9. AUSTRALIAN AGRICULTURE IN A CLIMATE OF CHANGE

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Abstract

Australian agricultural systems are likely to be significantly affected by current and future climate changes. These changes will occur in the context of a variety of other issues, requiring adaptive management and policy responses that reduce vulnerabilities to a range of factors. We demonstrate how three such factors (climate change, population growth and consumption patterns) could interact to affect wheat exports both negatively and significantly, and how adaptation could reduce this risk. We discuss how there are many farm-level adaptations to existing systems that could bring substantial benefit in the early stages of climate change. However, these benefits tend to plateau with larger degrees of climate change (approximately above 2°C), requiring more transformational changes to agriculture. These transformations may include change in land use, change in location of agricultural activities or increased diversification of income streams. The role of science in adapting Australian agriculture to climate change is most likely to be enhanced by effective partnerships and engagement processes with farmer groups and other on-ground decision makers who can identify barriers to adoption and what may be maladaptive practices. There is also a strong case for increasing engagement with industry and government policy groups to integrate climate change adaptation with other concerns including mitigation, and also in the exploration of alternative governance arrangements.

Introduction: climate change in the context of global changes

The evolution of agricultural systems in Australia has been shaped by both long-term climatic changes and year-to-year climate variability. This is evident in the historical and ongoing choice of enterprise mix by more than 140 000 farmers that determine land use and the location of specific agricultural industries. Climate interacts with factors such as soil types, management, technology, input costs and product prices to influence production levels, product quality and profitability. Consequently, if Australia experiences a significant shift in climate, systemic changes in Australian agriculture will occur.

This chapter provides an overview of farm-level adaptation responses that may be appropriate for Australian agriculture in response to a broader set of impacts. In particular, we explore both incremental adaptations and more transformative changes and the relationships between these. We do not detail the broader development of adaptive capacity in agricultural communities (see, for example, Nelson *et al.* 2007, 2009), nor the policy responses and governance structures that may support this (see, for example, Nelson *et al.* 2008) due to space

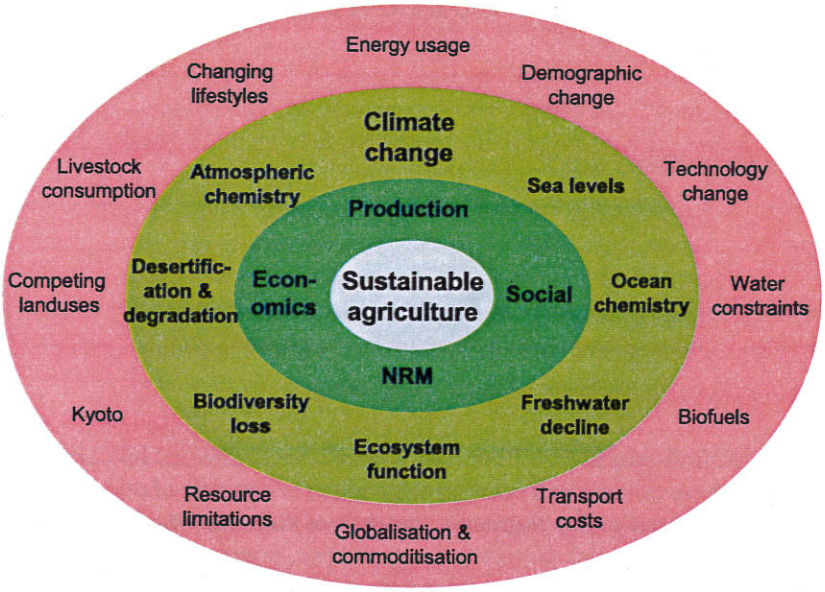

Figure 9.1: Agriculture: managing multiple sources of uncertainty/drivers of change.

considerations. For the same reason, this chapter does not address the issue of reducing net greenhouse gas emissions from the farm sector.

Climate change adaptation is likely to be a key and growing part of meeting the ongoing challenge of developing sustainable agriculture in Australia, and it needs to contribute not only to enhanced production options but also to economic, social and natural resource management goals (Figure 9.1). Climate change adaptation will interact strongly with other key management issues facing agriculture. Such issues include freshwater decline, biodiversity loss, degradation of the natural resource base, among others (Figure 9.1). In many situations these issues will need to be managed in parallel in order to ensure that adaptation responses are enduring. For example, both current and projected declines in freshwater availability in south-east Australia will interact with ongoing reform of water resource policy. These issues in turn are a function of large-scale social, economic and policy drivers such as demographic change, trends in consumer preferences, ongoing technology changes and alterations in attitudes towards energy use and alternative fuels (Figure 9.1). We provide an example of these interactions in this chapter, exploring climate change, population growth and consumption patterns via a case study.

The interactions between climate change and other issues and drivers within this nested hierarchy means that climate change adaptation should not be dealt with in isolation from these factors but rather pulled into the mainstream of policies, programs and practices associated with them (e.g. Adger *et al.* 2007; Howden *et al.* 2007). However, mainstreaming also poses some risk that adaptation will be lost amongst other more immediately urgent, politically consuming or tractable agendas, including global mitigation efforts.

Adaptation approaches

The huge diversity of agricultural activities adapted to diverse local environments across Australia suggests that an equivalent diversity of adaptation options exists. For example, in wheat-based cropping systems alone there are many potential adaptations which include, amongst other options, changes in varieties or species (e.g. summer crops), planting times, crop density and row spacing, nutrient management and rotations, crop residue and soil water management, pests, disease and weed management and altering the mix of livestock (see, for example, Howden *et al.* 2002). These can be implemented singly or in combination. A comprehensive review of these adaptation options dealing with the grains, cotton, sugar, rice, horticulture and vegetables, viticulture, broadacre livestock, intensive livestock, forestry, marine fisheries and water resource sectors in Australia is available (Stokes and Howden 2009).

Adaptations are only now starting to be explored in ways that facilitate uptake in either the management or policy domains. For example, participatory research with grains farmers has started to explore a wider range of adaptation options in a combinatorial approach and in a whole-farm context (see, for example, Crimp *et al.* 2008). These adaptations are being formulated in a probabilistic way so as to fit in with the way in which farmers examine and evaluate risk, i.e. in terms of probabilities or chance. For example, Figure 9.2 shows the exceedence curve of wheat yields from Brim, northern Victoria for a baseline of historical climate and current crop management practice. This is compared with potential yields resulting from warmer and drier climatic conditions likely by 2030 (i.e. climatic change resulting from the high A1FI emissions scenario and high climate sensitivity) with current management practices or with a range of management adaptations. This shows considerable benefit from the full suite of adaptations in the dry 50% of years, but with little benefit in the years with the highest 50% of yields.

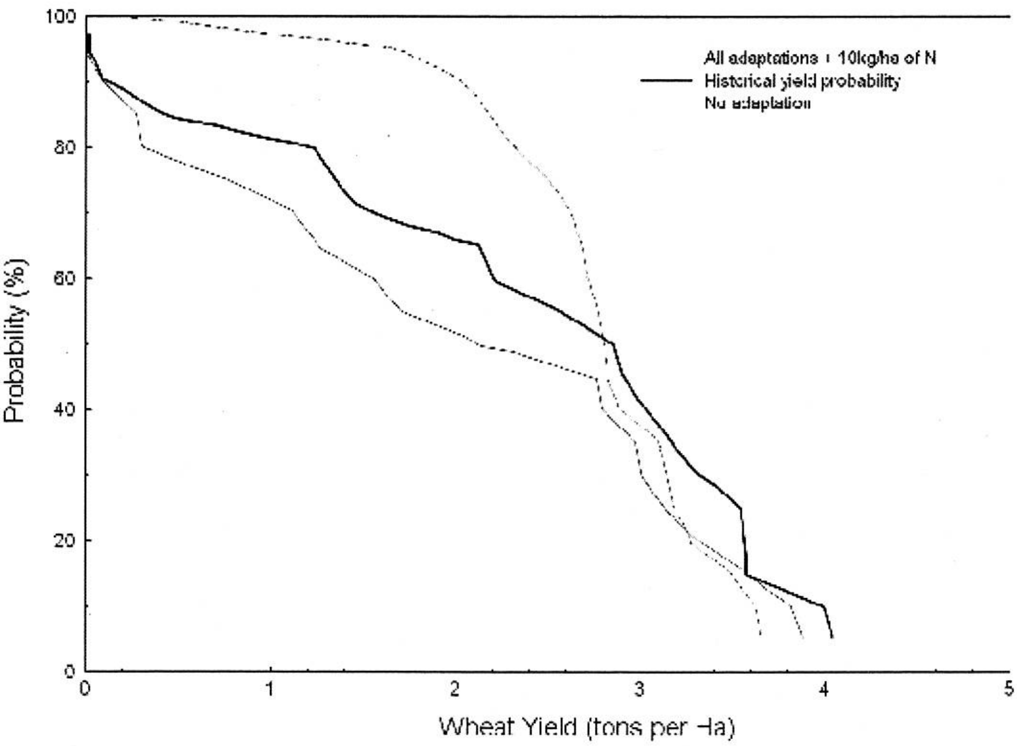

Figure 9.2: Wheat yields from Brim, Victoria for a high climate change scenario for 2030 showing the probability of exceeding specific yields under current climate and management practices and the climate change scenario with either current practices or with all management adaptations.

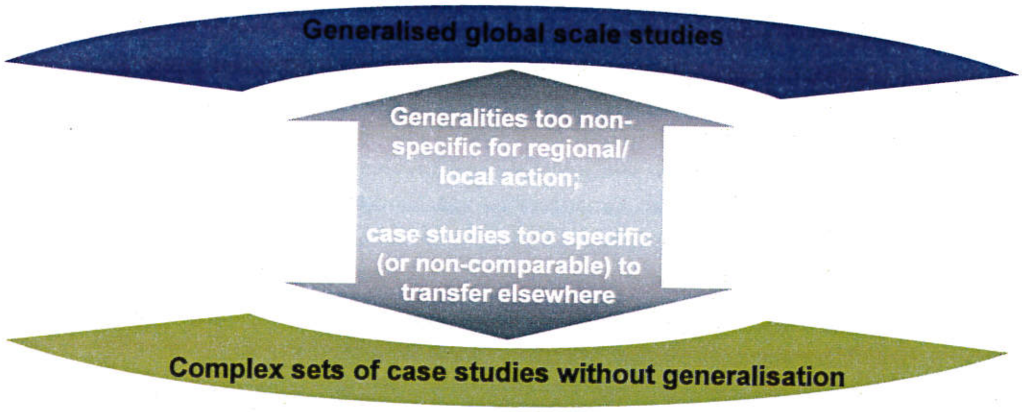

Figure 9.3: The need to seek necessary but sufficient complexity to inform decisions between generalised, large-scale studies with little local relevance and complex sets of local studies that are difficult to generalise.

These types of intensive participatory processes generate detailed case study responses for specific situations. Furthermore, they can be used to explore farm financial implications, investment strategies, barriers to adoption and potentially maladaptive practices. These processes, however, are resource-intensive and cannot be implemented in the numbers needed to include all the decision makers in the sector nor to allow robust scaling up of the results to national level for broader policy decisions. As discussed below, they also tend to focus adaptation effort on incremental technical responses within existing activities, potentially overlooking more transformative opportunities to adapt.

An alternative approach for national scale assessments is to use very general adaptation responses (see, for example, Heyhoe *et al.* 2007).These, however, lack the detail needed for local implementation and can be difficult to relate to realistic changes in farm management practices (Figure 9.3). Consequently, one middle way between these two extremes is to work with communities, industries and government to identify a diverse set of adaptation options and the general contexts in which each is appropriate (Figure 9.3). However, approaches of this kind need to be evolved via participatory engagement with communities, industries and governments in order to move beyond academic interest exercises towards empowering adaptation by decision makers.

One way of creating and implementing this approach is to combine local knowledge with systems modelling to provide a menu of options for different amounts of rainfall and temperature change (Figure 9.4). Adaptations proposed through implementation of this approach by farmers in the Brim region of Victoria have included reducing the proportion of higher risk crops grown (e.g. legumes, fallow on a regular basis on heavier soils (crop less); selecting for shorter season varieties and more heat-tolerant crops; reducing stocking rates and retaining more stubble to conserve soil moisture; considering growing more fodder crops, and reducing reliance on wheat cropping. Farmers can explore this menu at varying levels of detail, taking into account their knowledge, aspirations, attitudes, skills and practices.

The value of these types of within-system management adaptations to climate change could be substantial. For example, for the Australian wheat industry just two of these management adaptations (change in varieties and time of sowing to match the prevailing climate) could provide average annual benefits of between $150 million and $500 million per year by 2070 (Howden and Crimp 2005). The greatest benefits in this study occurred under conditions

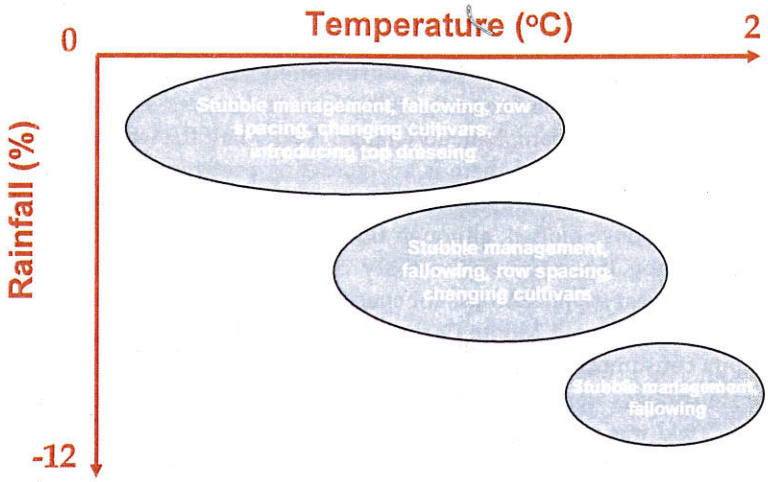

Figure 9.4: A simple typology of adaptation responses for cropping systems for varying scenarios of rainfall and temperature from Brim, Victoria.

of high climate change. Additional benefit is likely if a more comprehensive set of incremental adaptation options were to be considered (Howden *et al.* 2007). In the case study below, we extend this previous work to explore a significant, positive consequence of effective adaptation – the extent to which it will contribute to wheat exports, offsetting the anticipated effects of climate change and increased domestic demand arising from population growth and consumption patterns.

Climate change adaptation interacting with population growth and consumption patterns: a case study

Background

Wheat is the major crop in Australia. Production exceeds domestic consumption on such a scale that about 74% (15 million tonnes per annum (p.a.)) of the wheat produced each year is exported, earning about 4% of Australia's total exports, averaging \$3.1 billion p.a. since 1990 (ABARE 2009). These exports contribute about 12% to the international trade in wheat. The extent to which Australia's wheat exports contribute to global food security depends on a complex set of social, economic and institutional factors beyond the scope of this chapter. We note, however, that to the extent that Australian exports firstly increase access to food by vulnerable groups and secondly, reduce the proportion of household budgets spent on food, other things being equal, higher exports can be said to contribute to greater global food security.

Wheat production is highly sensitive to climatic influences, with the difference between wheat production in a wet year and a dry year being almost a factor of three. Previous studies have indicated that the projected higher temperatures and lower rainfall across wheat-growing regions is likely to reduce yields. This is despite the generally positive effects on yields of elevated atmospheric carbon dioxide concentrations which increase water- and light-use efficiency (see, for example, Howden 2002). In this study, we assess the likely impact of projected changes in rainfall, temperature and elevated carbon dioxide on national wheat production and exports with and without farm-level adaptation.

Method

Australia's net exports of wheat are the difference between domestic production and consumption and change in stocks. Domestic wheat consumption varies with population size, and changes in per capita consumption due to changing food preferences, as incomes grow and the relative price of substitutes and complements change. Nearly half the wheat consumed in Australia is used to feed livestock, and there is an increasing preference for grain-fed livestock products as incomes grow. In the future, an increasing proportion of Australia's wheat production may be used to produce biofuel, although this is not considered further here due to the uncertainty surrounding the economic viability of this industry. Rather than generating specific scenarios of wheat supply and use for specific climate change projections, we took an alternative approach which used Monte Carlo simulation across changes in climate, population and per capita consumption to create probability distributions of likely future outcomes.

Yield response surfaces were developed for 10 regions across the major Australian wheat growing regions. Yield was modelled as a function of increased carbon dioxide level, higher temperatures and altered rainfall assuming current farming technology and crop management practices (Howden and Crimp 2005). A modified set of yield response surfaces was developed using farm-level management adaptations of changes in varieties and planting times to match the climates projected for 2070 as closely as possible. These response surfaces were sampled using Monte Carlo methods drawing on regional climate change projections from eight GCMs using the A1FI scenario, the scenario which most closely matches recent emission trajectories (Canadell *et al.* 2008). Correlations between carbon dioxide level, temperature and rainfall change were derived from GCM output and used in the sampling.

Population projections published by the Australian Bureau of Statistics (ABS 2008) were used for 2030 and 2050, with interpolated values for 2070 being from Series A (50 million (M)), B (39 M) and C (33 M). These scenarios of population growth were used to define a triangular distribution from which to sample. Aggregate annual per capita wheat consumption has been increasing rapidly over the past decade, from approximately 200 kilograms per person (kg/capita) to 330 kg/capita (ABARE 2009). Future per person consumption was conservatively assumed to lie between 300 and 400 kg/capita/year with a mid-range scenario for sampling of 325 kg/capita/year. Exports were calculated as the difference between production and domestic consumption. Total domestic consumption for a given sample was calculated as the product of population and per capita consumption. This involves the rather strong assumption of no change in relative prices, a factor that must be considered when interpreting the results. It is valid in this simple analysis to the extent that wheat is expected to continue to be a major international food commodity in 2070. This partial analysis provides a simple framework for considering supply responses due to adaptation in isolation from other changes.

Results

The results of the case study indicate that climate change will interact with increasing domestic wheat consumption to reduce wheat surplus for export significantly. In the event of the worst-case climate change scenario, assuming no effective adaptation and high population change, Australia could become a net importer of wheat as soon as 2050 (Figure 9.5). At 2070, if there is no effective adaptation to climate change, there is a 26% chance of Australia having to import wheat to meet domestic demand. The worst-case scenario for 2070 is that Australia could become a net importer of 15 million tonnes/year of wheat. This is approximately the same amount as Australia currently exports. Even the median case has only a small surplus to export (2.5 million tonnes/year). When practical adaptations to climate change are introduced

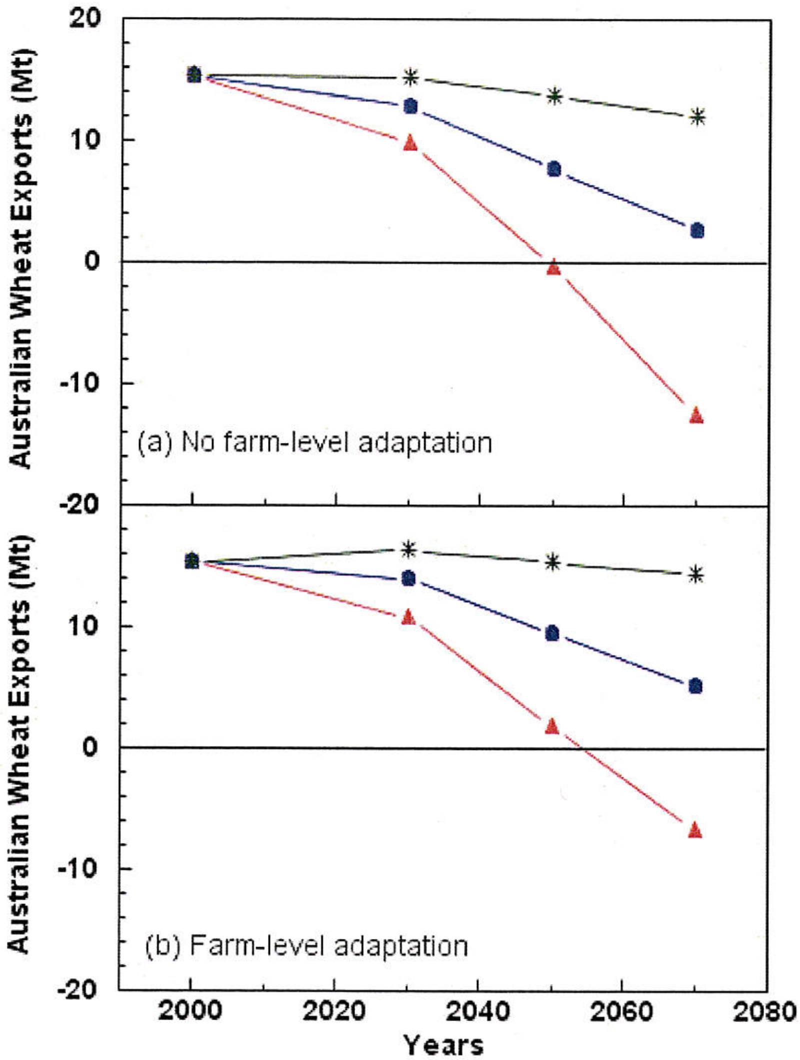

Figure 9.5: Wheat exports (million tonnes per year) from Australia from the present to 2070 assuming (a) current on-farm adaptation practices and (b) farm-level adaptation to climate changes. The lines show the maximum, median and minimum results.

into the analysis, the chance of becoming a net importer of wheat in 2070 is reduced to 10% and for the median case the surplus is doubled to about 5 million tonnes/year. Hence, adaptations significantly reduce the likelihood of problematic export outcomes.

Discussion

This preliminary study has necessarily used a range of simplifying assumptions, but these have been conservative in terms of both impacts and adaptation effectiveness. Also it has not included climate variability, ongoing yield improvements, land use change or market-based feedbacks within Australia, nor global changes to markets as a result of climate change and other factors (see, for example, Fischer *et al.* 2005). Australia's comparative advantage in wheat production, for example, is expected to decline relative to other countries, potentially reducing the demand for Australian exports.This study, however, has highlighted the importance of placing climate change in the context of other key drivers as well as the critical importance and substantial benefit of developing effective adaptation options.

Limits to adaptation: incremental and transformational change

The example above showed that there could be significant benefits from even a small number of relatively simple, incremental changes to existing farming systems. Importantly, there are hundreds of such adaptations with many of these now starting to be identified and tested (Stokes and Howden 2009). However, the benefits of these types of adaptations are likely to plateau as more extreme climate changes are experienced over the coming decades. For example, practices such as zero till, stubble retention and crop canopy management will allow continued production even with substantial rainfall reductions. However, even these techniques will provide limited additional benefit in the face of more severe declines in rainfall. When expressed as the ratio of yields with adaptations compared to yields without adaptation (the benefit from adaptation), this typically shows a rapid increase in benefit with small amounts of climate change, but with this benefit levelling off with larger amounts of climate change (Figure 9.6). That is to say, there are limits to the effectiveness of incremental adaptations. This response has been found in both national responses for wheat (Howden and Crimp 2005) and with a global meta-analysis of crop responses (Howden *et al.* 2007). Interestingly, in both cases, the plateau started at around 2°C temperature rise, although the point at which the adaptation benefit levels off is rainfall-dependent (Figure 9.6).

The existence of limits to the benefits of incremental adaptations raises the question as to how Australian agriculture may adapt under the scenarios of much greater change than the 2°C indicated in the analyses above. A 0.9°C temperature rise has already been experienced,

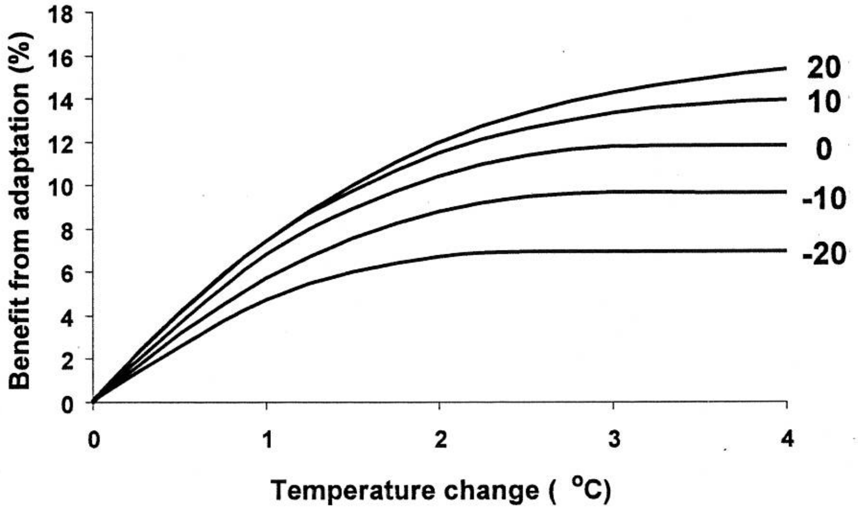

Figure 9.6: The benefit of incremental adaptation for the Australian wheat industry (expressed as % increased in yield from the case with no management adaptation) with increased temperature and various scenarios of rainfall change (modified from Howden and Crimp 2005).

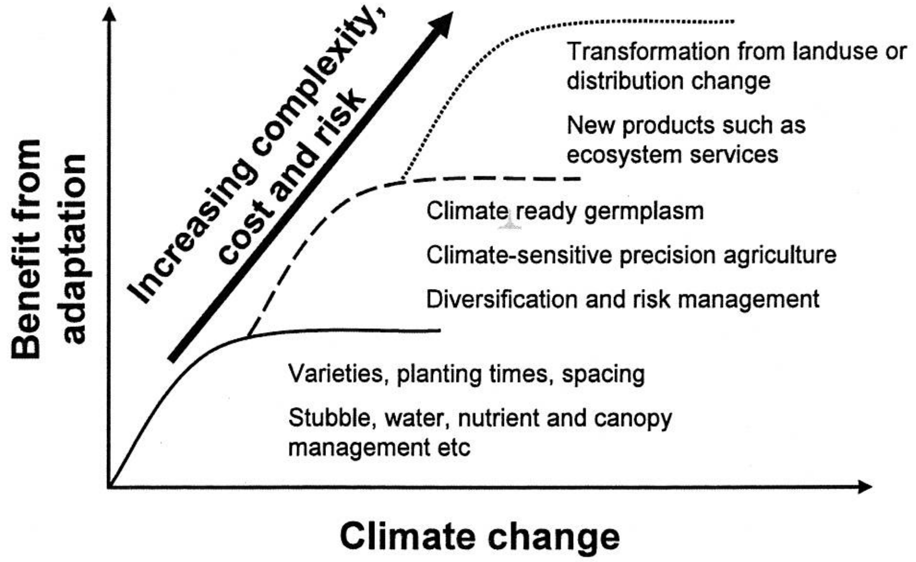

Figure 9.7: Hypothesised relationship between incremental and more transformational adaptations as climate change increases, indicating possible types of adaptations and the likely increasing complexity, cost and risk associated with the more transformative adaptations.

meaning that Australia is already almost halfway to the 2°C change. We suggest that there are a range of more transformative changes that could be considered in addition to incremental adaptations of existing agricultural systems. For example, there are options for more substantial adaptations such as development of more climate change-adapted crops and livestock, more effective integration of climate into precision-agriculture operations and broad-scale diversification of farm household incomes (Figure 9.7). In the event that the climate changes even further, there may be more transformative options such as major alteration of land use at a location or change in the location of significant industries or diversification of products such as ~~from~~ provision of ecosystem services including carbon sequestration.

These changes are not necessarily sequential. For example, there are already instances in Australia where industries are reported to be making transformative changes primarily as a result of climate changes. These examples include 1) the development by the Peanut Company of Australia of areas in the Northern Territory away from their historical base in south-eastern Queensland; 2) the adoption of cropping in the high rainfall grazing zones of southern Australia which were previously too wet for cropping, and 3) the search for alternative rice-growing locations following extended periods of very low water allocations in the irrigation areas of south-eastern Australia. As we move from incremental to transformational changes; however, it is likely that the complexity, cost and risk of the changes increases (Figure 9.7). There are likely to be several key roles for science in terms of supporting transformational change. These include helping design robust agricultural systems which meet triple bottom-line goals, provision of the underlying technological options for farmers to use (e.g. appropriate genetic material) and risk assessments associated with their introduction, policy research into institutional settings that may impede or support transformation and social research to understand the transformation, processes in both the groups that transform and those that choose not to. This research may enable us to avoid repeating some of the mistakes of past large-scale agricultural developments.

Conclusion

There is likely to be a major role for science in helping Australian agriculture adapt to climate change. This will require, however, a reframing of our science away from carrying out climate impacts studies, which are part of problem definition, towards adaptation studies which focus on solutions. Adaptation is inherently a localised and context-specific social activity, thus requiring new approaches and skills. Critical issues relate to developing not only technically effective adaptation options but also understanding the limits to these, the potential for maladaptation and pathways to adoption. Discussions about the potential need and opportunity for more transformative changes are likely as the climate changes further, requiring new science and industry partnerships, new and robust technologies and analysis techniques and effective communication strategies. Integration of climate change adaptation and mitigation is likely to be increasingly requested by both the farming and policy communities and the science community needs to be intensifying efforts in this respect. Lastly, there is likely to be increasing demand for stronger links between science and policy and analysis of alternative governance models, but the institutional arrangements to support this in Australia are generally lacking. Clearly, there are many adaptations that will be needed for Australian agriculture to prosper in a variable and changing climate.

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