

Australian agriculture adapting to climate change: balancing incremental innovation and transformational change

Andrew Ash¹, Rohan Nelson², Mark Howden² and Steve Crimp²

¹CSIRO Climate Adaptation National Research Flagship, 306 Carmody Rd, St. Lucia, QLD 4067

²CSIRO Climate Adaptation National Research Flagship, GPO Box 284, Canberra, ACT 2601

Introduction

As the reality of climate change is being increasingly accepted, attention is rapidly shifting from describing the likely impacts of climate change to addressing the challenges of adaptation. Australian agriculture, which already has to manage extreme climatic variability, is in a position to be leading Australian industry in innovative and proactive responses to climate change - and it needs to be as it is amongst the most vulnerable sectors in Australia (PMSEIC 2007, IPCC 2007). It is highly likely that climate change will add further complexity to the current challenges of managing environmental and market risk.

Assessing the likely economic and social costs of climate change has so far been tackled at a broad scale but early estimates (Gunasekera et al 2007, Heyhoe et al. 2007, Howden and Crimp 2005, Howden et al. 2007) suggest significant impacts at regional and national scales e.g. 5% loss of GDP by 2050. Adapting to climate change can reduce these costs and Heyhoe et al. (2007) suggested at the regional scale that adaptation may halve the likely economic impact of climate change. Howden and Crimp (2005) assessed the value of some simple agronomic adaptation options for the Australian wheat industry and found that these will likely increase farm-gate income by an average of between \$150M and \$500M per annum by 2070. A recent review of climate change adaptation in Australian agriculture (Stokes and Howden 2008) has identified a range of adaptation options that are common across industries and these are summarised in Table 1.

Incremental vs transformational change

There are many potential incremental adaptation options available to offset projected impacts (Howden *et al.*, 2007). These incremental adaptation options often involve build on existing approaches to better manage climate variability, technological fixes e.g. new plant varieties, improved water use efficiency, etc., to much more significant change in enterprise mix and land use change (Table 1). Implementation of these options is likely to have substantial benefits under moderate climate change for some cropping systems (Howden and Crimp 2005; Howden and Jones 2004). This has been clearly demonstrated in the past with incremental innovation to environmental, policy and economic drivers a hallmark of agriculture's success in Australia.

In terms of climate there are some good examples of where this type of adaptation has already occurred. For example, in central Queensland there has been a significant reduction in frost incidence in the last 50 years and since the 1980s there has also been quite a changed pattern of rainfall which no longer strongly favours summer cropping. The reduction in frost incidence and the development of new varieties means that wheat is now planted three to four weeks earlier than in the 1950s (Stephens and Lyons 1998). Adapting to the reduced frost risk means that farmers can almost double their gross margins compared with a farming strategy that ignored the trends in climate (Howden et al. 2003).

Table 1. Summary of adaptation options for primary industries ranging from building on existing approaches to climate adaptation, to new technologies to transitional and transformational adaptation.

Climate data and monitoring
Maintain effective climate data collection, distribution and analysis systems to link into ongoing evaluation and adaptation. Develop climate projections that can be downscaled so as to be relevant to farm and catchment scale.
Build on existing policy initiatives
Develop linkages to existing government policies and initiatives and into integrated catchment management so as to enhance resilience to climate change.
Seasonal forecasting
Facilitate the adoption of seasonal climate forecasts to help farmers, industry and policy incrementally adapt to climate change whilst managing for climate variability.
Communication
Ensure communication of broader climate change information as well as industry-specific and region-specific information as it becomes available.
Accepting Uncertainty
Enhance capacity for land managers and supporting institutions to deal with uncertainty.
Breeding and selection
Increased effort in biotechnology and breeding with access to global gene pools so as to have suitable varieties and species for higher CO ₂ and temperature regimes and changed moisture availability.
Pests, diseases and weeds
Maintain or improve quarantine capabilities, sentinel monitoring programs and commitment to identification and management of pests, diseases and weed threats.
Nutrition
Adjust nutrient supply to maintain grain, pasture and fruit quality through application of fertiliser, enhanced legume-sourced nitrogen inputs or through varietal selection or management action..
Water
Increase water use efficiency by 1) effective water allocation and trading systems that allow for climate variability and climate change, 2) improve water distribution systems to reduce leakage and evaporation, 3) developing farmer expertise in water management tools (crop models, decision support tools) and 4) enhancing adoption of appropriate water-saving technologies.
Landuse change and diversification
Undertake risk assessments to evaluate needs and opportunities for changing varieties, species, management or landuse/location in response to climate trends or climate projections. Support assessments of the benefits (and costs) of diversifying farm enterprises.
Managing transitions
Develop policies and mechanisms to provide technical and financial support during transitions to new systems that are more adapted to the emerging climate.

The recent shift in rainfall patterns has resulted in more opportunistic cropping and farmers can now respond much more nimbly to prevailing seasonal conditions than previous set cropping patterns (Stokes and Howden 2008). It could be argued that these adaptation examples highlight responsive rather than proactive adaptation. However, through the use of climate change projections and crop management simulation models the benefits of planned management strategies to adapt to climate change can be clearly demonstrated. For example, under a ‘mid’ range global warming scenario local Birchip (mallee region of Victoria) seasonal temperatures are projected to increase between 0.6 and 1.1°C and annual rainfall is projected to decline by 4 to 8% compared to the 1990 historical baseline. In a continuous mixed cropping system this quantum of climatic change resulted in a 15% decline in simulated yields. With the introduction of an additional fallow median wheat yields improved by 30% (Crimp et al. 2008)

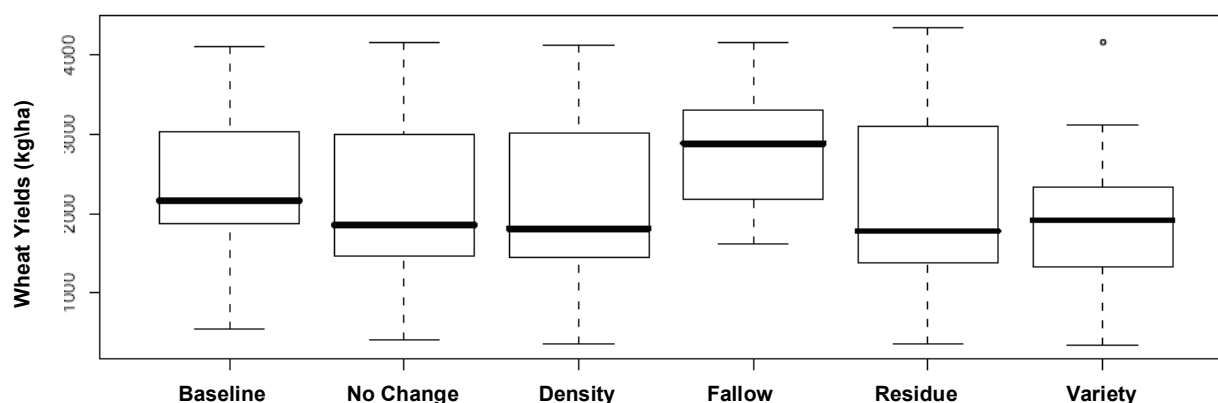


Figure 1: Birchip – Simulated wheat yields (kg/ha) for a continuous cropping system under current climate conditions (baseline- 1957 to 2006) compared with simulated wheat yields under warmer and drier conditions under different management options. These include no change in current management ‘No Change’, reduced planting density ‘Density’, increasing fallow/pasture ‘Fallow’, increasing residue retention ‘Residue’ and choosing shorter season varieties ‘Variety’. The lower and upper edges of the box represent the 25th and 75th percentile yield values, the black line represents the 50th percentile yield and the upper and lower whiskers represent the 1 and 100 percentile yield values.

However, it is highly unlikely that even well planned incremental innovation will suffice in response to some of the future projected climate changes as recent syntheses of the value of adaptation options to agriculture suggest that there are significant limits to the benefits of adaptations within existing agricultural systems (Easterling et al. 2007, Howden et al. 2007). These studies concluded that more transformational change will be required to adapt to more significant climate changes. So a major challenge for agriculture is to plan ahead and determine where and when incremental adaptation will not be sufficient to cope with climate change and to develop approaches that will be required to address transformational change in land management and land use. This level of forward planning is unprecedented in Australian agriculture and needs to be supported by both science and policy.

This is just not a simple case of acquiring more certain climate change projections and determining which areas may no longer be climatically suitable for current agricultural activities. Other factors that need to be considered include social and economic vulnerability, adaptive capacity, new technologies, governance systems, and policies such as structural adjustment (Howden et al. 2007).

To illustrate this point there have been over the last year or so calls for some farming regions in marginal environments to be eased out of farming ahead of the projected climate changes. However, many factors other than climate determine vulnerability (Nelson et al. 2005) and within marginal environments there are some farmers who are struggling and are not viable while others are at the forefront of innovation and risk management and are both economically viable and environmentally sustainable. This highlights the complexity of vulnerability and adaptive capacity and the potential dangers in a 'one-size-fits-all' policy. Clearly climate change will put some regions of Australia under immense economic, social and environmental stress with implications for both individual farmer and rural community viability.

Transformational change to address these climate changes need to be developed with a full systems understanding of the climatic, economic and social forces at work. This is partly because the combined economic and environmental drivers of global change may interact in surprising ways. For example, the significant ongoing changes in climate predicted by the IPCC will impact an Australian agricultural sector that is under constant change from international market forces. This is dramatically illustrated by a continuous consolidation of farms since the mid 1960s associated with long term declines in farmers' terms of trade. Farm numbers in Australia have fallen from around 200,000 in 1966-67 to around 130,000 in 2004-05, resulting in significant economic and social change in rural communities. In this transformational change process, larger and more efficient farms have been able to increase their profitability through technical and management innovations that increase their productivity. However, these changes have also led to social impacts in some regions, such as the depopulation and economic decline of some rural communities.

Climate change will therefore impact Australian agriculture against a backdrop of constant economic and social change, and these impacts will occur at multiple scales. Most fundamentally, climate change will affect the relative productivity of alternative land uses, as changes in rainfall and temperature differentially impact different types of crop and livestock. The viability and vulnerability of alternative agricultural land uses will also depend on the effect of climate change on world prices, as climate changes affects the relative productivity of Australia's trading partners and competitors. All of these changes will take place against a changing institutional context, including changes in greenhouse mitigation policy such as carbon trading schemes that agriculture.

The kinds of transformational change that Australian agriculture is likely to experience through the combined influences of climate, world markets and policy can be illustrated by a simple analysis of agricultural resource use in Australia. A simplistic but analytical useful measure of the agricultural land use in Australia can be created by converting cropping areas and livestock numbers to an equivalent sheep carrying capacity. This provides a partial relative measure of both the extent and intensity of agricultural land use (see Nelson and Lawrance 2004 for an explanation of this method).

Figure 2 shows how significant changes in commodity markets and policy have changed the trajectory of agricultural land use in Australian agriculture against a backdrop of seasonal climate variability. For example, favourable seasonal conditions combined with strong international demand led to boom conditions in the Australian beef industry in the early 1970s. However, import restrictions introduced primarily by the United States, but also by Japan, led to a precipitous drop in prices, resulting in graziers deciding to not sell their cattle, resulting in unprecedented cattle numbers, supportable only because of record high rainfall. Subsequent return to drier conditions and realisation that there had been a long-term shift in prices resulted in

cattle numbers falling (McKeon et al. 2004). Similarly, in the late 1980s, increases in a wool floor price saw a transformational shift in agricultural land use towards sheep grazing. As Australia is the world's major exporter of wool, a burgeoning stockpile resulted in a slump in global wool prices. This forced an end to the floor price system, which along with strong crop prices resulted in a significant shift in land use back to grain production.

The potential for climate to fundamentally alter the relative productivity of alternative land uses is illustrated by changes in the intensity of agricultural land use since the late 1990s. Generally favourable seasonal conditions between 1997-98 and 2001-02 facilitated a significant increase in grain production that was not matched by declines in sheep grazing. This led to unprecedented levels of agricultural land use intensity in the wheat sheep zone. Similarly, persistent drought since 2002-03 has led to a reduction in the intensity of agricultural land use in the wheat sheep zone, contributing to high grain prices.

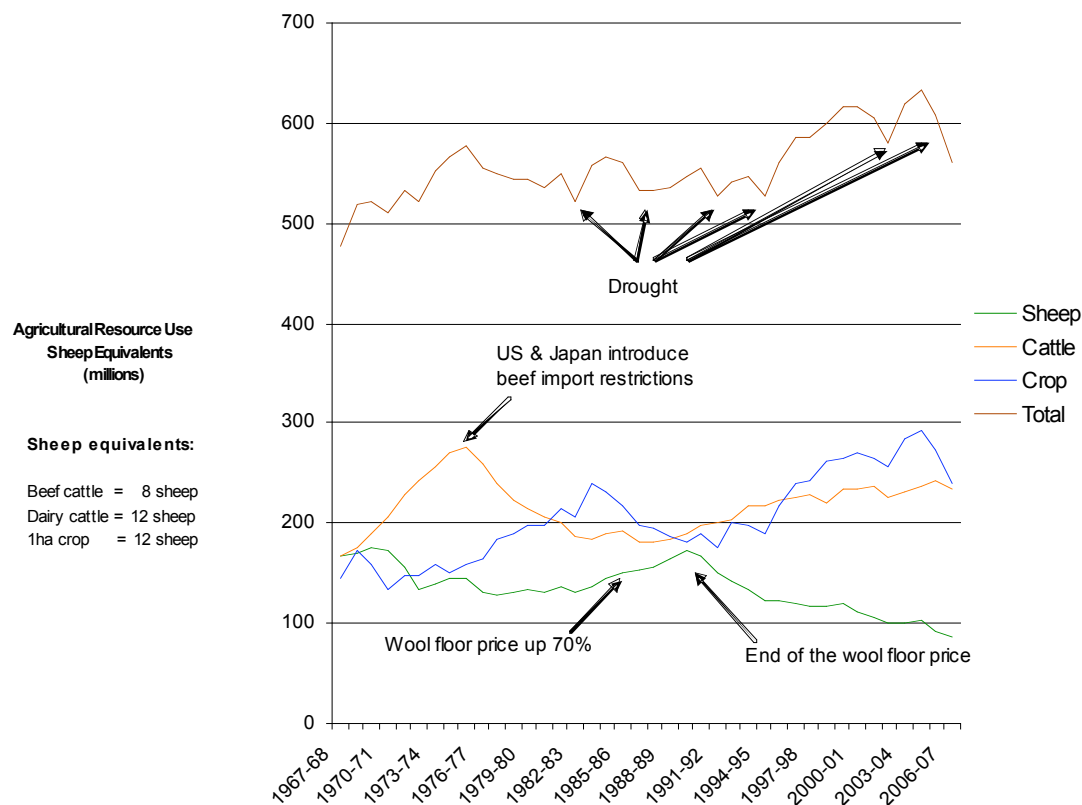


Figure 2: Resource use in Australian agriculture (see Nelson and Lawrance 2004)

Successful adaptation to the combined influences of climate, world markets and policy will need to be transformational in several ways. Perhaps most importantly, the multiples scales at which climate change is likely to affect Australian agriculture could require an unusual degree of coordinated adaptation between farmers, communities, industries and governments across those scales (Figure 3). Effects to adapt and adopt sustainable farming practices in response to climate change will need to be considered within broader opportunities to change enterprise mix on farm, as well as the mix of on- and off-farm livelihood activities. Adaptation within farm enterprises will in turn need to be coordinated with industry and regional development policy aimed at creating new opportunities for rural communities. At the broadest scale, the role of agriculture in

the national economy needs to be constantly reviewed against the changing productivity of other sectors, in part influenced by trade policy and international relations.

PURPOSE

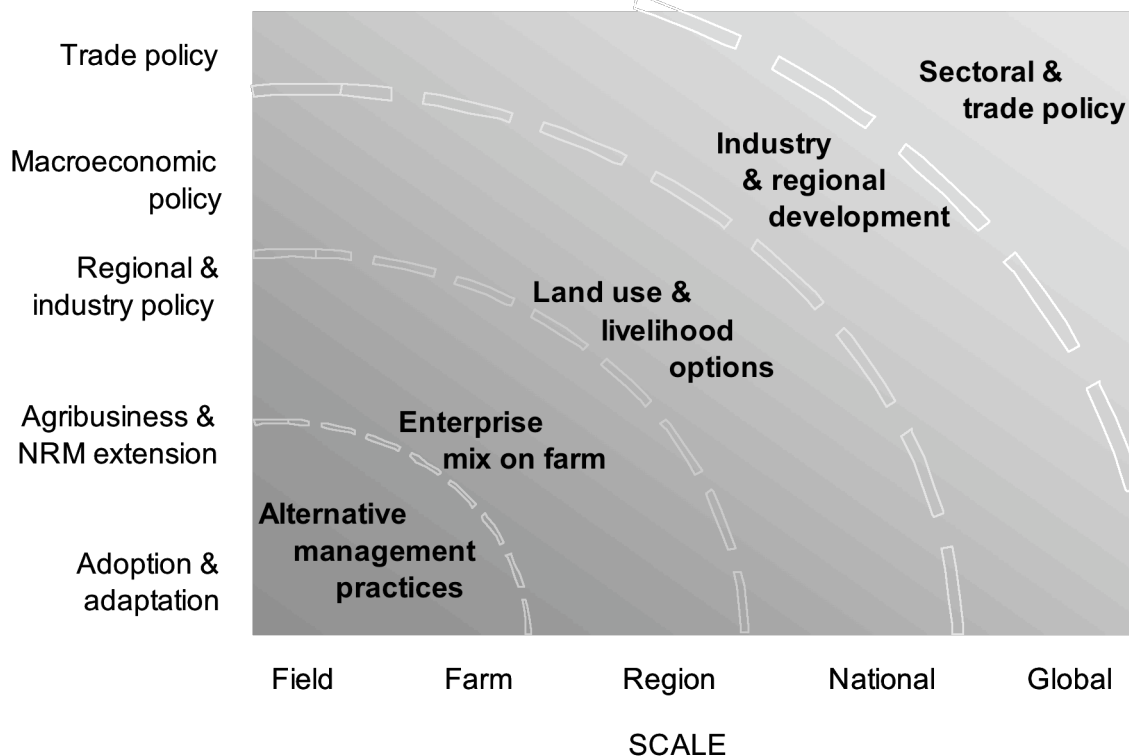


Figure 3: A conceptual map of coordinated adaptation for Australian agriculture across nested scales.

Barriers to adaptation and approaches to overcoming them

At the field and farm scale, many of these adaptation options build on existing approaches to better manage climate variability or rely on technological fixes e.g. new plant varieties, improved water use efficiency, etc. There is clearly a strong case for investing in these adaptation responses. However, there is often an assumption that governments, industries and individual landholders have the capacity to implement adaptation options where in reality there are attitudinal, social, behavioural, institutional or environmental barriers to adopting adaptation measures. Howden et al. (2007) has suggested a number of approaches to overcome these barriers to build adaptive capacity and to change the decision environment. These include:

1. Acceptance that climate change is real and will amplify over the coming decades. Effective communication and unambiguous detection and attribution of climate change will facilitate acceptance of climate change.
2. Confidence that the projected changes will significantly impact on farming enterprises. This requires systems research with industry participation and effective communication strategies that can demonstrate clearly the impacts of climate change even though climate projections may have uncertainties.
3. Technical and other management options available and targeted to specific regions and industries (e.g., improved crop, forage, livestock, forest germplasm; nutritional management).
4. Early warning of likely major land use changes resulting from climate change that allows early policy intervention in supporting transitions and structural adjustment. Options include

direct financial support, alternative livelihoods not so dependent on agriculture, building social capital and community resilience, infrastructure development, new land use and land tenure arrangements..

6. Adaptive management and governance in policy, institutions and industries that support agriculture. Regular monitoring of adaptation approaches to assess their costs, benefits and effects with efficient feedbacks to policy and management to facilitate continuing adjustments and improvements in adaptation.

Clearly, adapting to climate change is more than just a farm-level activity. It will require close collaboration between the biophysical science, social science and economic research communities in tandem with industry and governmental policy-makers.

References

Crimp, S.J., Gaydon, D., DeVoi, P. and Howden, M. (2008). On-farm management in a changing climate: A participatory approach to adaptation. BCG Cropping Manual 2008 (in press).

Easterling W., Aggarwal P., Batima P., Brander K., Erda L., Howden M., Kirilenko A., Morton J., Soussana J-F., Schmidhuber J., Tubiello F. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. (Eds. Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE), pp273-313, (Cambridge Univ Press, Cambridge, UK).

Gunasekera, D., Kim, Y., Tulloch, C. and Ford, M. (2007). Climate change: impacts on Australian agriculture. *Australian Commodities*, vol. 14, no. 4, December quarter, pp. 657-676.

Heyhoe, E., Kim, Y., Kokic, P., Levantis, C., Schneider, K., Crimp, S., Nelson, R., Flood, N. and Carter, J. (2007). Adapting to climate change: issues and challenges in the agriculture sector, *Australian Commodities* vol. 4, no. 1, March quarter, pp. 167-178.

Howden, M. and Jones, R.N. (2004). Risk assessment of climate change impacts on Australia's wheat industry. In: *New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress*, Brisbane, Australia, 26 Sep – 1 Oct 2004.

Howden, S.M and Crimp, S.J. (2005). Assessing dangerous climate change impacts on Australia's wheat industry. In *MODSIM05: International Congress on Modelling and Simulation: Advances and Applications for Management and Decision Making: Melbourne 12-15 December 2005: Proceedings*. (Eds A. Zerger, and R. M. Argent), pp. 505-11. (Canberra: Modelling and Simulation Society of Australia and New Zealand).

Howden, S.M., Meinke, H., Power, B. and McKeon, G.M. (2003). Risk management of wheat in a non-stationary climate: frost in Central Queensland. In: D.A. Post (ed) *Integrative modelling of biophysical, social and economic systems for resource management solutions*. MSSANZ Inc., Canberra, Australia. pp. 17-22.

Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M., and Meinke, H.M. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences*, 104:19691-19696.

IPCC (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

McKeon G, Hall W, Henry B, Stone G, Watson I (2004) 'Pasture degradation and recovery in Australia's rangelands: learning from history.' (Queensland Department of Natural Resources, Mines and Energy: Brisbane, Qld).

Nelson, R. and Lawrance, L. 2004. Resource use in Agriculture. *Australian Commodities* 11(1), pp. 27-29.

Nelson R, Kokic P, Elliston L, King J (2005) Structural adjustment: a vulnerability index for Australian broadacre agriculture. *Australian Commodities* 12, 171–179.

PMSEIC (Prime Minister's Science, Engineering and Innovation Council Independent Working Group) 2007. *Climate Change in Australia*, Report prepared for the Prime Minister's Science, Engineering and Innovation Council, Canberra, June
(www.dest.gov.au/NR/rdonlyres/CE5D024E-8F58-499F-9EEB-D2D638E7A345/17397/ClimateChangeinAustraliareport.pdf).

Stephens, D.J. and Lyons, T.J. (1998). Variability and trends in sowing dates across the Australian wheatbelt. *Australian Journal of Agricultural Research* 49: 1111-1118.

Stokes, C.J. and Howden, S.M. (2008). An overview of climate change adaptation in Australian primary industries – impacts, options and priorities. (CSIRO: Canberra).