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Challenges for Australian Agriculture

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Agriculture is a complex, sophisticated and indispensable component of modern Australian life. Climate change is heightening these characteristics. It is simultaneously increasing the agriculture sector's vulnerability: underlining its reliance on nature and fossil fuels, exposing its weaknesses, and testing its ability to rapidly adapt to new circumstances.

The phenomenon of climate change represents far more than physical change for farmers and their families. The introduction of a national Carbon Pollution Reduction Scheme (CPRS) and associated rises in the cost of agricultural inputs, interest in the ecological role of farms and the introduction of water trading, a loss of agribusiness services in some areas and an exacerbation of social hardship, involves political, economic and social changes for agriculture that are simultaneously challenging the sector at multiple levels and underlining its importance and potential.

To understand the challenges climate change poses for Australian agriculture, we need to appreciate six points about agriculture: (1) its indispensability, (2) its sensitivity to climate change, (3) its existing complexity and vulnerability, (4) its potential to adapt to inevitable climate change, (5) its role in causing climate change, and (6) its role in mitigating future climate change. These points are covered in turn below, before some directions for the future are outlined.

Food Security, Food Miles and Feeding the Planet

The first fact to note about agriculture in any discussion of climate change is that it is indispensable. Its food products are essential for our existence and that of millions across the globe. Although obvious, this fact is often overlooked. In Australia, as in other rich countries, agriculture is often positioned as a legacy of the past, clinging on alongside more sophisticated industries like those of the cerebral knowledge economy. It is positioned in this light as an endeavour more suited to developing nations who, with their cheap land and labour, are seen as perfectly positioned to act as the global food bowl, feeding distant, richer countries characterised by glittering city lights and neatly bounded wilderness interspersed with romanticised relics of past rural life. Yet, at a national level, 'moving on' from agriculture to less climate sensitive or less polluting industries is not an option. In Australia, as elsewhere, we need instead to massively improve our food-production system.

As the global population rises towards 9.8 billion by 2050 — up a massive 72% from 5.8 billion in 1995 — agriculture is becoming of ever-greater importance. Australia currently exports two-thirds of its total agricultural production, and is the world's second-largest exporter of cotton, beef and sheep meat. While the Food and Agriculture Organisation (FAO) predicts that our domestic food needs and those of other industrialised countries will remain stable or even decrease, they expect those of Asia and Latin America to double, those in West Asia and the Arab world to increase threefold, and those of sub-Saharan Africa to increase five- to sevenfold.[1] With regional food-production capability poorly matched to predicted growth in demand — especially as population growth consumes the food, water and other resources needed for agriculture — many countries are going to be increasingly reliant upon food imports to meet their nutritional needs.[2] Some countries, and many individuals within them, are already unable to afford such purchases and rely instead on their own dwindling production.

Food production is being placed under further pressure as undernutrition in developing countries is tackled and diets change through increasing living standards and globablisation. Most notably, meat consumption is increasing rapidly. With 11 plant-derived calories required to produce one calorie of beef, this shift has serious conse-

quences for the resources needed to produce food.[3] Combined with the greenhouse-gas emissions produced by livestock — discussed further below — this has serious implications for climate change.

The above necessitates that global food trade will continue to increase. However, many nations are also increasingly looking to bolster their internal food supply. This is in recognition of the vulnerability that reliance on external food markets creates and the carbon cost of transporting food. Combined with the production, processing, packaging, storage and refrigeration requirements often involved in getting food from 'farm gate to dinner plate', the further we transport our food can greatly increase its carbon footprint.[4] While the carbon cost of such transportation is often outweighed by how energy intensive different forms of agricultural production and different products are — with most of Australia's agriculture very low in embedded energy relative to international competitors — concern about the environmental and economic costs of 'food miles' (how far a food product has travelled) is heightening. Effort is starting to be placed in shortening supply chains and creating 'distributed production and consumption systems'.[5] Associated with an increasing interest in the quality and growing conditions of agricultural products, the local food movement is already a serious force in the United Kingdom and the United States and is of rising prominence in Australia. Overall, as both a source of domestic and international supply, the value of Australian agriculture is increasingly being recognised.

Sensitivity to Climate Change

Not only is agriculture of critical and rising importance, but it is particularly sensitive to climate change impacts. Agriculture is uniquely dependent upon nature. Its 'production units' are individual plants and animals and it is almost entirely reliant upon the natural climate. As such, it will be more directly affected by climate change than virtually any other human activity.

Agriculture within Australia is predicted to be especially badly affected.[6] With temperatures across the country projected to rise by around 1°C on average, annual rainfall projected to decline by between 2% and 5%, and droughts and heatwaves to increase,[7] productivity on many Australian farms will fall, in some cases drastically. Other troubling feedback loops are also in play, such as signs

that land degradation is increasing under drought conditions due to a combination of physical and economic stresses. While fewer frosts and more carbon dioxide (a fuel for plant photosynthesis) may temper the impact on productivity somewhat (at least in the short term), climate change means it is going to be extremely difficult to maintain — let alone increase — our agricultural productivity.

For dryland farms (those reliant only on local rainfall), the impact of reduced total rainfall under climate change will be heightened by the timing of the decline, which will mostly occur during the pasture and crop-growing months of winter and spring. Rainfall events will also become more intense but less frequent, increasing the uncertainty associated with them. Together, these factors mean that precipitation will be less reliable, and the rain that does fall will be less useful for plant growth. For irrigated farms, the rain that falls will also be of less use for plant growth because a reduction in rainfall leads to a proportionately greater reduction in streamflow (water flowing into storages). In the Murray-Darling Basin, for example, a 10% drop in rainfall leads to a 35% drop in streamflow.[8] Australia's river systems have the lowest and most variable streamflow of any continent.[9]

Until recently, irrigated agriculture has been insulated from reductions in local rainfall by its access to distant water sources, such as the dams of the Murray-Darling Basin. The ongoing drought across southern Australia, however, has demonstrated how vulnerable irrigators are when rainfall deficiencies extend across entire basins. Australian irrigators are currently facing an unprecedented 'double drought' in which neither their local rainfall nor external water sources are supplying enough water for production. As a result of reduced rainfall, lower water availability and higher temperatures, irrigated agriculture in the Murray-Darling Basin — which produces 40% of Australia's agricultural produce — is projected to fall by 12% by 2030 and by up to 92% by 2100, if adequate mitigation measures are not undertaken.[10]

Some of the most profound challenges climate change poses for farming families are of a social nature. Rural communities as a whole are particularly vulnerable to climate change. Because of their location within drier parts of Australia, their more direct exposure to 'the elements' — including natural disasters like fires and floods — and the more basic level of services they often have, many rural commu-

nities are set to be more severely affected by climate change than their urban counterparts. The weakening of rural communities by climate change has serious consequences for farming families, whose ability to stay as a family in farming is often reliant to a large degree on the opportunities and support provided by their local community.[11] In turn, in many cases rural communities' vulnerability to climate change impacts is being exacerbated by their reliance upon the agricultural sector. Farming family members usually contribute to their local community through a wide variety of employment, education and social roles. Combined with the 'trickle down' economic effect of farm-based spending in local communities and the direct employment provided to non-farm rural people on farms and downstream food processing, agriculture and the agricultural population underpins the economic and social sustainability of many rural communities.

Complexity and Vulnerability

The agricultural sector's ability to cope with the changes outlined above is hampered by the increasing complexity and vulnerability many farming families face. Both at the individual farm level and that of the industry as a whole, an expanding realm of factors is coming into play, cutting across scales, sectors and seasons. Farmers' day-to-day decisions about what to grow and how to grow it are being made against a background of multitudinous and often uncertain considerations: from the global financial crisis and input prices, to futures markets and currency values, soil degradation and biodiversity loss, environmental regulations and animal-welfare concerns, agronomic advances and machinery requirements, employment law and computing needs, planning restrictions and community support, superannuation structures and succession plans, as well as physical and mental health considerations. Influenced by far more than what is inside the farm gate, farming decisions are made in an ongoing process of reflection on current circumstances, evaluation of past actions and predictions of future scenarios. They require individuals to continuously assess and integrate an overwhelming amount of information from diverse sources and to manage the uncertainty inherent in applying generic broad-scale ideas to one's own situation.

Climate change is profoundly adding to the complexity farmers face, both as an additional consideration and through its interaction with other factors. One of the ways it is adding complexity is via the scientific and educational response it has generated, as institutions of all sorts seek to better understand and communicate to farmers what is likely to lie ahead. Whether focused on the climate itself, predicted economic implications, or potential adaptation measures like new crop varieties, this effort is adding substantially to the large amounts of information farmers are meant to be absorbing and applying. More profoundly, this information generation points to the serious epistemological challenge that climate change represents for farmers.[12] By fundamentally altering what the future holds and what 'best management' looks like, climate change is throwing into question the value of past experience or local knowledge; knowledge that all farmers have traditionally relied on to a degree — often a great degree — in making their decisions. This devaluing of past experience and local knowledge as a reliable guide to the future is undermining farmers' confidence and increasing their reliance on often complicated external information at a time when confidence is badly needed and attention is short.

Making farming additionally complex in Australia is the fact that most of it is undertaken by families and most of those families live on the farm. The farm is therefore a home and a lifestyle as well as a business. It means more to family members than simply a source of income. Indeed, in the face of highly variable farm profits the importance of the farm income is diminishing for many farm families as they diversify their income streams through off-farm work to reduce their financial risk. Combined with the growing trend for farm families to reduce their financial risk by investing farm profits off-farm, this diversion of time and energy off-farm threatens to reduce the viability of the farm in the long term.

Many farming families in south-eastern Australia are being forced to look at alternative income because of the dry and drought conditions they have been facing for the past few years, and in some cases the past one to two decades. Symptomatic of climate change — or at least of what climate change has in store — the long stretch of dry and drought conditions they have experienced has increased their vulnerability to future unfavourable conditions. By severely limiting

the rewards they have received from farming and eroding what buffer they have to cope with costly poor seasons, the ongoing drought has pushed many to the limit of their financial, physical and mental reserves. It has sensitised them to pre-existing difficulties such as declining terms of trade, negative public perceptions of agriculture, soil degradation, and introduced new problems like agri-business closures, family stresses and poor health, as well as raising the stakes of their farm decisions, adding pressure to an already pressurised decision-making environment.[13]

Although relatively little social research has been conducted into the effects of drought and concurrent pressures on farming families, that which has been done points to the high level of stress and anxiety among the farming and broader rural community. In a recent review of the literature, Fragar and colleagues found that 'self-reported levels of distress in farming and rural communities are high'.[14] The emotional impact of the drought has many sources, from witnessing stock go hungry and land degrading, to worry about debt, workload, scuttled retirement plans, or the future of one's family, local community and sector.

Among this, climate change itself is a source of mental distress. Climate change represents a problem of unprecedented size and severity; a global and long term threat that increasingly seems difficult to avert and devastating in its consequences.[15] The very existence of this threat is affecting rural communities' responses to the current drought.[16] Climate change's characterisation as an unending pattern of worsening conditions is challenging farming families' belief in the cyclical nature of good and bad times and, with it, the optimism with which they typically approach each new season. As such, climate change is challenging their hope and expectation that the current drought will end and that they will recover. In turn, the immediate pressures created by the current drought are worsening the feelings of hopelessness and disempowerment that climate change is engendering in many.

Adaptation Potential

Although responding to climate change is difficult for the reasons outlined above and action is not currently widespread within Australian agriculture, the sector does have a proven ability to adapt to changing climatic conditions.

Australia has always had an extremely variable climate. Over the past 100 years, average rainfall, for example, has fluctuated between three and eight metres, with regional rainfall showing even greater variability.[17] Over this time, farmers have adopted a range of techniques to prosper in such a climate. These include being flexible in what they sow and when, combining enterprises that prosper in different conditions, and using financial instruments to spread their income across good and bad years. Australian farmers have also demonstrated an ability to adapt to increasingly dry climatic conditions. Crop varieties that cope better in drier conditions have been developed and adopted; practices to retain soil moisture, such as working the soil less and building up organic matter, are increasingly being used; and in some cases farmers have changed enterprise types to better meet new local conditions. Some farmers are also demonstrating an ability to adjust to new markets of the sort that are likely to arise indirectly as a result of climate change. In particular, as the water market has been deregulated and water has become increasingly scarce and in some cases expensive, some farmers have diversified their enterprises and formed cooperatives to buy inputs and/or to value-add to and sell their primary products.

Similar techniques are needed to adapt to the physical, economic and institutional issues arising out of climate change. However, further thinking and action is also needed. The traditional approach to adapting to cost-price squeezes of the type created by climate change has been to increase the quantity of production,[18] notably through increasing fertiliser use[19] or, if money is an issue, by 'mining' soil fertility by dropping fertiliser use below nutrient replacement levels.[20] There is emerging evidence that some farmers are doing the latter to cope with the pressures of the current drought.[21] However, such approaches are obviously not viable over the long term, which climate change demands we consider. Combined with the fact that climate change itself is reducing the productive capacity of much land in south-eastern Australia — both directly and through new water regimes — it is clear that alternatives are needed and will require some radical changes. In some marginal production areas it is likely that adaptation will involve accepting that agriculture is no longer a viable or appropriate land use. In other areas agriculture will

continue, but in substantially different forms both in terms of what is grown and how it is grown.

One of the major challenges for adaptation is that the pace of change at the farm level is limited. Many of the adaptation measures suggested by off-farm experts are likely to be costly for farmers in the short term. All change carries risks and costs, even if only in time and energy lost in exploring them. The more a new practice differs from one's current practice, the greater the mental, financial and other costs involved in the transition. Decades of research into agricultural extension points to the importance of taking a farmer perspective and recognising how difficult the changes being asked of them are, regardless of how rational any particular practice change may seem to outside observers. This is especially the case in the current situation, where the urgency of climate change adaptation is countered by the minimal financial, mental and physical reserves that many farmers have to work with. As discussed above, the stakes are high on many farms and the adoption of any new practice is thus especially risky. In the words of Ian Gray and colleagues, from the perspectives of farmers, 'the kind of changes being mooted appear gradual, but may be precipitous at the local farm level'.[22] It is also clear, however, that in the context of climate change continuing with business as usual is an even riskier option.

Greenhouse Gas Emission Contribution

Not only is agriculture one of the industries most vulnerable to climate change, it is also one of the most responsible. Unlike the geographic split that broadly exists between the nations highly exposed to climate change and those largely responsible for the problem, agriculture is both a chief victim and perpetrator of climate change. In fact, the biggest impact that most of us have on the environment is through the food we eat. As a recent report by the Victorian Eco-Innovation Lab notes, in Australia 'food choices could make a much bigger difference to household sustainability than direct water and energy use'.[23] At the household level, approximately 28% of our greenhouse-gas emissions and half our water use stems from the production, storage and transportation of the food we consume.

At the national scale, agriculture is Australia's second-largest emitter, accounting for around 16% of Australia's greenhouse-gas emissions, and exceeded only by stationary energy.[24] Agricultural emissions come from a range of farming activities, including methane from rice fields, application of nitrogen fertiliser, burning of savannas and crop residues and, where it is done, land clearing. By far the largest contribution, however, comes from manure management and digestion in sheep and cattle (approximately 70% of Australian agricultural emissions and 11% of net national emissions).[25] It is livestock emissions that make Australia the third- largest agricultural emissions per capita country in the world.[26]

Potential Contribution to Mitigation

Thankfully, there are opportunities to turn around agriculture's contribution to climate change. Indeed, there are opportunities for the sector to redesign itself as a major carbon sink rather than a carbon source, and to play a significant role in our effort to minimise climate change.

There is a growing array of on-farm management changes that farmers can use to mitigate their emissions. Methane from animal digestion, for example, can be reduced through practices such as vaccinations and chemical inhibitors. Some of these practices can be implemented now while others are technically feasible, but have not yet proven cost effective. Increasing the amount of carbon sequestered in the soil is possible through changes to tillage practice and vegetation cover. Estimates of the carbon-sequestration potential of these practices range greatly, but many can be put into practice immediately. Because of the other benefits they confer —including increased oxygen and moisture in the soil — they are likely to provide a net return to growers. It may also be possible to reduce nitrous-oxide emissions from fertiliser use by up to 80% through fertiliser management, soil and water management, and fertiliser additives.[27] Like soil conservation, these measures may be able to achieve a net return for the farmer, although much more research is needed.

In some regions it will be possible to change to lower-emissions enterprise types. Where the climate allows cropping, for example, farmers may find that, as the price of methane emissions rise, crops are more profitable than beef cattle or sheep. It is important to note,

however, that while this shift would see a net reduction in emissions, in some areas it could be seriously at odds with land and biodiversity conservation objectives.[28]

Another option is for farmers to change land use and 'farm' other forms of biosequestration, such as long-term forestry and environmental plantings. Polglase and colleagues estimate that in Australia environmental plantings could be profitable across nine million hectares and achieve an annual rate of carbon sequestration of 143 Mt CO_2-e per year. Other forms of biosequestration are estimated to achieve carbon sequestration in excess of 100 Mt CO_2-e per year.[29] Combined, there is huge potential to reduce net emissions in this way, contributing significantly to Australia's net reductions as a whole. Given the extent to which climate change is likely to reduce the productivity of some areas of Australia, biosequestration may also provide the only income-generation opportunity in such places.

Unlike the other big emitters in Australia — stationary energy and transport — agriculture is not being asked to pay for many of its emissions immediately as measuring, verifying and charging farmers for the direct emissions they produce remains very difficult.[30] Nevertheless, under the emissions trading scheme to be introduced in 2010, farmers will be indirectly charged for the emissions associated with agriculture via higher prices for agricultural inputs such as fertiliser, agrichemicals and, potentially, fuel. Gunasekera and colleagues estimates a $40 per tonne price on emissions would see a rise in production costs for livestock of 3% and for cropping of 4.5%.[31]

If the difficulties of including agriculture in an emissions trading scheme can be overcome, the sector may then also face direct costs for its emissions, including the powerful ones produced by livestock. This would see a rise in production costs of 18% for livestock and 6% for cropping, based again on an emissions price of $40 per tonne.[32] Work by the Garnaut Climate Change Review indicates that agricultural industries such as beef and dairy cattle and sheep will be disproportionately affected relative to virtually any other agricultural industry or Australian export.[33] Due to their high exposure to international trade, farmers in these livestock industries will not be able to pass on this cost to consumers and will have to accept lower profit margins — which may not be possible — or change industries.

Overall, mitigation of agricultural emissions is not only essential for agriculture, but for our national and global effort to reduce climate change. It is also going to demand a whole new level of adaptation from farmers, adding to the challenge they face in adapting to direct climate change impacts and in managing a drought-affected and complex farming environment. What is needed to assist them in this process and help to ensure that we and the rest of the world have enough food and a sustainable environment into the future? It is to this final topic that we now turn.

The Consequent Challenges: Three Major Areas of Need

Integration Across Issues and Scales

Agriculture needs a 'third revolution': a rethink and restructure that makes it not only more climate friendly, but more water, biodiversity, community and health friendly, as well as more productive. Climate change is but one of multiple interrelated issues faced by the sector and society in general. It is too often viewed as a discrete technical issue rather than as a challenge that needs to be addressed from multiple angles and mainstreamed into actions that achieve other diverse objectives. Critically, tensions need to be acknowledged. Our imperatives to secure food, energy and water, for example, are in part in competition.[34] Biodiversity, rural social sustainability and human health objectives add to the complexity and difficulties. If these issues are viewed in isolation, measures may be adopted that negatively impact other important goals. Biofuel production, for example, may provide a renewable energy source, but use a lot of water and decrease land for food production. Likewise, water-saving techniques in agriculture such as drip irrigation can carry a relatively high energy cost. It is vital that we do not settle for easy, narrow answers and instead think hard and broadly to identify win-win approaches, such as improved soil stewardship.[35]

As well as adopting a cross-issues view, we need to adopt a cross-scale one. We need to find responses that do not involve outsourcing our problems to other nations, regions or local areas. Exporting our food needs rather than our food to other countries, for example, would not solve the challenges inherent in food production; it would just move them, possibly to countries that are less equipped to deal with them than we are.

Policy Signals, Incentives and Infrastructure

Clear policy signals are needed to direct and inspire action in agriculture. Chief among these are more ambitious medium-term targets for mitigation and higher carbon prices. Also essential are realistic incentives — financial or otherwise — for uptake of mitigation measures. These incentives need to avoid perversity and take into account the full range of carbon-related activities on farms, including not only those that produce emissions (which Australia has agreed to count under Kyoto), but those that remove them (which Australia is yet to agree to count). Stronger incentives, integrated solutions and more diverse income streams will only be made available to farmers if both the 'good' and the 'bad' side of farming's carbon ledger are included in this way.

Agriculture's positive contribution to climate change mitigation needs to be integrated into a broader policy move to properly reward farmers for the production of ecosystem services more generally. We need to recognise agriculture's land management as well as food-production function and reward good practice. Requirements for environmental labelling of agricultural products would allow consumers to add a market signal to the push for climate and ecosystem-friendly products.

At the community and sector levels, government can further enable and direct change by providing appropriate infrastructure. The future distribution of agriculture and pattern of enterprises will be influenced by what resources, such as rail facilities and research centres, as well as schools, hospitals and other resources essential to community wellbeing, are available in different areas. There is a valuable opportunity to not only help agricultural industries and communities distribute themselves in a climate change-ready manner, but to take a lifecycle view and reduce the carbon footprint of their products and the food system at large. The potential for decentralised systems of climate-appropriate food production, processing and consumption to concurrently fulfil environmental, economic and social goals deserves close attention.

Information, Innovation and Learning

A major impediment to farmers' ability to adapt to climate change or optimise their mitigation strategies is a lack of accurate information.

In terms of understanding and planning for likely climate- change impacts, although much work has been done at the national and State levels, large uncertainties remain. Furthermore, little progress has been made in generating regional or local scale information, although it is known in general that some areas will be affected very differently to surrounding areas due to their particular characteristics. The range of possible changes in physical parameters such as temperature and rainfall remain too large to enable farmers to base decisions upon such predictions. Action is needed on three fronts: the uncertainty bands must be reduced, information needs to be localised as much as possible, and, recognising that there will always be some level of uncertainty, probabilities of a smaller range of scenarios should be developed and farmers trained in how to apply the probabilities to develop a risk-based approach.

Past neglect of agricultural research and development must be redressed and funding provided for research into numerous aspects of agriculture, including the relationships between different farm components and those aspects previously cordoned off as natural-resource management. 'Social factors' such as impediments to adaptation also demand research attention. It is also essential for the quality of solutions and their acceptance among the farming community that farmers are intimately involved in the search for and testing of new approaches.

Information is only of value to the extent that it helps to inform decision-making. Individuals must be helped to access, understand, learn, evaluate and, if appropriate, apply — mentally, financially and socially — the new information they are presented with. Such training and assistance needs to be well funded and include generic models and tools to assist farmers to manage uncertainty by developing a portfolio of options and creating flexibility in their approach.

Ideally, these capacity building tasks will form part of a broader agenda to better develop the institutional and cultural conditions that are needed for rapid system-wide innovation, social learning and the sharing of experience. As Andrew Campbell notes, the challenge facing agriculture entails an unprecedented learning challenge:

> We will need to learn, to innovate and to share knowledge better than we ever have in the past, especially at the grassroots level. We will need to make the best possible use of the rich variety of local knowledge, assisted by the best available science, smart policies and supportive institutional frameworks.

> We will need ways of engaging a broad cross-section of agricultural producers and of working and learning together from the scale of individual fields to farms to whole communities, landscapes and watersheds.[36]

Part of the conditions required is improvement in governance, including greater integration of national, State and regional-level initiatives and regulatory frameworks to remove duplication and antagonistic messages from a farmer perspective, including those regarding risk. It would also be sensible to build on existing sources of agricultural innovation and learning, such as some of the innovative community farmer groups that already exist, to enable them to rapidly progress their work and connect with others.

Conclusion

This chapter has argued that agriculture is an indispensable, climate-sensitive, vulnerable, complex, adaptable and climate-changing human activity. It is an industry that is playing — and will increasingly play — a significant role in both causing and addressing the climate change crisis. It is also an industry that all of us are affected by and — through our citizen and consumer roles — one that all of us affect. To create the 'third agricultural' revolution that is required to address climate change and to generate the government and research responses needed to assist the industry down this challenging path, all Australians need to be more informed, concerned and active about the industry and the communities it represents. It is hoped that this chapter goes some way towards achieving this goal.

Endnotes

1 Food and Agriculture Organisation. (2008). *Assessment of the World Food Security and Nutritional Situation*, Thirty Fourth Session, Agenda Item II, October 2008, Committee on World Food Security, United Nations, Geneva.

2 Battisti, D., & Naylor, R. (2009). Historical warnings of future food insecurity with unprecedented seasonal heat. *Science, 323*, 240–244.
Cribb, J. (2008). *The coming famine: Constraints to global food production in an overpopulated, affluent and resource-scarce world: The scientific challenge of the era.* Julian Cribb and Associates Discussion Paper.

3 Eshel, G., & Martin, P. (2006). Diet, energy and global warming. *Earth Interactions, 10, 1–17.* Reijnders,

L., & Soret, S. (2003). Quantification of the environmental impact of different dietary protein choices, A*merican Journal of Clinical Nutrition, 78*(Suppl.), 664s–648s.

4 Weber, C., & Matthews, H.S. (2008). Food-miles and the relative climate impacts of food choices in the United States. *Environmental Science and Technology, 42*, 3508–3513.

5 Larsen, K., Ryan, C., & Abraham, A. (2008) *Sustainable and secure food systems for Victoria: What do we know? What do we need to know?* (VEIL Research Report No. 1). Melbourne, Australia: Victorian Eco-Innovation Lab, Australian Centre for Science, Innovation and Society, University of Melbourne.

6 Stokes, C., Howden, S., Gifford, R., Meinke, H., Bange, M., McRae, D., Roth, G., Gaydon, D., Beecher, H., Reinke, R., Crimp, S., Park, S., Inman-Bamber, G., Webb, L., Barlow, E., Hennessy, K., Whetton, P., Booth, T., Kirschbaum, M., Battaglia, M., Stone, G., Cobon, D., Ash, A., McKeon, G., Miller, C., Jones, R., Hobday, A., & Poloczanska, E. (2008). *An overview of climate change adaptation in Australian primary industries: Impacts, options and priorities.* Canberra, Australia: CSIRO.

7 CSIRO & BoM. (2007). *Climate change in Australia: Technical report 2007*. Melbourne, Australia: CSIRO.

8 Jones, R., Whetton, P., Walsh, K., & Page, C. (2001). *Future impact of climate variability, climate change and land use change on water resources in the Murray-Darling Basin: Overview and draft program of research*. Melbourne, Australia: CSIRO.

9 Walquist, A. (2008). *Thirsty country: Options for Australia.* Sydney, Australia: Allen and Unwin, and Jacana Books.

10 Quiggin, J., Adamson, D., Schrobback, P., & Chambers, S. (2008). The implications for irrigation in the Murray-Darling Basin, Report commissioned by The Garnaut Climate Change Review: Final Report. Melbourne, Australia: Cambridge University Press.

11 Rickards, L. (2008). *Critical breaking point? The effects of drought and other pressures on farming families.* Report for the Birchip Cropping Group, Birchip, Victoria. Available at http://www.bcg.org.au/resources/Critical_Breaking_Point_Final_Report_May_2008.pdf

12 Gray, I., Lawrence, G., & Sinclair, P. (2008, November). *The sociology of climate change in regional Australia: Farmer capacity for change amid drivers for consensus and certainty in an uncertain environment*. Paper presented at the Agri-Food Conference, University of Sydney, Australia.

13 McGuckian, N., & Rickards, L. (in press). Social dimensions of mixed farming systems. In P. Tow, I. Cooper, I. Partridge & C. Birch (Eds.), *Rainfed farming systems.* Sydney, Australia: Springer.

14 Fragar, L., Henderson, A., Morton, C., & Pollock, K. (2008). *The mental health of people on Australian farms — The facts.* Canberra, Australia: Rural Industries Research and Development Corporation and Australian Centre for Agricultural Health and Safety. See also: Sartore, G-M., Kelly, B., Stain, H., Albrecht, G., & Higginbotham, N. (2008). Control, uncertainty and expectations for the future: A qualitative study of drought on a rural Australian community. *Rural and Remote Health, 8*, 950. Available at http://www.rrh.org.au). Rickards, op. cit.

15 See Blashki, G., Burke, S., Fritze, J., & Wiseman, J. (2008). Hope, despair and transformation: Climate change and the promotion of mental health and wellbeing. *International Journal of Mental Health Systems, 2,* 13. Available at http://www.ijmhs.com/content/2/1/13

16 Berry, H., Kelly, B., Hanigan, I., Coates, J., McMichael, A., Welsh, J., & Kjellstrom, T. (2008). Rural mental health impacts of climate change, *Garnaut Climate Change Review,* June 2008

17 Bureau of Meterology. (2009). *Australian Annual Rainfall, 1900–2000.* Available at http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi?variable=rain&region=aus&season=0112

18 Gray et al., op. cit. They conclude that, under climate change, 'it might be predicted that producers will find it increasingly difficult to stay on the land without continuing to exploit natural resources' (p. 6).

19 Campbell, A. (2008). Food, energy, water: Conflicting insecurities (and the rare win-wins offered by soil stewardship)'. *Journal of Soil and Water Conservation, 63*, 149A–151A.

20 See, for example, Richards, C., Lawrence, G., & Kelly, N. (2005). Beef production and the environment: Is it really 'hard to be green when you are in the red'? *Rural Society, 15*, 192–207.

21 See Rickards, op. cit.

22 Gray et al., op. cit., p. 1.

23 Larsen et al., op. cit, p.7.

24 Department of Climate Change. (2008). Australia's national greenhouse accounts. *Australian greenhouse emissions information system*. Retrieved February 12, 2008 from www.ageis.greenhouse.gov.au

25 Department of Climate Change, ibid.

26 Garnaut, R. (2008). *The Garnaut climate change review: Final report*. Cambridge University Press, Australia.

27 de Klein, C., & Eckard, R. (2008). Targeted technologies for nitrous oxide abatement from animal agriculture. *Australian Journal of Experimental Agriculture, 48,* 14–20.

28 Flannery, T. (2008). *Now or never: A sustainable future for Australia* (Quarterly Essay, 31). Melbourne, Australia: Black Inc.

Price, R. (2008). Grazing. In D. Lindenmayer, S. Dovers, M. Harris-Olson & S. Morton (Eds.), *Ten commitments: Reshaping the lucky country's environment* (pp. 119-124). Melbourne, Australia: CSIRO Publishing.

29 Polglase, P., Paul, K., Hawkins, C., Siggins, A., Turner, J., Booth, T., Crawford, D., Jovanovic, T., Hobbs, T., Opie, K., Almeida, A. & Carter, J. (2008). *Regional Opportunities for Agroforestry Systems in Australia: A report for the RIRDC/L&WA/FWPA/MDBC Joint Venture Agroforestry Program*, RIRDC, Barton, ACT.

30 There are many real issues associated with first, measuring emissions from agriculture and land-use change and then including them in an emissions trading scheme. The three main ones are: the inherent variability of biological processes; the permanency of sequestration; and the vast number of business entities involved is huge.

31 Gunaskera, D., Tulloch, C., Ford, M., & Heyhoe, E. (2008, June) Climate change: Opportunities and challenges in Australian agriculture. *Proceedings of Faculty of Agriculture, Food & Natural Resources Annual Symposium 2008,* University of Sydney, Aystrakua

32 Gunasekera et al., ibid.

33 Garnaut, op. cit.

34 Campbell, op. cit. Larson et al., op. cit.

35 Campbell, op. cit.

36 Campbell, op. cit., p.151A. See also Campbell, A. (2008). *Paddock to Plate: Food, farming and Victoria's progress to sustainability* (Future Food and Farm Project Background Paper). Melbourne, Australia: Australian Conservation Foundation.

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