmer must use the POAMA seasonal forecast for 7 years to be 95% sure of exceeding the income received without using a forecast. This payoff time drops to 3 years at the 80% confidence level. Without a forecast, 80% of a wheat farmer's income will come from 40% of the years. Using a forecast allows the farmer to make the same income in just 15% of years. A reduction in the number of years with above median rainfall is one possible consequence of climate change. This result demonstrates how a seasonal rainfall forecast can be used to maintain farm income despite a decrease in the number of wet years.

TITLE CLIMATE ANALYSER – A TOOL FOR USING CLIMATE INFORMATION AND FORECASTS IN DECISION MAKING

Theme Impact Modelling/Forecasting
Primary Author David Freebairn
Institution RPS
Email david.freebairn@rpsgroup.com.au
Co-Authors Colin Creighton
Key search words Near real time, decision support, POAMA, prior conditions

Project Rationale

A challenge is to turn raw weather observations (data) and forecasts into information that decision makers can access. Computer based decision support tools have provided ready access to climate date and a range of data analyses (e.g. Rainman, Howoften?, Howwet?, Potential Yield Calculator, Flowering Calculator, TACT to name a few). Skill is improving in multi-week forecasts and this represents an opportunity for tactical decision making. A recent review of climate tools documented a need to build on the best features of existing tools and user experience. Weaknesses in current tools include: difficulty in use, including access to climate data; limited capacity for customization or inclusion of derived values (e.g. heat sum); and limited presentation of forecast skills.

Key questions posed in design of information products are; how can recent weather data, long term climate data and forecasts be integrated to support decision making and what are the best formats for presenting information to growers? As part of a Managing Climate Variability Project managed by the Grains Research and Development Corporation, a "Climate Analyser" is being designed from a user question perspective, building an interface that is easier for farmers to access near real time weather data and climate forecasts.

Framework

Our conceptual model of a system driven by weather is shown in Figure 1. This framework recognises that in many situations, recent past conditions can be influential in setting up future expectations as well as the weather during the production cycle. For example: where crops depend on accumulated soil water and nitrate; or tree flowering is conditioned by the recent water and temperature conditions.

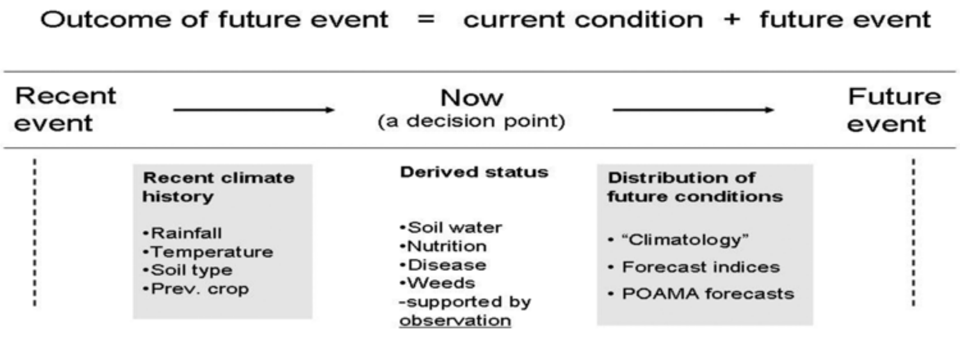

Figure 1. Schematic of the linkages between recent events and future possibilities.

The project builds on experience gained over the last 20 years of grower and advisor use of decision support tools. Tools developed will be delivered on the WWW and mobile phone Apps and will access near real time data from the BOM. Prototypes will be available for market testing in 2011.

TITLE MAKING SENSE OF CLIMATE MODELLING AT REGIONAL AND CATCHMENT SCALES

Theme IMPACT MODELLING/FORECASTING

Primary Author Dr Stuart Corney
Institution Antarctic Climate & Ecosystems Cooperative research Centre (ACE CRC)
Email Climatefutures@acecrc.org.au
Co-Authors Stuart Corney[1], Jack Katzfey[2], John McGregor[2], Michael Grose[1], Greg Holz[1], Chris White[1], James Bennett[1,3], Suzie Gaynor[1] and Nathan Bindoff[1,2]
[1]Climate Futures for Tasmania, Antarctic Climate and Ecosystems CRC
[2]Centre for Australian Climate and Weather Research, CSIRO Marine and Atmospheric Research
[3]Entura

Key search words global climate models, regional climate models, dynamical downscaling, biophysical models, hydrological models, climate change,

Global climate models (GCMs) provide the best estimates for assessing potential changes to our climate on a global basis. However, GCMs have a coarse resolution (typically about 200 km to 300 km) and assume an average climate across each cell. However across regions and catchments, there are significant differences in climate, especially where complex topography like the Great Dividing Range play a key role in generating weather. Climate change information from GCMs is of limited value at the primary production and catchment level.

Connecting global climate models and regional biophysical/hydrological models

Without locally relevant information, decision-makers (for example local governments, state governments and industries) cannot develop appropriate adaptive responses to the effects of climate change. Regional responses often require conceptual models (such as biophysical or hydrological models), calculated agricultural indices (such as growing degree days) or knowledge of changes to the likelihood of extreme events on a regional scale. Conceptual models require inputs such as rainfall and temperature, often in daily time steps. Future-climate input for these models is commonly created by perturbing historical datasets with changes based on output from GCMs. An alternative approach is to use high-resolution regional climate models to dynamically downscale GCM projections to provide a more detailed picture of climate change at the regional level.

Dynamically downscaling global climate models

We have undertaken an extensive climate modelling program to inform the Tasmanian Government and primary industries of likely changes to the regional climate of Tasmania to 2100. The modelling program dynamically downscaled six GCMs to a final resolution of about 10 km over Tasmania. Two emissions scenarios were used for each GCM (a high and a low) and the simulations covered the period 1961 to 2100. This climate modelling output is currently available for more than 140 variables in six hourly time steps via the Tasmanian Partnership for Advanced Computing web-portal.

Making sense of global climate models at regional and catchment scales

We successfully modelled Tasmania's past climate by reproducing Tasmania's climate at the regional level, including the mean, variability and complicated spatial structure of Tasmania's rainfall, temperature and other important variables. We demonstrated that climate modelling output can be used directly as input for biophysical and hydrological models in order to project changes to key agricultural outputs such as ryegrass yield or water catchment yields, for the calculation of agricultural indices and to examine the changes to the likelihood of extreme events at an applicable scale.

High-Resolution Climate Information for Australia

The Climate Futures for Tasmania climate modelling program was only made possible through collaborative investment and input from stakeholders. We have scoped and calculated the investment needed to replicate the climate modelling program on a national scale. Providing high-resolution (about 10 km) climate simulations across Australia to the end of 21st century, that is suitable for application at the regional and catchment level, is vital to enable grass-roots adaptation responses.

TITLE FORECASTS IN SEASONAL RAINFALL IN SWWA

Theme Impact modelling / Forecasting
Primary Author Dr Fiona Evans
Institution Department of Agriculture and Food WA
Email fiona.evans@agric.wa.gov.au
Key search words Forecast, seasonal, rainfall

Climate change projections indicate that south-west Australia (SWWA) will experience a drying climate with declining growing season rainfall and rising temperatures. However, seasonal variability will remain the dominant driver of adaptation at the farm level. Strategies used by farmers to manage uncertain rainfall include the diversification of farming enterprises, use of no-till, fallowing, choice of crops and cultivars, adjustment of nitrogen fertiliser applications, summer weed control, dry seeding and increased row-spacing. Forecasts of seasonal rainfall made at managerially relevant times of year should enable farmers to modify farm management to maximise returns in good seasons and minimise losses in bad seasons. However, current use of seasonal forecasts is limited by perceived low levels of skill, and limited availability of long-lead forecasts at appropriate times of year.

Uncertainty in seasonal forecasts arises from uncertainty in the observational data, uncertainty arising from the choice of model structure and uncertainty due to the chaotic nature of atmospheric processes. When making forecasts, it is important to produce and effectively communicate information about the uncertainty of the forecast.

We present a system for forecasting growing season rainfall in SWWA that uses novel predictors derived from global climate data within sophisticated statistical models. The forecasts take the form of probability distributions that describe the most likely rainfall total as well as the uncertainty around it. We demonstrate a range of products designed to enable farmers and policy makers to use the forecasts appropriately to make decisions about how to manage the coming season.

THEME

PLENARY PRESENTATIONS

TITLE

FARMING AND FOOD SYSTEMS FOR A CARBON, WATER, ENERGY AND NUTRIENT-CONSTRAINED WORLD: WHAT SORTS OF KNOWLEDGE DO WE NEED, AND HOW MIGHT WE ACQUIRE AND SHARE IT?

Presenter Andrew Campbell[1]

Over coming decades, rural landscapes and natural resources will become increasingly contested. The era of abundant, cheap fossil fuel energy is coming to a close due to oil depletion and the increasingly widespread pricing of carbon. Inherent climate variability, exacerbated by underlying climate change, will place increasing pressure on water resources. Rising energy prices will drive up the cost of transport and nutrients, particularly agrichemicals and fertilisers. Population growth and changing demographic and consumption patterns will see increasing demand for food, but the traditional means of increasing food production through expanding and intensifying the footprint of agriculture will be increasingly squeezed by land, water, energy, nutrient and carbon constraints. In rich countries like Australia, public and consumer concerns about biodiversity conservation, landscape amenity, water quality, animal welfare, public health and safety and fair trade, seem unlikely to diminish.

Against this backdrop, it would make sense for Australian agriculture to set some high level strategic objectives over the next 20 years. For example: to double food production; to double water and energy productivity; to become a net producer rather than consumer of energy; and to become carbon-neutral.

This presentation will explore how such objectives might be achieved, and their implications for agricultural research and extension, from research investment through to broader community engagement.

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1 Professor Andrew Campbell is the Director of the Research Institute for Environment and Livelihoods at Charles Darwin University. He is also Chair of the Terrestrial Ecosystem Research Network, a Director of the CRC for Future Farm Industries and a Visiting Fellow at the Fenner School of the ANU. He was Managing Director of Triple Helix Consulting from 2006-10 and Executive Director of Land & Water Australia from 2000-2006.

TITLE **THE RDCS DELIVERING THE GOODS, FOR THE PAST TWENTY YEARS, AND THE NEXT TWENTY YEARS**

Presenter Dennis Mutton
Institution Council of Rural Research and Development Corporations

The Rural Research and Development Corporations (RDCs) are a central component of the rural RD&E system. With annual research expenditure of around $500 million per annum, the RDCs have substantial influence on the direction of the research effort. The close links with industry, Government and the science community ensure that there is continuous input into the research, planning and priority setting process.

RDC R&D is funded through a unique model of co-investment between industry and Government. This government-industry partnership model has been operating successfully for over 20 years, and ensures that industry stakeholders have the opportunity to share in R&D investment, leading to outcomes that are practical and relevant. The model is an effective working alliance that delivers benefits for both industry and the wider community.

RDC investment in R&D reflects the Rural Research and Development priorities that have been set by Government to drive innovation and to improve productivity in the rural sector. This investment underpins the competitiveness and profitability of Australia's agricultural, fisheries and forestry industries. Work funded through the RDCs also supports the sustainability of primary production and the national resource base.

There are 15 RDCs covering virtually all of the agricultural industries. These RDCs bring together industry and researchers to establish R&D strategic directions and to fund projects that provide industry with innovation and productivity tools to compete in global markets.

The recent Productivity Commission draft report on the rural RDCs has recognised the strengths of the RDC model, including the close links with industry that maintain the relevance of R&D, and a systems integration role within the rural RD&E Framework.

However, the Productivity Commission has made a number of recommendations that, if endorsed by the Government, have the potential to severely impact on the level of investment in rural RD&E in Australia. In particular, the recommendation to significantly reduce Government funding for the RDCs through a reduction in the cap on matching contributions, will have adverse consequences for productivity growth and community well being.

The RDCs believe that a number of mechanisms can be implemented to improve the RD&E system by building on the strengths of the current RDC model. These mechanisms include Government, in consultation with the RDCs and other key stakeholders, clearly defining the priorities for cross-sectoral and public good R&D. The RDCs also believe that the responsibility for managing identified public good R&D and cross-sectoral collaborative projects can be undertaken within the existing structure, including the strategies under the National RD&E Framework and other collaborative initiatives.

TITLE GROWING MORE FOOD WITHOUT GROWING EMISSIONS: THE GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Presenter Laura Hogg
Institution New Zealand Ministry of Agriculture and Forestry
Email laura.hogg@maf.govt.nz

The Global Research Alliance on Agricultural Greenhouse Gases brings countries together to find ways to grow more food without growing greenhouse gas emissions.

Agriculture plays a vital role in food security, poverty reduction and sustainable development. The agriculture sector is particularly vulnerable to the impacts of climate change and faces significant challenges in meeting a dramatic increase in global food demand while reducing its contribution to global greenhouse gas emissions.

The Global Research Alliance is focused on research, development and extension of technologies and practices that will help deliver ways to grow more food (and more climate resilient food systems) without growing greenhouse gas emissions.

The Alliance brings countries, organisations and individuals together in a bottom-up, voluntary network to increase international cooperation, collaboration and investment in agricultural greenhouse gas research. The Alliance will help improve the understanding and measurement of agricultural emissions. It will also find better ways to share research results, technologies and best practices, and get these out to farmers on the ground.

The Alliance is centred on three Research Groups, covering the broad areas of Cropping, Paddy Rice and Livestock, and two key issues that cut across these three Groups: soil carbon and nitrogen cycling, and inventory/measurement issues.

Thirty one countries are now members of the Alliance, with more expected to join in the coming months.

www.globalresearchalliance.org

CCRSPI is a joint initiative of the rural research and development corporations; the state and territory governments; the Australian Government Department of Agriculture, Fisheries and Forestry; and the CSIRO.

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