Final report

Australia’s Agricultural Future: Returns, Resources and Risks

A report prepared for

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Expert Working Group, *Securing Australia’s Future*
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Consultant team

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1. Executive summary

Large market opportunities may arise for Australian agriculture in the decades ahead given the expected large increases in per-capita incomes in many emerging economies. Not only will the demand for food increase, but a likely change in diets to more meat, dairy, and horticultural and viticultural produce provides the opportunity for the Australian agricultural sector to grow and for exports to increase.

Increased demand in overseas markets does not necessarily translate into realised benefits in Australia. To gain a share in the rapidly increasing global demand for food, Australian agriculture needs to be profitable and sustainable in its use of natural resources while effectively managing evolving risks including climate and biosecurity risks.

Possible barriers in responding to the anticipated growth in the demand for food include:

1. The export market to some large countries like China and India may not grow to the extent expected because rapid technical change will allow them to expand domestic production and/or because longstanding concerns for self-sufficiency lead to continuing intervention to encourage domestic production.
2. Other countries may increase their market share because their production costs fall, or because their access to markets increases through trade negotiation, or because they successfully overcome pest and disease problems presently barring them from the more highly priced markets.
3. Australia may be unable to increase supply due to domestic production constraints making Australian agriculture less competitive with other countries as a result of inadequate research and development (R&D), climate variability, biosecurity hazards or other supply risks, or because of domestic economic conditions that may shift inputs away from agriculture and to other sectors in the economy.

Understanding both the future agricultural opportunities and the possible barriers to achieving this potential, and how they may be overcome, is the key to ensuring Australia's future agricultural prosperity. A review of the state of Australian agriculture from the perspective of returns (productivity and profitability); resources (water, land and soil, biodiversity and people) and risks (market access risks, sovereign risks associated with government policy, price risks for outputs and inputs and production risks related to weather and pests and diseases) highlights both the strengths and limitations for Australian agriculture.

The key strengths of the Australian agricultural sector are:

1. A highly capable agricultural sector which includes farmers with a capacity to manage price and production risks and with a high level of labour productivity, a well-developed service sector and competitive markets for key inputs (land and water). Australian farmers are technically efficient in that many operate close to their production frontiers.

2. A large agricultural land base, warm climate and adequate water, if used when plentiful and if the agricultural production type is matched to the landscape, has helped make key parts of the sector internationally competitive.
3. A long history of food exporting and proximity to, and close trade relations with, large and growing food-demand countries provides both favoured access and supply chains to increase the value of future exports.
4. An efficient market-oriented economy that includes favourable fiscal and monetary conditions relative to other developed economies and well-developed infrastructure in terms of transport, communications, health and education.

The key risks to the Australian agricultural sector are:

1. Total factor productivity growth of about 1% or less over the past two decades (half its rate in previous decades) which may be expected to restrict the supply response from Australian farmers and threatens their competitiveness both relative to other Australian sectors and relative to the agricultural sectors of other export countries.
2. Mismatch between farmscapes and healthy functioning landscapes such that, in some locations, the natural capital that supports future food and fibre production has been degraded. Such a decline makes it more costly to respond to increased food demand, but also risks depleting key environmental assets contrary to community and market expectations and may pose risks in terms of future market access.
3. Inadequate consideration and planning for catastrophic risks, such as major droughts, climate change and incursions by exotic pests and diseases, that have the potential to damage market access and reduce production.
4. A shrinking public scientific capacity in agriculture and inadequate support and research for the current and possible public-good benefits associated with farming that maintains the environmental integrity of the landscape and the environmental assets valued by the whole of community.
5. A high and growing proportion of older workers in the agricultural sector may restrict the future supply response from Australian farmers and possibly result in the loss of skills and experience needed for supply growth.

Australian farmers, relative to many other countries, operate in a market economy with very low levels of intervention by government. Given appropriate market signals, Australian agriculture has a transformative opportunity to progress and grow in ways which can be described as *opportunistic diversification and sustainable intensification.* Opportunistic diversification describes the ability of farmers to choose enterprise combinations and input use that are profitable for the highly variable conditions that they face with respect to soil quality, soil moisture and water availability. Sustainable intensification means that agricultural production increases without depleting key natural capital such as soil fertility, biodiversity, and water and air quality and supports the long-term interests of farmers and the wider community, in both Australia and possibly overseas.

The incentives that some farmers face in using some natural resources diverge from the interests of the community. Some combination of profitable environmentally friendly technologies, market mechanisms, including certification schemes with respect to environmental and animal welfare standards, along with appropriate supporting regulation, is required to better align farmer and community incentives. Aligning farmer and community incentives may maintain or enhance market access while retaining the quality of environmental assets and heritage values.

We contend that the reliance on markets and low levels of government regulation and intervention remains a key approach to a prosperous Australian economy where resources are used to their best ends. Nevertheless, to achieve agriculture's full potential it is critical that government respond to market failures where the economic incentives faced by farmers lead them to resource-use patterns that are counter to their long-term interests and which do not meet community expectations. As agriculture is the largest user of Australia's land base and freshwater, the community has legitimate expectations about how environmental services are used by farmers. It is also important that market failures that impede profitable agricultural production are ameliorated to allow Australian farmers to take full advantage of market opportunities.

We have identified several possible market failures in the agricultural sector:

1. Under or misallocated investment in basic R&D and farmscape to landscape applied R&D that generate new knowledge not only about agricultural technologies, but also about agriculture's impact on the environment, climate change and variability, invasive pests and diseases and their management, and the scientific basis of phytosanitory trade regulations and environmental and animal welfare certification schemes.
2. Under resourcing of knowledge dissemination and technologies not embodied in specific agricultural inputs with a heavy information or management component, and which have positive spillovers to environmental services for both other farmers and the community.
3. Inappropriate prices of inputs and wastes that do not adequately account for the costs imposed on others from the use of these resources.
4. Inappropriate signals for the actions and outcomes of farmers in the provision of public-good conservation benefits.

Without being too prescriptive or exhaustive in the range of possible responses by government, we recommend the following actions:

1. Government and industry need to increase their investment in R&D in the areas where scientific capacity is crucial to increasing productivity without compromising important natural capital needed for future food and fibre supplies and to meet community expectations about the conservation of key environmental assets. Scientific capacity is required to support Australia's participation in developing international protocols related to agriculture for environmental protection (including certification schemes), biosecurity, phytosanitory provisions of trade agreements and animal welfare, and for

the on-farm implementation of these protocols. Given that technologies which are both environmentally friendly and profitable are likely to require substantial public information, management and public policy components, industry and public funding is likely to be required to enhance their adoption.

2. Both the design and implementation of R&D need greater attention and be directed toward increased support for farmer-initiated innovation which underpins an opportunistic behaviour and diversification that builds resilient farmscapes and landscapes. This is not about reducing the importance of basic research through existing R&D corporations, but it is about investing in and supporting farmer innovation and the diversity of emerging knowledge networks and practices that promote opportunistic and diversified resilient farmscapes. Market failure in R&D is ameliorated by balance, both in the research portfolio from basic to applied, and in funding from industry and government.
3. Governance issues in the RDC (Research and Development Corporation) model need careful review as they may not be generating outcomes sought by industry and community stakeholders. One option is a return to inclusion of a government representative on the RDCs and requiring regular independent audits. The Productivity Commission has a useful recommendation that an increasing graduated uncapped levy might encourage an increase in investment, but additional behavioural economics research is required to identify other mechanisms which might encourage greater industry participation.
4. A ‘rethink’ is required about what farmscapes deliver in terms of public benefits that include both market and non-market values and what is the ‘duty of care’ by farmers in the terms of the landscape they manage. Public support is required to develop and trial market-based mechanisms to better align the incentives to farmers in their use of natural resources and the community’s values for these resources. Joint industry and public support is needed to develop voluntary land-use, environmental and animal welfare certification schemes supported by regulation, where necessary, to preserve and enlarge access to markets that value these characteristics.
5. Past and failed approaches to drought relief in agriculture must not return that would keep farmers on the land where agricultural practices are not suited to the landscape. This is counterproductive and will not promote an industry that is internationally competitive and one that effectively manages risks.
6. Catastrophic risks in terms of market access, biosecurity and climate change demand a coordinated approach to risk management that does not ‘crowd out’ existing risk management by farmers, and supports landscape recovery from ‘megashocks’ in terms of biosecurity or climate variability. This is best accomplished by public interventions that recognise the benefits of markets in promoting risk management (such as for water), risk-smoothing with tax averaging for farmers, risk management with the provision of key information and risk reduction, especially in terms of biosecurity and adaptation to climate change.

2. *Key insights*

Our work suggests there are a number of fundamental challenges that must be faced to capture the opportunities and potential of Australian agriculture into the future:

1. ***To gain a share in the rapidly increasing global demand for food*** Australian agriculture needs to be profitable and sustainable while effectively managing evolving climate and biosecurity risks. The responsiveness of farmers and agribusiness to overseas market signals will determine the success of the sector in capturing a share of these expanding markets.
2. ***The profitability of Australian agriculture*** depends on how efficiently it uses resources (its productivity) and on the relative prices of Australian agricultural products (the terms of trade). The sector needs to be developing low cost technologies that are recognised as being environmentally and animal welfare friendly and that could enhance market access. To be profitable and meet community expectations in the long run, the sector needs to conserve its natural resource base and key environmental assets.
3. ***Market failure is pervasive*** and takes the form of underinvestment in research underpinning the development of low cost technologies and the management of natural resources, the collective management of risks such as invasive pests and diseases and climate change, and the provision of information. Negative externalities associated with the use of natural resources by farmers and positive externalities in terms of insufficient support for the public-good actions of farmers are pervasive market failures.
4. ***Government and industry can apply a range of 'tools'*** to influence both supply (production costs) and demand (product quality) which can ameliorate market failure. Market-based approaches, where applicable, should be favoured because of their likely efficiency in directing resources. Outcomes in terms of impacts on profitability and sustainability should be monitored and assessed against costs.
5. ***Total Factor Productivity growth in agriculture*** has already halved in the past two decades and there is evidence that this is linked to the decline in public investment in agricultural research which began in the 1970s. The long lags between investment in research and development (R&D) and consequent productivity growth are still not widely understood. The extent of market failure in the provision of agricultural research and related issues about how research should be funded remain contentious despite strong evidence of high returns to such investments. It is no longer possible using published ABS data to track investment in agricultural R&D that addresses environmental as well as plant and animal socio-economic objectives.
6. ***Industry and government need to strengthen Australia's agricultural R&D capacity*** not only to ensure adequate productivity growth, but to develop technologies that ameliorate market failure in areas where the interests of farmers and the community diverge. Such capacity is required for developing technologies that are profitable to farmers and deliver improved environmental outcomes, particularly in adapting to and mitigating climate change and meeting biosecurity risks, and that provide an objective

basis for Australia's contribution to internationally recognised product certification schemes and phytosanitory regulations within trade agreements.

7. ***Knowledge delivery*** and intensive management systems are and remain an integral part of the farm business. Steps to foster farmer-driven innovations and knowledge-intensive agricultural systems will likely require new mechanisms involving greater subtlety and flexibility in ways that support opportunistic diversification and sustainable intensification. Many of these technologies are not embodied in specific agricultural inputs and their profitability is difficult to discern. Hence their development will often require industry and/or government support.
8. ***Water reform and economic analysis***. A vigorous water reform process will need to continue based on National Water Initiative (NWI) principles. Reforms should support a framework that encourages innovation and the return of sufficient water to stressed rivers, floodplains, wetlands and estuaries in southern Australia. In developing water resources in prospective northern, east coast and Tasmanian rivers, agriculture will be best served by ensuring alignment with the NWI principles including appropriate cost recovery, and be subject to robust and transparent analysis of costs and benefits. Mistakes made in the south in terms of over-allocation of water, subsidies for and 'lock-in' of water infrastructure need to be avoided.
9. ***Strategic land-use planning***. Access to soil and land that is well-suited to agricultural productivity will be critical to Australia's agricultural future. It is clear that now and into the next decades there will be increasing pressure on good quality agricultural soil and land. Strategic regional scale land-use planning using a whole-of-landscape framework, coupled with regional governance and ownership by industry, community and government, will become an important tool for agricultural industries and communities. Such planning will need to manage the competition for agricultural land from other sectors of the economy such as mining, unconventional gas production and urban expansion.
10. ***Building regional natural resource management capacity***. Current problems facing soil and land management signals the need to build the knowledge and the human capacity and governance arrangements to manage the Australian soil and landscape more sustainably. Rebuilding regional delivery by working with landholders and Landcare groups is one way forward. The benefit of a regional model is that it operates at a scale large enough to manage the pressures on our landscapes, yet is small enough to use local knowledge of farmers and landholders to tailor solutions to suit those landscapes.
11. ***Establish sustainability credentials for Australian agriculture***. There is scope for the Australian Government to support the development of voluntary, industry-based farm certification—the CLM (Certified Land Management) Scheme, for example—so that suppliers, retailers and consumers can have confidence that products satisfy environmental standards and meet animal welfare standards. Such certification may give those who participate in such schemes access to markets that value these characteristics. To be effective, such schemes must be built into the International Certification Standards covering commodities produced in Australia, and be coupled with strong and effective public regulation to reinforce and extend environmental sustainability in production,

trade, and consumption arenas around the world. One way forward is an 'Australian Standard for Sustainable Agriculture' which was negotiated as a component of international agribusiness and government. A possible 'Australian Sustainable Agriculture Standard' would need to include whole lifecycle analysis of energy, water, land and biodiversity inputs. Internationally, agribusiness and leading food manufacturing corporations are developing sustainability standards, but it seems that Australian businesses and food corporations are not fully part of this emerging trend.

12. ***Payment for ecosystem services and stewardship arrangements***. Australian agriculture of the future has the challenge and the opportunity to see itself as a set of carefully managed agro-ecosystems nested and connected into the biophysical processes of the landscape. Given this view of landscapes, the ultimate managers and custodians of the major part of Australia's biodiversity and natural heritage are farmers and Indigenous landholders. Incentives to promote desirable forms of landscape stewardship can take many forms ranging from regulation, through market-based instruments to direct payments for some key assets. An important principle is to avoid 'crowding out' incentives for innovation by the sector itself in meeting its duty of care. There is, however, evidence emerging of policy options and operational procedures for delivery of ecosystem services including use of a 'catchment care' set of principles that can help manage the nexus between public and private benefit.

13. ***Risks and Australian farming***. Australian farmers suffer greater risks (market access risks, sovereign risks associated with government policy, price risks for outputs and inputs and production risks related to weather and pests and diseases) than their counterparts in many other OECD (Organisation for Economic Co-operation and Development) countries. Nevertheless, they have been highly effective at managing risks given competitive markets for key inputs (such as land and water) and outputs coupled with a well-functioning and competitive financial sector.

14. ***Risks and market intervention***. A case can be made for market intervention to assist farmers to manage catastrophic production risks brought about by invasive species, extremely rare weather-related events, and market risks associated with access to export markets, in addition to large and unexpected hazards. Appropriate interventions by governments include: (1) Establishing markets that promote risk management, such as the creation of water markets to allow farmers to better risk-manage droughts; (2) Risk smoothing, such as schemes that allow farmers to smooth their incomes by tax averaging over high- and low-income periods; (3) Risk management, such as providing historical data and up-to-date forecast of key risk variables and assistance and advice in risk management; and (4) Risk reduction, such as the coordination of actions to monitor and contain pests and diseases and the building of infrastructure, such as levies, to reduce risks of flooding. Such support must avoid providing funds to farmers whose enterprises are misaligned to the land and climate-scapes that increase production risks, augments the costs paid by taxpayers, and exacerbates social costs.

15. ***Resilience and risks***. Reducing the likelihood, or diminishing the consequences of, catastrophic risks embraces a landscape or a systems perspective where protecting the health of the landscape is necessary to support the ability of farming systems to provide

food and fibre. The Australian agricultural sector and rural communities will likely need assistance to adapt to climate change, and to manage weather-related, biosecurity and market access catastrophic events. Such government assistance should augment rather than replace farmer-initiated risk management actions. Such public assistance must, at all costs, avoid 'crowding out' of individual risk management. Instead, assistance should create incentives for farmers and their communities to adapt with ex-ante actions that increase capacity and the recovery speed of the landscape following catastrophic events.

16. ***Opportunistic diversification and sustainable intensification***. Australian agriculture is at a crossroad where 'business as usual' is unlikely to deliver on the opportunities of emerging economies in Asia, nor effectively respond to future production and market risks. A transformative opportunity exists that would support opportunistic diversification and sustainable intensification. This requires avoiding a mismatch, via government intervention, of farming enterprises within landscapes that are ill-suited to certain types of farming. It demands managing landscapes and farmscapes in ways that not only produce food and fibre, but in ways that ensure landscapes are resilient to adverse shocks and for the long-term benefit of farmers and communities. Such an approach demands that farmers fully assume, and be supported, in their role in the conservation of Australia's rich biodiversity, scarce natural resources, and cultural and natural heritage.

3. Introduction

The world's population is projected to increase from nearly 7.2 billion today to 8 billion by 2030, and more than 9 billion by 2050 under a medium growth scenario. As well as population growth and urbanisation, per capita income growth is projected to more than double by 2050. Many more people, with much higher average incomes, will result in greater food consumption while changes in diets will result in a greater proportion of meat and dairy consumed by an emerging Asian and African middle class. The Food and Agriculture Organization (FAO) and Pardey et al. (2014) project that world food demand may increase by 70% by 2050, with much of the projected increase in global food demand expected to come from rising consumer incomes in regions such as Asia, Eastern Europe and Latin America.

This increase in world demand is likely to create opportunities for food exporters in Australia. China is expected to account for 43% of the increase in global demand, while India contributes 13% of this growth (Linehan et al. 2012). The projected increase food demand is expected to be the greatest for vegetables and fruit, meats, dairy products, cereals and fish partly because of an expected change in diets as consumer incomes increase. Linehan et al. (2012) conclude that Australia is in a good position to meet some of this higher demand because it has a comparative advantage in the production of several agricultural products and also because its proximity to China relative to competitors such as Brazil and Argentina provides for lower transport costs.

Australia has long been a major exporter of the products of broadacre agriculture, a production system well-suited to its economic and climatic conditions. A key question is whether these comparative advantages will continue under the anticipated impacts of climate change. Sanderson and Ahmadi-Esfahani (2011) have quantified the future patterns of comparative advantage in broadacre agriculture, given the projections of several global climate models. They find substantial resilience and robustness in Australia's comparative advantage under a number of climate-change scenarios and that, overall, Australia continues to enjoy a comparative advantage in grain crops and livestock. They observe that for Australia, adverse climate-change acts marginally to diminish the comparative advantage in grain crops, while slightly enhancing that in livestock. Given that Australia has in the past a strong research and development base, and its agricultural R&D capability has ranked among the best in the world (PMSEIC 2010), and has generated high returns in the past (Mullen 2007), there is a case for building further capacity and investment in finding a diversity of sustainable intensification of agriculture solutions that have adaptation strategies for climate change.

This positive outlook could lead to some complacency amongst farm business managers and policy-makers about the future profitability and competitiveness of the sector. Such complacency is misplaced. There are keen competitors for these markets some of whom have higher rates of growth in agricultural productivity and are investing more in R&D than Australia. Moreover, Australian agriculture sits in this global transformation wherein growth in agricultural production under 'business as usual' could contribute to the planet approaching, or even passing, its safe operating space. Thus, both the global and national challenge is about balancing future food consumption and supply while managing for risk and variability, and promoting the sustainable use of energy, water, biodiversity and ecosystem services. How these global influences affect Australia's agricultural future, as one of a dozen key net agricultural exporting nations, and how to meet these challenges and to capture market opportunities while being both competitive and ecologically sustainable, are the key underlying themes of this report.

The report is prepared at a time of active public examination of agriculture's role in the Australian economy, along with its productivity growth, profitability, environmental sustainability and competitiveness. The Australian Government's *Agricultural Competitiveness Green Paper* is a key policy document, while the 2013 National Farmer Federation's *Blueprint for Australian Agriculture* along with the PEW Trust's *The Modern Outback – Nature, People and the Future of Remote Australia* offer useful perspectives.

The focus of our report is on identifying areas where the market left to itself would not deliver outcomes in the agricultural sector preferred by the community as a whole and identifying appropriate responses by government and industry to these areas of market failure.

In the next section important trends in some of the key components of Australian agriculture are briefly described because they are form a common baseline for the substantive sections of the report on returns, resources and risks.

The returns section of the report notes that the profitability of the sector is driven by productivity and the terms of trade. Past trends and future prospects for both are reviewed. The productivity of Australian agriculture relative to other sectors such as mining is reviewed because of its implications for the competitiveness of agriculture. The implications of climate change for productivity are canvassed. Finally the trends in agricultural research and development (R&D) are reviewed because this is an area of market failure where government interventions are required to ameliorate otherwise inevitable underinvestment. Evidence is presented that the substantive decline in productivity growth in Australian agriculture can be partly attributed to the decline in public investment in R&D and so the challenge for industry and government is reverse this situation.

The resources section attempts to provide insight as to the nature and magnitude of the resources in water, land, biodiversity and people that is available to support and underpin Australian agriculture into the future. It examines the increasing pressure on all these resources, identifies some of the critical issues in future resource utilisation and draws attention to the need for not only new knowledge in natural resource management but highlights the importance of future innovative policy to consolidate maturing markets such as for water and the need for new research and policy development to foster strategic land-use planning, and regional natural resource management. The analysis points to market failure in the flow of ecosystem services that are essential for sustainable production of food and fibre which protect life-support systems and heritage assets valued by the whole of Australian society. It also canvasses the contribution an objective voluntary and internationally recognised scheme whereby the environmental and animal welfare credentials of Australian farmers could be established leading to better access to markets that value these characteristics.

The risks section assesses four principal risks faced by Australian agriculture that include:

- Market risks associated with access to output markets that can be affected by supply chains, and also rules of access.
- Sovereign risks associated with state and national government policies in terms of taxes and subsidies and what farming practices are permitted.
- Price risks in terms of the prices received for commodities as well as prices paid for key inputs, such as fuel and fertiliser.
- Production risks in terms of the level of production that includes weather-related hazards such as insufficient water, but also by other factors such as pests and diseases that may change over time.

In general, Australian farmers suffer greater market, price and production risks than their counterparts in many other OECD countries. Market risk is greater because Australia exports a higher proportion of the value of its agricultural produce and, thus, is subject to greater potential interference in terms of access while production risks are higher in Australia in terms of key crops as a result of a more variable climate than most other countries.

Australian farmers are highly effective at managing normal risks and also transferable risks provided that there exist competitive markets for key inputs (such as land and water) and outputs coupled with a well-functioning and competitive financial sector. The case for public assistance in terms of managing risk in agriculture is in periods of catastrophic risks, especially in the context of either market risks or production risks. The justification for intervention is the existence of a market failure whereby government action may generate a more economically-efficient outcome than in the absence of intervention and includes support for risk smoothing, risk management and risk reduction.

4. The changing nature of Australian agriculture

Australian agriculture has successfully developed in one of the driest parts of the world with by far the most infertile, most nutrient-leached soils of any continent. Change and adaption to variability in climate and markets is a feature of Australian agriculture. Agriculture, especially wool, established Australia as a thriving economy with a substantial workforce, service industries and large port cities. Australian agriculture benefited from many different agricultural practices, formal and informal land grants, overseas capital and access to relatively cheap labour. Combined with invention, ingenuity and hard work this led to Australia becoming a leading exporter of wool, meat and grain (Australian Government 2014). For over 100 years, from the 1840s to the 1950s, the Australian economy was seen to be 'riding on the sheep's back'. Since 1900 there has been a dramatic decline proportionally in the income from wool, and an expansion of the cropping area and diversification of crops, a significant increase in cattle industry and the development of a variety of profitable agricultural export industries.

Significant factors in agriculture's international competitiveness and comparative advantage include access to large areas of suitable land and rainfall and water, use of technology, workforce skills, market proximity, institutional settings and policy frameworks (Keogh 2014). The successful export sectors generally involve extensive, rather than intensive production systems. This suggests that Australia's large areas of land and adequate rainfall for cropping and pastoral activity, even with a highly variable rainfall and climatic patterns, generates a competitive advantage. This is despite the fact that water availability for dryland and irrigated agriculture has always been a major limiting factor in Australian agriculture. As consequences, of generally low soil fertility and low highly variable rainfall is that, average Australian rain-fed crop yields are low, and are less than a third of the crop yield in North America, Europe and China. In response to these low yields, Australian crop farmers are efficient and resourceful in the use of inputs such as pesticides and fertilisers because potential yields are insufficient to justify high levels of expenditure on crop inputs (Keogh 2014). Australian broadacre crop farmers are also world leaders in grain yield per millimetre of growing season rainfall and per unit of fertiliser. As a result, Australian grain producers are internationally cost competitive.

While historically agriculture played a dominant role in the economy, its relative importance has declined in recent decades despite the fact that in absolute terms, agricultural output has more than doubled over the four decades to 2003–04 (Productivity Commission 2005). The number of people employed in agriculture has declined from 14% to 3% and its contribution to gross domestic product (GDP) is now less than 3%.Agricultural exports have almost tripled in value (in real terms) since the mid-1970s.

In 2012–13 the gross value of total Australian agricultural production was $48.0 billion. As shown in Figure 1, the most important agricultural commodities by value are livestock meats

($13.2 billion) which is dominated by cattle $(7.7 billion) followed by poultry and sheep meats each yielding some $2.2 billion in value while cereal crops earn some $10.6 billion.

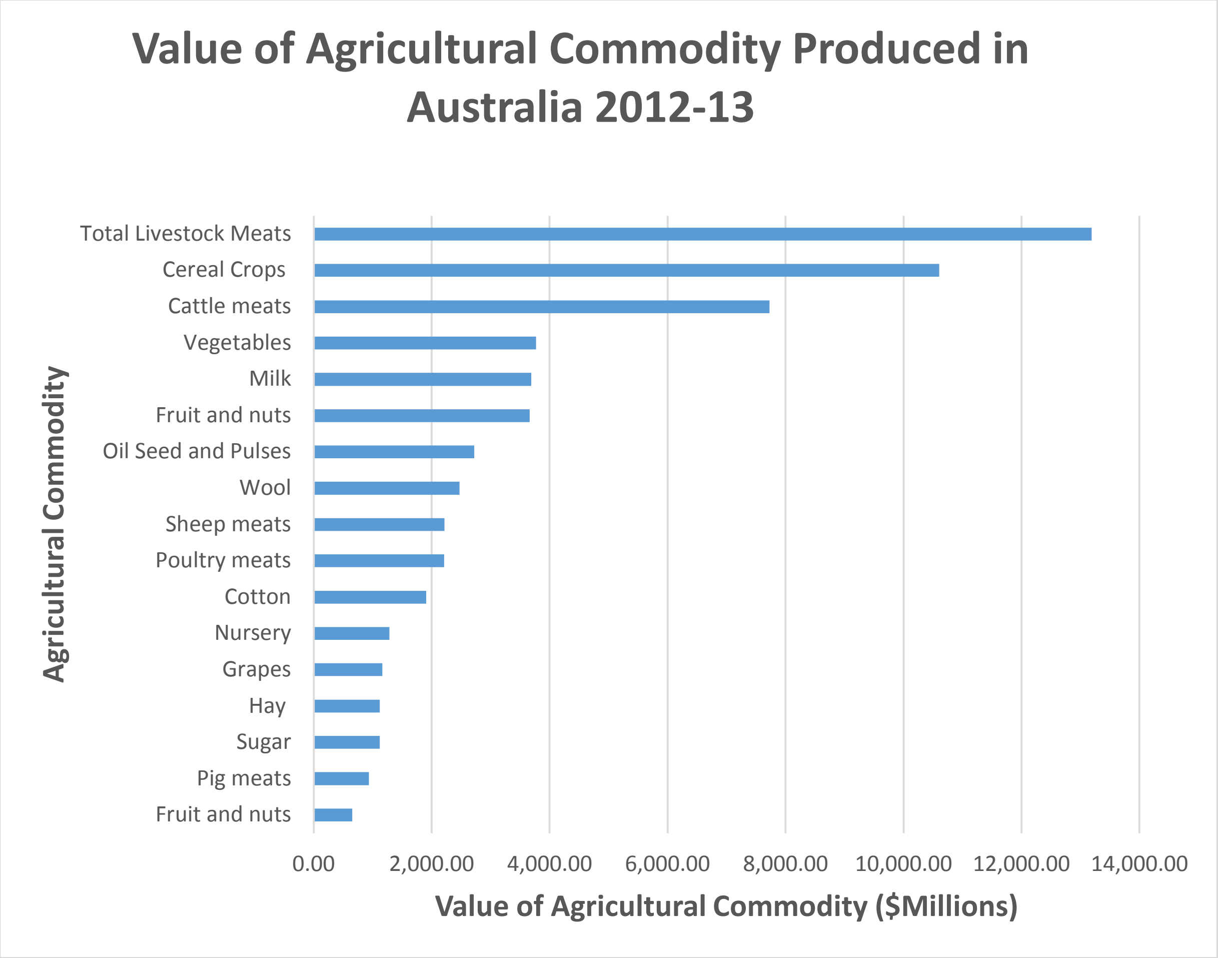

Figure 1: Value of agricultural commodities produced in Australia during 2012–13. Source: ABS, 75030DO001_201213 Value of Agricultural Commodities Produced, Australia, 2012–13.

By world standards, Australia is a small global food and fibre producer (Commonwealth of Australia 2014). As shown in Figure 2, Australia only produces around 1% of the value of agricultural production globally.

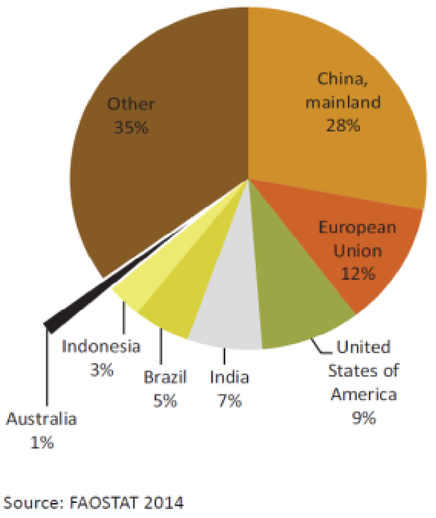

Figure 2: Australia's share of global agricultural production in 2011.
Source: Commonwealth of Australia 2014.

Other than wool, the production of Australia's largest agricultural sector is less than 4% of global production. By comparison, China has four times the number of cattle Australia has (ABARES 2013a) while other countries such as Brazil and Argentina have a large potential to produce agricultural products in which Australia specialises (Commonwealth of Australia 2014).

Nevertheless Australia is a major contributor to world trade in Agricultural commodities. In 2011 (FAO World Trade Statistics at: http://faostat.fao.org/site/342/default.aspx). Australia was the 19th largest exporter of agricultural commodities in the world where major crop exports include broadacre grains, oilseeds and legumes and also more intensive crops such as wine, rice, sugar, cotton, grapes, bananas, and potatoes. Australian livestock exports include beef, wool and dairy products, and sheep, pig and poultry meats. In terms of value of world trade, in 2011 Australia was the largest exporter of wool, beef and veal while the second largest exporter of barley and sheep meat, third largest exporter of cotton, and fourth largest exporter of wine and wheat.

Relative to its size in the Australian economy, agriculture provides a disproportionately large share of Australia's exports however this has been declining in recent years. However in 2012-2013 total agricultural exports were valued at $38.3 billion and the top 10 agricultural export commodities in that year is set out on Figure 3.

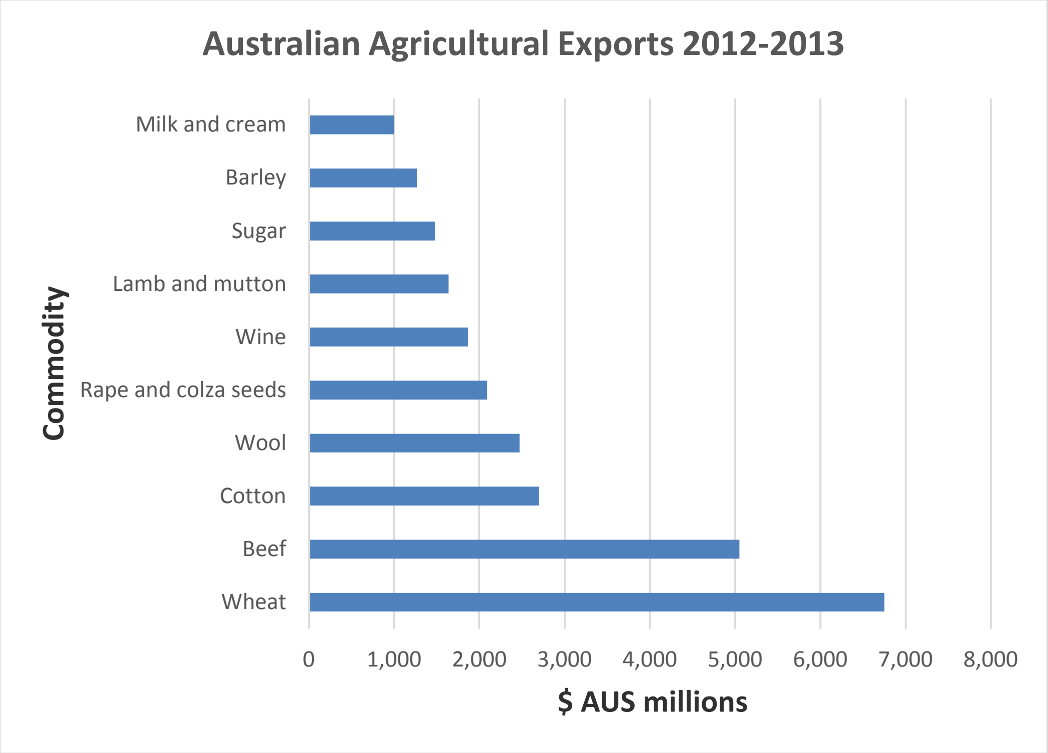

Figure 3: Value of 10 largest Australian agricultural exports.
Source: http://www.dfat.gov.au/trade/negotiations/trade_in_agriculture.html.

Historically, Australia has processed only a small fraction of the food and fibre it produced and remains an exporter of largely unprocessed agricultural commodities. Thus unsurprisingly, an increasing share of food products consumed by Australians is processed overseas and, in some instances, this involves agricultural products grown in Australia and shipped overseas for processing. Over the last 20 years processing of Australian agricultural products within Australia has undergone a significant decline. In 2011, Australia had become a net importer of processed foods. Imports of edible preparations in 2013 were valued at $1,986 million while exports were valued at $992 million, thus generating a trade deficit of $994 million (Potard 2014). While exports of processed food are now increasing, the rate of growth in these exports is much lower than the growth rate of imported processed food. Approximately 50% of the imported processed food is from Singapore with New Zealand (NZ) and the United States of America (US) the next most important sources of processed food. Watson (2014) argued that a lack of processing capacity is not necessarily a disadvantage to Australian agricultural producers while Annison (2014) made the claim that food security for Australians requires a vibrant local food manufacturing sector able to meet all the needs of the consumer.

While Australia is very successful at exporting bulk unprocessed commodity, Australia does not have an internationally recognised brand in food, with the possible exception of some major wine exports and the role of Sun Rice as a world Trader in rice and finished products. Potard (2014) argues that this lack of Australian brand champions sits in contrast to the advantage given to NZ dairy product by way of the Fonterra brand, particularly in Asia.

The number of farm businesses decreased from some 145,000 in the late 1990s to about 135,000 in 2011. The number of large farms (greater than 2,500 ha) and small farms (less than 50 ha) have both increased over the last 20 years. In 2011 (see Figure 4) the census found that 22.1% of Australian farmers were in mixed crop and livestock enterprises while the next largest group (20.3%) were in beef cattle production. Another 8.3% were engaged mixed livestock farming and specialised sheep accounted for little over 7%. Other common types of farming businesses include dairy cattle farming (6%), mixed sheep-beef cattle farming (5%) and grape growing (4%).

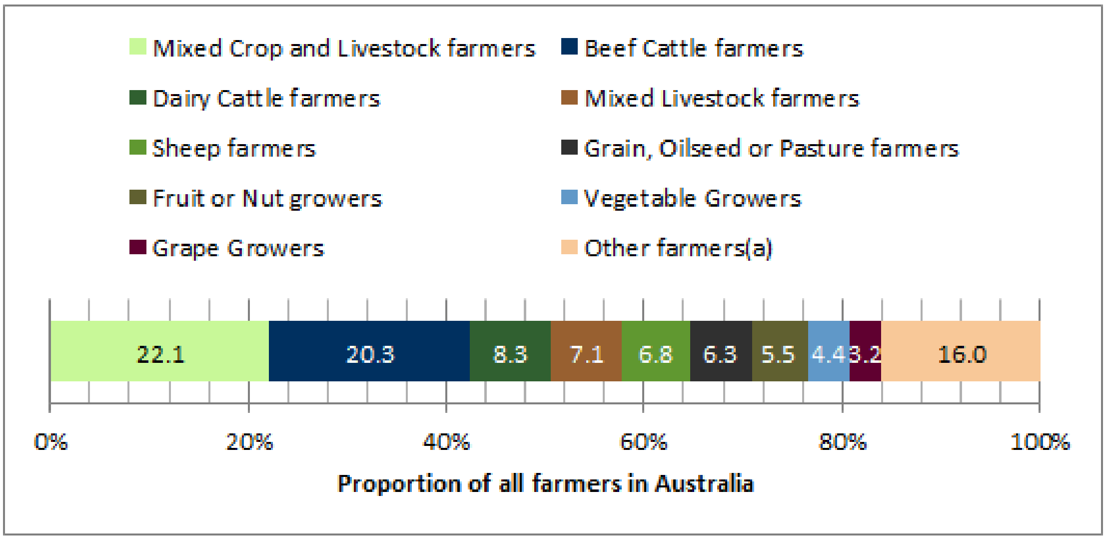

Figure 4: Distribution of Australian farmers in agricultural production enterprises during 2011. Source: ABS 2011, Census of Population and Housing. Note (a) includes sugar cane growers, poultry farmers, flower growers and apiarists, etc.

There are various ways of measuring the size of farms including physical area and whole farm receipts (Jackson and Martin 2014). Between 1977 and 2013 ABARES farm survey data revealed that the average area of broadacre farms increased from about 5,000 ha to 7,000 ha and average whole farm receipts grew from about $300,000 after smoothing, to just over $400,000, with both measures growing at about 1% per year. Receipts grew more rapidly than area from the mid-1990s as a result of greater intensification and a shift to high value crops according to Jackson and Martin. Similarly for dairy farms, the quantity of milk grew more rapidly (by 2.5 times) than the area farmed (by 1.5 times) over the 1977–2013 period.

Despite agricultural production being increasingly concentrated in large farms, the majority of Australian farms are comparatively small. There is now a pronounced bi-model distribution by size of Australian farms. In 2010–11, just over half (55%) had an estimated value of agricultural operations of less than $100,000 (ABS 2012). There were, however, a small number (7,700 or 6%) of large farms with estimated agricultural operations in excess of $1 million. This disparity represents the diverse nature of farming in Australia that ranges from small, often family-owned businesses, to very large family and corporate businesses. The majority of farms are also small in terms of land area, with around a third covering less than 50 hectares (36%), and a similar proportion (36%) between 50 and 500 hectares. By contrast, there are a small number (100) of massive farms that each occupied more than 500,000 hectares, which is more than twice the land area of the Australian Capital Territory

(ABS 2012). The largest 20% of farms now account for 80–90% of output. Small farms derive the great proportion of household disposable income from off-farm sources.

Foreign investment in Australian agriculture includes the purchase of farm land and agricultural companies. While noting that foreign investment, primarily from the United Kingdom, has been a key factor in the historical development of Australian agriculture there are increasing concerns about foreign ownership of farms and agricultural processing companies. As a consequence, the Australian Government is in the process of establishing a foreign ownership register for agricultural land.

The 2014 Agricultural Land and Water Ownership Survey released by the Australian Bureau of Statistics reports an increase of 4.7 million hectares of agricultural land with some level of foreign ownership, relative to 2010. Overall, there are some 50 million hectares out of a total of 450 million hectares that have some degree of foreign ownership. In terms of agricultural businesses, a recent survey by the Australian Bureau of Statistics indicates that about 99% of such businesses in Australia are entirely Australian-owned. That said, some of the larger, and indeed the largest private land owner, the Australian Agricultural Company, that controls 7.2 million hectares is reportedly 60% owned by interest in the United Kingdom, the US and Malaysia (Keogh 2009). Further, foreign-owned agribusinesses play an important role in terms of the dairy industry, grains industry, sugar industry, cotton industry and in meat packing, among others.

The principal downside to foreign ownership is that returns are repatriated to owners overseas. It has also been argued that large foreign–owned multinationals may be able to use their market power to disadvantage Australian farmers in terms of the prices they receive. The upside of foreign ownership is that foreign investors can enhance market access through their global supply chains, introduce new practices and technologies that increase profitability, and provide working capital that may otherwise not be available to increase production and also value in the sector.

The age profile of farmers has changed markedly over the past few decades as set out in Figure 5. The median age of farmers increased by nine years between 1981 and 2011, while the median age of other workers increased by just six years. Over the same period, the proportion of farmers aged 55 years and over increased from 26% to 47%, while the proportion of farmers aged less than 35 years fell from 28% to just 13%.

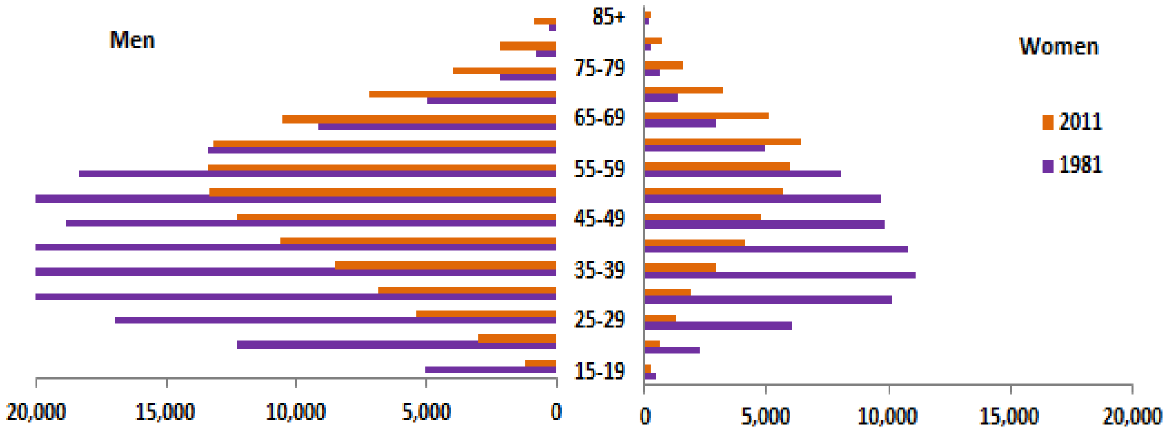

Figure 5: Change in age distribution of Australian farmers over 30 years from 1981 and 2011. Source: ABS Census of Population and Housing, 2011.

Agriculture is one of the largest direct and indirect employers in Australia, providing over 350,000 jobs in 2010–11. Agriculture also represents a significant input into many other industries, particularly the food processing industry, which had a turnover of $65 billion per year and a value added of $24 billion per annum.

4.1 Returns

On average, profitability in Australian agriculture is low, particularly given the riskiness of the business that is driven by highly variable markets for both outputs and inputs and perhaps, greatest of all, the highly variable nature of the Australian climate especially in terms of the frequency and severity of droughts and floods. The average rate of return, including capital appreciation, across all broadacre farms over the 20 years to 2012–13 was just 4.2%, and 1.1% excluding capital appreciation (Commonwealth of Australia 2014). Over the same period, dairy farming averaged a 4.4% rate of return and 2.2% excluding capital appreciation. For horticulture, the average return over the five years to 2011–12 was 3.2% (Commonwealth of Australia 2014). These average rates of return, however, mask considerable variation, with the highest performing farms performing considerably better (Keogh 2010; Commonwealth of Australia 2014).

Larger farms generally earn higher rates of return. This may arise because larger farms may be better managed and have better access to new technologies. It is not just a case of ‘get big or get out’ but adopting new technologies appears to be important in increasing farm profitability as discussed further below.

In view of the high level of income variability relative to other OECD countries experienced by Australian farmers it is important for farmers to maintain present high and stable equity levels as a buffer against this variability. Martin (2013) reported that while farm debt has about doubled since 1998[1] for both broadacre and dairy farms, the equity ratio has remained high at 90% for broadacre farms and 80% for dairy farms. He reported that in 2012 about 6% of broadacre farms and 15% of dairy farms had equity levels of less than 70%, indicating limited additional borrowing capacity. The increase in average debt per farm arose from on-farm investment and higher working capital requirements associated with larger farms and a higher proportion of cropping. Most debt is held by a small proportion of the larger broadacre and dairy farms.

Profitability is function of productivity and the terms of trade (TT, ratio of prices received for outputs to prices paid of inputs). Total factor productivity (TFP) growth has fallen from an average rate of over 2% per year from 1952 to the mid-1990s to less than 1%, even when adjusted for climate variability (Hughes et al. 2011). Performance within the sector has been mixed over the last three decades with the cropping industry recording the highest productivity gains, and the sheep and sheep-beef industries the lowest (Productivity Commission 2005). Sheng et al. (2010) estimated that a significant proportion of this slowdown can be attributed to a stagnant or declining level of public investment in agricultural R&D since the 70s.

The decline in the agricultural sector's terms of trade, the ratio of prices farmers receive for outputs relative to prices paid for inputs, has been an important source of pressure for adaptation and change by Australian farmers (Productivity Commission 2005; Commonwealth of Australia 2014). The rate of decline in terms of trade was 2.6% per annum from 1953 to 1994, but over the period from 1994 to 2012, it slowed to less than 1.0% per annum.

Information generated by R&D has the characteristics public goods, particularly its non-rivalry in use, which leads to market failure in the form of underinvestment. A key challenge in to increase investment in R&D by industry and government. Australia's agricultural sector has to compete with other sectors of the Australian economy and the agricultural sectors of other countries. While increasing investment in R&D is important to restoring productivity growth, other source of growth may come from reducing regulatory burdens, improving the efficiency of the rural research, and the building human capital and knowledge systems (Gray et al. 2014). These issues, along with prospect for demand growth, are reviewed in the 'Returns' section.

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[1] We use the convention that 1998 refers to the financial year 1998–99.

4.2 Resources

Land and soil resources

About 60% of the Australian continent is used for agriculture or some 456 million ha. Livestock grazing on natural vegetation and modified pastures uses 94% of this area and is predominantly in the arid and semi-arid regions of Australia. Cropping land occupies a much smaller portion of the continent, at approximately 20 to 32 million ha depending on droughts, rainfall patterns and climate variability. Irrigated agriculture occupies even less land area at about 2.5 million ha including horticulture which occupies 0.5 million ha. The past 25 years has seen an increase of about 12 million hectares in cropping and a decrease in pastoral land. The larger part of the decrease in pastoral lands is associated with the increase in areas of formal nature conservation, areas of minimal use and other protected areas including Indigenous uses. Collectively, these non-agricultural uses occupy around 283 million hectares or 37% of Australia.

Agriculture in southern Australia post-WWII witnessed dramatic increases in productivity as the result of the use of superphosphate fertiliser and the establishment of legume-based exotic pasture improvement. This development had a profound effect on the carrying capacity of livestock and boosted the effectiveness of rotations in the dominant sheep-wheat farming enterprises. For some 30 years Australian agriculture made use of biologically-fixed nitrogen to drive yield increases in grain production. There are, however, limits to the nitrogen that can be delivered by these processes and the issues of liming and soil acidification need to be managed. Since the 1970s, fertiliser use has grown significantly and has been responsible for substantial increases in crop yields. This pattern of agricultural development is set out in Figure 6.

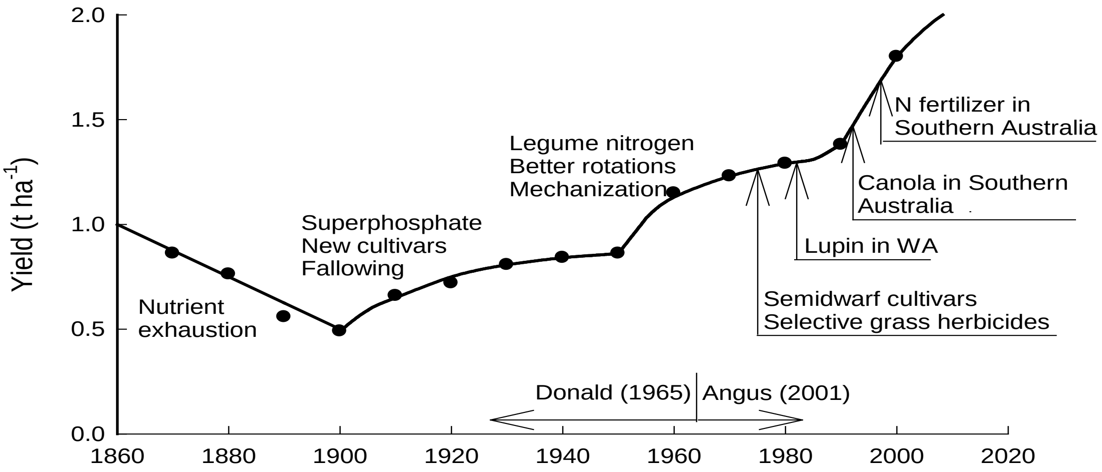

Figure 6: Decadal growth in Australian wheat yields and technologies driving changes. Source: Donald (1965) modified by Angus (2001).

As a result, fertilisers have become a major direct cost in agricultural production but this also imposes indirect costs such as contamination of waterways, freshwater and marine environments (PMSEIC 2010). Fertilisers also require large energy inputs in their manufacture and fertiliser use in Australian agriculture has been built on access to relatively cheap fossil fuel energy in farm operations and transportation, but increasingly, energy use is in the production of the fertilisers and pesticides will be an increasingly important issue in the future.

In addition to the dependence of Australian agriculture on energy for fertiliser production is the uncertainty in the long-term supply and thus cost particularly of phosphorus (Cordell et al. 2009; Cordell and White 2011) and potassium. The 2008 food and phosphate fertiliser price spikes triggered increased concerns regarding the depletion timeline of phosphate rock reserves. While estimates range from 30 to 300 years, and are shrouded by a lack of publicly available data and substantial uncertainty, there is a general consensus that the quality and accessibility of remaining reserves are decreasing, and costs will increase (Cordell and White 2011). Optimising the management of phosphorus in Australia’s production systems is critical and demands much more attention than it currently receives (Cornish 2010; Simpson 2011).

There are significant challenges in decoupling food production from dependency on energy-intensive inputs, such as fuels, fertilisers and pesticides. Ultimately the nutrient in food has its origins in the soil and while there is significant scope involving the use of rotations incorporating legumes to reduce nitrogenous fertiliser it is known that the phosphorus requirements for legumes are significantly higher than for cereals. Hence, increasing use of legume rotation systems gives need for increased attention to improvement in the management and recycling of nutrients particularly P in light of the absolutely essential nature of P to agriculture and the need to manage against finite phosphorus reserves.

There have been many changes in farming methods over the past 200 years and Australian farmers have had to be adaptable, as well as resilient and inventive. The challenges of Australian agriculture in terms of production include: highly variable climate; the need to effectively manage relatively poor soils, loss of soil carbon, with consequences of acidification, salinity, soil erosion and the need for careful and well-targeted use of fertilisers; over-clearing of native vegetation; over-grazing of pastoral lands; over-extraction of water from rivers and groundwater; exotic and native weeds and animals. These have all tested Australian farmers who have also had to respond to declining terms of trade and a volatile international export markets. As a result, and overtime, farming has become more mechanised and reliant on technologies, as well as adoption ecological principles in seeking to become more sustainable and resilient to market and production risks.

Soil management to control erosion and conserve water led to the widespread adoption of conservation tillage systems in 1980s (Freebairn and Silburn 2004; Bowmer 2011). Drivers for change leading to adoption of conservation tillage systems were equal or better profits, and development of new tillage equipment and herbicide technology facilitating rapid adoption over next 30 years. New challenges to sustainable production include genetic resistance in target species of the knock down herbicide and the appearance of agri-chemicals in water bodies (Henzell 2007). Also, better water storage associated with conservation tillage may exacerbate deep drainage and salinity risk.

This success story in the journey towards more sustainable cropping practice illustrates that most apparent solutions usually carry issues which require on-going research and development to deliver continuous change and improvement. The emergence of pasture cropping (Bruce et al. 2005, 2012; Millar and Badgery 2009) from farmer innovation (see box on pasture cropping) is seeking to address these issues in conservation farming to reduce production costs and provide environmental benefits at the catchment scale as well as on farm.

Land management systems in general, and stubble farming systems in particular, are important drivers of water resource condition but the integration of land and water management appears to have been downplayed and under-funded in recent years (Bowmer 2011). Building agricultural production systems that connect and integrate with the biophysical flows and cycles of Australian catchments and landscapes (Williams 1991, 1995, 2006; Cocks 1992; Chartres et al. 1992; Williams and Saunders 2005; PMSEIC 2010) to deliver ecosystems service in addition to food and fibre is very much a work-in-progress (McKenzie and Williams 2014).

The large areas of land suitable for grazing livestock under highly variable, but usually adequate rainfall, in conjunction with relatively warm conditions means that livestock can be grazed on pasture year-round, rather than having to be fed and sheltered over winter. Australian sheep and cattle farmers have been world leaders in the use of both native pastures and nitrogen-fixing improved pastures, rotational grazing and grain finishing to improve livestock productivity, while remaining highly cost-competitive in international markets (Keogh 2014).

Water

Rainfall and its very high variability, both in seasonal and annual distribution patterns, and availability and access to groundwater and stored surface water, have shaped Australian agriculture. Australians consume about 25,000 GL of water annually, of which 70% is used in agriculture. Water use in irrigated agriculture in Australia is greatly dependent on rainfall patterns and the management of the 80,000 GL capacity of public water storages. Irrigated agricultural water use has varied from less than 7,000 GL at the peak of the Millennium Drought to nearly 12,000 GL prior to, and following this drought. In 2012–13 the gross value of irrigated agricultural production (GVIAP) for Australia was $13.4 billion or some 28% of gross value of agricultural production (GVAP). Typically, GVIAP represents between 28 and 32% of GVAP and is produced from only 0.5% of Australia's agricultural land.

The scarcity and tradability of irrigation water in Australia has encouraged farmers to increase water-use efficiency in terms of growing irrigated crops and horticulture. For many crops Australian water use efficiencies, defined by productivity levels per-litre of water, are some of the highest in the world. This productivity performance of irrigation means that

Australian irrigated crops have important comparative advantages in global markets. While perhaps counter-intuitive, there is evidence that annual irrigated crops, like cotton and rice, are ideally suited to Australia's variable climate, enabling farmers to maximise production when water is available, and to avoid planting such water intensive crops in dry years. The concept of opportunistic sustainable intensification of irrigated crops, such as cotton and rice, may represent an emerging form of Australian agriculture (Keogh 2014). For opportunistic sustainable intensification to be economically viable requires integration with other enterprises. An example of diversification and integration is pasture cropping (Bruce et al. 2012) which is a recent development on the wheat-sheep mixed farming enterprise that has, for decades, managed well the viability between crop and livestock markets and the highly variable climate in Australian agriculture (Moore 2009; McKenzie 2014).

Biodiversity

Australia has experienced the largest documented decline in biodiversity of any continent over the past 200 years. Under the EPBC Act more than 50 species of Australian animals have been listed as extinct, including 27 mammal species, 23 bird species, and 4 frog species. The number of known extinct Australian plants is 48. Australia's rate of species decline continues to be among the world's highest, and is the highest in the OECD (ABS 2010; Commonwealth Government 2011).

Since European settlement, about 13% of Australia's vegetation has been cleared. This includes 34% of rainforest, 30% of Mallee, 60% of coastal wetlands in southern Australia, 31% of Eucalyptus open forest, 99% of temperate lowland grasslands and 34% of Eucalyptus woodlands. The comprehensive WWF report (Taylor et al. 2014) conclude that many ecosystems meet criteria to be considered threatened with collapse as a result of historical (pre-1972) and more recent (post-1972) clearing or degradation of native vegetation as a result of land use change. Further (Taylor et al. 2014) indicate that clearing, fragmentation or habitat degradation are recorded as threats to 76% of nationally threatened species.In the marine environment, similar loss of habitat is occurring, with important breeding areas such as mangrove forests declining around Australia's coastline.

Whilst broad-scale clearing has been reduced in Australia since 2002, native vegetation is still being cleared faster than it is being replaced. A net loss of around 260,000 hectares of forest per year occurred between 2000 and 2004, mainly from clearing for agriculture and urban development (ABS 2010). While most vegetation clearing and degradation has been due to agricultural expansion and many ecosystems and species have been threatened, this was largely an unintentional and unforeseen result and in some cases, government policy encouraged land clearing (Taylor et al. 2014). Native vegetation laws exist in most states and are currently under review in NSW (Byron et al. 2014) and Queensland and while maintenance of a regulation framework is important there is increasing evidence that new approaches are required beyond regulation to better manage native vegetation so to maintain or improve environmental outcomes with respect to salinity, water quality, land and soils, and biodiversity, with particular emphasis on not driving native flora and fauna to extinction. The use of incentives built around transparent and accountable market based instruments for stewardship payments, provision of ecosystems service and biodiversity offsets established in Europe, have been trialled and found useful in some Australian States and are suggested as part of vegetation reform in NSW following the recent review (Byron 2014). Taylor et al. (2014) outline similar policy options to address biodiversity loss. Underpinning these emerging mechanisms is the need to see agricultural land management connected to large-scale landscape and catchment management of Australia's natural resources.

People

The agricultural workforce has a number of distinctive features that include: a high proportion of self-employed, family and casual workers; long job tenure; and a relatively old workforce with relatively low education levels and low employee wages. The last two decades have seen an increase in the number of employees and a fall in employers and contributing family workers. The educational attainment of workers has also improved (Productivity Commission 2005).

Off-farm employment has become increasingly important to maintaining family farm incomes. Since 1990, the proportion of farm families deriving income from off-farm wages and salaries increased from 30% to 45%, with average earnings rising from $15,000 to $33,500 per year. Succession is now a priority business issue for farmers. Approximately one-third of all farmers are women.

There is evidence that formal training in the agriculture, farm and food sector is in decline and in the tertiary sector, universities for a decade have been reporting declining enrolments in agricultural science courses. This raises concerns about the future availability (Pratley and Copeland 2008) of trained scientists and skilled farmers despite apparent job opportunities in the agricultural production and agribusiness markets (Pratley and Hay 2010). A decline in scientific capacity into the future when knowledge and innovation is seen as critical to increase both productivity and environmental sustainability appears to be a significant risk facing Australian agriculture.

4.3 Risks

Climate variability and change

Drought continues to shape and characterise Australian agriculture. The social, economic and environmental impacts are deeply etched in Australian society. Australian governments therefore have a long history of intervening and providing drought support for farmers. The framework for determining exceptional circumstances is based on several criteria including meteorological conditions, agronomic and stock conditions and farm income levels and, in theory, should be an event of more than 12 months in duration and be a one in 20 or 25 year event (ABARES 2012). It was developed initially as part of the 1992 National Drought Policy that recognised that providing assistance in response to a drought as 'a national disaster' does not support good risk management practices by farmers. From 1997, assistance has been provided in terms of Exceptional Circumstances Interest Rate Subsidies, Exceptional

Circumstances Relief Payments (for basic income support to meet living expenses) and a Farm Management Deposit Scheme (allows farmers to set aside pre-tax income in good years for use in low-income years) (ABARES 2012).

Agriculture contributes about 15% of Australia's total carbon emissions and has the potential to sequester carbon in soils with changed incentives and agricultural practices that promote soil organic matter. The Carbon Farming Futures program, implemented in 2014 by the Australian Government, is intended to ensure that advances in agricultural practices enhance agricultural productivity and sustainable land use under a changing climate. Beginning in 2015, farmers will be eligible to compete, based on the lowest cost emission reductions, for support from a $2.55 billion fund available to businesses, households and landowners to verifiably reduce their emissions.

Biosecurity

Biosecurity refers to an integrated approach to managing risks to human, animal and plant life that is, typically, associated with the early recognition, containment and prevention of pest and disease threats. Despite a record of preventing some diseases endemic in other countries, Australian agriculture remains vulnerable to emerging pest and disease threats because of its relative isolation as an island continent. As a result of this isolation, a number of pathogens and diseases that are found elsewhere in the world, such as foot-and-mouth disease, do not currently exist in Australia.

Given that the potential economic losses of catastrophic risk associated with biosecurity could in the billions of dollars, Australia's agricultural future is dependent on effectively managing biosecurity risks. Biosecurity risk management includes monitoring and surveillance and risk analysis. It also involves assessments of complementary risks because other risks, such as climate change, may increase the farm land vulnerable to disease and pest incursions.

5. Returns

The challenge for Australian agriculture to remain profitable and competitive

John Mullen

5.1 Introduction

The objective of this part of the report is to review likely trends in key factors important to the ongoing profitability of Australian agriculture, the sector's ability to compete for resources within the Australian economy, and prospects in international markets.

Rapid economic growth in emerging economies where income per capita and population are rising suggest a positive outlook for Australian agriculture. This positive outlook could lead to some complacency amongst farm business managers and policy-makers about the future profitability and competitiveness of the sector. Such complacency is misplaced, as there is strong evidence globally that major developing nations are investing heavily in agriculture, and other sectors of the Australian economy are also experiencing strong growth and out-competing Australian agriculture for scarce resources.

While the outlook is positive, Australian agriculture faces increased competition in both domestic and international markets and for essential resources within Australia. A resumption of strong productivity growth is a key factor contribution to the continued profitability of the sector. Investment in research and development (R&D) is one policy lever available to government to enhance productivity and profitability and is the immediate focus of attention. A major concern is that public investment in agricultural R&D in Australia is declining and contributing to the slowdown in productivity growth in the sector.

Governments influence productivity and profitability in multiple ways including mechanisms to ensure the quality, safety and environmental attributes of Australian products, and access to market through trade agreements. They also provide a range of infrastructure services including education, property rights, transport and communication.

Productivity growth has contributed strongly to growth in output in Australian agriculture, as is highlighted in Figure 7. The real gross value of production for the Australian agricultural sector, which started at about $40b (2013$s) in 1953 has been consistently about $45b since the mid-1990s. Such a low rate of growth in the sector over 60 years is surprising. If we crudely assume that productivity grew at the rate of 2% per annum then, in the absence of this growth, the current value of agricultural production would only be approximately A$12 billion per annum, only 30% of the actual value of agricultural production in 2013

(Mullen 2012). Overall, productivity growth since 1953 accounts for about half the value of agricultural production in 2013.

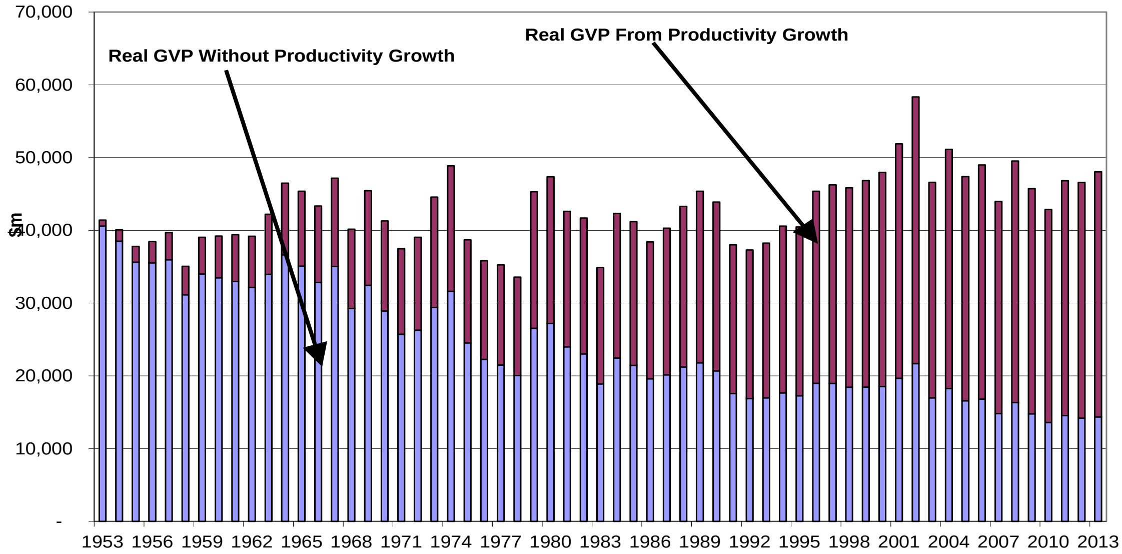

Figure 7: The value of productivity growth to Australian agriculture, 1953–2013 (A$2013). Source: Derived by the author from ABARES data in Australian Commodity Statistics.

There is evidence that productivity growth has slowed, not just as a result of poor seasons, but also because of declining levels of public investment in agricultural research and development. There are also concerns that growth in agricultural productivity may be slowed by accelerating climate change (eroding natural capital and requiring more inputs) which some expect will impact on Australian agriculture to a greater degree than on other exporters.

5.2 Profitability, total factor productivity and the terms of trade

5.2.1 Calculation of rates of productivity growth

Economists define total factor productivity (*TFP*) as the ratio of the volume of all outputs (Q) to the volume of all inputs (X) for a farm.

$$TFP = Q / X$$

In the case of a production system involving a single output, say wheat, and a single input, say an area of land, when all other inputs are ignored then *TFP* is equivalent to crop yield per hectare. However, other inputs such as fertiliser and water are used to grow wheat and so a simple yield measure per hectare is not an adequate measure of farm productivity. *TFP* growth occurs when, over time, the ratio of all outputs to all inputs increases which may, or may not, coincide with a rise in yield per hectare which represents only a partial factor productivity measure.

Measuring productivity in the normal multi-output, multi-input agricultural production environment is difficult because a change in yield in say, the wheat enterprise, very often has an impact on inputs and outputs in say, the beef enterprise. Total factor productivity attempts to measure gains in the efficiency with which all inputs are combined to produce all outputs[2].

ABARES has published measures of TFP based on their annual farm surveys of a large sample of farms across Australia. It conducts these analyses for broadacre and dairy farms (farms which earn most of the income from dairying). Since 1986, the Australian Bureau of Statistics (ABS) has also published estimates of TFP growth by sector, from National Accounts data (and using a value added rather than gross value measure) (ABS 2013). Most recently, ABARES has developed a measure of productivity growth for the whole agricultural sector dating back to 1949. These measures and their trends are explained more fully below.

5.2.2 The relationship between productivity and profitability

Productivity growth provides little advantage to a farm business unless it results in increased profitability. It is, therefore, important to understand the relationship between farm productivity change and profitability.

Consider the relationship between productivity growth, profitability and the terms of trade (the ratio of prices received by farmers for outputs to prices paid by farmers for inputs). Profitability may be defined as the ratio of growth in income to growth in costs, and can be represented as (O'Donnell 2010):

$$PROF = \frac{P\,Q}{W\,X} = TT \times TFP$$

Intuitively, this equation equates an index of value, *PROF*, with a quantity index, *TFP*, times a price index, *TT* (the terms of trade), the ratio of *P* prices received for outputs to *W* prices paid for inputs[3]. Growth in productivity only translates directly into growth in profitability if the terms of trade are constant. Further, changes in the terms of trade may induce changes in some of the sources of productivity growth.

Government can influence the terms of trade through negotiating better market access, providing a cost-effective regulatory environment guaranteeing that Australian products

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[2] Some prefer the term multifactor productivity (MFP) to TFP in more explicit recognition that in practice not all outputs and inputs are accounted for in the calculation.

[3] *P* and *W* are aggregate prices defined such that *PQ* is total revenue and *WX* is total costs.

comply with food safety, animal welfare and environmental health description, and by providing adequate infrastructure.

5.2.3 Components of TFP

While calculated TFP provides information about overall changes in the ratio of inputs to outputs for a business or industry, it does not provide information about why the ratio has changed. Intuitively, there are a range of different factors that could result in a change in TFP, and understanding these factors provides an opportunity to better target how TFP might be influenced by management or policy measures.

O'Donnell (2010) has detailed how TFP can be decomposed into productivity growth from technical change and productivity growth from a group of efficiency measures, some of which respond to changes in the terms of trade. In understanding productivity, an important concept is the concept of a *production frontier* for a particular production system which relates output on the vertical axis to inputs on the horizontal axis for the most efficient farms.

The factors influencing TFP growth are as follows:

- **Technical change (TC)**: shifts the production frontier outwards so that more output is achieved from the same inputs. An important source of technical change is new technologies arising from investment in research and development (R&D). Other sources of technical change may include infrastructure.
- **Technical efficiency (TE)**: the difference between the performance of average farms and the best farms. In other words, a movement towards the production frontier. Investment in extension and education contributes to efficiency.
- **Scale efficiency (SE)**: the extent to which a farm business is at its most efficient scale, given available technologies and management systems.
- **Mix efficiency (ME)**: the extent to which a farm business manager has selected the best mix of inputs and enterprises in order to maximise the output of the business.

O'Donnell pointed out while TFP is directly related to technical change and technical efficiency, an increase in terms of trade (TT) might encourage firms to sacrifice scale and mix efficiency, and hence TFP, in the pursuit of profit and vice versa.

5.2.4 TFP and unmeasured changes in natural resource flows

The availability and quality of data on inputs and outputs is a key problem for the measurement and analysis of productivity.

Farming activities can result in negative and positive externalities whereby the full costs or benefits from farming are not represented in the prices of inputs and outputs. This, in turn, creates a divergence in the interests of individual farmers and society. For example, farming activities may lead to changes in the quantity and quality of water leaving farms that have an impact on other farmers and communities downstream. While traditional measures of TFP adequately represent the incentives facing farmers, some of the efficiency gains may come from exploiting unpriced natural resources and hence, from society's viewpoint, the gains in efficiency are much smaller than from the farmers' viewpoint, and vice versa for when farming activities enhance environmental factors. In recent decades, as an appreciation has grown of the economic significance of environmental service flows from natural resources, governments have sought to introduce pricing (either incentives or penalties) for some users of natural resources so that there is less divergence in interests between users and the broader community. It is likely that because of these changes, a decreasing proportion of productivity growth in agriculture can be attributed to the unpriced degradation of natural resources.

A significant proportion of publicly-funded R&D seeks not only to enhance productivity, but also to deliver better environmental outcomes. In assessing the returns from public investment in R&D, the benefits of improved environmental outcomes should be valued together with the gains from improved productivity, but estimating the value of these unpriced environmental outcomes is rarely attempted.

5.3 Past trends in key parameters in agriculture and other sectors

5.3.1 Trends in TFP in broadacre agriculture

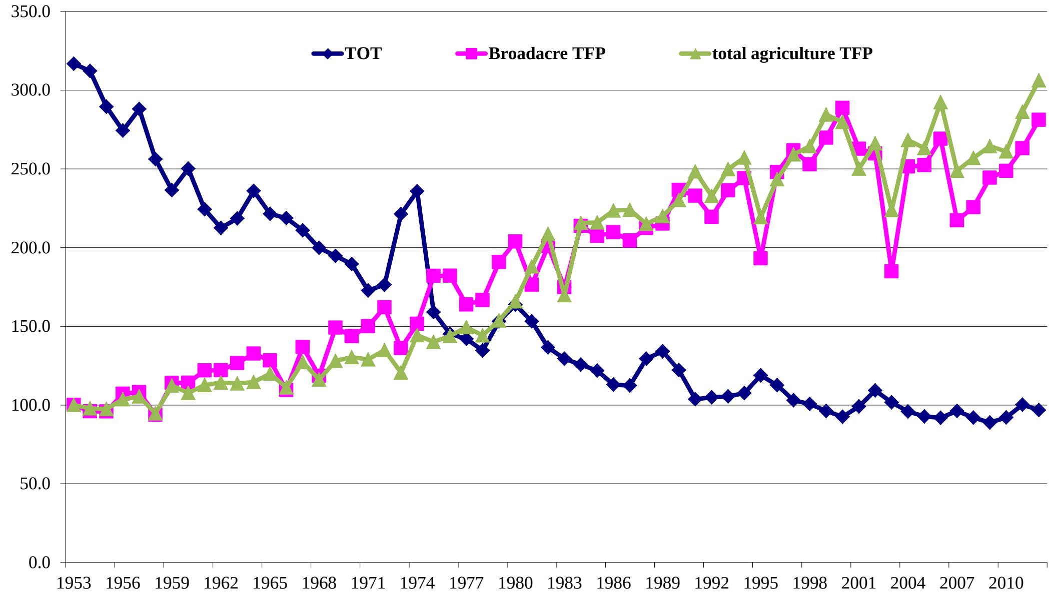

Figure 8: TFP and TT in broadacre agriculture, 1953–2013.
Source: Derived by the author from ABARES data.

ABARES has conducted farm surveys over many years for broadacre agriculture, encompassing the extensive grazing and cropping industries (but not intensive livestock or irrigated agriculture and only recently for horticulture), and for dairying (Gray et al. 2014a). Data from these surveys are used to follow trends in productivity using gross output measures. Most broadacre farms in Australia jointly produce several crop and livestock commodities and, hence, TFP must be measured at a whole farm level.[4]

TFP for Australian broadacre agriculture increased almost threefold, from an index of 100 in 1953 to 289 in 2000. It then declined to 185 in 2003 and 217 in 2007 as a result of drought, reflecting a run of poor seasons, before increasing to 281 in 2013 (Figure 8)[5]. This TFP series is highly variable, falling in 21 of the 61 years, reflecting seasonal conditions. Such variability makes it difficult to discern trends in the underlying, more stable rate of technical change. The average annual rate of TFP growth over the entire period was 1.8% per year, more than 0.5% per year lower than the long-term rate previously reported (in Mullen 2007, for example).

Total factor productivity grew at the rate of 2.3% per annum from 1953 to 1994, but since 1994 there has been no significant growth. TFP has grown each year for the five years since 2007. It's possible that this represents a run of good seasons rather than a return to the higher rates of technical change of earlier decades because underlying factors such as investment in R&D have remained low.

Recently, ABARES has developed a measure of productivity for the whole of the agricultural sector since 1949 (Gray, Leith and Davidson 2014, p. 164). This measure is graphed in Figure 9. Except for a period in the 1970s, it has tracked the broadacre measure closely, but is less variable. Productivity in the agricultural sector grew at the rate of 2.1% from 1953 to 2012. Its growth rate to 1994 was 2.5% but has been much lower, 0.7% per year, since 1994.

Sheng et al. (2014) have analysed the relationship between farm size and productivity growth for broadacre agriculture using ABARES farm survey data. They derived a relationship whereby returns to size consist of a returns to scale effect (from a proportional change in all inputs) and an input substitution effect. The input substitution effect is zero when inputs increase proportionally.

When Sheng et al. disaggregated farms by size, according to their dry sheep equivalent capacity, they found that large farms had larger capital–labour and materials–labour ratios than small and medium-sized farms. This suggests that different technologies were being used. They concluded that productivity differences due to farm size were more likely caused by differences in production technology than from scale effects due to farm size. This finding is evidence that supports the view that larger farms, in general, have a faster uptake of innovations.

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[4] ABARES monitors the productivity of segments within broadacre agriculture — such as specialist sheep producers or specialist crop producers — but does so using stratified samples from their overall farm survey still at a whole farm level.

[5] ABARES has made some revisions to prices for the series since 1977 which explains small differences reported here from previously reported data in Mullen (2012), for example.

Smaller farms may be able to remain efficient by using these technologies without necessarily increasing in scale. However, they pointed out that many of these technologies are now heavily information-based rather than embodied and hence there is a role for government (and presumably industry) in 'building capacity, sharing information, supporting training and facilitating R&D' (p. 21).

5.3.2 TFP and terms of trade

Changes in TFP can be compared with changes in the terms of trade faced by farmers as a partial indicator of whether Australian agriculture is becoming more or less competitive. The conventional wisdom is that the terms of trade facing Australian agriculture have been declining inexorably. While the terms of trade declined for about 40 years from 1953 (Figure 9), since the early 1990s the rate of decline has been much slower. While the TFP index grew from 100 in 1953 to 281 in 2012, the terms of trade index declined from about 317 to 97, at a rate of 2.1% per year over the period 1953 to 2012. This decline was faster than the rate of productivity growth in broadacre agriculture.

Without the benefit of a decomposition of TFP back to 1953, as outlined by O'Donnell (2010) and Hughes et al. (2011), it seems likely that because growth in TFP has largely been offset by the decline in the terms of trade, there has been little change in the profitability of the sector as a whole (from the equation above). This may explain, in part, why the real value of agricultural production has hovered around the A$45 billion mark consistently for only the last decade.

5.3.3 Correcting TFP measures for climate variability

Properly accounting for climate variability is critical to correctly assessing the relative importance of technical change and technical efficiency in Australian farm productivity data. Hughes et al. (2011) has emphasised that unless climate variability (estimated using soil moisture data) is properly accounted for, the extent of technical inefficiency is likely to be overstated. Once adjusted for climate, the TFP growth series appears to be less variable. It seems likely that if the series in Figure 9 were adjusted for climate, it would have fluctuated more narrowly around the 250 level and showing little growth since the mid-1990s.

Upon decomposing their adjusted TFP series, Hughes et al. (2011, p. 35) found that for the period 1978 to 2008, climate-adjusted TFP and technical change (TC) for broadacre cropping in Australia both grew at an annual rate of 1.53% with a decrease in technical efficiency of 0.31% exactly offset by a gain in scale and mix efficiency. Since 2000, climate-adjusted TFP has only grown at a rate of 0.24%, but technical change has grown a little more strongly at the rate of 0.4% per year. This slowdown is consistent with the findings of Sheng et al. (2010).

It is of concern, that even after climate variability has been fully accounted for, it may be the case that productivity growth will not return to a rate close to 2% (as experienced from 1978 to 2000), especially given the continuing decline in public investment in agricultural R&D.

The slowdown is more pronounced in western and northern regions as compared to the southern region (GRDC regions).

Hughes et al. (2011) found that since 2000, gains from technical change were offset to a considerable degree by a decline in technical efficiency. Together, trends in these two measures mean that, 'while farms overall are improving, the average farms have not been able to improve at the same rate as the best farms'. Despite this declining trend, the *level* of technical efficiency across regions and farming types averaged 0.8 which suggests that Australian broadacre cropping farmers are close to the production frontier.

The relative contribution of technical change and technical efficiency to productivity growth has potentially important policy implications with respect to the proportion of funds devoted to R&D (that seeks to shift the production frontier, technical change) compared to extension (that seeks to move more farmers towards the frontier, technical efficiency). Hughes et al. (2011) found that while technical change made the largest contribution to TFP growth since 1978 (1.53%), the level of technical efficiency has been drifting down at the rate of –0.31% per year, and this rate of fall becomes relatively more important to the much smaller rate of technical change since 2000 (0.4%).

5.4 Implications of climate change for agricultural TFP

Climate variability is a longstanding feature of Australian agriculture. As Crean et al. (2013) pointed out:

> *[F]armers facing climate risk have to plan for a range of possible seasonal conditions other than the ones that ultimately occur. This means that farmers do not use resources as they would if climate conditions in the approaching season were known.*

Lower productivity is one of the costs of uncertainty.

Climate variability and some underlying rate of climate change are already reflected in observed rates of TFP growth (Hughes et al. 2011). The observed rate of growth is lower than what might be expected if farmers were certain about coming seasons.

There remains a great deal of uncertainty not only about the extent of climate change at a regional level, but about how climate change will translate into changes in the pattern and level of agricultural output. Kingwell (2006) found general agreement in the climate change science literature that temperatures were likely to rise across Australia — indicating a southward shift in temperate agriculture — but implications for rainfall were much more uncertain with at least some regions likely to experience an increase. Kingwell (2006) pointed out that the impact of climate change will be revealed not just in altered production possibilities, but also through changes in the demand for, and supply of, agricultural inputs and outputs.

It is not yet possible to determine the likelihood that these projections of rainfall and temperature change across various geographic locations will be realised. Nevertheless, climate-change scenarios can be developed and their potential implications for farm productivity growth assessed. A first step is to think heuristically about the relationship between productivity growth and technical change. Figure 9 provides an illustration, abstracting from other sources of productivity growth. The dark blue line represents the unobserved rate of technical change made possible by investment in research. Simplistically, the other coloured lines represent a series of discrete climate-change events, each one of which causes an immediate reduction in the absolute *level* of productivity before growth resumes at the same rate as the underlying rate of technical change. Starting at the origin, TFP grows along the dark blue line until the first climate-change event drops the level of productivity to the black line and then TFP growth resumes along the pink line until the next discrete climate event takes the level again back to the black line. The envelope of these discrete steps, the black line, is the observed rate of productivity growth.

The observed rate of productivity growth includes not only technical change, climate change and farmers' adaptation to climate change, but other sources of productivity growth. The rate of productivity growth at least to the year 2000 was relatively robust which suggests that the rate of technical was outpacing any possible declines due to climate change or climate variability. Nevertheless, the rate of productivity growth adjusted for climate variability has only been 0.24% since the year 2000 (technical change, 0.4%) (Hughes et al. 2011). Thus a projected increase in climate change in coming decades may pose a real threat to productivity growth unless the rate of technical change was to also accelerate.

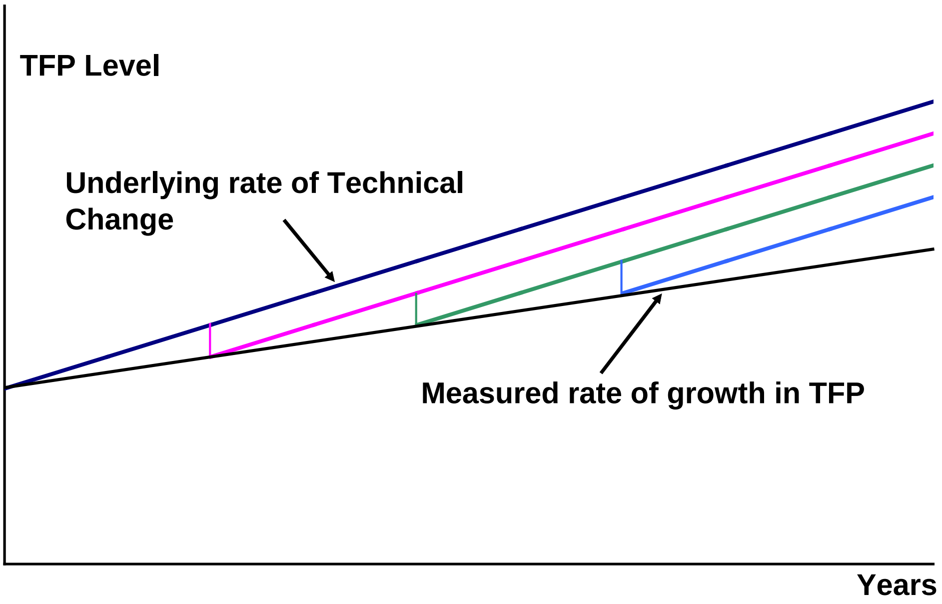

Figure 9: A conceptual model of how climate change impacts on TFP.

Heyhoe et al. (2007) assessed the potential impacts of climate change in productivity terms for major broadacre enterprises in a number of Australian regions using models, partly based on ABARES' farm survey data. The scenarios examined included wheat, beef, sheep meat and wool in New South Wales (NSW) and Western Australia (WA) under low and high rainfall conditions. If climate change leads to higher rainfall then productivity is projected to increase in all cases. Lower rainfall is projected to lead to decreases in the level of TFP, especially for wheat, which in 2030 is projected to be lower by 4.2% in NSW and by 7.3% in WA. Allowing farmers some ability to adapt to climate change reduces these losses by about half to 2.1% in NSW and 3.6% in WA.

It is instructive to focus on the low rainfall wheat scenario for NSW and to assess implications for the growth rate of productivity. Setting the level of productivity at an index of 100 in 2007 and allowing it to grow at 2.0% per year means that by 2030 the index will be 158. If TFP is climate-adjusted by 0.4% per year[6] then the productivity index will be 110 in 2030. If the level of productivity of wheat growing in NSW falls by 4.2% by 2030 then the new levels will be 151 for unadjusted TFP growth and 105 for climate-adjusted TFP growth. The rates of TFP growth leading to these new lower levels of productivity are 1.8% and 0.003%. If farmers adapt such that the decrease in the level of productivity is only 2.1%, then by similar reasoning, TFP growth rates fall by a smaller amount to 1.9% and 0.003%. In another paper, Gunasekera et al. (2007) assumed a 17% decline in productivity in 2050 based on work by Cline (1992)[7]. Following Heyhoe et al. (2007), the decline in productivity in 2050 may be about 9% with adaption. Using the same procedure as above, this translates into a decline in the rate of TFP growth from 2.0% (an index value of 234) to 1.8% (an index value of 213), a similar result to Heyhoe et al.

In summary, it seems that were TFP to continue to grow at the rate of 2% per year, then the impact of climate change is projected to be relatively small. By comparison, if the rate of technical change is as low as 0.4% per annum, then if climate change were to result in lower rainfall in southern Australia it would likely offset any growth that occurs in TFP.

5.5 TFP and competitiveness

5.5.1 Concepts of competitiveness

Part of the rationale for the strong interest in international comparisons of agricultural productivity growth relates to 'competitiveness'. All other factors unchanging, increased productivity within a sector lowers real output prices and improves international competitiveness and, thus, 'Productivity growth is central to the performance and international competitiveness of Australia's agriculture sector' (Productivity Commission 2005).

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[6] This is equal to the rate of technical change estimated by Hughes et al. (2011) since 2000 and so here the assumption is that in future, changes in technical efficiency and scale and mix efficiency cancel out as they did over the whole 1978–2008 period.

[7] It is not clear whether Cline uses a measure of TFP or partial productivity measures.

Gopinath et al. (1997) suggest that what determines international agricultural competitiveness is the productivity of a country's agricultural sector relative to domestic non-agricultural sectors and also when compared with relative agricultural productivity of its major competitors. Defined in this manner, competitiveness is closely aligned with the concept of *comparative advantage*. The theory of comparative advantage suggests that a country should export goods and services that it is relatively more productive in creating, and import those goods and services that it is relatively less productive in creating.

The principal notion behind comparative advantage is the concept of 'opportunity cost'. In an economy-wide context, the opportunity cost of producing agricultural products is the value obtained from the employment of those same factors of production (land, labour, capital) in producing goods in another area of the economy. The challenge is for the agricultural sector to use available factors of production more profitably than other sectors of the economy.

Previously, Mullen and Crean (2007) reported that productivity growth in Australian agriculture, over the period 1975–99, had been up to four times higher than that in the rest of the Australian economy, whereas in a selection of Organisation for Economic Co-operation and Development (OECD) countries, the agricultural sectors in these countries averaged about twice that in other sectors (Bernard and Jones 1996). Australian agriculture, while ranking 14th in the rate of agricultural productivity growth over the period from 1970 to 1987, had the third best ratio of agriculture TFP to non-agriculture TFP, suggesting the sector retained its competitiveness over the period (Bernard and Jones 1996).

ABARES is a partner in a study that will in the future allow consistent comparisons of agricultural TFP between countries. However, to date only a comparison between Australia and the United States (US) has been concluded. Sheng, Nossal and Ball (2013) found that TFP in Australian agriculture was lower than that in America in 1961 and has since grown at about the same rate (1.6% per year) and so remains at about 70% of US TFP[8]. Sarker (2014) assessed the competitiveness of the wheat industries of Canada and Australia between 1961 and 2012. He found that the competitiveness of both industries had declined and is partly attributable to lack of progress at the World Trade Organization (WTO). The Australian industry has gained ground on the Canadian industry over this time. Consistent multilateral data on agricultural TFP for a range of countries including China, India and Brazil is not presently available.

It is easier to assess the performance of Australian agriculture against that of other sectors of the Australian economy. This can be done using data on productivity by sector for the Australian economy assembled by the ABS.[9] The data is for a group of 12 sectors (referred to here as the *market group*) from 1986 to 2013.

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[8] Sheng et al. also reported Canadian data which is presently under review.

[9] The ABS estimates of TFP (it uses the term multifactor productivity, MFP) are different from those published by ABARES. The ABS measures are for the agriculture, fisheries and forestry (AFF) sector as a whole and they are a

Table 1: ABS estimates of TFP growth by selected sectors since 1986.
Source: Derived by the author from ABS (2013).

	1986 – 1991	1991 – 1996	1996 – 2001	2001 – 2006	2006 – 2013	**1986 – 2013**
Growth rate in MFP (%):						
Agriculture, Fisheries Forestry	3.08	2.00	5.27	3.22	0.46	**2.6**
Mining	3.84	2.46	1.08	–4.14	–2.29	**0.0**
Manufacturing	0.66	0.28	1.23	–0.32	–0.50	**0.2**
Communication	4.27	4.30	0.22	0.41	0.30	**1.8**
Market Sector	**0.72**	**1.76**	**1.61**	**1.02**	**0.49**	**1.1**
Ratio to Market Sector:						
Agriculture, Fisheries Forestry	4.3	1.1	3.3	3.2	0.9	**2.4**
Mining	5.3	1.4	0.7	–4.1	–4.6	**0.0**
Manufacturing	0.9	0.2	0.8	–0.3	–1.0	**0.2**
Communication	6.0	2.4	0.1	0.4	0.6	**1.6**

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value added (rather than a gross value) measure of productivity. Value added measures grow more strongly than gross value measures.

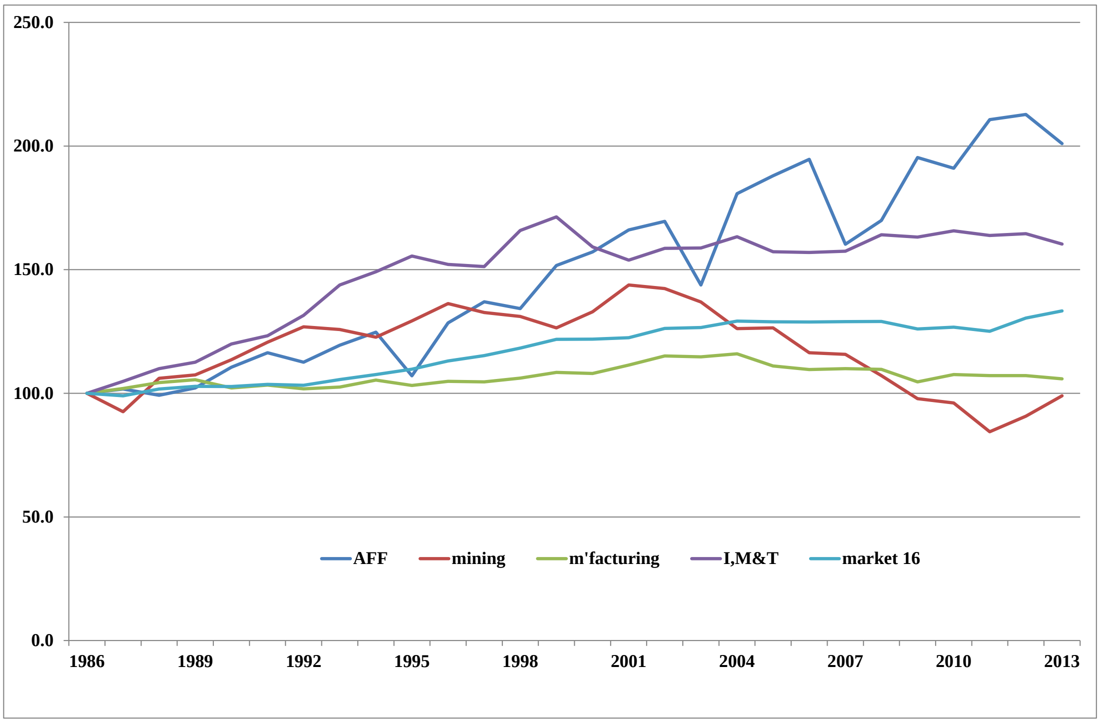

Figure 10: Trends in TFP by selected sectors since 1986.
Source: Derived by the author from ABS (ABS 2013).

Productivity growth for the market group averaged 1.1% per year from 1986 to 2013 (Table 1). Productivity growth in the agriculture, fisheries and forestry (AFF) sector averaged 2.6% per year (about 2.5 times that for the market group) followed by the information, media and telecommunications (I,M&T) sector which averaged 1.8% per year (less than two times the market group). It is noticeable from Figure 10 that whereas TFP growth in agriculture rebounded from about 2006, TFP growth in other sectors has been flat. Up to 2006, the market group had been growing at an average rate of 1.3% per year.

5.5.2 Mining and agriculture

From Table 1 the productivity performance of the mining sector has been poor, declining markedly from 2001 until 2011.

The puzzle with respect to the relative performance of productivity in the agriculture and mining sectors can be partly resolved by reference to the relationship between profitability, productivity and the terms of trade that is discussed above. Profitability (and hence GDP) is also driven by the terms of trade. Between 2000 and 2010 the price of iron ore rose by a factor of 3, the price of coal by a factor of almost 2 and metal prices rose even more strongly. In contrast, the ABARES index of agricultural prices received only grew by about 20%.

The relationship developed by O'Donnell presented above can be adapted in the following way:

$$\frac{PROF_A}{PROF_M} = \frac{TFP_A}{TFP_M} \cdot \frac{TT_A}{TT_M}$$

where *A* is agriculture and *M* is mining.

The profitability of agriculture relative to mining improves if TFP grows more rapidly in agriculture, as has been the recent history and declines if the TT in agriculture declines relative to that in mining, as has been the case until 2011.

Gregory (1976) pointed out that rapid growth in the mining sector leads to an appreciation of the Australian dollar (and/or domestic inflation) and a decline in the price of internationally-traded goods relative to non-traded goods. Given that Australia is a price-taker in most markets, an appreciation of the Australian dollar likely results in a fall in the Australian dollar price of, say, wheat. This change in relative prices of traded and non-traded goods is reflected in a decline in the relative terms of trade between agriculture and mining and, hence, in the relative profitability of agriculture.

Additionally, Syed et al. (2013) explained the apparent poor productivity performance in terms of using marginal resource deposits that were previously unprofitable and using proportionally more inputs in their operations, so as to increase rates of extraction. Hence high prices (an improvement in TT_M) encourage extraction from lower quality resources and this leads to a decline in productivity (as expected from the O'Donnell model). They found that 'after removing the influence of both deposit quality depletion and production lags, the MFP growth rate in Australian mining increases from an average annual rate of negative 0.65 to positive 2.5 per cent between 1985–86 and 2009–10' (p. 2).

The mining sector has grown from a share in gross domestic product (GDP) for Australia from 5.8% in 1986 to 8.0% in 2014 while the share of agriculture has declined from 2.5% to 2.0% (derived from ABS 5204 2014, Table 5). This suggests that in recent decades, agriculture has become less competitive for resources with mining although not necessarily with other sectors.

5.6 Future prospects for the demand for commodities and their prices

The future competitiveness or profitability of agriculture will be influenced by trends in the global demand for food and other natural resources and changes in their relative prices. Specific influences include the rapid economic growth of China and India, Australia's success in negotiating free trade agreements and global trade reform, and prospects for supply and demand for primary products.

5.6.1 Economic growth in China and India

Anderson and Strutt (2014) used the GTAP model to make projections (from a 2007 baseline to 2030) about the impact on rapid economic growth in China and India (and other emerging economies) on the global demand for imports of agricultural products and other primary resources. They pointed out that China and India are heavily populated, and yet relatively resource poor, which is complementary to economies in Australasia, Latin America, the Middle East and Africa which are lightly populated and relatively abundant in land and other primary resources, such as minerals.

If these Asian countries grow at the rate assumed (7% for China GDP and 6% for India) then their share of world GDP will increase from 14% in 2007 to 32% in 2030 with per capita income growing from 25% of the world average to 57%. Growth of this magnitude provides opportunities for natural resource rich (NRR) countries like Australia. Exports of non-farm primary products by the NRRs are projected to increase strongly (from a share of 8.5% to 10.1%) and their share of global exports of farm products is projected to rise from 2.1% to 2.9%. Food self-sufficiency in China is projected to fall from 97% to 87% and in South Asia from 100% to 95%. Real per capita food consumption is projected to more than double.

The demand for grain and soybeans by China to feed livestock is expected to be such that China will account for 32% of global grain consumption (up from 12%). There will also be large increases in its share of the use of fossil fuels and minerals. Anderson and Strutt projected that the real international price of farm products will rise by 2% by 2030, whereas the price of non-farm primary products will fall by 5% under their baseline scenario. The implied rate of growth in agricultural productivity in Australia under their baseline scenario was 2.4% per annum which is more than double recent experience. If Australia's agricultural TFP growth was halved, then presumably, Australia would not enjoy the same increase in exports to China and India as under the base scenario.

For a scenario where growth is one-quarter slower in India and China, the prices of primary products are projected to fall by 7%, rather than increase by 2%. For a scenario where TFP for primary products grows at a rate of 1% less globally, then the prices of primary products are projected to be 10% higher, rather than 2% lower.

Maintaining self-sufficiency in staple food crops is a policy which governments in China and India seem reluctant to abandon. Hence, another plausible scenario is one where China and India seek to maintain self-sufficiency in some staple crops even at some cost to their own consumers in the form of higher prices for non-staple foods. Anderson and Strutt (2013) found the rate of tariff protection required to maintain self-sufficiency far exceeded World Trade Organization (WTO) commitments. Instead, Anderson (2014) proposed another scenario whereby China invested in public goods like agricultural R&D. Achieving a 97% level of self-sufficiency would require its associated TFP to grow 2% more rapidly than under the baseline scenario.

5.6.2 Global influences on supply and demand

Pinstrup-Andersen (2012) reviewed the current debate about global food security including projections of rising food prices by the Food and Agriculture Organization (FAO) and the International Food Policy Research Institute (IFPRI). He concluded that while price volatility is likely to continue, real food prices need not rise provided that governments refrain from altering price signals for short-term political gain and instead invest in infrastructure past the farm gate to encourage farmers to exercise a latent capacity to increase production.

Similarly Pardey et al. (2014a) were more conservative than some in their assessment of the challenges surrounding food production through to 2050. Instead of a doubling of food production they estimated that a rise of about 70% (or 1.3% per year) by 2050 would meet the challenge even with a continuation of the slower rate of growth in yields over the past decade. They estimated that the use of land for crops needs to increase by less than 10%.

Until 2011, with a sharp decline in 2008 with the Global Financial Crisis, the prices of resources such as iron ore and coal have risen steeply driven by the fast-growing economies of China and India. Commodity prices have already declined from their peak, and the value of Australia's dollar has also fallen in 2014 benefiting exporters. The World Bank's (2014) longer-term projections have both agricultural and resources prices (in real terms) falling out to 2025. Its projections are provided in Table 2 and show the prices for energy and metals and minerals incur falls of 11% and 12%, respectively, whereas the agriculture index is projected to fall by 17%.

A key price for Australian agriculture is the exchange rate. In recent years, the high rate of investment in the mining sector has led to a spike in the exchange rate but it has already fallen substantially in 2014 to a level that benefits agricultural exporters.

5.6.3 The impact of free trade agreements

Australia has recently concluded free trade agreements with Korea, Japan and China and is in negotiation with India and Indonesia. Other multi-country agreements are under negotiation. The main sectors to benefit from the concluded trade agreements are dairy, beef, horticulture and wine with tariffs being eliminated over a number of years, if not immediately, although it seems some quotas will remain in force. The mining sector is also a major beneficiary of these agreements.

The prices of Australian farm products will be lowered in these countries and hence Australia is likely to gain a greater share of these markets and Australian farm export prices are likely to rise. Whether Australian farmers receive a premium over expected world prices depends on the extent to which access to these markets for Australian competitors remains restricted. In some cases, Australia is only gaining the degree of access that is already enjoyed by some of its competitors, such as New Zealand.

The downside is that sectors not covered by these trade agreements may be worse-off as their relative profitability declines. It is noticeable that staple food grains such as rice and wheat are generally not included in these agreements as might be expected when self-sufficiency in staples is still a sensitive issue. How these gains and losses play out in broadacre agriculture where farmers typically grow grains and raise livestock will depend on the shares of these enterprises in farm income and the technical possibilities of changing the composition of output in response to changes in relative prices.

Table 2: World Bank price projections for selected commodities (2010 $US). Source: Derived by the author from World Bank (2014).

		actual real prices		projected real prices	
		1980	2013	2015	2025
Coal	$/mt	61.5	79.7	70.3	80.4
Crude oil	$/bbl	56.5	98.1	89.7	85.0
Iron ore	$/dmt	43.1	128.0	98.0	105.0
Copper	$/mt	3345.5	6913.0	6451.0	5470.0
Wheat US HRW	$/mt	264.8	294.4	267.2	221.2
Cotton	c/kg	3.2	1.9	1.8	1.9
Beef	$/kg	4.2	3.8	4.4	3.4
Energy index			120.1	111.1	106.6
Metals and minerals index			85.6	81.4	75.5
Agriculture index			100.2	95.6	83.3

The projections for agricultural prices out to 2030 by Anderson and Strutt (a 2% rise by 2030) and the World Bank (a fall of about 20% by 2025) are markedly different. We have not attempted to reconcile these projections although it could be that the World Bank projections are based on faster rates of growth in agricultural productivity than Anderson and Strutt and perhaps a slower growth in the world economy, particularly in China and India.

While the trend in agricultural prices will be an important factor influencing the growth of Australian agriculture, it is likely that the volatility in agricultural prices will be costly for Australian farmers to manage. Domestically, Australian farmers will need to adopt on- and off-farm strategies to manage this uncertainty. Internationally, as seen in 2007–2008, sharp price spikes threaten food security in poor countries and give rise to social unrest.

5.7 Prospects for agricultural productivity growth

Agricultural productivity growth has slowed in Australia and also other developed countries (Alston and Pardey 2009, 2014). By contrast, agricultural productivity is growing strongly in some middle-income countries such as Brazil, India and China (BIC) (Fuglie and Wang 2013).

In looking forward, a focus on trends in partial measures of productivity such as crop yields and labour productivity might be less abstract and more insightful. Beddow et al. (2009) reported that for wheat, maize, rice and soybeans, yield growth was slower in 1990 to 2007 than for 1961 to 1990 for both high- and middle-income countries. Grassini et al. (2013) in assessing yield gains in major crop producing countries since 1965 found that yield gains were best represented by linear models with breakpoints and plateaus rather than exponential models. They found 'widespread deceleration in the relative rate of increase of average yields of the major cereal crops during the 1990 – 2010 period….' (p. 9) where the relative yield gains was estimated as the trendline yield divided by the rate of gain.

A question that arises is whether yield growth rates can be restored by increased investment in R&D or whether all the 'low hanging' gains have been made and the prospect of future technology development and productivity gains is less promising than in the 1961 to 1990 period.

Fischer et al. (2014) reviewed the prospects for global food security and increasing crop yields. After allowing for an increase in cropping area, they estimated that to meet the demand for food in 2050, on- farm yields (FY) of staple crops have to increase at a relative rate of at least 1.1% per year (estimated as yield as a % of yield in 2010 or 45% in total over 2010 yields). By comparison, over the past 20 years, the relative rate of yield growth has been 1% for wheat, rice and soybean and 1.5% for maize.

On-farm yield is less than potential yield (PY) or water-limited potential yield (PYw). Many factors contribute to this yield gap. Notably in general, it is not profitable for farmers to operate at PY and close the yield gap entirely. The closing of the yield gap is also constrained by off-farm factors like infrastructure, regulation and rigidities in markets. In reviewing past performance, Fischer et al. (2014) found no crops where PY (technical change) was zero and they found for most crops (except wheat and soybean) the gap between PY and FY was large enough to suggest scope for narrowing this gap.

Looking to the future, Fischer et al. (2014) argued that closing the yield gap is the 'most assured and rapid means' of increasing FY. The means to do this are partly through breeding to improve pest and disease control, but more importantly through increasing the adoption of better farming technologies. They argued that the most likely avenue for increasing PY is through breeding using molecular techniques and in the case of crops like wheat, exploiting hybrid vigour. They are optimistic that their goal of FY growth of better than 1.1% per year could be attained.

Fischer et al. took a global perspective in assessing crop yields and food security. The challenge of meeting the 1.1% yield growth is, perhaps, harder for the Australian cropping industry. This is because Australian farmers are relatively close to the production frontier (Hughes et al. 2011) and so the scope for closing the yield gap through greater adoption of existing technologies is smaller. Moreover, Gray et al. (2014) pointed out that reform of market interventions in previous decades has meant that the scope for further efficiency gains through these means is limited. Anderson (2014) also emphasises that, in addition to progress at WTO and increased R&D, other ways in which Australian agriculture could become more competitive included further reductions in protection of Australia's manufacturing sector, easing restrictions on foreign investment in Australian farms and businesses, and investment in infrastructure to lower costs along the food chain.

Tester (2012) noted Australia's lower wheat yields and slower growth in yield compared to other countries and suggested that this can be at least partly explained by less access to irrigation and hence less opportunity to exploit nitrogen fertiliser. Brennan and Quade (2004) pointed to the consequences of lower growth in wheat yields in Australia. They estimated that CIMMYT research had increased world wheat yields by 12.2% which caused world prices to decline by 7.4%, but Australia's yield increases from CIMMYT varieties was only 4.6%. They pointed out that had Australia not invested resources in capturing some spillovers from CIMMYT research and in adapting CIMMYT material to Australian conditions, then the welfare losses to Australia would have been much larger. Brennan and colleagues (Brennan and Bantilan 2003; Brennan et al. 2003) reported similar findings for research on other crops in CGIAR centres.

Brennan and Quade's work underlines the challenge Australia faces in achieving comparable productivity gains to other countries. Pardey et al. (2012) pointed out that middle-income countries will increasingly become important sources of new technologies. Capturing and adapting spillover technologies from middle income as well as traditional high-income countries, appears worthwhile but may be difficult under existing levels of R&D funding in Australia.

Tester (2012) was optimistic that technological innovations in research including information and communication technologies (ICT), genomics and bioinformation, genetic modification and hybrid breeding, can 'improve incremental changes … and provide occasional step changes' (p. 34). Goddard (2012) also identified ICT and genomics as sources of productivity growth in livestock industries.

It would seem that while scientists are confident that yield and productivity gains are still attainable, a strong commitment to investment in R&D is required. This seems particularly true for Australia because, on present trends in crop yields and productivity, there is a danger of becoming less competitive even with the opportunities provided by increasing world demand.

The type of research identified by Tester and Goddard spans the spectrum from basic to applied research and extension. Hence, even in partnership with the private sector, a strong commitment to basic research is likely to be required. It appears that many of the technologies to close the yield gap will be 'disembodied' and information-laden and, hence, the role of extending these technologies will likely require industry and possibly public funding.

Supply Response in Australian Agriculture

Observation of how farmers change their cropping patterns in response to relative changes in the prices of similar crops and, in the case of irrigated agriculture, to the price of water, suggests that the ability of farmers to alter supply is quite high, particularly for crops. Supply response at more aggregated levels such as cereal grains or livestock is less responsive (less elastic) partly because of technical considerations about cropping rotations, crop/livestock interactions and the length of breeding cycles in livestock, but is still likely to exceed one (% change in quantity exceeds % change in price) over a period of several years. Many econometric estimates of the response (% change in quantity) of Australian agricultural products to price changes (%) are less than one, but this likely reflects difficulties in estimation.

5.8 The relationship between research and development and productivity in agriculture

5.8.1 Returns to investment in agricultural R&D

The Productivity Commission (PC) (2011) accepts that investment in agricultural R&D in Australia has made a significant contribution to agricultural productivity growth. The original econometric analysis for broadacre agriculture by Mullen and Cox (1995) estimated that from 1953 to 1988 the *rate of returns* from public investment in R&D had been in the order of 15–40%. The most recent updating of that analysis was by Sheng et al. (2011), who used a longer time series dataset that accounts for foreign 'spill-ins' of technology and a research strategy adapted from Alston et al. (2010). They estimated a rate of return of nearly 30% from their preferred model. The analysis also showed that there are long lags in the order of 35 years, from the commencement of research and when its impact becomes small.

These findings about the returns to agricultural R&D in Australia are consistent with international studies. Goucher (Council of the Rural Research and Development Corporations 2010) reviewed the study by Alston et al. (2000) of rates of return analyses worldwide. Alston et al. found that the average of the estimates of the rate of return to research only (from 1,144 studies) was 100% per annum. The range was wide, but less than 10 estimates (less than 1%) found a negative rate of return. Goucher summarised the findings from the 154 Australian and New Zealand (NZ) studies reviewed by Alston et al. The average estimated rate of return from these studies was 87% per annum.

A recurring criticism is that most of these studies use the internal rate of return (IRR) as their summary financial criteria. The IRR assumes that benefits during the life of the project are reinvested at the IRR. Hurley et al. (2014) converted the IRRs reported in previous studies to a modified IRR (MIRR) where they set borrowing and reinvestment rates and found the median MIRR was 9.8% compared to a median IRR of 39%. Similarly, an as yet unpublished study, using a similar dataset to Sheng et al. (2011) found causation from R&D to TFP and estimated that the MIRR from public investment in broadacre R&D in Australia was just over 10%.

These aggregate econometric studies are consistent with the many reputable benefit–cost analyses at a project level conducted in Australia by state departments of agriculture and by private consultants for the Research and Development Corporations (RDCs). Much of this material is referenced in the recent report from the Productivity Commission (2011) and Mullen (2011). Prevailing high rates of return to research provide strong support for the longstanding hypothesis that there remains some degree of underinvestment in agricultural research in Australia, as well as globally.

Two further observations can be made. First, all the econometric analyses at an aggregate level and most of the project level benefit–cost analyses focus on quantifying industry benefits, but 'spillover' benefits in the form of gains in environmental and human health and in social and scientific capacity are, at best, identified qualitatively. These 'spillovers' are widely accepted as a potential source of market failure requiring some form of government intervention. One point of contention is that the Productivity Commission argues that, providing industry benefits are sufficiently high, there is no need for government intervention. Alternatively, it may be argued that there may be little incentive for industry to ensure that these 'spillover' benefits are actually taken up by the community, and that some degree of public investment is required to ensure these benefits are captured by the community.

Second, the incentives facing farmers and RDCs are much higher than estimated returns to total investment in R&D because they only pay a share of the research and development costs.

5.8.2 Investment in agricultural R&D

Despite this strong evidence of the contribution of public R&D to agricultural productivity growth, public financial support for R&D has been declining since the 1970s. The longest series on R&D investment was first assembled by Mullen et al. (1996) from 1953 to 1994, and then supplemented with ABS survey data to 2009, as described in Mullen (2007). Expenditure was attributed to research providers, rather than funders. As a result, expenditure by state departments of agriculture or universities, for example, includes funds obtained from rural RDCs. Attention was focused on the expenditures for *socio-economic outcomes*[10] related to farm production, but investment in R&D for the fisheries, forestry, environment and processing of farm products for socio-economic objectives was not included.

Total public expenditure on agricultural R&D in Australia grew from A$160 million in 1952–53 to almost A$1,100 million in 2000–01 before declining markedly to A$780 million in 2008–

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[10] As defined by the ABS classification of R&D activities.

09 (in 2013 dollars) (Figure 11). Expenditure growth was strong to the mid-1970s, but has essentially been static since that time although there was a spike in investment in 2001. Likewise, agricultural research intensity, which measures the investment in agricultural R&D as a percentage of GDP, grew strongly in the 1950s and 1960s, but has been drifting down from about 4.0–5.0% of agricultural GDP in the period between 1978 and 1986 to less than 3.5% in recent years.

Private sector investment in R&D has been rising, but is unlikely to exceed 20% of total agricultural R&D investment at present, not including RDC contributions. Keogh et al. (2010) finds that private sector R&D investment is complementary to public sector R&D investment in Australia, rather than a substitute. Given the small size of the Australian agricultural market, it is likely that nearly all private sector R&D is focused on the applied end of the spectrum.

This information on investment in agricultural R&D is dated and it is no longer possible to extend this series from published ABS sources, even though it is likely that this information is still being collected. Investment in R&D is a key policy intervention to promote productivity growth and yet it is now no longer possible to track trends in investment nor to assess the efficacy of this tool in contributing to productivity growth. This indicates a data gap in terms of measuring past agricultural performance.

Economy-wide gross expenditure on R&D (GERD) was about $31b in 2009 ($2013)[11]. It increased by a further $1b to 2012. Hence, at best, investment in agricultural R&D has been similarly static since 2009 in real terms, but with substantial budget cuts to CSIRO and contraction in many State Government departments of agriculture in the past two years, investments may now be contracting[12].

5.8.3 R&D and TFP growth

Sheng et al. (2010) found that the observed slowdown in R&D investment, along with poor seasonal conditions, contributed to the slowdown in broadacre TFP growth. This slowdown is a response to recent decades of stagnant public sector R&D investment, and also the long time-lags associated with returns to such investment noted above.

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[11] Investment in some sectors in some years is now 'carefully' modelled by the ABS rather than being based on survey returns.

[12] The OECD reports a series on investment in R&D as part of its assessment of support to Australian agriculture. The source of this series is not described. It has always been 10–20% lower than the Mullen/ABS series. However, this series has shown declining investment in public agricultural R&D since 2009.

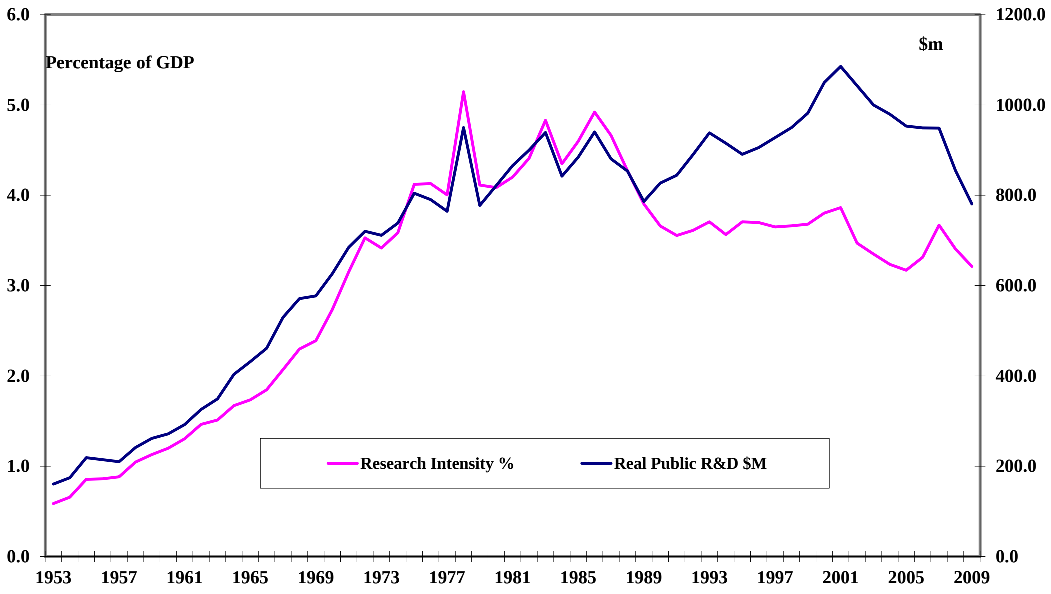

Figure 11: Real public investment and research intensity in Australian agricultural R&D. Source: Derived by the author from various public sources including ABS R&D data.

All econometric analyses find long lags of 35 to 50 years between R&D investment and gains in productivity. On this basis, it is possible that the present halving in productivity growth can be attributed to declining investment in R&D since the late 1970s. A further implication of these long lags is that were investment in R&D to be ramped up, the resulting gains in productivity are unlikely to start appearing for a decade or more. Pardey, Alston and Chan-Kang (2013) have warned that, given the rundown in scientific capacity in public research institutions in the US, the doubling of public R&D investment that they have called for needs to be phased in over years. A similar observation likely applies to Australia.

Sheng et al. (2011, Table 7, p. 34) examined the consequence for productivity growth under various scenarios about the future funding of R&D. Their scenarios were based on real public investment in agricultural R&D in 2007[13] and the elasticity of TFP with respect to research knowledge stocks. One scenario involved increasing research investment permanently by 10% (A$170m) from 2008 and assuming that the growth rate for TFP started at its long-term average of 1.96%. Given the long lags, it is not surprising that the growth rate in agricultural TFP only increased to 2.02% for the period to 2020. Only when lag effects to 2050 were accounted for did the long-term growth rate average 2.09%, but it still remains a small response.

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[13] Note the heading in their Table 7 is somewhat misleading.

Sheng et al. also examined scenarios where R&D was maintained at 3.1% of the gross value of agricultural production (GVAP) or the level of research intensity[14] attained in 1978. Under this scenario (based on ABARES projection of GVAP to 2015), TFP growth might be expected to increase to an average rate of about 2.4% per year once the long lag effects began to be of influence after 2020. Thus it would seem that to achieve a growth in TFP approaching 2.5% per annum, domestic investment in research has to be increased to over 3.0% of GVAP, a major reversal to the trend over the past three decades.

5.8.4 The role of extension

Data on public and private expenditure on extension services is scarce. Mullen et al. (1996) derived a series by applying budget shares derived from management information systems used by the state departments back in the 1990s to total expenditure by the departments. These budget shares have never been updated and so the confidence bounds around the updated series on extension used by Sheng et al. (2011) are larger. Nevertheless, it is highly likely that public expenditure on extension has fallen at least as much as expenditure on R&D. The nature of public extension services has also changed markedly to the extent that advice tailored to particular farms is now rarely available. There has been a marked increase in the private extension services through consultants and agribusiness firms but the level of expenditure associated with this is unknown.

Hughes et al. (2011) noted a decline in technical efficiency (although the level of technical efficiency remained high) and the estimates by Sheng et al. (2011) suggested that the returns from investment in extension were higher than those from R&D. Nevertheless, arguments about market failure in the provision of extension are harder to make than in the provision of R&D.

5.8.5 R&D funding in other countries

This Australian experience mirrors, to a large extent, what is happening to public agricultural R&D in other developed countries. Alston and Pardey (2014b, p. 139) found that the share of rich countries in public agricultural R&D declined from 58% in 1960 to 48% in 2009. The share of the Asia Pacific region (including India and China) grew from 20% to 31% over the same period. By 2009, investment by middle-income countries was about the same as that by rich countries.

Reviewing the implications for the 2014 US Farm Bill, Pardey et al. (2014) found that a proposed small nominal rise in R&D would do little to redress recent reductions in investment and a rundown in US public research capacity. The private sector now funds 56% of food and agricultural R&D. They pointed out that public and private research is

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[14] Note research intensity here is defined in terms of the gross value of agricultural production rather than in terms of agricultural gross domestic product. The GDP measure in 1978 was 5.1%, also a maximum.

complementary, with the private sector working at the more applied end of the research spectrum building on the more 'blue sky' research undertaken in the public sector. The danger of devoting more resources to applied research is that while rates of return and TFP growth may be more certain in the short run, they may also be lower in the long run than a portfolio with a strong component of basic research.

5.8.6 Market failure in providing agricultural R&D

Research processes necessarily deliver both private and public goods. While it makes sense that the private sector largely fund research delivering predominantly private goods and the public sector fund research delivering predominantly public goods, this problem of jointness means that there is no simple theoretically-sound formula to apply to determine where the boundary between public and private funding lies.

The Australian RDC model is uncommon in the way in which industry is required to contribute to the funding of research through a levy matched by a government grant. The RDC model ameliorates the 'free-rider' problem while largely preserving the benefits from the non-rival nature of new knowledge. Numerous enquiries have failed to identify ways to improve this model that are unambiguously welfare enhancing. This should not be surprising given the likely extent of market failure and certainly government should insist that research that is funded should generate values to the broader community. The RDC model has been based on the RDCs commissioning research predominantly from state departments, CSIRO and the universities. An emerging challenge to this model is the loss of scientific capacity, particularly in the state departments and CSIRO, as public investment has contracted.

Suggestions that the RDCs be encouraged to fund more industry research and that some proportion of the matching grant be diverted to a research institution tasked with only undertaking public-good research (Productivity Commission 2011), or that more public research funds be directed to partnerships with private firms (recent policy suggestions by government ministers), ignores the fundamental problem that by definition, the beneficiaries of research cannot be fully excluded from enjoying its benefits and have little incentive to reveal their true willingness to pay for these services. Consequently, investment in agricultural research is always going to be less than that desired by the community. The costs of a rigid demarcation between those institutions that do industry research and those that do public-good research is that the benefits from the non-rival nature of new knowledge and economies from jointness are reduced.

Despite the consistent findings of high returns to agricultural research investment in Australia and the consequent likelihood of market failure, the case for public investment in agriculture is contested with the Productivity Commission (2011) report recommending a halving of the RDC levy because it doubts that the matching grant has called forth much additional research from industry.[15] It expects that were the government to reduce the gross value of agricultural production (GVAP) cap for a matching grant to 0.25%, the RDCs would increase their levies to offset this reduction. In other words, it holds the view that public sector is 'crowding out' industry investment.

Mullen (2011) reviewed the 'crowding out' hypothesis and suggested that such a scenario would most likely be typified by low rates of return to research and pressure to reduce levy rates. Observed high rates of return are only consistent with crowding out in the unlikely scenarios of either sharply diminishing returns to future research and/or constraints on the supply of research services.

There are good reasons why RDCs will face resistance to increases in R&D levies. It should not be surprising that farmers understate their true willingness to pay for research under the common uniform levy of the RDC model (see Alston and Fulton 2012). Remaining incentives to 'free ride' are complemented by heterogeneity in the resource endowment of farms and in the applicability of particular technologies. In addition, the long lags in the development of new technologies may be a disincentive to increasing levies. This disincentive arises not only because farmers may not receive any benefits in their working life, but more likely it is because they do not appreciate the contribution to their present farming system of past research efforts, nor foresee how present research efforts may change farming systems decades hence. Some of these arguments are noted in the Productivity Commission report which also argued for a stronger culture of impact assessment within research institutions for the benefit of stakeholders.

The Productivity Commission (2011) suggested that the current matching grant capped at 0.5% of the gross value of production created a 'mindset' benchmark which perhaps some have interpreted as an optimal level of investment (p. 148). We are concerned that there seems to be some degree of gamesmanship between government and industry groups arising from the matching grant arrangement discouraging either side from making the first move to increase investment.

We suggest that further thought be given to trialling an increasing graduated uncapped levy, similar to the two-tier system suggested by the Productivity Commission (p. 177). Such an arrangement might encourage an increase in investment by industry beyond present levels.

The Productivity Commission also addressed RDC governance issues. In particular they argued that board members be selected for their skills and experience rather than the industry sector they represented. The Commission did not support the view in many proposals (which the authors of this report share) that there be a government representative on RDCs, as was the case when the model was first established because of potential conflicts of interest. They also called for regular independent monitoring of the performance of the

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[15] The PC argument is also based partly on a contested assessment, not pursued here, that public support for agricultural research is much higher than for research in other sectors.

RDCs including the scientific merit of their portfolios and their final impacts. Some argue that no further strengthening is required but the Commission was not convinced pointing to concerns about whether 'all AWI's (Australian Wool Innovation) performance issues are being carefully addressed' (p. 258) and we share its concerns about the lack of independent auditing processes.

The more recent Green Paper on agricultural competitiveness (Commonwealth of Australia 2014) considered agricultural R&D and extension as one of eleven policy areas impinging on competitiveness. Unfortunately, no reference was made to the stagnation in investment in R&D in Australia as a likely cause of the present slowdown in productivity growth despite reference to other ABARES research in this area. While reference was made to the long lags in the initiation of R&D and the application of the technology on farm, most of the recommendations were related to better coordination and more efficient management of research resources to develop technologies of immediate 'practical on-the-ground' relevance. Overall, the Green Paper did not evaluate the basic research end of the spectrum and to what extent public funding is required.

Other recent reviews (NFF Blueprint for Agriculture 2013 and PMSEIC 2010) provided stronger support for increasing agricultural R&D in Australia. They also make clear that the scope of R&D activities is not just the development of technologies to enhance farm productivity, but extends to the scientific support required to protect Australia's natural resources, and to provide a scientific basis for describing the food safety, quality and environment attributes of farm products. This also includes research to support regulation and differentiated marketing, and to allow the development of market mechanisms for unpriced outcomes that may be underprovided if these types of research activity were left to industry.

The challenge for agricultural science policy is to generate productivity growth. One way this may be supported is to secure higher rates of investment by both government and industry that exploits the jointness between industry outcomes in the form of new technologies and public-good outcomes in the form of gains in scientific capacity, and new knowledge about the management of environment and human health issues. The gains to society from exploiting the non-rival nature of new knowledge and ameliorating market failure seem of far greater significance than those from additional efforts to reduce 'free-riding'.

5.9 Conclusions

The profitability and future growth in Australia's agricultural sector are driven by its growth in productivity and the terms of trade it faces. In this section we have reviewed past trends in these key parameters and assessed what these trends might be in the future in the light of fast changing demand and supply conditions both domestically and internationally.

Productivity in Australian agriculture grew at a rate of 2.0% from the 1950s until about 2000 and was high relative to other sectors of the Australian economy and the agricultural sectors of OECD countries. Much of this growth in TFP has come from technical change which, driven by R&D, shifts the production frontier outwards. It has been highly variable because of climate variability.

It is a concern that growth in agricultural productivity has slowed certainly since 2000 but perhaps from as far back as 1994 (Sheng et al. 2010) to a rate of less than 1%. Hughes et al. (2011) developed a measure of broadacre cropping TFP adjusted for climate variability. By this measure, growth in TFP between 2000 and 2008 was 0.24% per year with the rate of technical change faring a little better at 0.4% per year. It is tempting to think that now a more normal run of seasons has returned, TFP growth will again resume this long-term 2.0% rate but the current evidence (Sheng et al. 2010; Hughes et al. 2011) likely suggests otherwise.

It seems that a significant proportion of this slowdown in growth can be attributed to the stagnation in public investment in agricultural R&D since the late 1970s, and the more marked decline in recent years. This decline in investment has occurred despite strong evidence that the returns to research have been high, and that the lag between investment and impact on productivity is high. Moreover, high rates of return seem more consistent with a hypothesis that there is market failure in the provision of research services.

The funding of agricultural R&D has been subject to several Productivity Commission Inquiries but the inherent public-good characteristics of the knowledge generated by research and the inherent jointness in public- and private-good outcomes make unambiguous improvements to the existing RDC model difficult to identify. We support the suggestions in the 2011 Inquiry that an uncapped increasing public grant might provide an incentive for increased industry contributions. We also support increased auditing of the performance of the RDCs particularly relating to how projects are assessed for their scientific merit and the balance of likely industry and public-good outcomes.

The suggestion that the rate of growth of TFP could stay at less than 1.0% rather than recover to a long-term rate of 2.0%, poses a challenge for the future competitiveness of agriculture, both domestically and internationally. It seems likely that to maintain TFP growth in the 2.0–2.5% per year range, investment in agricultural R&D has to be returned to a level of 3.0% of agriculture’s GVAP (or 5% of GDP). This is a major challenge for government and industry.

Other sources of productivity growth such as technical efficiency seem unimportant relative to research-driven technical change. Most empirical work suggests that Australian farmers are operating close to the production frontier although Hughes et al. (2011) suggest a drift away from the frontier in recent years. While climate change offsets productivity growth, its impact would be reduced if TFP growth were to resume a 2% per year trajectory.

Strong productivity growth in the rest of the economy could boost agricultural productivity. Gains in infrastructure, telecommunications, microeconomic reform and education have an impact on agriculture. These links have not been properly explored empirically.

Domestically, agriculture has to compete for resources with other sectors of the economy such as the mining sector and also faces demands for better environmental outcomes as discussed in the next section. Climate change and biosecurity risks also threaten productivity and are discussed in a later section.

Internationally, high growth countries like India and China provide promise of growing markets. Scenarios about future supply and demand conditions in developing countries are highly uncertain. Some have argued the world demand for food will double by 2050 and Pardey et al. (2014a) have estimated growth more conservatively at about two-thirds larger than current output. Moreover, the competition to fill these markets will be strong. Recent trade agreements show promise for some sectors of Australian agriculture such as the dairy, beef and wine sectors but notably grains have received little consideration, perhaps reflecting a continuing drive for self-sufficiency in staple foods in some large countries. There is also evidence that agricultural productivity growth in developing countries such as Brazil, India and China, where R&D investment is now so strong, is faster than in developed countries such as Australia and this will enhance their competitiveness in the expanding market for food in coming decades.

6. Resources

John Williams

6.1 Introduction

This section of the report examines the key resources and factors that determine sustainable agricultural production in Australia. Ultimately, future Australian agricultural production will depend on access to people and their human capital, to water, soil, nutrients and a range of ecological services derived from a healthy functioning agro-ecosystem sustainably connected to its landscape.

The *Agricultural Competitiveness Green Paper* (Commonwealth of Australia 2014) highlights the identification and building of the water infrastructure needed for Australia's future water supply needs: ensuring sustainable and productive use of natural resources for economic growth and development, improving our knowledge of sustainable resources use, and managing weeds and pests. It states accurately, in our view, that:

> *The future of agriculture depends on sustainable use of natural resources. Globally competing land-use pressures, limited surface water supplies and depleting reserves of groundwater are constraining the resources available for farming. Australian farmers, even more so than their global competitors, must adapt to climate variability. Effective management of environmental risks facing agriculture is likely to help safeguard future productivity and competitiveness.*

This section will focus on key inputs such as soil and water to agriculture, and also examine the impacts of agriculture on native flora and fauna within the context of the ecological infrastructure and the ecosystem services biodiversity provides for agriculture and the wider society as a whole. Importantly, this resources section will describe the people resources and human capital driving Australian agriculture and the issues of knowledge generation, management and engagement in farming communities that will be critical to agriculture in the future. It will also examine the potential environmental and other constraints to maintaining or growing the supply of agricultural products.

6.2 Australian water resources and agriculture

Living in the driest inhabited continent which exhibits the most highly variable annual and seasonal rainfall patterns on the planet (Peel et al. 2001; McMahon et al. 2007), indicates that the agricultural future of Australia will be strongly determined by the manner in which water resources are understood, allocated, used, managed and governed, as this most scarce resource limits production.

Total long-term mean runoff from Australia is approximately 387,184 gigalitres (GL) with a sustainable yield of groundwater of 25,780 GL to give Australia approximately 413,000 GL of water available annually (Chartres and Williams 2006, see Table 2). The best estimate of how much water can be diverted and turned to human use is approximately 105,000 GL per annum. At present, Australians extract about 70,000 GL, discharge largely via hydro and thermal power generation some 50,000 GL and consume about 25,000 GL, of which 70% is used in agriculture (Chartres and Williams 2006).

To reduce this risk and to ensure stability of water availability under Australia's very high variability in rainfall and runoff, Australians store more water per person than any other country. Currently Australia has storage capacity for surface water of approximately 80,000 GL, about 25% of continental runoff. The largest storage capacity of 30,035 GL is in the Murray–Darling Basin (MDB) followed by 22,073 GL in Tasmania and 10,710 GL in the Timor Sea (Ord) Drainage Division. The water storages for the Australian Drainage Divisions shown in Figure 12 are set down in Figure 13, noting that Tasmania has multiple drainage basins. This provides a context for subsequent discussion of location, nature and magnitude of Australia's potentially exploitable extraction for agriculture.

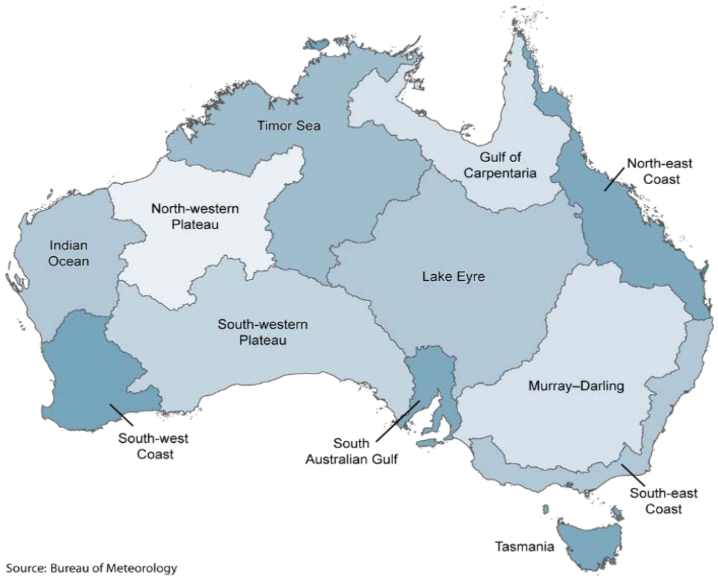


Figure 12: **Australian drainage basins**.
Source: Australian Government, Department of Environment at:
http://www.environment.gov.au/science/soe/2011-report/4-inland-water/1-introduction/1-2-resources-and-use

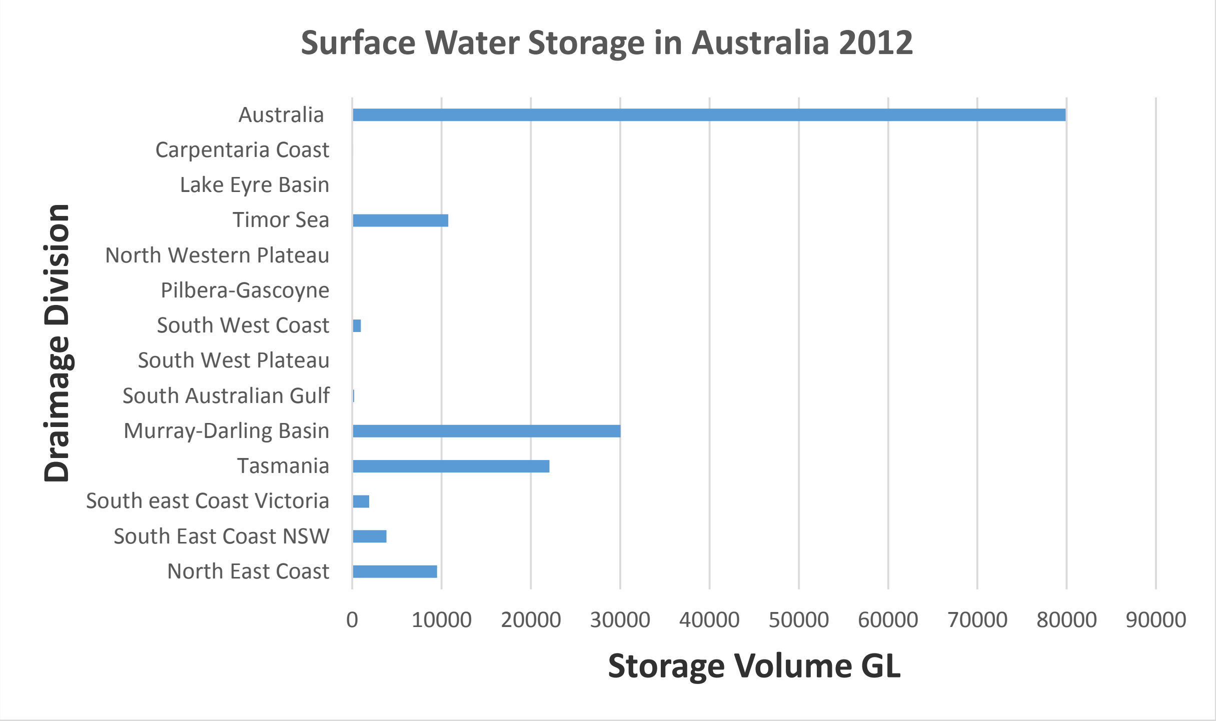


Figure 13: Surface water storage capacity in Australia 2012.
Source: Bureau of Meteorology (2012).

Water was used in the Australian economy during 2011–2012, in the following ways. Of approximately 400,000 GL of Australian runoff, some 74,925 GL of water was extracted for the environment. Electricity and gas supply industries extracted 58,632 GL, mostly for hydro-electricity generation which returned around 92% to the environment. Water consumption by all industries was 14,303 GL where agriculture consumed the largest volume of water at 9,418 GL, representing 59% of Australia's water consumption in 2011–12, followed by the water supply and sewerage services industry (2,029 GL, 13% of the total consumption), households (1,715 GL, 11%), mining (677 GL, 4%) and manufacturing (557 GL, 3%).

Water use in Australia has a large variability reflecting, as it must, the rainfall variability. This is shown in Table 3.

Table 3: Australian water use in years 2000–1, 2004–5 and 2008–9 and water use in States for 2008–9.
Source: Australian Government, Department of Environment at:
http://www.environment.gov.au/science/soe/2011-report/4-inland-water/1-introduction/1-2-resources-and-use

Australian Water Use				2008-2009							
	2000–01	2004–05	2008–09	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Agriculture	14 989	12 191	6996	2001	1435	2144	788	325	264	35	2
Electricity and gas	255	271	328	92	123	82	2	27	–	1	–
Manufacturing	549	589	677	150	158	148	88	61	50	22	–
Forestry and fishing	40	47	101	1	1	6	2	89	3	–	–
Household	2278	2108	1768	536	342	308	122	326	69	39	27
Mining	321	413	508	66	6	118	22	257	18	21	–
Water supplya	2165	2083	2396	1329	558	297	111	64	22	9	7
Other industriesb	1106	1063	1327	387	367	249	79	176	30	27	11
Total	21 703	18 767	14 101								

6.2.1 *Agricultural water use, gross value and water markets*

Agricultural water use in irrigated agriculture in Australia is greatly dependent on the rainfall seasons and management of the 80,000 GL of public storages. Figure 14 shows the agricultural water use since 2002.

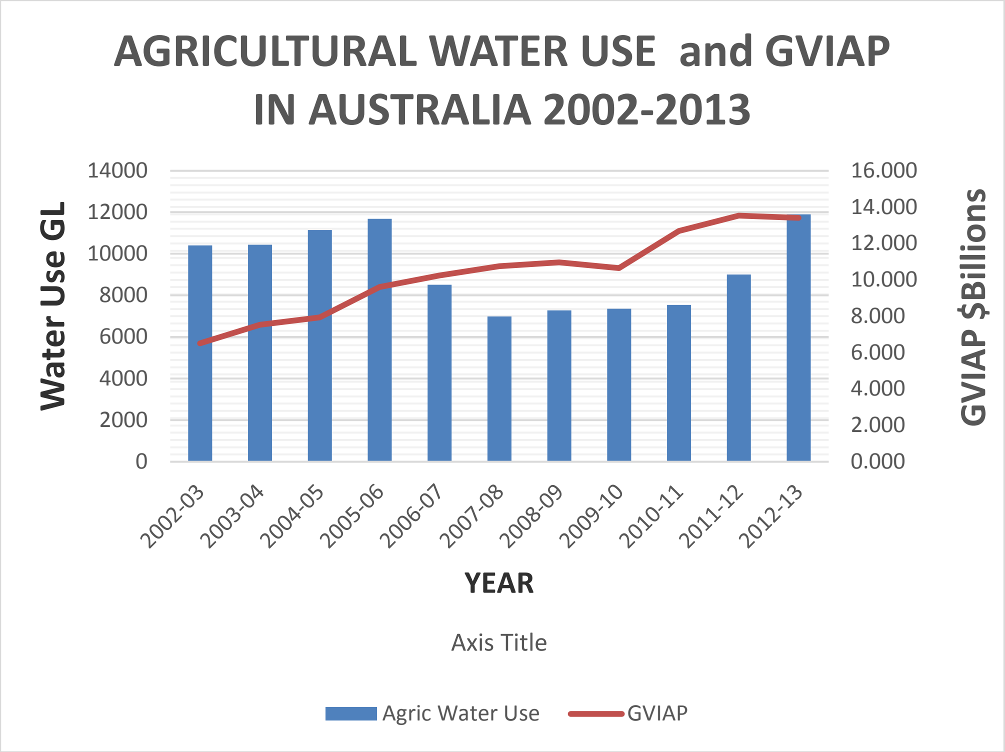


Figure 14: **Agricultural water use and gross value of irrigated agricultural production (GVIAP) in Australia for years 2002 to 2013.**
Source: Australian Bureau of Statistics at:
http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/A5A4DA2DF9F997A0CA2571AD007DDFD4?opendocument

Agricultural water use has varied from less than 7,000 GL in 2007–2008 at the peak of the Millennium Drought to nearly 12,000 GL prior to, and following, the drought. The water use and GVIAP shown in Figure 14 indicate that water use and GVIAP are not correlated. During the drought, the GVIAP held near-constant despite the large fall in water use. The adaption and use of water markets over that time has been shown to be a very important means to insulate to GVIAP from water use variation (Kirby et al. 2014; Grafton et al. 2011, 2012, 2014; Grafton and Horne 2014).

In 2012–13, the gross value of agricultural production (GVAP) was $48.0 billion of which GVIAP was $13.4 billion representing 28% of agricultural production. In 2011–12, the gross value of irrigated agricultural production (GVIAP) constituted 29% of the total gross value of agricultural production (GVAP) for Australia. Over many years the percentage of irrigated agriculture to total Australian agricultural gross value has ranged between 28% and 32%. In the Murray–Darling Basin (MDB), the GVIAP totalled 36% of GVAP in 2011–12 and it is consistently of this order. In Tasmania, some 57% of gross value of agriculture is contributed by irrigated agriculture. The three commodities with the highest proportion of irrigated GVAP were rice (with 100% of GVAP being irrigated), grapes (with 93% of GVAP being irrigated), and cotton (with 92% of GVAP being irrigated).

The gross value of irrigated agriculture is of fundamental importance when considering water use in terms of either scarcity or as a constraint to Australia's agricultural future productivity. For 2011–12, the agricultural water use in irrigation for each of the commodities is displayed in Figure 15 along with the gross value for that commodity.

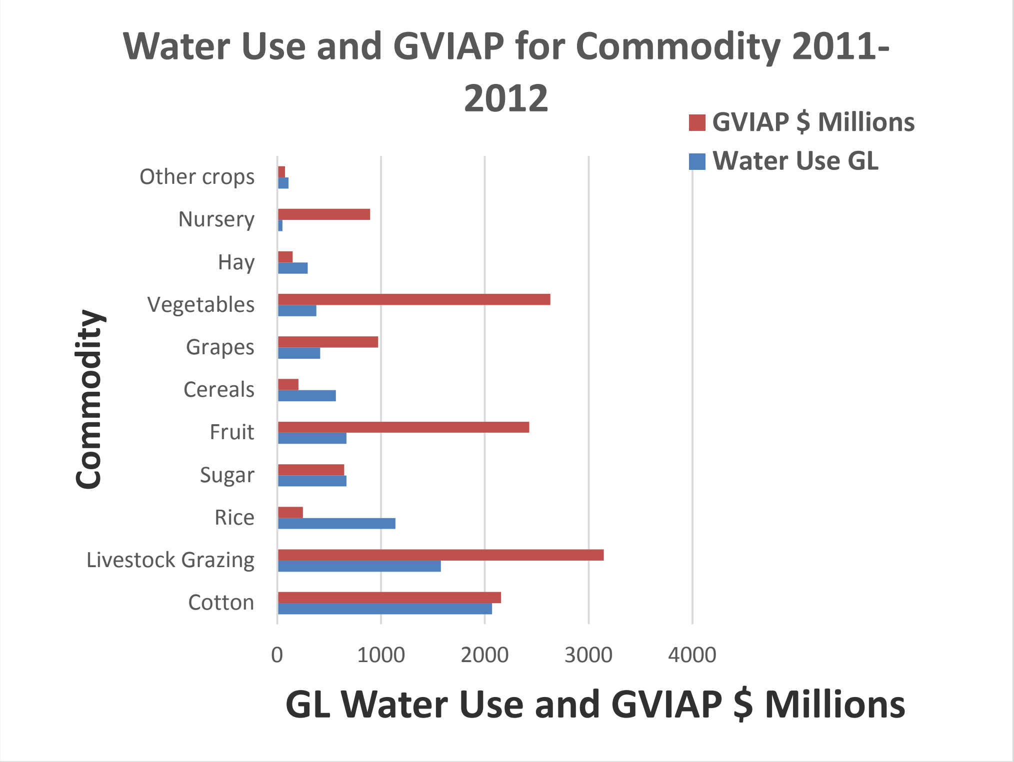


Figure 15: Commodity water use and gross value for irrigated agriculture in Australia 2011–12. Source of data: **http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/4610.0.55.008Main%20Features42011-12?opendocument&tabname=Summary&prodno=4610.0.55.008&issue=2011-12&num=&view**

The gross value per unit volume of water used

Typically, there is a very large difference between the gross value of the commodity (as in Figure 15) and the gross value per unit volume of water used to produce that commodity. This is shown in Figure 16 for each commodity.

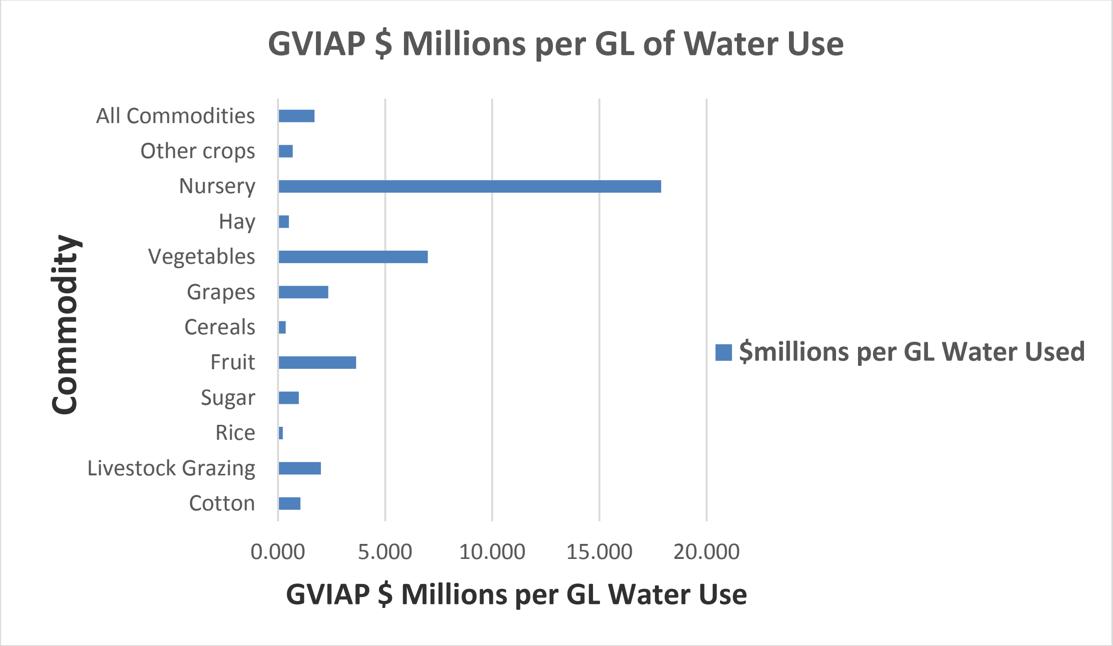


Figure 16: **Commodity value per volume of water used in Australian irrigated agriculture 2011–12. Source of data:**
http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/4610.0.55.008Main%20Features42011-12?opendocument&tabname=Summary&prodno=4610.0.55.008&issue=2011-12&num=&view

The use of water in nursery industries generated a gross value of $17 million for each GL of water used by these enterprises while the vegetables, fruit, grapes and grazing livestock (dairy, beef and sheep meats) generated $7 million, $3.6 million, $2.3 million and $2 million per gigalitre (GL) of water used, respectively, in 2011–12. Most other commodities generated less than $1 million per gigalitre of water used.

Overall, Australian irrigated agriculture in 2011–12 generated a real gross value of $1.7 million per gigalitre of water used. This compares with $1.54 million and $1.45 million per gigalitre of water used in 2007–08 and 2009–10 during the Millennium Drought.

Water markets

The development of water markets has been an important economic lever to improve the allocation of water use to highest value in agricultural use (Grafton et al. 2011, 2012; Grafton and Horne 2014; Kirby et al. 2014). Thus there is a strong evidence-based case for continuing the development, facilitation and regulation to support water markets as a vital part of Australia's agricultural future.

Riverina Rice: some characteristics of Opportunistic Diversification and Sustainable Intensification

Australia's annual rice production is directly related to the amount of water available. Most rice is grown by general security irrigators who receive their water last in the hierarchy of allocations. They are also the first to have allocations reduced in times of water shortages. Traditionally, Australian farmers produced around 1.2 million tonnes of rice each year from approximately 150,000 ha. However, during the Millennium Drought, production levels dropped to 19,000 tonnes due to water restrictions and in recent years production has returned to pre-drought levels.

A rice crop forms one part of a farming system. It is only planted when the conditions are suitable. Rice is grown from October until March and in rotation with other crops such as wheat, barley and maize. Many of these crops grown in rotation with rice utilising the residual soil moisture after the rice crop is harvested. This means that rotations do not require further irrigation and allows for further water savings and more efficient water usage, and effectively provides growers with two crops from the one application of water.

Essentially, the rice industry is able to operate in an opportunistic manner by using water when it is available and close down production when it is not available. This makes it well-suited to Australia's variable climate. Rice growers have introduced a number of adaptation strategies to respond to reduced water availability, including water trading, on-farm water-use efficiency and diversification. When water is not available or too expensive, other sources of income are generated including integration with livestock, particularly sheep, off-farm sources of income through investments in the share market, off-farm employment, contract sowing and harvesting and operating related retail enterprises.

Water can account for 20% to 30% of the total variable cost of rice production. Thus, growers have strong incentives to reduce water use without affecting productivity to improve profit margins and also to avoid rising water tables and salinity. In the past 15 years, rice growers have increased production per hectare by 60% while at the same time decreasing water use per hectare by 30% such that, internationally, Australian rice production uses less water per hectare than other countries and is consistently in the top 4 of water-efficient producers.

Average Australian yield is 9 tonnes/ha, but some farms have recorded yields as high as 14 tonnes/ha while the world average is about 4 tonnes/ha. Productivity with improved water management technology over a 15-year period has increased from 0.4 to around 1.0 tonnes of rice per ML of water.

When water is available for irrigation, rice is a major user of water in Australia, accounting for some 11% of irrigated water use. Despite the high and increasing productivity per unit of water the $ value per unit of water for rice is low. ***Sun Rice*** through progressive food processing and innovative food products development can turn the rice in a ***ready-to-eat meal*** to have a value equivalent to over $10,000 per tonne of rice.

Careful water management of rice farms is needed to ensure both environmental sustainability and rice productivity. Land and Water Management Plans are the cornerstone of environmental initiatives in the irrigation areas of the Riverina.

References:

Dunn B, Gaydon D and Dunn C (2010). *Saving water, lifting efficiency.* Industry & Investment NSW, Yanco, Agricultural Institute and CSIRO Sustainable Ecosystems, Queensland. IREC Farmers Newsletter, Spring, 2010.

Hyder (2010). Rice Industry Case Study-conducted for The Central Murray *Strengthening Basin Communities* project and the Riverina and Murray Regional Organisation of Councils (RAMROCs) Cluster Group, Sydney, October 2010. http://www.berriganshire.nsw.gov.au/Portals/0/documents/central%20murray%20%20synthesis%20report%20part%202%2022%20Dec.pdf

6.2.2 Future water resources for agriculture

Australia is at the crossroads in terms of its ability to cope with increasing water scarcity in that it has to determine a mix between the more expensive capital and environmentally risky options of more storages and water infrastructure, and a minimisation of these via better water reuse strategies and increased water efficiency. This can be facilitated by a next generation of water reform building on the National Water Initiative (NWI) and appropriate COAG (Council of Australian Governments) arrangements and agreements. It is encouraging that the *Agricultural Competitiveness Green Paper* also stresses the importance of NWI principles.

In particular, the Green Paper principles, in terms of water, include:

- *Projects need to be nationally significant and in the national interest.*
- *There must be strong State or Territory Government support with capital contribution and involvement of the private sector and, where appropriate Local Government. The investment should provide the highest net benefit of all options available to increase access to water, taking into account economic, social and environmental impacts.*
- *Projects should address a market failure which cannot be addressed by proponents, State and Territory Governments or other stakeholders and limits a project of national significance from being delivered.*
- *Projects should align with the government's broader infrastructure agenda to promote economic growth and productivity, or provide a demonstrable public benefit and address a community need.*
- *Projects should align with the National Water Initiative principles including appropriate cost recovery and, where full cost recovery is not deemed feasible, any subsidies are fully transparent to the community.*
- *If providing capital, a consistent, robust analysis of costs and benefits is used and assessment is undertaken by Infrastructure Australia or similar experts.*

Building on the NWI principles, along with adoption and implementation of the robust investment principles declared in the Green Paper, will prove to be of paramount importance to Australia's agricultural future.

In 2010–2011, Australia had over 1.96 million ha under irrigation. Almost 75% of this was in the southern states (NSW, Victoria, South Australia, Tasmania), with Queensland, the Northern Territory and Western Australia accounting for 536,000 ha. Together, this irrigated area of agriculture used approximately 12,000 GL of water and generated about 30% of gross value of agricultural production. Thus access to increased water supplies supports the expansion of Australian agriculture.

What are the potentially exploitable water resources for agriculture?

Australia's water resources are not only temporally but also spatially highly variable. This variability is due to the hydrological form and function of the catchments, but also a result of the large diversity of climatic conditions ranging from Mediterranean winter-dominant rainfall patterns to the monsoon summer-dominant rainfall sequences of the humid and semi-arid tropics. In addition, the level of development in Australia's water resources ranges from heavily regulated rivers and groundwater resources to rivers and aquifers in almost pristine condition (Chartres and Williams 2006).

Over 65% of Australia's runoff is in the three drainage divisions located in the sparsely populated tropical north (Timor Sea, Gulf of Carpentaria and North-East Coast as in Figure 12). By comparison, most large urban cities are situated in southern regions with irrigated agriculture principally located in the Murray–Darling Basin where only 6.1% of the national runoff occurs. Thus at first glance it appears that Australia has significant water resources, but the populations and agricultural activities are concentrated where water resources are most limited. This apparent mismatch has generated considerable political interest and resulted in scientific studies into the development of water resources for agriculture in northern Australia. While there is greater runoff in northern Australia, much more work remains to be done before there are reliable estimates of how and where Australian water can be best captured and used for agriculture.

A continental scale assessment

Petheram et al. (2010) provide a useful peer reviewed continental scale assessment of Australia's potential for irrigation. They provide a methodology to give a first order estimate of the potentially exploitable yield from catchments across Australia using streamflow data and modelling assembled by the CSIRO Sustainable Yields Project, and a methodology building on much older work by the Australian Water Research Council (AWRC 1988). Their estimates of the potential exploitable yield is show in Figure 17 for the drainage basins illustrated in Figure 12.

They conclude that, despite northern Australia generating approximately 64% of the continent's runoff, only 45% of Australia's potentially exploitable yield is located in that portion of Australia, due to unfavourable streamflow characteristics, storage constraints and large evaporation losses. Nevertheless, at this scale of examination of northern Australia the three drainage divisions of Timor Sea, Gulf of Carpentaria and the North-East Coast potentially have some 36,000 GL per year of potentially exploitable water. Tasmania has some 19,000 GL per year or approximately 25% of the total potentially exploitable water yield.

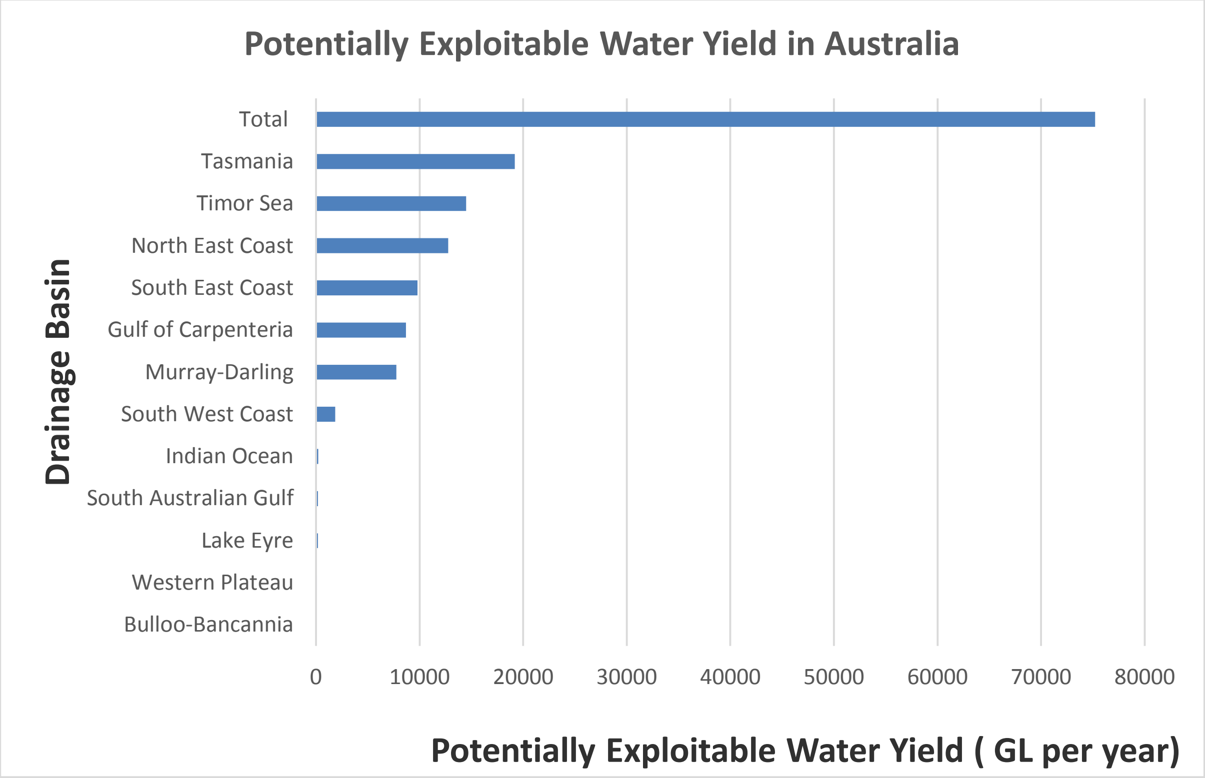


Figure 17: **Potentially exploitable water yield in Australia.**
Source: Petheram et al. (2010), Table 4.

While a continental scale assessment shows where large potentially exploitable water is located, it does not consider critical issues such as representative irrigation requirement (Petheram et al. 2010) and the host of land, soil and topographic issues. To cover these issues, a much smaller spatial scale resolution is required.

The three tropical drainage divisions and Tasmania are where there appears to be significant potential for agriculture on the basis of water resources. The challenge and opportunity for Australia's agricultural future is to build productive and sustainable access to these additional resources using NWI principles along with economic, social and environmental analyses. These challenging issues are dealt with at length by the Northern Australia Land and Water Taskforce (2009b).

6.2.2.1 *Water resources for irrigated agriculture in north Australia*

Current irrigation in north Australia

In northern Australia, the major large-scale irrigation schemes are in the Lower Burdekin River in north Queensland, the Ord River Irrigation Area (ORIA) in the far north of Western Australia, and the Katherine–Douglas–Daly Area (KDDA) in the Northern Territory (Petheram et al. 2008). The Lower Burdekin is northern Australia's largest irrigation area with around 80,000 ha of irrigated land used predominantly for growing sugar cane using a combination of groundwater from the Burdekin Delta and surface water from the Burdekin River. The land under irrigation is in the North-East Drainage Basin.

The Ord River Irrigation Area (ORIA) consists of 13,000 ha of irrigated land that has, over its 50-year history, been used for a wide variety of crops, including cotton, rice and sugar cane, but which is now used principally for sandalwood and horticultural crops. It relies entirely on surface waters harvested from the Ord Catchment and stored in Lake Argyle and Lake Kununurra. The Katherine–Douglas–Daly Aquifer (KDDA) irrigates around 2,200 ha of perennial horticulture and field crops such as maize, peanuts and forage and utilises groundwater extracted from the Daly Basin (Petheram et al. 2008). The current expansion of the Ord (Stage II) will bring the irrigated area to 28,000 ha (Western Australia Department of State Development 2013).

Surface water resources in north Australia

There is an extensive suite of reports and some peer reviewed literature now available focused on establishing the potentially exploitable water for irrigation in northern Australia. The CSIRO Northern Australia Sustainable Yields Project (CSIRO 2009a), supported by a large array of technical reports, is a key study. This was followed by the Northern Australia Land and Water Taskforce (NALWT 2009) and, in the past five years, a number of reports principally by CSIRO for Commonwealth Departments and, most recently, the Office of Northern Australia within the Australian Government Department of Infrastructure and Regional Development (Ash et al. 2014; Grice et al. 2013a).

The Northern Australia Sustainable Yields Project (CSIRO 2009a) outlined the characteristics and emerging constraints to water resource development in capturing the large runoff of nearly 200,000 GL from the three drainage divisions of the Timor Sea, Gulf of Carpentaria and northern North-East Coast. The report signals that opportunities to increase water storage are limited, because across the Timor Sea and Gulf of Carpentaria Drainage Divisions most rainfall falls near the coast where the landscape is generally flat. As a result, there is little opportunity to increase surface water storages. The main exception to this is in the Van Diemen region in the catchments surrounding Darwin. Opportunities are mainly in the upper reaches of catchments; however, in these areas rainfall is lower and more sporadic, and potential evapotranspiration is highest. Indeed, in northern Australia, storages would have large evaporation losses. In the headwaters of the Mitchell and other Cape York catchments, where rainfall is higher and there is higher relief, there are opportunities for surface water storages, but environmental flow regimes will be of critical importance. In the northern North-East Coast Drainage Division, because of the high relief away from the coast, the potential for surface water storage is good, but high evaporation rates mean that storages can rarely be large enough to survive through the dry season. The sanguine analysis from the CSIRO Northern Australia Sustainable Yields Project further concludes that:

> *High variability in streamflows also necessitates larger carry-over storages compared to rivers in southern parts of the country (or elsewhere in the world), for a given rainfall regime. Drought severity is also greater than elsewhere and, to be able to provide for runs of multiple dry years, future storages would require two to 10 times the volume of a similar supply for elsewhere.*

As part of the CSIRO Northern Australia Sustainable Yields (NASY) work, Petheram et al. (2009) provided new and detailed streamflow modelling across the three drainage divisions (see Figure 12 and Figure 17) of northern Australia to try to determine a potential divertible volume from these catchments. Petheram et al. (2009) (their Figure 38 on page 51) found eight river basins were estimated to have potentially divertible volumes greater than 1,500 GL per year. These are the Fitzroy, Ord, Victoria, Daly, South Alligator, Roper, Mitchell and Wenlock River Basins. The majority of the Australian Water Resources Council river basins south of the Mitchell River Basin in the Gulf of Carpentaria have a divertible yield of less than 250 GL per year, largely because of very low relief, which limits the development of reservoirs and hence acts as a major constraint to potentially divertible yield. It should be noted, however, that this is a broad analysis and that economic, social, cultural or environmental factors were not considered. Appropriate consideration of these factors would serve to further constrain the divertible yield volumes.

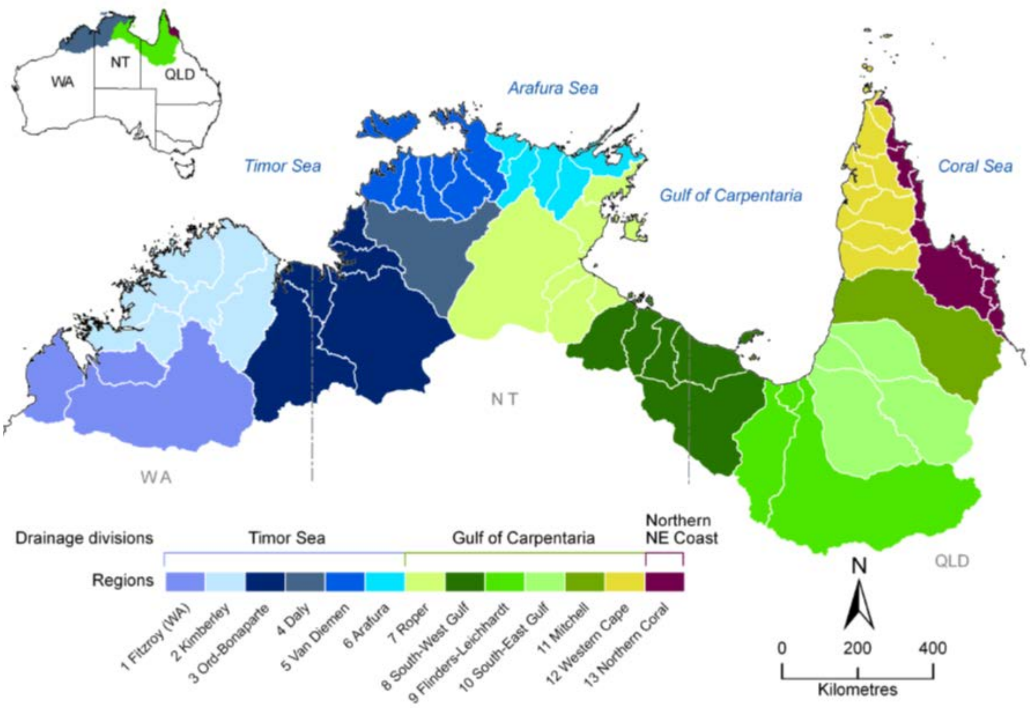


Figure 18: River basin boundaries used in the CSIRO Northern Australia Sustainable Yields Project for the three drainage divisions.
Source: Petheram et al. (2009).

The streamflow predictions of Petheram et al. (2009) for the eight river basins identified by Petheram et al. (2009) as having exploitable yield above 1,500 GL per year were converted using the methodology and data of Petheram et al. (2010) to give first-cut estimates of exploitable yield for the eight basins examined in the NASY project, and also for the Gilbert and Flinders Catchments.

The results are provided in Figure 19.

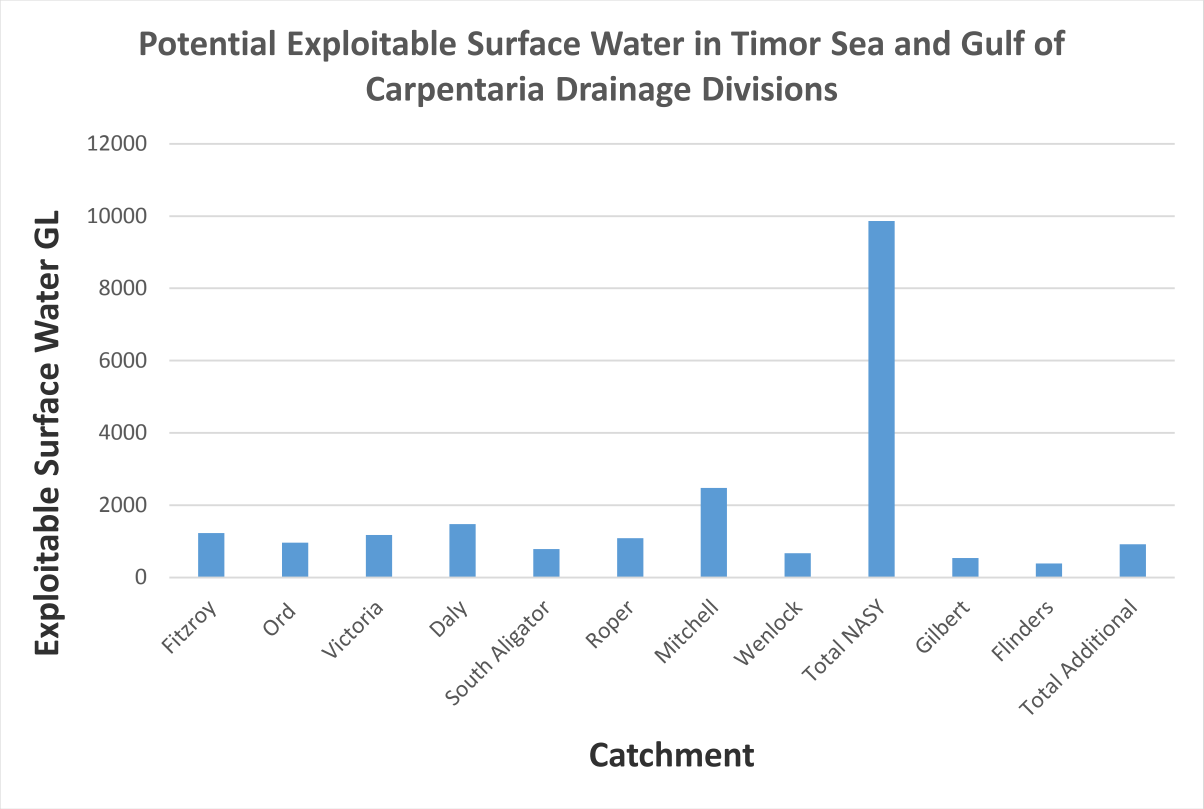


Figure 19: Estimates of potential exploitable surface water in Timor Sea and Gulf of Carpentaria Drainage Divisions using methods of Petheram et al. (2010).

Whilst preliminary, estimates suggest that approximately 10,000 GL per year of exploitable yield exists in these eight catchments. For the Gilbert and Flinders Catchments, preliminary estimates were 538 and 383 GL per year, respectively.

In more recent and detailed work using the best hydrological analysis tools available, Petheram et al. (2013a) provide estimates of 630 and 140 GL per year for the Gilbert and Flinders Catchments.

Subsequent work by Petheram et al. (2013b) proposed that the two prospective in-stream dams (Green Hills and Dagworth Dams) which, when combined, are capable of delivering to crops approximately 250 gigalitres (GL) of water in 85% of years to irrigate some 20,000 to 30,000 ha supporting year-round mixed irrigated and dryland cropping. They also find that there is more soil suited to irrigation in the Gilbert Catchment than there is water to irrigate it.

Water capture and storage options (Petheram et al. 2013b) for the Flinders Catchment show that off-stream storages, such as farm dams, provide the most promising method for supporting large-scale irrigation development in the catchment. Combined off-stream storage is capable of delivering crops with approximately 175 gigalitres (GL) of irrigation water in 70 to 80% of years. This is approximately half of the full storage potential (350 GL) of off-stream storages. Thus there is the potential for an irrigation development totalling 10,000 to 20,000 ha, supporting year-round mixed irrigated and dryland cropping. In total, the six most promising in-stream dams in the Flinders Catchment are, collectively, capable of delivering approximately 80 GL to crops in 85% of years.

Groundwater resources in north Australia

The limited data and assessment available (Cresswell et al. 2009; Northern Australia Land and Water Taskforce (NALWT) 2009a; Grice, Watson and Stone 2013b) assembled for the Northern Australia Land and Water Science Review in 2009 suggest that 600 GL per year of extractable groundwater could be available to irrigate between 50,000 and 120,000 ha in northern Australia, depending on the type of crop and irrigation efficiency. This represents less than 0.08% of pastoral land and 0.05% of the drainage basins examined (see Figure 17). The 600 GL per year, which has a large degree of uncertainty (Cresswell et al. 2009), is primarily derived from three basins namely the central Daly–Wiso and Georgina; the coastal section of the Canning Basin; and the Great Artesian Basin, each of which has an estimated extractable groundwater volume of over 100 GL per year. The remainder of the estimated 600 GL per year appears to be made up of smaller aquifers (10 to 100 GL) distributed across the southern sections of the Daly–Wiso and Georgina and the inland portion of the Canning Basins.

Summary: water resources and agriculture in north Australia

Based on other analysis of exploitable water for agriculture in the Timor Sea and Gulf of Carpentaria, it is probable that the estimates of availability for agriculture is very much smaller than the 23,178 GL per year provided by Petheram et al. (2010). It is plausible that exploitable water for irrigated agriculture may approach 10,000 GL per year, but this appears to be near the upper limits when set against more detailed and recent analysis for the Flinders and Gilbert Catchments. In short, there is increasing evidence that the volumes of water that can be captured tend to be much smaller than broad scale assessments. For example, our broad scale water assessment for the Gilbert was 538 GL per year, but after detailed analysis it appears that approximately 250 GL per year are available for the feasible storages. This is without consideration of the economic, social, cultural or environmental factors. Likewise in the Flinders, where our broad scale assessment suggested some 383 GL per year were available, but careful hydrological and engineering scrutiny indicates 175 GL per year of off-stream storages is more feasible.

Overall, there are water resources available to be captured in north Australia, but they are very much smaller than what has been implied in the past from a simple consideration of streamflow information (Petheram et al. 2010). The challenge for Australia's agricultural future will be to find innovative ways to identify the opportunities and subject any water withdrawals to the best science available and employ the NWI principles. Innovation in water use will also be important in reconciling alternative use and non-uses of water. For instance, irrigation mosaics that consist of a patchwork of dryland and small irrigation areas is an alternative approach to traditional large-scale contiguous irrigation systems (Bristow et al. 2008; Grice, Watson and Stone 2013b). Current evidence suggests that mosaic irrigation patterns are well suited to spatially variable and relatively small groundwater systems where recharge mechanisms operate at highly variable spatial and temporal patterns provided they are operated at a small proportion of the systems sustainable yield, (Bristow et al. 2008; Cook et al. 2008). In particular, mosaic irrigation is well-aligned to capture increased productivity and resilience when integrated with the beef industry (Figure 20 below).

Figure 20: Mosaic irrigation for north Australian beef industry.
Source: Grice, Watson and Stone (2013b).

6.2.2.2 Water resources for irrigated agriculture in Tasmanian Drainage Basins

Surface water

The Tasmanian drainage division is computed (Petheram et al. 2010) to yield nearly 20,000 GL per year of potentially exploitable water, the largest for all of Australia's drainage divisions. Tasmania also has the smallest representative irrigation requirement of approximately 330 mm per year which affords considerable efficiency in water use and water productivity. The CSIRO Tasmania Sustainable Yields Project (TasSY) has completed a detailed assessment for five of the six major catchment basins which are illustrated in Figure 21.

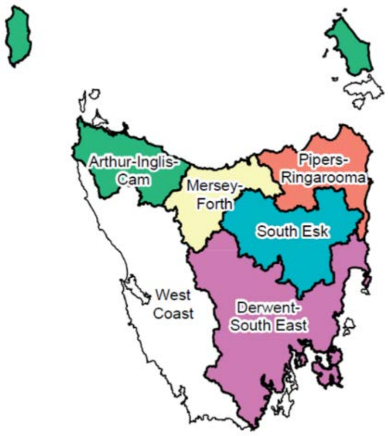


Figure 21: The catchment basins for Tasmania.
Source: CSIRO (2009c).

The annual streamflow for the Tasmanian drainage division is approximately 47,423 GL of which the West Coast accounts for 25,608 GL that is extensively used for hydro-electricity generation. The remaining 21,815 GL per year flow in the other five basins studied by CSIRO TasSY. These have a mean annual rainfall under historical climate of 1,046 mm of which some 440 mm is winter-dominated runoff.

Mean annual streamflow is 21,815 GL per year of which about 636 GL per year (3%) is extracted for use. At 6% of the streamflow, the South Esk region has the highest level of extraction relative to other regions. The main rivers of most catchments are perennial, flowing for more than 95% of the time. Groundwater extraction is 38 GL per year, most of which occurs in the Arthur–Inglis–Cam (42%) and Mersey–Forth (46%) regions as projected.

Using the same streamflow data and modelling of CSIRO (2009c), and the methodology of Petheram et al. (2010), we have estimated the potentially exploitable water for the five river basins in Tasmania, excluding the West Coast. The preliminary results are shown in Figure 22.

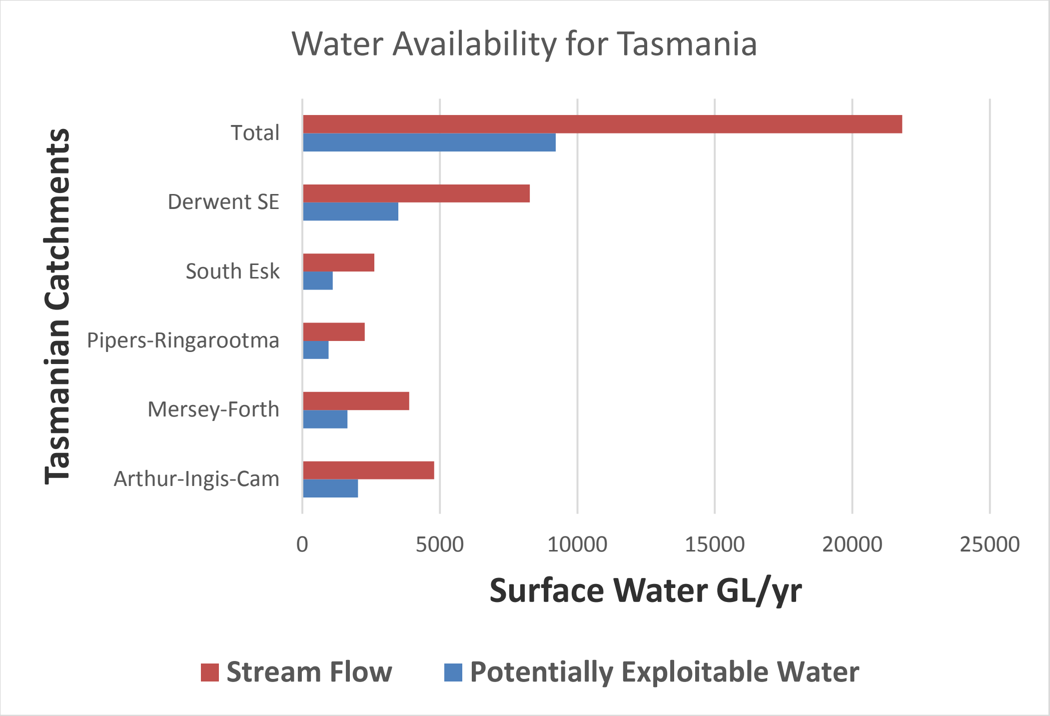


Figure 22: Estimated annual potentially exploitable water yield and annual streamflow for five river catchments in Tasmania.

These estimates suggest that there is potentially an exploitable yield of surface water in these five catchments approaching 10,000 GL per year. The current future development of irrigation in these catchments is planned to take current annual extractions from 636 GL to about 756 GL (CSIRO 2009c) and is sustainable below the exploitable yield of surface water. In Figure 23, the planned extraction and estimates of exploitable yields of surface water show that extractions are a small percentage of our estimates of exploitable yields. Nevertheless, CSIRO (2009c) shows that despite this low level of extraction relative to estimates of exploitable yield, discernible and in some cases significant, ecological impacts are evident. This serves as a signal about how water extraction affects catchment, estuary and near-shore environments. These landscapes can be adversely impacted by what appear to be small shifts in stream hydrology when only means are examined. This is an issue which will need to be part of the understanding and science used to evaluate water available for agriculture in Australia's agricultural future.

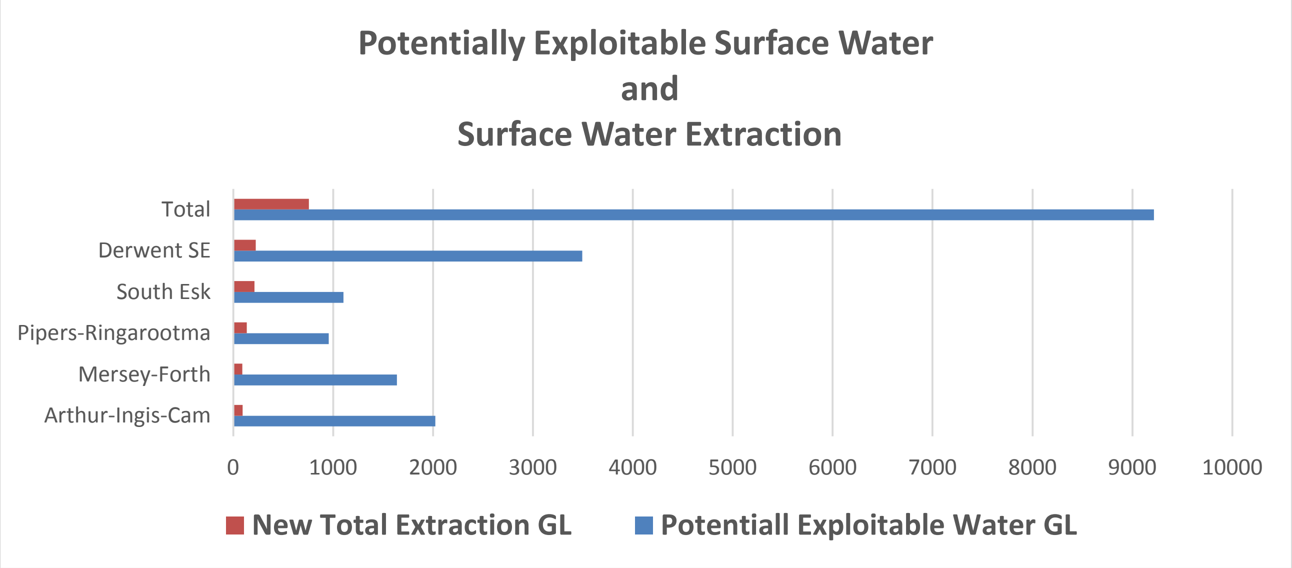


Figure 23: Planned surface water extraction and estimated potentially exploitable surface water in Tasmania. Source: Based on CSIRO (2009c); Petheram et al. (2010) methodology.

Groundwater

The current groundwater extraction is 38 GL while the estimated sustainable groundwater recharge is around 1,085 GL per annum.

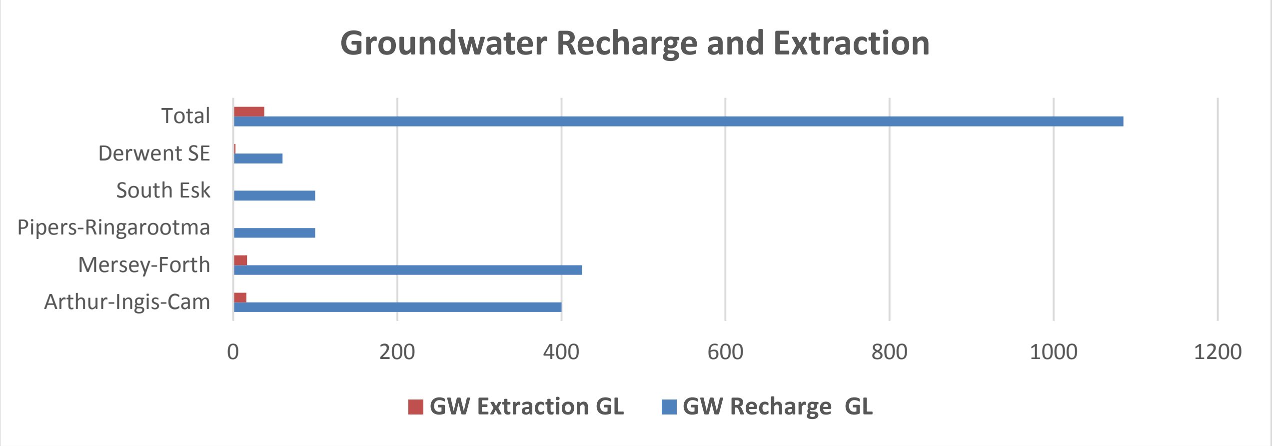


Figure 24: Estimates of groundwater recharge and current levels of extraction in Tasmanian catchments. Source: Based on CSIRO (2009c).

Most of this groundwater extraction of 38 GL per year occurs in the Arthur–Inglis–Cam (42%) and Mersey–Forth (46%) regions. Under the wet extreme historical climate, extraction as a percentage of recharge is, on average, less than 2% over all groundwater assessment areas combined (see Figure 24). Future development of groundwater was modelled by increasing extractions to 25% of recharge in the Mella, Togari, Wesley Vale and Scottsdale groundwater assessment areas. Such increases are expected to have only localised impacts on groundwater levels and gaining or losing streams in irrigated parts of these areas (CSIRO 2009c).

Summary: water resources and agriculture in Tasmania

In summary, there appears to be similar levels of exploitable water in Tasmania as there is in the Timor Sea and Carpentaria drainage divisions in north Australia. In Tasmania, the current level of extractions for groundwater remain small (1 to 2%) of groundwater recharge. It appears the Tasmanian opportunities will not be constrained by access to water, but constrained by suitable soils and topography. The *Agricultural Competitiveness Green Paper* identified a number of new irrigation possibilities in these catchments for evaluation and development. Most of these proposals are for small-scale regional schemes using both surface and groundwater often operating as an irrigation mosaic in the landscape, rather than large contiguous irrigation areas. Despite this low level of extraction relative to estimates of exploitable yield or groundwater recharge, the early signals (CSIRO 2009c) of discernible, and in some cases significant, ecological impacts are evident.

Australia's agricultural future will need to equip itself with science and understanding about how water extraction adversely affects catchment, estuary and near-shore ecological environmental function and assets. This is an issue which will need to be part of the understanding and science used to evaluate water available for agriculture in determining Australia's agricultural future. In the Tasmanian Drainage Basins this will be of particular importance to ensure that agricultural development of water resources does not compromise the use of the ecosystems and also tourism, fishing, and recreational use activities and the heritage values of the Tasmanian landscapes and ecosystems.

6.2.2.3 Overview: potentially exploitable water resources for agriculture in Australia

Exploitable water resources for agriculture exist in Tasmania and the three drainage divisions of tropical Australia. The exploitable yields appear from our work to be in the order of 10,000 GL each for both Tasmania and northern Australia drainage divisions of Timor Sea and Gulf of Carpentaria. It has been estimated by Petheram et al. (2010) that the North-East Coast Drainage Division could generate approximately 12,000 GL per annum of potential exploitable yield. Nevertheless, studies over the past 15 years, particularly in northern Australia, but also in Tasmania, have shown that the water that can be potentially captured and the land area that can be irrigated is very much smaller than initially anticipated.

Based on these estimates and the experience to date on how broad-scale estimates tend to be very much reduced under more detailed hydrological, land suitability and engineering analysis, it would appear that the total potentially exploitable yield of water that could be captured for future irrigated development in Australia is of the order of 25,000 GL.

The Northern Australia Land and Water Taskforce (2009b) in their report to government on sustainable development in northern Australia illustrates some of the social, economic and environmental issues, their complexity and some of the knowledge, tools and the human processes that will need to be part of Australia's agricultural future. They draw attention to the biophysical reality that:

> *All water is fully in use. The water balance is closed; even "wasted" water running out to sea is needed by estuarine systems and near-shore ecosystems. Underground, groundwater supports riparian vegetation, maintains perennial reaches of many rivers and provides a dry-season source of water. Whilst current levels of use are low relative to total water stocks, any perturbation will have consequences through the hydrological cycle.*

Water is needed for vital ecosystem services and in all systems, each with its special sensitivity, as represented by the diversity of Tasmania and northern Australia. International literatures (Rockström et al. 2014; Grafton et al. 2014) draw attention to the need for integrated land and water stewardship to sustain wetness-dependent ecological functions at the landscape scale and a stronger emphasis on green water management for ecosystem services. Thus growth in extractions without an understanding of environmental risks (at the very least before and after control studies) is fraught with danger and exposes all Australia to the risk of having to embark on very expensive correction of over-extraction, as witnessed in the Murray–Darling where over $12 billion of taxpayer funds has been allocated to addressing this problem.

Currently, there are methodologies (Grafton et al. 2011; CSIRO 2012; Akter et al. 2014) available to combine hydro-ecological response model outputs and non-market economic values of wetland inundation to estimate a unit price of environmental water. These approaches provide a robust, scientifically and economically valid method to estimate the marginal value of environmental water and to quantitatively evaluate the trade-offs involved in water allocation decisions across competing uses for water. They show, for Australian river systems that during the Millennium Drought investing in water for the ecological infrastructure and services drawn on by enterprises other than agriculture derive economic benefits greater than the economic benefit from irrigated agriculture. For example, the CSIRO (2012) study in the MDB estimated that while the costs of recovering 2,800 GL per year of water for the environment were an annual A$542 million reduction in the gross value of irrigated agricultural production across the Basin in the long term, the economic present value of additional Basin-wide enhanced habitat ecosystem services arising from floodplain vegetation, waterbird breeding, native fish and the Coorong, Lower Lakes, and Murray Mouth was between A$3 billion and A$8 billion. Australia's agricultural future will need to draw on such approaches to ensure governments and industry do allocate water in ways that do not compromise the future economic benefits of healthy rivers, wetlands, estuaries and near-shore environments.

The *Agricultural Competitiveness Green Paper* establishes a principle that capital investment by government and the private sector in future irrigation development should be subject to a consistent, robust analysis of costs and benefits. Despite the exhortation, this is rarely done (Economists at Large 2013). Public funding of irrigation infrastructure can be justified as public-good (particularly when infrastructure removes the risk of damage to environmental assets such as drainage and salinity management) and could be underprovided, but there must be ways found to cover these costs. To date, it has been rare that they have been recovered and, thus such costs represent subsidies to irrigated agriculture. A classic case is the Ord River Irrigation Schemes. Public investment in Ord Stage One from 1958–1991 was $613 million in 1991 dollars (Hassall & Associates 1993a, b; Campbell 2011; Economists at Large 2013) to extract a public benefit of $102 million. In other words, for every $1 invested in the ORIA the public received 17 cents. The net private benefit over that period was about $14 million, (Campbell 2011) and only 4,400 hectares of a potential 70,000 hectares was being cropped at that stage. This unviability had been predicted Davidson (1965; 1982). In the twenty years since 1991, the area under crop has grown to more than 15,000 hectares and the gross value of agricultural production to around $100 million while the public investment increased to approximately $379 million by 2009 (Economists at Large 2013).

Recently Wittwer and Banerjee (2014) used a model of the Australian economy to examine the impacts of developing irrigated agriculture in the Flinders and Gilbert Catchments in north-west Queensland. Using three alternative forecast baselines in terms of supply and demand they concluded that, for the business-as-usual baseline, there is a welfare loss from irrigation development, even with an optimistic shift in farm productivity and factor endowments in north-west Queensland. In the second run, baseline demand for Australia's exports is assumed to grow at a faster rate and there was a small welfare gain. Their simulations show that there are impacts of both supply and demand shifts on the welfare outcome, but on balance, clear welfare gains do not arise from the potential irrigation development. Dent (2014) examined the net economic benefits of allocating northern Australia's divertible surface water to irrigation, a scheme that would require significant investment in infrastructure for dam and canal construction. Dent (2014) used a Ricardian hedonic approach to forecast the economic value of constructing major new irrigation schemes that would be capitalised into agricultural land values along with publicly available data to define the cost of constructing large water storages and distribution infrastructure, as well as on-farm irrigation infrastructure. His analysis found that that the costs of turning northern Australia into an irrigated food bowl are likely to exceed even the most optimistic benefits that would be capitalised into land prices by a multiple of between 1.1and 3.2.

In summary, Australia's agricultural future will be shaped by the need to examine public and private investment and market failure, where it occurs, to determine how exploitable water resources in Australia are best utilised. The need to apply good science and robust economics to public policy is fundamental to supporting an internationally competitive agricultural sector.

A most important issue for water resources in agriculture is the competition agriculture faces, and will face, if unconventional gas exploration and development continues to expand, as is currently foreshadowed. The issues are now relatively well articulated for both coal seam gas (CSG) (Williams et al. 2012, 2013; NSW CSE 2014a, b) and shale gas (Cook et al. 2013) in Australia. Unconventional shale gas requires access to water for fracking processes while in CSG, the coal seal must be dewatered by lowering water pressure in the seam to atmospheric pressure. This creates a gradient to the seam from all other water sources in the geological stratigraphy. This de-watering increases water flow towards the coal measure. Currently, agriculture under NWI principles must have an entitlement and a specified allocation of groundwater for its use. A similar requirement is needed in all Australian jurisdictions for gas extraction.

It will be increasingly important that regulatory and land-use planning reforms address water conflict issues as the uncertainty, social, economic and environmental issues around the interface between agriculture and gas production will be a significant constraint to agricultural futures. This is especially so given that many potentially important CSG gas fields are beneath areas of prime agricultural land.

The way forward is for the effects of CSG operations on water resources, food and fibre production systems, and biodiversity to be managed in a whole-of-landscape framework (Williams et al. 2012; 2013) that takes account of long-term cumulative impacts. It involves:

- Understanding regional landscape capacity and determining if there is capacity for the development without crossing landscape limits.
- Updating current development approval processes so that new developments can only be approved on the basis of landscape limits, and the expected cumulative impacts of the existing and proposed developments.
- Using insights gained from whole-of-landscape cumulative risk assessment and aligned with the limits and thresholds to landscape function, to establish regulation, leading practice, monitoring and compliance arrangements to manage risks.

Building trust is a key to securing a social licence to operate for any major resource project, including agriculture and unconventional gas operations, and it is important to have a transparent approach to collection and dissemination of reliable data (NSW CSE 2014).

Over the past 20 years, a vigorous water reform process is underway that is focusing on governance, productivity and environmental issues. This will need to continue so to meet the opportunities and challenge of building sustainable access to the potentially exploitable yields outlined in this analysis. It requires a level of commitment by industry, community, state and federal governments to promote the reforms to ensure that all industries, including mining and gas production, work within NWI principles. In addition, there will be an ongoing need to oversee continued reallocation of water from irrigation activities in over-allocated rivers and groundwater to river and groundwater flow.

The capacity to manage periods of adjustment, including through water trading, will be difficult, but critical to success (Grafton and Horne 2014). The reforms should establish a framework that allows water trade and economic incentives to develop, and that encourage and support innovation increases in water productivity across industries, while also returning sufficient water to our stressed rivers, floodplains, wetlands and estuaries in southern Australia. Such water reforms should help avoid mistakes made in the south as our northern, east coast and Tasmanian rivers come under increasing developmental pressure.

6.3 Land and soils

6.3.1 Land use for agriculture in Australia

The total area of land used for agriculture in Australia in 2005–06 was almost 456 million ha or about 59% of the continent (ABARE–BRS 2010). Livestock grazing on natural vegetation and modified pastures is the most widespread activity, accounting for 429 million ha or 55.8% of Australia and 94% of total agricultural land use. Much of pasture farming occurs in the arid and semi-arid regions of Australia. Other agricultural uses occupy a much smaller portion of the continent, including cropping (27 million ha or 3.5% of Australia) and horticulture (0.5 million ha or less than 0.1%).

In 2005–06, intensive land uses, a class which includes intensive plant production in glass houses and nurseries and animal production in poultry, piggeries and feedlots, manufacturing, residential, services, utilities, transportation, mining and waste, occupied a relatively small proportion of the continent (3 million ha or 0.4%), mainly centred around the capital cities (ABARE–BRS 2010).

Approximately 283 million ha (36.7%) of Australia was used for conservation and natural environments. This was made up of formal nature conservation which occupied 7.4% of Australia, other protected (including Indigenous) lands which occupied around 13%, and other natural areas with minimal production use which occupied a further 16% (ABARE–BRS 2010).

The comprehensive report by Mewett et al. (2013) concluded that broad trends in agricultural land use change since 1992–93 are as follows:

- Agriculture remains Australia's dominant land use, but there was a decrease of around 18.8 million ha (4% of the agricultural area) between 1992–93 and 2005–06.
- The area of grazing decreased by 6% between 1992–93 and 2005–06. Over the same period, the area of land used for cropping increased by 39% to 27 million ha (3.5% of Australia's land area). These changes vary across the country, as shown by Figure 25. Since 2006, area under cropping has continued to increase from 27.5 Mha in 2009 to 32.1 Mha in 2011 and was 31.6 Mha in 2013.

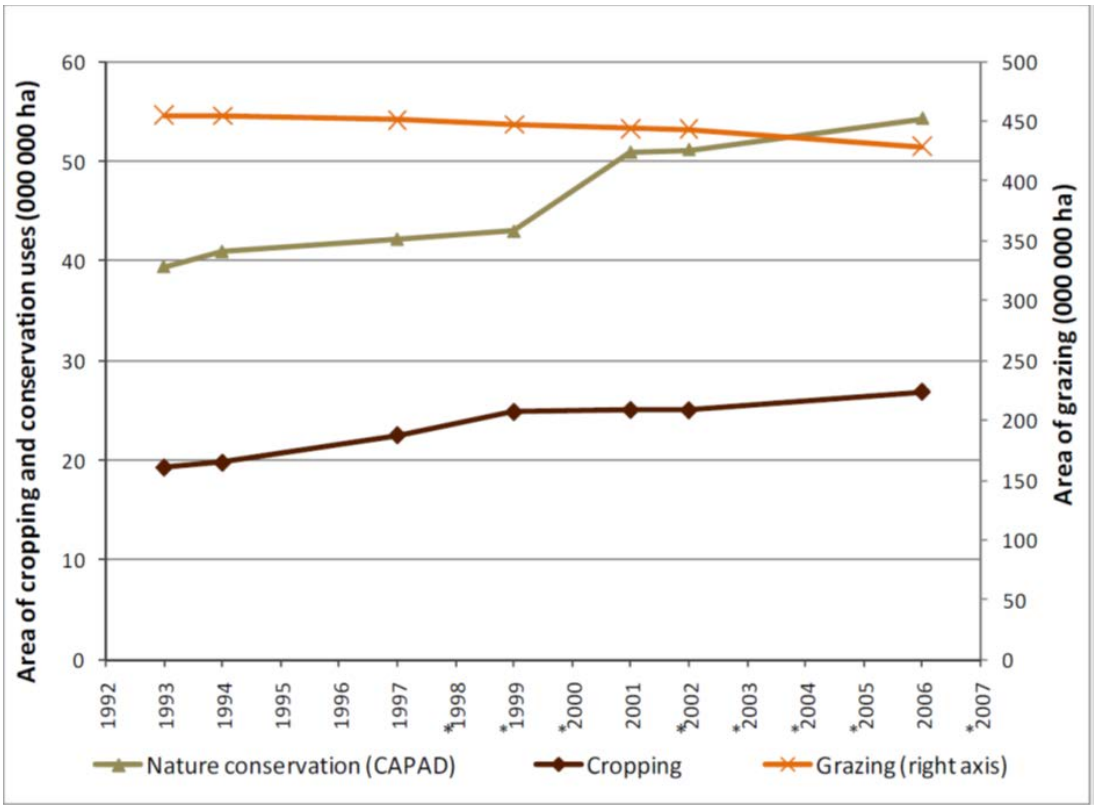


Figure 25: Change in area of selected land uses between 1992–93 and 2005–06 based on ABARES national scale land use map.
Source: Mewett et al. (2013).

In 2005–06, areas of minimal use, nature conservation and other protected areas, including Indigenous uses, occupied around 282 million hectares or 37% of Australia. Between 1992–93 and 2005–06, the area of formal nature conservation increased by 15 million ha (37%). In some regions, decreases in the area of land used for grazing are associated with increases in the area of land used for cropping and nature conservation.

The number of farm businesses decreased from 144,860 in 1997–98 to 135,447 in 2010–11. The number of large farms (greater than 2,500 ha) and small farms (less than 50 ha) both increased between 1997–98 and 2010–11. Changes in farm size can arise from a range of factors including pressures to increase economic productivity and efficiency as well as sub-division for peri-urban lifestyle blocks or for more intensive production. While the growth in peri-urban areas (those that lie on the fringe of the major built-up areas of cities) can compete with agricultural land, and the loss of agricultural land to urban growth is important, these changes do not necessarily translate into a decrease in the value of agricultural production. For instance, the Melbourne Statistical Division comprises only 2% of the total area of Victoria's agricultural holdings in 2010–11, but this area produced 13.4% ($1.2 billion) of the state's agricultural commodities by value.

Mining is also expanding into agricultural lands and some prospective new coal seam gas developments are in areas of high-value agricultural activity.

While the national picture suggests relatively modest changes in area for key land uses between grazing, cropping and nature conservation in the last 20 years, an increase in cropping of 12 Mha and increase in nature conservation of 15 Mha are both significant changes to agriculture.

6.3.2 What are the land and soil issues for Australia's agricultural future?

The soil system is of fundamental importance to agricultural productivity yet it performs many functions. It produces biomass, stores and filters water, stores and cycles nutrients, is a large carbon store, hosts biodiversity and stores our geological, paleontological and archaeological heritage. Soil is essentially a non-renewable resource, because it forms and regenerates very slowly, but can degrade rapidly. Some types of degradation, such as nutrient exhaustion, can be corrected, but this correction may be very costly. However, other forms of degradation, such as soil erosion, are difficult to remedy. Prevention is the key (SOE 2011).

Australia's soils are generally very old, and large areas are generally low in carbon and plant nutrients. There are very fertile and highly productive soils usually based around grey and black cracking clays as featured in the Darling Downs and the Liverpool Plains of NSW, and are Australia's premium agricultural cropping lands.

The key for agriculture is to recognise that Australia does have limited areas of high quality soils and that most of its soils under cropping require a high level of soil management to maintain and improve fertility and overall soil health.

Soil and land degradation will continue to be issues requiring resolution

Although much progress has been made, soil and land degradation remains an important issue for Australian agriculture. Soil processes, including acidification, erosion and loss of soil carbon, will increasingly affect Australia's agriculture unless they are carefully managed. Acidification and erosion currently affect significant areas of land, although wind erosion has decreased in response to more effective land cover. Soil carbon is central to maintaining soil health and can also be either a source or sink for greenhouse gases depending on agriculture land management (SOE 2011).

Community and farming interests in soil and land degradation appear to be increasing, but building a consistent approach in government and industry policy waxes and wanes. The appointment of an Advocate for Soil Health by the Federal Government is some reflection that many in community see better-management of soils and their health to be a matter of public concern.

Campbell (2008) examines the case for greater investment in soil management and concludes that:

> *Australia will struggle to meet its greenhouse objectives, manage its water supply crisis, ensure the security of its food supply and the income it derives from food exports, or improve the resilience and profitability of its farming systems, without a renewed focus and re-energising of efforts to improve soil management. That will require a more strategic and cohesive national approach to overall public investments in soils. Such investment will need to include substantial renovation of the underlying infrastructure of data, information and professional capacity, based on genuinely national monitoring, research, education and extension initiatives. This will lead to the rebuilding of soils literacy among natural resource management (NRM) professionals in the field, which Australia will need if land users and the wider community are to be assisted through a very challenging period of environmental change.*

Soil and land degradation is an issue difficult to resolve as it is a perplexing mix of private, public and intergenerational interests where the costs and benefits are distributed differently and often separated over time and space. The benefits of degradation are short term, but the costs of degradation are long term and generate impacts away from the location of the cause of the degradation, especially in terms of salinity and erosion. Local soil erosion may have its major expression in the sedimentation, destruction of river habitat and eutrophication downstream when the cause is gully or sheet erosion in the upper catchment. Similarly, salinization of rivers and streams is often distant to where the change in water balance took place that caused the salt to move and may have occurred many years earlier.

What are the key soil and land degradation that will need to be addressed by Australia's agricultural future?

Soil acidification

Large areas of acidic soils occur in New South Wales, Western Australia, Victoria and Tasmania. The National Land and Water Resources Audit (NLWRA) estimated that 50 million hectares of the agricultural zone are already suffering from acidification of soil surface layers and 20 Mha from subsoil acidification (NLWRA 2001; Campbell 2008). In the absence of remedial lime applications, it has been estimated than an area of 29 to 60 million hectares would reach a soil pH of 4.8 (below which plant growth is limited) within 10 years and a further 14 to 39 Mha would reach a pH of 5.5 (below which acid-sensitive plant species will not grow). The current rate of lime applications is at least an order of magnitude below the level needed to restore pH levels to a satisfactory range and to keep them in that state (NLWRA 2001a; Campbell 2008). Soil acidification is of greatest concern (SOE 2011) in situations where agricultural practices increase soil acidity through use of high-analysis nitrogen fertilisers and large rates of product removal and where the soil has a low capacity to buffer the decrease in pH when nitrates are leached down the profile. Soil acidification is driven, ultimately, by a change due to agricultural activity in both the water and nutrient flows and cycling in the soil profile. In cropping systems, the financial margins are usually sufficient to allow lime addition but in many pastoral operations the margins are insufficient to ensure its application. The challenge of acidic soils has, in part, been driven by the selection of acid-tolerant exotic legumes and grasses which mask the reduction in soil pH through a slowing of productivity loss with declining soil pH until thresholds of aluminium dissolution in clay in soil are exceeded. Use of legumes and a requirement to apply lime was first recorded in Roman times but in Australia this has been ignored and little lime is used compared to the USA and Europe where it is routine practice, particularly where legumes are used, with the consequence of a large and relatively low cost lime industry being developed. In Australia, generally, the cost of lime application is much more expensive and as a consequence, is used sparingly. Soil acidification in Australia is now perhaps a signal of a market failure to value soil condition and see declining pH as an erosion of natural capital.

Soil erosion

While there have been major improvements in controlling soil erosion through improved farming systems, biological control of rabbits and practices such as minimum tillage, trash retention and re-vegetation of gullies and sand dunes, soil erosion (Campbell 2008; SOE 2011) remain a major problem in Australia. Hillslope erosion remains high in the tropical north while gully erosion persists as the major erosion process affecting river conditions in southern and eastern Australia. Wind erosion and generation of dust storms (McTainsh and Tews 2007) in marginal cropping lands and pastoral lands of the arid regions, while reduced in recent decades in part due to adoption of conservation tillage particularly in the Mallee, and general improvement in maintenance of higher levels of groundcover over recent years continues to be an important degradation process (Commonwealth Government 2011a, p. 296).

Sediment and nutrient loads to rivers and estuaries

Sediment delivery to streams, rivers, estuaries and near-shore marine zones, as a consequence of soil erosion, is substantial in many catchments, particularly in the MDB, coastal NSW, south-east Queensland and south-west Victoria. Nearly 19,000 tonnes of total phosphorus and 141,000 tonnes of total nitrogen are exported to Australia's coast each year from areas of intensive agriculture, notably in north Queensland, Moreton Bay and New South Wales (Campbell 2008).

Dryland and irrigation salinity remain important

The rate of dryland salinization of land to 2050 as provided by NLWRA (2001b) was overestimated. This, in part, is because the projections did not account adequately for the long lags in rainfall sequences (Rancic et al. 2003) which drive the salinity process. Thus the Millennium Drought's impact on landscape water balance has slowed the expression of soil salinization but the salt impacts to rivers and streams remain an issue that needs careful monitoring. Groundwater tables have dropped in many regions, shrinking saline discharge areas and drying some up completely. It is possible that a warming, drying climate across southern Australia may reduce the symptoms of secondary salinization and their impacts on dryland agriculture. Nevertheless, the most important impacts of dryland salinity have always been off-farm. This is because while projected decreases in rainfall and bigger declines in runoff will lead to reduced salt yields in most regions of southern Australia, they will result in even greater reductions in streamflow. As a consequence, the concentration of salt in streams will tend to increase, even as water tables continue to drop. While climate change in southern Australia may reduce the area of agricultural land directly affected by dryland salinity, it will not reduce the amount of salt already in the system, and water quality impacts are likely to get worse. In semi-arid tropics where some increase in rainfall is expected, under climate change it is possible that salinization issues will move north (Williams et al. 1997).

Soil carbon management

Soil carbon stocks are low in many Australian agricultural systems. Conversion from native vegetation to agriculture typically reduces soil carbon by 20–70% (SOE 2011). This reduction is often associated with declining soil health and significant emissions of GHGs. It is generally acknowledged that more conservation-minded land management can increase soil carbon stocks, and have a significant impact on national and global emissions. This opportunity is the motivation behind many schemes around the world that aim to restore soil carbon stocks, including the Australian Government's Carbon Farming Initiative (SOE 2011).

There are three basic forms of organic matter in soils. The particulate organic carbon, the humus organic carbon and the resistant organic carbon. Soil particulate carbon is readily built-up and readily reduced, but to increase humus carbon and resistant carbon is a very long-term process. It is hard to build-up humus and resistant carbon in most cropping practices and rotations.

The fundamental insight is that, even under improved systems of land management, carbon stocks can be less resilient than those developed over long periods under native vegetation. Sanderman and Baldock (2011) recently reviewed replicated Australian field trials with time series data, providing an important new insight into carbon dynamics in agricultural systems. They concluded that, although the implementation of more conservation-minded land-management practices will lead to a relative gain in soil carbon, absolute soil carbon stocks may still be on a trajectory of slow decline. Sanderman et al. (2010) highlight the inevitable trade-off between agricultural production (i.e. carbon exports in the form of crops, fibre and livestock) and carbon sequestration (capture and storage) in soils.

Australia's agricultural future will need to encompass soil management that maintains and builds, where possible, the stores of carbon in Australian soils under climate variability and climate change.

Soil fertility and precision agriculture (PA)

Fertiliser management to maximise efficiency of delivery and minimise leaching and loss to waterways and streams benefits broadacre grain farming. These benefits arise especially from the technological advances around precision agriculture. It will be critically important that Australian agriculture further increase the efficiency of fertiliser applications, particularly phosphorus. Rapid technology advance such as precision agriculture and tools, such as drones, to monitor spatial and temporal plant responses, and soil condition, will assist in this challenge.

Australian farmers have a strong record of rapid adoption of technology to capture efficiency benefits. Precision agriculture seeks to exert more control over a production system by recognising variation and managing different areas of land differently, according to a range of economic and environmental goals. A number of enabling technologies are critical to precision agriculture. These include the global positioning system (GPS), geographical information systems (GIS), soil sensors and yield monitors which, with GPS, enable yield maps for each paddock to be collected and displayed 'on-the-go' during harvest. With these technologies being increasingly affordable while continuing to develop quickly, growers are better able to observe, understand and manage the variability in their production systems by tailoring fertiliser inputs to soil and plant requirement. Precision agriculture can also be used as a tool to help match land use to land capability. This helps address sustainability issues by optimising profitability in the productive parts of the landscape while conserving biodiversity and the natural resource base in less productive parts. Robertson et al. (2007) showed from a detailed survey of cereal farms that Australian grain growers have adopted precision agriculture systems that are profitable, are able to recover the initial capital outlay within a few years, and also see intangible benefits from the use of the technology. This work also shows that the use of, and benefits from precision agriculture varies from farm to farm, in relation to farmer preferences and circumstances.

6.3.3 Solutions to finding incentives for improved soil and land management need to be found as part of Australia's agricultural future

Mullen (2001) describes the challenges of how to better-manage soil and land degradation. A key finding is that soil and land degradation is a source of market failure or inefficiency. Because of attenuated property rights, the costs associated with land degradation are not wholly shared by producers and consumers of agricultural products but are imposed on present and future generations. The incentives for the present generation of farmers to avoid degradation are weak unless it directly impacts on their productivity. The non-point nature of the externalities with many forms of land degradation also means that precise farm-level control mechanisms, whether they be of a market or regulatory nature, are not available under present technologies (Mullen 2001).

Addressing market failure – a difficult issue

To assist farmers to farm sustainably, the externalities associated with land degradation and impact on the environment should be incorporated into the cost of food, fibre and water. Currently they are the hidden subsidies borne by the environment (Wentworth Group 2002). The fact that the cost of food rarely includes the cost of maintaining the natural resource base from which it is produced indicates of market failure (Mullen 2001; Williams and McKenzie 2008; McKenzie and Williams 2014). This market failure will need to be addressed in the future so to provide agriculture with the 'market pull' for sustainably produced food and fibre. Evidence is that, despite a huge push at the production end of agriculture to deliver sustainably produced food, there is currently a very weak market pull for sustainably produced products. This is a global problem, with producers of sustainably certified products everywhere faced with higher production costs and questionable benefits (Bhaskaran et al. 2006; Blackman and Rivera 2010; Buckley 2013; Tennant and Lockie, 2013).

The proliferation of Australian certification schemes (e.g. Gleeson 2007) may have confused buyers and created suspicion by consumers. To date, these schemes are poorly recognised by international buyers of Australian farm produce. Further, Australian-only certification schemes cannot be used for compliance in product sourcing without the risk of offending international trade laws. For private voluntary farm and food certification to have an important role in the future, it is important that Australians engage in developing international standards to ensure that they are accommodating of Australian conditions. International standards are also needed so that Australian produce meets such requirements as the sourcing standards of multi-national companies and to access emerging Asian markets for high-quality produce. One option is that the Australian Government provides funding for peak non-government organisations to participate in these standard processes (e.g. Australian commodity councils of growers, development and environmental organisations).

There is increasing evidence (Raynolds et al. 2007; Blackman and Rivera 2010; Buckley 2013; Schmidt et al. 2013; McKenzie and Williams 2014) that certifications which seek to raise ecological and social expectations are likely to be increasingly challenged by those that seek to simply uphold current standards. The vulnerability of these initiatives to market pressures highlights the need for private regulation to work in tandem with public regulation to enhance social and environmental sustainability. Public regulations are also increasingly seen as essential to reinforce and extend environmental sustainability in production, trade, and consumption arenas around the world (Raynolds et al. 2007).

Voluntary markets, particularly those incorporating concepts of producer-driven 'landscape labelling' (Gleeson 2007; Taylor et al. 2014) have an important role to play. Further, a strong regulatory framework is required that supports these markets so that all food reaching consumers in Australia is produced in ways that minimise the damage to the natural resources and environment.

There appears to be scope for the Commonwealth Government to support the development of voluntary, industry-based sustainable farm certification so that suppliers, retailers and consumers can have the confidence that these products satisfy environmental standards. This is necessary if farmers are to receive financial market benefits from managing their farms sustainably. To be effective these standards must be built into the international certification standards covering commodities produced in Australia. They must also be supported, in tandem, with strong and effective public regulation to reinforce and extend environmental sustainability in production, trade, and consumption arenas around the world. Such an approach requires an Australian standard for sustainable agriculture which could be negotiated as a component of international agribusiness and government. This could include an *'Australian Sustainable Agriculture Standard'* that incorporates a whole lifecycle analysis of energy, water, land and biodiversity inputs.

Internationally, agribusiness and leading food manufacturing corporations are developing sustainability standards. It appears Australian businesses and food corporations are not part of the emerging trend. If Australian agriculture seeks to be a key provider of high-quality food products to the rising Asian middle class (ATSE 2014; Gleeson and Quinn 2013), it should seriously consider building on Australia's reputation for providing safe and nutritious food. A first step would be to address the inconsistencies in food safety regulations between Australian jurisdictions, and the barriers faced by domestic producers compared to imports. While 90% of fresh food is still locally grown, an increasing proportion of processed food is being imported, particularly fruit, vegetables and seafood (DAFF 2013). By imposing greater domestic regulations without changing the overall foundations of the food system, Australia has not fostered its own 'clean and green' producers, and may encourage consumers to shop elsewhere. In addition, regulating the import of, say, Vietnamese prawns, should be based on the same sort of common international phytosanitory standards that were recommended in the paragraphs above.

Building regional natural resource management capacity

Campbell (2008) signalled the need to build the knowledge and the human capacity to manage Australian soil and landscapes more sustainably. He suggests that rebuilding regional delivery of natural resource management, knowledge, perspectives, planning and building capacity through facilitation and empowerment of landholders and Landcare groups is a way forward that over the last 15 years has been shown to work well (Natural Resources Commission 2010). This is contentious because Australian governments have long debated the value of incorporating regional natural resource management concepts into the land-use planning process. In recognition of this debate, over the past decade Australia has moved to a regional model for natural resource management. There is increasing evidence that integrated catchment planning and management (Williams 2012; Wilde 2013) of these complex biophysical, economic and social issues, at the regional scale at which these landscape processes function, is an essential precondition to a healthy and productive environment, regardless of whether people live in urban, coastal or rural regions (Natural Resources Commission 2010; Wentworth Group 2014).

There are 54 regional natural resource management bodies across Australia. They work with landholders, citizens with a passion for public land protection, and agencies of governments with the aim of achieving healthy and productive landscapes that support local communities and those industries that depend on a healthy environment. The benefits of a regional model is that it operates at a scale large enough to manage the pressures on our landscapes, yet is small enough to use local knowledge to tailor solutions to suit those landscapes.

Strategic land use planning

Access to soil and land that is well-suited to agricultural productivity will be critical to Australia's agricultural future and there will be increasing competition with non-agricultural uses for good quality agricultural soil and land. Both NSW (NSW DPI 2011; NSW DP&E 2012) and Queensland put this in place with strategic land-use planning at regional scales in order to manage the growing competition between agriculture and mining for gas and coal. The Standing Council on Energy and Resources (SCER 2013) has also developed *The National Harmonised Regulatory Framework for Natural Gas from Coal Seams* to address, in part, this issue. The competition for agricultural land is not only with mining, but includes urban development. Strategic regional scale land-use planning, coupled with regional governance and ownership by industry, community and government, should become an important tool for agricultural industries and communities to manage this competition for agricultural land (Williams et al. 2012, 2013; NSW CSE 2014a; Wentworth Group 2014; Byron et al. 2014).

6.4 Landscape biodiversity

Agriculture can be described as a suite of ecosystems that are managed to yield food and fibre. These agro-ecosystems, their ecological infrastructure and biodiversity deliver the ecosystems services required for plant and animal production. The farm is, therefore, a cluster of ecosystems variously connected to the ecosystems of the broader catchment and landscape. A key to sustainable agriculture, therefore, is to consider how the farm is integrated with the catchment and landscape as a whole. It is the connection between the agro-ecosystems via landscape ecological, hydrological and bio-geochemical processes that drive landscape function and determine the impact of agriculture on the catchment and landscape.

If an integrated framework is applied to agriculture, it becomes clear that landscape biodiversity is central to sustainable agriculture in harnessing agro-ecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism. Biodiversity, in this context, is both internal and external to agriculture. Biodiversity is defined simply as the variety of all life forms and their patterns in space — the different plants, animals and micro-organisms, the genes they contain and the ecosystems of which they form part. Importantly, it consists not only of the genes and the life forms themselves, but also includes the interactions between them and the environment. Thus there are three interactive levels of biodiversity: diversity at the genetic, the species, and the ecosystem levels. The term therefore covers a large array of ecological complexity and it is generally poorly understood (Saunders and Walker 2001).

Conservation and maintenance of biodiversity is important to our life support systems

From an anthropocentric viewpoint, our survival depends on biodiversity as some of its elements provide the critical life support systems that make human life possible. These are the healthy, functioning ecosystems that maintain the atmosphere, including the air we breathe, regulate the climate, produce fresh water, form soils, cycle nutrients, and dispose of wastes, control of pest organisms, and provide crop pollination (Saunders and Walker 2001). These ecosystem services are of critical importance to agriculture.

The community also has a very strong non-use demand for some if not many dimensions of biodiversity.

6.4.1 What are the major threats to biodiversity in Australia?

Human threats to biodiversity in Australia are numerous. The State of Environment in 2011 concluded that the key threats to biodiversity in Australia are:

- Fragmentation of habitat;
- Climate change;
- Land-use change;
- Invasive species and pathogens;
- Grazing pressure;
- Altered fire regimes; and
- Changed hydrology.

The most frequently cited threats in listings under the Environmental Protection and Biodiversity Conservation (EPBC) Act and resulting recovery plans are habitat fragmentation and the spread of invasive species. Additional pressures identified were oil and gas exploration and production, habitat alteration through urban expansion, and pollution including catchment run-off.

Figure 26 provides a conceptual framework assists in understanding how the drivers and pressures that affect biodiversity operate.

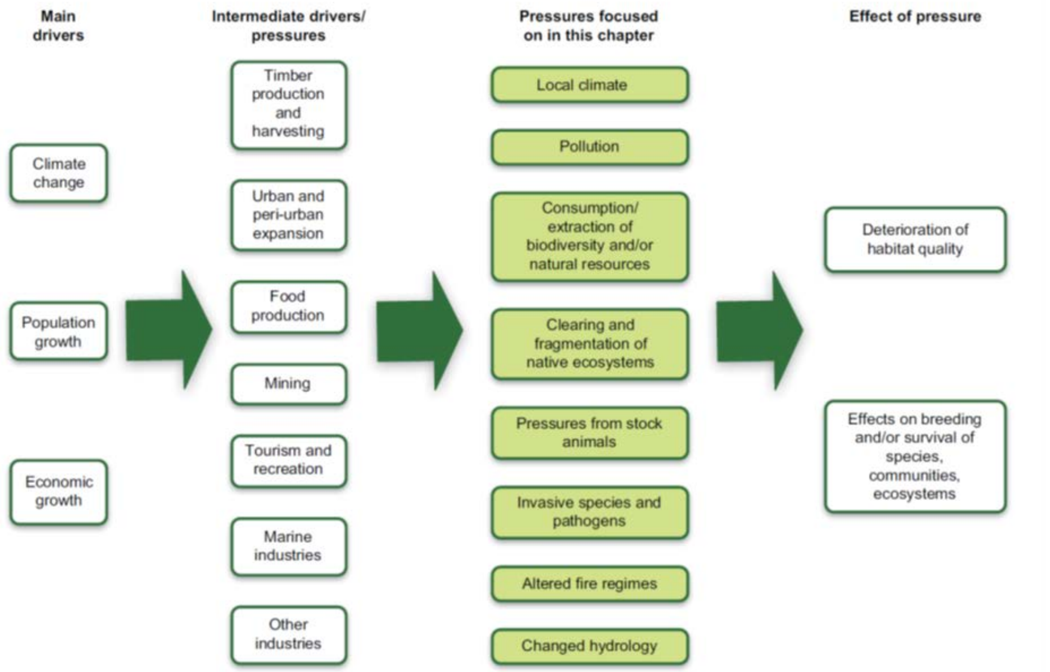
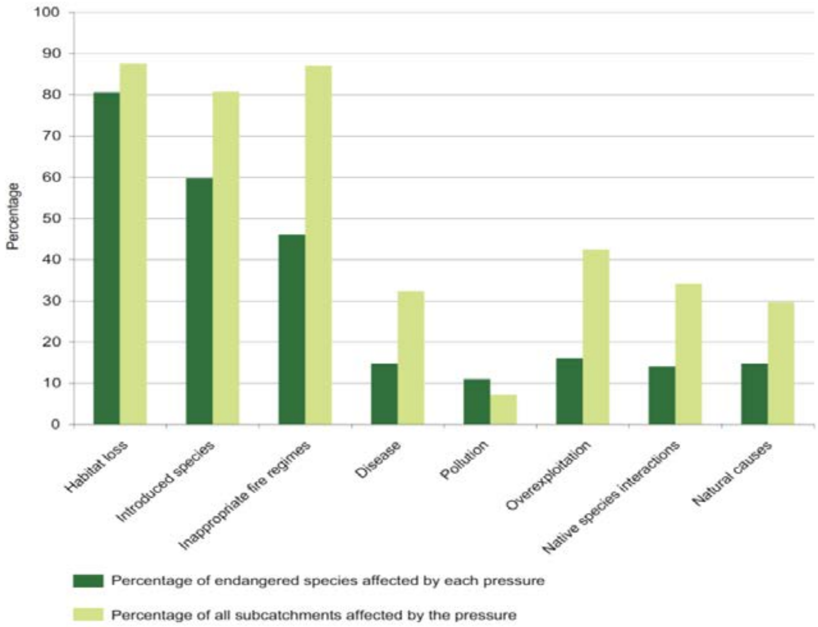


Figure 26: A conceptual framework for the drivers and pressures that impact on biodiversity.
Source: Australian Government (2011) page 618.

The relative importance of each of the pressures on biodiversity in Australia, as assessed by the 2011 State of the Environment Report, is illustrated in Figure 27.



Source: Evans et al.[87]

Figure 27: Pressures affecting species listed as threatened under the EPBC Act.
Source: Australian Government (2011) page 620.

Loss, fragmentation and degradation of habitat. One of the most significant factors in determining the health of ecosystems is the extent and quality of native vegetation (ABS 2010). The locations where species are declared to be threatened correlate closely with areas where native vegetation has been extensively cleared, and in regions where intensive development has occurred (Taylor et al. 2014). As urban areas expand, development continues to encroach on ecosystems surrounding cities and biodiversity of these areas is increasingly being degraded or lost.

Vegetation clearance has both immediate and longer-term impacts on biodiversity and ecosystems. A Queensland-based review estimated that clearing of one square kilometre of woodland results in the deaths of about 3,000 individual birds, 20,000 reptiles and 45,000 trees. It is not just the direct loss of vegetation that has impacts on species. Fragmentation of ecosystems, where species lose the ability to move between remaining areas of habitat, has longer-term impacts on the survival of many species. Isolation of individuals or groups in a population leads, over time, to a reduction in the genetic diversity of the entire population and possibly local, or complete, extinction of species (ABS 2011).

Since European settlement, about 13% of Australia's vegetation has been cleared. This includes 34% of rainforest, 30% of Mallee, 60% of coastal wetlands in southern Australia, 31% of Eucalyptus open forest, 99% of temperate lowland grasslands and 34% of Eucalyptus woodlands. In the marine environment, similar loss of habitat is occurring, with important breeding areas such as mangrove forests declining across Australia's coastline. Whilst broad-scale clearing has been reduced in Australia since 2002, native vegetation is still being cleared faster than it is being replaced. A net loss of around 260,000 hectares of forest per year occurred between 2000 and 2004, mainly from clearing for agriculture and urban development (ABS 2010). Taylor et al. (2014) conclude that nearly half of 5,815 terrestrial ecosystems, covering an area of approximately 257 million hectares across Australia, meet IUCN criteria for threatened ecosystems as a result of land clearing and degradation. This contrasts with just 66 ecological communities recognised as threatened under national legislation, but compares well with Queensland, which has a comprehensive system for mapping and assessing the conservation status of ecosystems. Further Taylor et al, (2014) provide evidence that tree clearing, fragmentation or habitat degradation are recorded as threats to 76% of nationally threatened species.

Invasive species. Invasive species are a major factor contributing to the loss of biodiversity in Australia. The negative effects of invasive animals do not just involve direct loss of species from predation, competition with native species and grazing impacts. They also negatively affect land degradation, soil erosion and changing habitats and landscapes. For example, a number of introduced mammals such as cattle, sheep, buffalo, pigs, horses, camels and goats cause extensive damage to vegetation, soils and water bodies through grazing and trampling.

The cost in monetary terms of introduced species on Australia's landscape is substantial. For instance, the cost of weeds to Australian agriculture alone is estimated to exceed $4 billion a year. This does not take into account costs associated with environmental, health or social impacts, which are often difficult to value.

Pollution, such as pesticides, nutrients and increased sediments can have serious effects on species and ecosystems. Pollutants poison plants and animals directly, as well as having broader impacts on ecosystems and the ability for species to survive in ecosystems. Toxins can stay in the environment for decades or longer and concentrate upwards along the food chain.

Changing fire regimes. Fire plays an important role in the management of Australia's landscapes. Many Australian species have adapted to fires and some ecological processes rely on fire to maintain their function. The increased severity and frequency of fire in fragmented habitats can seriously damage biodiversity as the refuges from fire cease to exist.

Changing climatic conditions. Climate change has emerged as one of the most significant threats to biodiversity in Australia. Severe impacts are expected for ecological communities across Australia including many important and iconic Australian landscapes, such as the Great Barrier Reef, the Australian Alps, many major river systems, and rangelands. The interaction of climate change with other threats, such as fragmentation of habitat, reduce the resilience of species and their abilities to adapt to a changing climate.

6.4.2 Biodiversity decline in Australia

Australia has experienced the largest documented decline in biodiversity of any continent over the past 200 years. Under the EPBC Act more than 50 species of Australian animals have been listed as extinct, including 27 mammal species, 23 bird species, and 4 frog species. The number of known extinct Australian plants is 48. Australia's rate of species decline continues to be among the world's highest, and is the highest in the OECD (ABS 2010; Commonwealth Government 2011).

6.4.3 Agriculture and landscape biodiversity

While Agriculture and food production is a driver for negative impact on biodiversity, it can also play a very important role in its maintenance and conservation, and not only for private benefit but for the public good.

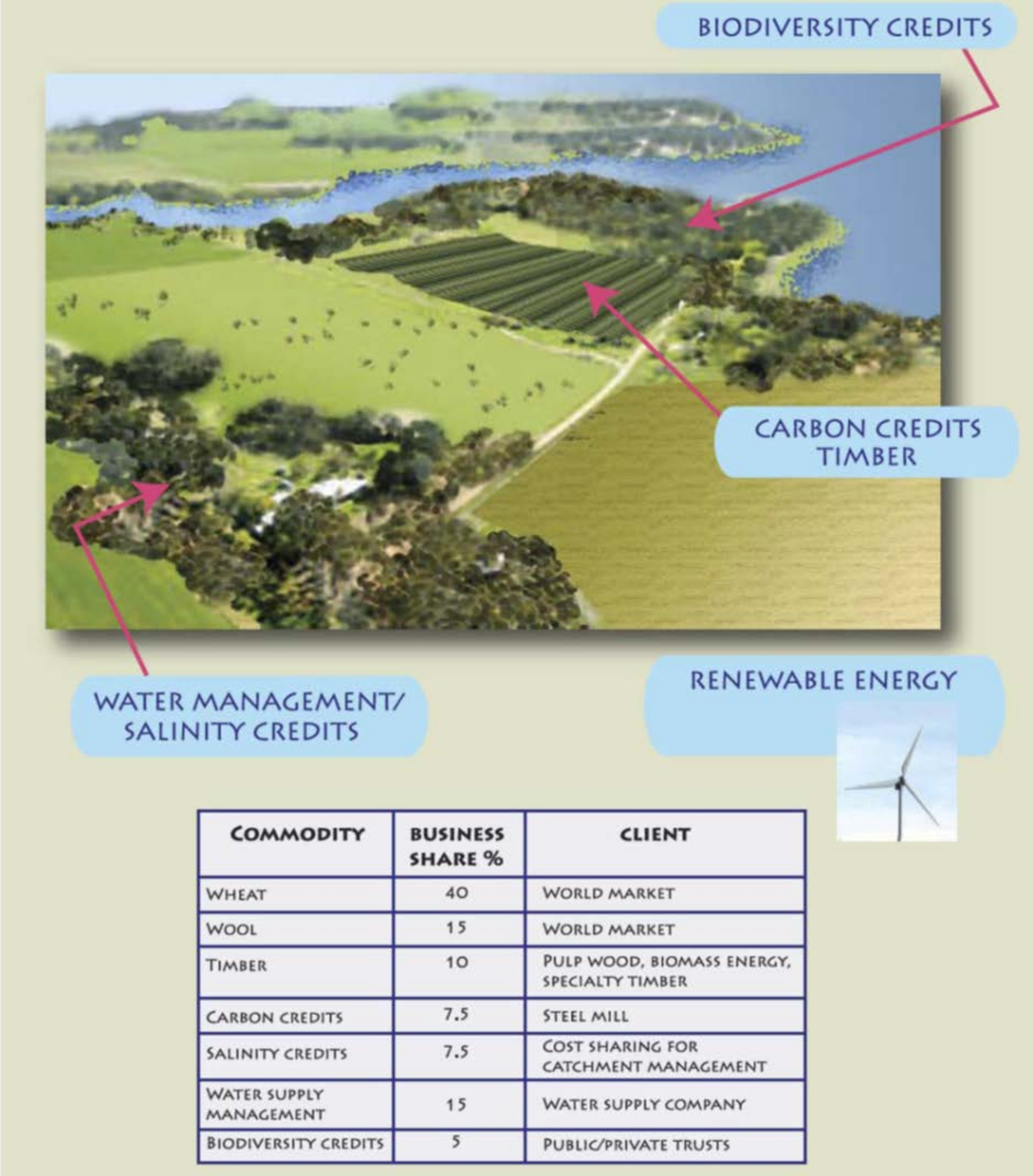
The most significant past and present pressures from agriculture on biodiversity are clearing and fragmentation of native ecosystems. Steps have been taken to limit clearing of native vegetation, but it remains a significant pressure in some areas, and the legacy effects of past clearing mean that the impacts are not yet reducing. Currently, the native vegetation regulation established about 10 to 12 years ago in both Queensland and NSW have been difficult to implement and are currently under review.

For Australia's agricultural future the management of native vegetation will be a most important issue, not only for biodiversity outcomes but it will need innovation and new ways forward. There is opportunity for agriculture to play a pivotal role in maintaining and improving landscape biodiversity. This arises not only from sustainable management of native vegetation, but also through the management of weeds, feral animals and bushfire. Most of Australian biodiversity exists on land managed by farmers and graziers and Indigenous land owners. Thus, the task for agriculture of the future is to find new and innovative ways to manage the biodiversity of the whole Australian landscape in concert with the increasing areas of conservation reserves and national parks. Taylor et al., (2014) propose government support for certified sustainable agriculture throughout the wider landscape and policy settings that provide tangible rewards to landholders who place high conservation value habitats under conservation covenants and implement certified sustainable agriculture through helping to establish and market independent, third-party certification systems and providing preferential access to funding from the National Landcare Program, Carbon Farming Initiative and other Australian Government, state/territory and regional conservation and natural resource management programs; and by making private conservation more attractive to landholders through tax and revenue reforms. These are all examples of the innovation and new thinking in policy to see Agricultural industries being key players in managing the landscape as a whole and agriculture is seen as more than the farm but the management of landscape ecosystem function of farms connected across the landscape and catchments. The recent review of Biodiversity Conservation Legislation in NSW (Byron et al. 2014) proposes a very similar approach to engaging agriculture and land managers to manage biodiversity at the landscape scale by capitalising on opportunities to not only identify areas of high-conservation value outside of the public reserve system but also promote private land conservation and provide funding their long-term on-going management.

There are many examples of important contributions made by agricultural land managers to positive conservation outcomes (Natural Resources Commission 2009). For example, between January 2006 and June 2008 under various NSW Government initiatives, 3,654,264 hectares of vegetation were conserved, managed or restored.

Pay for ecosystem services

A key function of agriculture is to manage the landscape, its rivers, wetlands and estuaries, in ways that produce ecosystem services for whole of society for present and future generations (Wentworth Group 2002; Alix-Garcia et al. 2003; Williams and Saunders 2005; Williams and McKenzie 2008; OECD 2010; Taylor et al. 2014; Byron et al. 2014). The agricultural community can no longer be expected to produce cheap, clean food and fibre, as well as provide a free service to maintain all the essential ecological functions of the landscape. This service should be recognised as a fundamental part of the economy, and paid accordingly (Wentworth Group 2014). In particular, sustainable agriculture requires a mosaic of new and old agricultural enterprises that yield food and fibre coupled with native ecosystems that provide a suite of ecosystem services. Currently, future generations are footing the bill for this present lack of conservation. A way forward is to support new markets for ecosystem services that could resemble Figure 28.



COMMODITY	BUSINESS SHARE %	CLIENT
WHEAT	40	WORLD MARKET
WOOL	15	WORLD MARKET
TIMBER	10	PULP WOOD, BIOMASS ENERGY, SPECIALTY TIMBER
CARBON CREDITS	7.5	STEEL MILL
SALINITY CREDITS	7.5	COST SHARING FOR CATCHMENT MANAGEMENT
WATER SUPPLY MANAGEMENT	15	WATER SUPPLY COMPANY
BIODIVERSITY CREDITS	5	PUBLIC/PRIVATE TRUSTS

Figure 28: The future farm of sustainable agriculture delivering food, fibre and ecosystem services. Source: Williams and McKenzie (2008).

Williams and McKenzie (2008) were optimistic that markets for ecosystem services would develop. As these markets developed, they expected an increasing proportion of farm income would be derived from the management of healthy landscapes, rivers, wetlands and estuaries, the production of clean water and the sequestration of carbon dioxide. They envisaged farmers as not only producers of food and fibre but also as the custodians and managers of the life support systems for society as a whole. The principles for identification, mapping and payments for maintenance of ecosystem infrastructure (Merchant, 2014) and for the resultant ecosystem services (Daily et al. 2009) provided, have received considerable attention in the last 15 years (Alix-Garcia et al. 2003; OECD 2010; Bizikova et al. 2013). A key concept in identification and payment for delivery of ecosystem services is the need to avoid the public paying for private benefit and thus crowding out incentives for innovation and efficiency in productivity and enterprise duty of care. Ecosystem service payment need to be directed to services beyond the individual duty of care and the management the natural resource base so it is able to sustain long term productivity of the enterprise. To clarify issues around this, Hatfield-Dodds (2006) argues that the catchment care principle offers a principle-based approach that encourages burden sharing rather than a winner takes all political game, and is likely to enhance the ability of societies to craft constructive policy responses to some of our most difficult environmental challenges. In addition to encouraging more adaptive governance and the protection of ecosystem integrity, his work suggests that the application of the catchment care principle provides a middle ground anchoring point for the political negotiation of policy changes.

When NSW farmers were asked to comment on the image given by Figure 28, the common concern was that there were too many land uses for one farmer to manage, given the current pressures they were under (McKenzie, in press). This is where the concepts of enterprise aggregation for a regional brand or product recognition and subsequent certification at a catchment or landscape scale — landscape labelling (Gleeson 2007; Ghazoul et al. 2009) may be useful. Such developments could allow farmers to create a pool of assets with shared management of marketable ecosystem services. Aggregated or otherwise, however, ecosystems services cannot be sold if there is no demand for them (McKenzie and Williams 2014) and place of regulation to establish the boundaries for the market will be always important (Byron et al 2014; Raynolds, et al. 2007).

Recent conservation approaches include publicly and privately funded market-based instruments. Most are unconnected, state-level biodiversity offset and banking programs, and conservation tenders or auctions for rivers, wetlands, bushland, soils and woodlands. The new markets for ecosystem infrastructure and provision of ecosystem services will need to and can be made to be compatible with critical inputs such as, carbon sequestration, soil and water condition and quality as well as biodiversity conservation.

6.5 People resources and Australian agriculture

Australia's rural workforce is characterised by the highest median age workforce in Australia at 48 years, a particularly high proportion (36%) of workers aged over 55 years, and a disproportionately low number of workers aged less than 35 years (PMEIC 2010). In addition to the changing age structure, changes in average farm size are impacting both positively and negatively on the availability of appropriately trained labour.

Many individuals are moving from rural Australia to larger regional centres or cities in search of greater work options, better health and education services. This, in turn, has dramatic effects on the regional skills profile, its labour pool and the general health and vitality of the local community (PMEIC 2010). It seems that many of the jobs in agriculture are not seen as attractive to a large proportion of the population. There is also evidence to suggest formal training in the agriculture, farm and food sectors is in decline and in the tertiary sector, universities for a decade have been reporting declining enrolments in agricultural science courses. This raises concerns about the future availability (Pratley and Copeland 2008) of trained scientists and skilled farmers despite apparent job opportunities in the agricultural production and agribusiness markets (Pratley and Hay 2010).

Securing an adequate supply of suitably skilled labour is vital in optimising Australia's agricultural productivity. Improving the skill level of the agriculture workforce is essential to enhancing innovation, strengthening competitiveness, boosting resilience and developing a larger capacity for the agriculture industry to capitalise on opportunities and contribute to global food security (PIMC 2009). A number of factors inhibit the agriculture industry in filling demand for workers. These include labour competition from other industries, negative messages about agricultural working conditions, an ageing population and a declining rural population (PIMC 2009). Impediments to meeting the industry's skills shortages include low levels of industry participation in education and training, low numbers of under-graduates and graduates in tertiary agriculture courses (Pratley and Copeland 2008), poor awareness of agricultural career pathways, and the limited capacity of the current education and training system to deliver innovative training solutions.

In addition, the knowledge needs and skills to drive innovation and productivity in Australian agriculture in the future is undergoing transformation. Teaching, research agencies and funding corporations will need to change to stimulate and drive this transformation.

6.5.1 Intensive management systems will be an integral part of the farm business

Modern agriculture can be characterised as intensive in terms of external inputs and energy use. What is less acknowledged is that it is becoming more knowledge intensive (McKenzie 2014). Agricultural systems and their management have become increasingly complex, underpinned by expensive capital investments, changing production technologies, volatile markets, social challenges and increased regulation (Kingwell 2011). Farming now employs a daunting range of technologies and practices that require the continual assimilation and assessment of new knowledge (Oreszczyn et al. 2010).

A greater knowledge intensity is required of both cropping and livestock systems. For example, cropping systems now require specialised skills to manage technical, biophysical, financial and marketing components of the business (Jackson 2010). Advances have also occurred in the livestock sector over recent decades increasing complexity and the knowledge required by graziers.

Many of these new technologies are disembodied (not incorporated in a new variety or machine) and they often have a dimension of reducing the impact of agriculture on the environment. The information and management content of these technologies is high, their profitability is often difficult to demonstrate and hence rates of adoption are low and slow. Input suppliers rarely champion these technologies. The slow rate of adoption of these technologies, especially those with positive environmental consequences, is not in the community's interest. This is an area of market failure to be addressed by industry and government.

Australian agriculture is already considered a highly skilled sector—with 70% of the sector working as managers, administrators or professionals (compared to 40% for national average). This is because the sector has a high proportion of small scale owner-operated businesses with few employees (AEC Group 2010). This increased complexity and has placed new and additional demand on farmers' existing knowledge and skills (Kingwell 2011).

At the same time as the knowledge intensity of agriculture has been increasing, the number of people working in the industry has been decreasing, concentrating human capital (knowledge and skills) in fewer individuals. The number of family farms has decreased significantly—by 30% between 1986 and 2006—involving the loss of approximately 42,000 farms (with smaller farms being absorbed into larger holdings). Australian agriculture also employs fewer people every year; between 2001 and 2006, employment fell by 19% (ABS 2008).

6.5.2 Steps to foster farmer-driven innovations and knowledge-intensive agricultural systems

There is a strong incentive for farm managers to maximise investments in knowledge and skills by specialising in fewer land uses or farm enterprises. Knowledge intensity is therefore one cause of the reduction in the number of land uses on individual farms. In the higher rainfall areas of the eastern and western wheat/sheep belts of Australia, there has been a shift from traditional mixed crop-livestock systems towards either crop or livestock systems (McKenzie 2014).

From 1992–93 to 2009–10, the area planted to crops (excluding pastures and grasses, and hay) increased by nearly 50%, while grazing area decreased by 6% (Lesslie et al. 2011, and Figure 21).

Greater specialisation places at threat the ecological diversity of agricultural landscapes. Knowledge intensity does not rule out sustainability, and may in fact be more benign than capital or energy intensity, but the rise in complexity and specialisation may undermine ecological diversity within agricultural systems. This is true where specialisation results in more intensive land management practices, less diverse cropping/livestock patterns, and negative environmental impacts. In other instances specialisation, for example in rotational grazing for livestock, can lead to increased perennial and native grass species diversity and ecosystem health. The challenge is to ensure that where specialisation occurs, it is not to the detriment of broader landscape sustainability (McKenzie 2014).

If greater human capital were available, then more than one type of specialisation, or greater division of labour, might be possible within individual farms, maintaining land use diversity. Along these lines, mixed farming itself could become a specialised skill rather than a compromise between enterprises. This would require acknowledging the human capital challenges facing mixed farming (McKenzie 2014).

Better recognition of the important role of human capital (knowledge and skills) is an urgent challenge, not just for farmers or for sustainability, but for the wider industry as a whole (McKenzie 2014). As a first step towards responding to this challenge, a better understanding of diverse agro-ecological systems is required (Dorrough et al. 2007). Unfortunately, past R&D efforts have largely focused on single system component or single enterprises, despite the fact that about half the world's food is produced in mixed crop-livestock systems (Herrero et al. 2010). Australian industry organisations are not exempt, and have neglected the interaction between crops and livestock for many years. What has resulted is a lack of information about the linkages and complexities of inter-relationships between enterprises on mixed farms, including feedbacks, trade-offs and positive responses (Villano et al. 2010, see pasture cropping box). Further, Australian agriculture will require new mechanisms involving greater subtlety and flexibility in the incorporation of contemporary scientific knowledge that support sustainable initiatives.

6.5.3 Sustainability often means multiple businesses in the single family or farm enterprise

To facilitate more sustainable enterprises the creation and dissemination of the knowledge to manage such enterprises is necessary. The key is to build human capital (knowledge and skills) by fostering farmer-driven innovation and by building knowledge networks.

From an innovation systems perspective, knowledge is something that is shared. Innovation is not defined as invention, but as the outcome of relationships between various actors who (re)combine knowledge from many different sources to achieve positive novel changes in a particular situation (Spielman 2005; World Bank 2006; Conroy 2008; Klerkx and Leeuwis 2008a, b; Felton et al. 2010).

Pasture Cropping: an example of Opportunistic Diversification

Pasture cropping is a land management technique in which a zero tilling technique is used to sow annual cereal crops into living perennial (usually Australian native perennial plants) pastures and having these crops grow symbiotically with the existing pastures with real and advantageous benefits for both the pasture and the crops.

Pasture cropping is thus the combining of cropping and grazing into one land management system where each one benefits the other. A farmer gets two products—crops and animals—from one piece of land. Three, actually, if you harvest the grass seeds as a potential food source, mimicking the Aboriginal people's use of native grasses.

It diversifies the enterprise and allows options to manage climate variability. In very dry years the annual crop becomes a fodder crop to augment the carrying capacity of the summer-growing perennial pastures. In most years the animals are removed and the grain is harvested.

The potential for profit and environmental health in being able to do this are enormous and now well documented and finding adoption in many regions of Australia. The innovation was conceived and developed by two farmers over 15 years ago when Colin Seis and his friend Daryl Cluff, experimented on Colin's property in central-western NSW. Colin has spent much of his time perfecting this technique and now also conducts workshops educating other landholders on the methodology. This development of the pasture cropping system over the years has led to many different types of winter- and summer-growing crops being grown without destroying the perennial pasture base.

The original concept of sowing crops into a dormant stand of summer-growing (C4) native grass, like red grass (*bothriochloa macra*) was thought to be a very inexpensive method of sowing oats for stock feed. This certainly turned out to be true; it was quickly learnt that there were many side benefits to direct drilling without the need for knockdown herbicide and a high level of soil cover was maintained all years around. Cropping methods used in the past require that all vegetation is killed prior to sowing the crop and while the crop is growing.

Pasture cropping works to the extent that the growth patterns of the pasture and cereal plants are different. In Mediterranean climates the strong pasture growth is in winter, and strong cereal growth in spring, while in some summer-dominant rainfall regions cereal growth is in winter and spring and the C4 perennial pasture growth is greatest in summer.

Over the years there were more advances with the technique where cereal crops in NSW, South Australia and Victoria were sown into winter-growing (C3) native perennial grass with good results such as oat crops yielding over three tonnes/ha. Additionally, there have been good results in Victoria and NSW, sowing summer forage crops into winter-dominant native perennial pastures. As a direct result of the ongoing work and the landholder education these same pasture cropping methods are being used to good effect in such diverse places as Scandinavia, USA and with similar methods in use in Argentina and Brazil. It was also learnt that sowing a crop in this manner stimulated perennial grass seedlings to grow in numbers and diversity giving considerably more tonnes/hectare of plant growth. This produces more stock feed after the crop is harvested and totally eliminates the need to re-sow pastures into the cropped areas.

Further reading:

1. Bruce et al. (2012). Pasture Cropping: effect on biomass, total cover, soil water & nitrogen http://www.pasturecropping.com/14-articles/13-pasture-cropping-effect-on-biomass-total-cover-soil-water-and-nitrogen
2. http://www.winona.net.au/farming.html
3. http://www.thesolutionsjournal.com/node/1261

Unfortunately, innovators are still characterised as high-end research and development of corporations and universities rather than individuals in smaller firms, and least of all farms. This reflects an ongoing assumption that innovation is the domain of scientists, researchers and corporations. Farmers can be (and are) potential sources and intermediaries of knowledge and innovation (McKenzie 2013).

Knowledge generation and the network interactions that allow for knowledge exchange are key processes of farmer-driven innovation (McKenzie 2013). Yet these processes are not well-understood at the farm level, nor are they well-reflected in policy approaches for agricultural innovation.

Creating enabling infrastructure and institutions, rather than policies that seek to make defined interventions, is likely to be more successful in promoting innovation (Breschi and Malerba 2001). In a study by McKenzie (2013), a range of strategies were used by farmers to gain insight and recombine knowledge and practices in order to innovate. These included: ongoing experimentation and testing of practices, ideas and outcomes on-farm; participation with like-minded peers in farmer groups; and proactively seeking advice and information from new sources.

Interventions to strengthen innovation capacity include creating stronger 'patterns of interaction across the whole range of actors involved in innovation' (Hall 2009). This requires creating the space for a diversity of interactions to occur.

Hence the call and need for interactive knowledge networks (with farmers, farmer groups, scientists, industry, and other actors) (IAASTD 2008). Such networks should have linkages to technically relevant information, new learning opportunities, flexibility in process, and ongoing evaluation.

6.5.4 Build knowledge networks through farmer-to-farmer knowledge exchange via farmer groups

Knowledge networks do not need to be rigidly conceived and organised. They may come and go over time (Wolf 2008). Informal networks, characterised by their emergent, ungoverned and unstructured nature, can be as effective as formal networks with their managed organisational structures (Allen et al. 2007).

One way to create knowledge networks is to support farmer-to-farmer knowledge exchange via farmer groups. There is a growing trend in Australia for farmers to join formal grower groups that, along with private agronomists, conduct their own on-farm research programs (Lawrence et al. 2007). In addition to the research value, it appears that a key reason for this trend is that these groups provide the 'like-minded' people that farmers identify as helping to maintain motivation, provide access to other innovative farmers, and function as an effective network for information exchange and moral support (McKenzie 2013). It seems new ways of engaging, based on the concept of multiple pathways for knowledge flows and flexibility, are being developed based for emergent networks — where the line between the landholder and professional expert becomes blurred (McKenzie and Williams 2014).

Birchip Cropping Group (BCG) – serving the Wimmera–Mallee

BCG conducts field research and demonstrations across the Wimmera–Mallee region of Victoria and delivers information to a broad range of audiences within the rural and farming community.

In 1992, a group of Birchip and district farmers, keen to see agricultural research in their region, established the Birchip Cropping Demonstration Sites (later to become BCG). Initially, their motivation was to see how grain varieties, pulse crops and agricultural products performed in local soils and conditions, and to share this information for the betterment of grain growers in the region.

From these humble beginnings, when over 500 people attended the first field day, clearly demonstrating a thirst for local, farmer-driven agricultural research, BCG has grown both in size and stature, now boasting 20 plus staff, over 400 members and a strong reputation for exceptional field research and professional extension activities.

Today BCG research trial sites are established across the Wimmera and Mallee, with trials looking at all aspects of farming including agronomics, farming systems (including livestock), climate, plant nutrition, disease, weed and pest management and risk management.

BCG is a registered research organisation, approved by the board of Innovation Australia and has built considerable capacity to perform, engage, and deliver contracted research and development. Qualifying organisations can claim taxation benefit by investing in research work with BCG, especially through utilising the contracting services by BCG. The organisation also offers the opportunity for companies providing good-quality, well-researched and supported products and services to the agricultural industry to become sponsors and have products showcased to the farming community.

Research is conducted on a variety of issues, soil types and farming systems to respond to member's input and specific needs. The 'Making Conservation Pay' program involves innovative projects tackling issues of sustainability, balancing production and conservation needs while 'Climate Research' includes projects tackling issues of sustainability, balancing production and conservation needs in the Wimmera and Mallee.

The first of BCG's social research projects was undertaken in 2007 and 2008 with the social and community program continuing to develop.

The group delivers an online crop modelling and climate analysis service. The *Yield Prophet*® is an on-line crop production model designed to present grain growers and consultants with real-time information about their crops, providing integrated production risk advice and monitoring decision support relevant to farm management. Operated as a web interface for the Agricultural Production Systems Simulator (APSIM), *Yield Prophet* generates crop simulations and reports to assist in decision making. The simulations provide a framework for growers and advisors to forecast yield, manage climate and soil water risk, make informed decisions about nitrogen and irrigation applications, match inputs with the yield potential of their crop, assess the effect of changed sowing dates or varieties and assess the possible effects of climate change.

BCG has built a large network of public and private research partners and collaborators as well as a significant body of corporate sponsors which support the ongoing work of BCG. See: http://www.bcg.org.au/

6.5.5 Build knowledge networks through participatory partnerships

Innovation demands sophisticated integration with local partners and continuous adjustments in institutional arrangements and partnerships through learning, and in response to changing circumstances (Hall 2006; World Bank 2006; Kiers et al. 2008). It also requires collaboration between scientists and practitioners, 'flexibility in land use and land use planning, and stronger engagement with communities, business and government' (Seabrook et al. 2011).

Building trust is crucial in collaborations, and maintaining this trust among partners is a key element of a successful partnership (Ashby 2009; Killough 2009). In particular, farmers will reciprocate only when governance structures value their input (Marshall 2008).

Partnerships should facilitate change, rather than promote a predetermined agenda. Partnerships are not an end in themselves (Sumberg 2005). It should explore the factors that farmers identify as useful to them. Moreover, it is important to ensure that over time farmers' priorities are not 'elbowed aside' by researchers' own agendas (Richards 2009).

Participatory research can be a good basis for new partnerships. Participatory research refers to a process of interaction between local and external actors to co-create innovations (Fisher and Carberry 2008). Participatory approaches are not new and include: Participatory Technology Development; Farmer First; Participatory Action Research; and Participatory Rural Appraisal approaches some of which have existed for decades, although largely applied in a developing country context (Reij and Waters-Bayer 2001a, b; Leeuwis 2002; Scoones and Thompson 2009). Unfortunately, farmers' knowledge remains undervalued and the traditional bias towards academic pathways of research dissemination remain.

6.5.6 Build knowledge networks through innovation intermediaries

Innovation is not just about frontier research and technology, but also about incremental problem solving, or the constant minor adjustments and improvements that farmers make to succeed (Hall 2006). It is an ongoing process, not a one-off event — something which is too easily overlooked when extension and research focuses on a single point of 'adoption' (Nicholson et al. 2003; Pannell et al. 2006). Implementation of new management practices and processes requires application and experimentation at the farm level.

Agricultural researchers need to move on from focusing on barriers to adoption, and instead put greater effort into understanding the dynamics of knowledge supply and demand, interactive networks, and opportunity creation among farmers. Research is also needed that moves beyond the dichotomy of local versus global knowledge, and informal versus formal science (McKenzie 2013) This does not discount the value of formal science or extension services. Extension and technical advisory services also remain important, particularly where they can assist in applying knowledge to local circumstances.

State and Territory governments have traditionally played a major role in extension delivery but have reduced funding in recent decades due to budget pressures and changing priorities leading to a deficiency in this area (Parliament of the Commonwealth of Australia 2007). Best estimates suggest that publicly-funded extension declined from 24% of total public agricultural RD&E in 1952–53 to around 19% in 2006–07 (Sheng et al. 2011). The gap in extension service provision is being filled by industry and private business providers (Commonwealth of Australia 2014; see also Birchip box) but there is concern that attention to environmental impacts might be overlooked.

Traditional extension services could be transformed into knowledge brokerage services, so that independent advice and evaluation can be provided in ways which accommodate the newly emerging knowledge networks. Extension agents have a long history of innovation and change and many are operating as network facilitators, whose role includes creating 'space' for stronger interactions and learning across the whole range of actors involved in innovation (McKenzie 2013) including in ways to support public goods produced on farms. As a new model, this could assist in rejuvenating rural networks and communities and resolve the current crisis in agricultural extension in Australia. Such an idea could build on the suggestion in the *Agricultural Competitiveness Green Paper* (Commonwealth of Australia 2014), by making better use of existing farm advice services such as the Rural Financial Counselling Service (RFCS) to deliver intermediary services. The need for new ways in managing knowledge in agriculture should be seen as an opportunity to rebuild the extension service in new and novel forms and not a cost shifting exercise to cut costs which are part of doing business to increase efficiency, productivity and sustainability of the farming sector.

6.5.7 Creating human capital by attracting new entrants to agriculture

Attracting new farmers to agriculture is another important step in building human capital. It is crucial in safeguarding the transfer of knowledge and expertise to future generations and to reinvigorate the sector with new talent, ideas and enthusiasm (Commonwealth of Australia 2014). This is needed because the number of young owner-operator farmers has declined since the 1970s. For instance, since 1976, the number of farmers under the age of 35 has fallen by more than 75% (Barr 2014).

The current *Agricultural Competitiveness Green Paper* (Commonwealth of Australia 2014) suggests that potential new entrants could be better supported through mentoring, networking and training opportunities – by building upon existing Australian Government, State and Territory government, and industry-led initiatives (Commonwealth of Australia 2014).

6.6 Water, land, biodiversity and people: an overview and conclusions

Exploitable water resources for agriculture exist in Tasmania and the three drainage divisions of tropical Australia. Based on this work and the experience to date which demonstrate that broad scale estimates tend to be very much reduced under more detailed hydrological, land suitability and engineering analysis, it would appear that the total potentially exploitable yield of water that could be captured for future irrigated development in Australia is of the order of 25,000 GL. The Northern Australia Land and Water Taskforce (2009b) in their report to Government on Sustainable Development in Northern Australia illustrates some of the social, economic and environmental issues, their complexity and some of the knowledge, tools and the human processes that will need to be part of Australia's agricultural futures. They draw attention to the biophysical reality that:

> *All water is fully in use. The water balance is closed; even "wasted" water running out to sea is needed by estuarine systems and near-shore ecosystems. Underground, groundwater supports riparian vegetation, maintains perennial reaches of many rivers and provides a dry-season source of water. Whilst current levels of use are low relative to total water stocks, any perturbation will have consequences through the hydrological cycle.*

Australia's agricultural future will need to equip itself with science and understanding about how water extraction adversely affects catchment, estuary and near-shore ecological environmental function and assets. This is an issue which will need to be part of the understanding and science used to evaluate water available for agriculture in determining Australia's agricultural future. It will be of particular importance to ensure that agricultural development of water resources does not compromise the future use of the ecosystems for tourism, fishing, and recreational use activities and the heritage values of the landscapes and ecosystems. Water is needed for vital ecosystem services and in all systems each with its special sensitivity as represented by the diversity of Tasmania and northern Australia. International literatures (Rockström et al. 2014; Grafton et al. 2014) draw attention to the need for integrated land and water stewardship to sustain wetness-dependent ecological functions at the landscape scale and a stronger emphasis on green water management for ecosystem services. Thus growth in extractions without an understanding of environmental risks (at the very least before and after control studies) is fraught with danger and exposes all Australia to risk of having to embark on very expensive correction of over-extraction, as witnessed in the Murray–Darling where over $12 billion of taxpayer funds has been allocated to addressing this problem.

The development of water markets has been an important economic lever to improve the allocation of water use to highest value in agricultural use (Grafton et al. 2011, 2012; Grafton and Horne 2014; Kirby et al. 2014) Thus there is a strong evidence-based case for continuing the development, facilitation and regulation to support water markets as a vital part of Australia's agricultural future. The capacity to manage periods of adjustment, including through water trading, will be difficult, but critical to success (Grafton and Horne 2014). If the reforms are able to establish a framework that allows water trade and economic incentives to develop and that encourage and support innovation increases in water productivity across industries should occur while also returning sufficient water to our stressed rivers, floodplains, wetlands and estuaries in southern Australia. Such water reforms should help avoid mistakes made in the south as our northern east coast and Tasmanian rivers come under increasing developmental pressure. In developing these water resources, agriculture will be best served by ensuring alignment with the NWI principles including appropriate cost recovery and be subject to robust analysis of costs and benefits assessment so that any subsidies are fully transparent. Australia's agricultural future will be shaped by the need to examine public and private investment and market failure where it occurs to determine how exploitable water resources in Australia are best utilised. The need to apply good science and robust economics to public policy is fundamental to supporting an internationally competitive agricultural sector.

There appears to be scope for the Australian Government to support the development of voluntary, industry-based sustainable farm certification, so that suppliers, retailers and consumers can have confidence that products satisfy environmental standards, and that farmers can potentially receive financial benefits for managing their farms sustainably. To be effective, such schemes must be built into the International Certification Standards covering commodities produced in Australia and be coupled with strong and effective public regulation to reinforce and extend environmental sustainability in production, trade, and consumption arenas around the world. One way forward is an 'Australian Standard for Sustainable Agriculture' which was negotiated as a component of international agribusiness and government. A possible 'Australian Sustainable Agriculture Standard' would need to include whole lifecycle analysis of energy, water, land and biodiversity inputs. Internationally, agribusiness and leading food manufacturing corporations are developing sustainability standards, but it seems that Australian businesses and food corporations are not part of this emerging trend. There is increasing evidence that certifications which seek to raise ecological and social expectations are likely to be increasingly challenged by those that seek to simply uphold current standards. The vulnerability of these initiatives to market pressures highlights the need for private regulation to work in tandem with public regulation to enhance social and environmental sustainability. Public regulations are increasingly seen as essential to reinforce and extend environmental sustainability in production, trade, and consumption arenas around the world (Raynolds et al. 2007).

Australian agriculture of the future has the challenge and the opportunity to see itself as a set of carefully managed agro-ecosystems nested and connected into the catchment landscape biophysical processes and as such, the ultimate managers and custodians of the major part of Australia's biodiversity. While experience is providing us with valuable lessons on how this might be done as stewardship and ecosystem payments, much innovation and new insights could be more strongly reflected in design and implementation. The learning of past decades resulted in much progress and strong foundations have been built. There is evidence emerging of policy options and operational procedures that can use payments to farmers for the delivery of ecosystem services over and above what may be considered an appropriate 'duty of care' established using such as the 'catchment care" principles of Hatfield-Dodds (2006). Now it is time to take it to the next level, to create genuine incentives at a scale and speed adequate to the task. This is a transformative opportunity for agriculture in Australia to manage the landscapes of the continent in ways that not only produce the food and fibre in a sustainable manner, but be the managers and operators of the conservation of the very rich biodiversity which is our Australian heritage and the foundations of our life support systems.

Access to soil and land that is well-suited to agricultural productivity will be critical to Australia's agricultural future. It is clear that now and into the next decades there will be increasing pressure from mining gas production and urban expansion on good quality agricultural soil and land. Strategic regional scale land use planning, coupled with regional governance and ownership by industry, community and government, will become an important tool for agricultural industries and communities in the future to manage the competition for agricultural land. Such planning would provide a social process and objective analysis of landscape capacity to accommodate long-term cumulative impacts within a whole-of-landscape framework.

Current problems facing soil and land management signals the need to build the knowledge and the human capacity and governance arrangements to manage the Australian soil and landscape more sustainably. Rebuilding regional delivery by working with landholders and Landcare groups is a way forward. Over the past decade, Australia has moved to a regional model for natural resource management which can be an effective means to secure the foundation for sustainable agriculture. The benefits of a regional model is that it operates at a scale large enough to manage the pressures on our landscapes, yet is small enough to use local knowledge of farmers and landholders to tailor solutions to suit those landscapes.

Understanding the dynamic nature of the knowledge networks in Australia need careful attention in the design of research and development programs and the dissemination of information, knowledge, and decision support. The social and technical complexity of agricultural enterprises is increasing as demands for increasing productivity and sustainability fall on managers of farming operations. Intensive management systems will be an integral part of the farm business as will farmer-driven innovations and the construction of farmer-to-farmer knowledge exchange networks via farmer groups. Knowledge networks through participatory partnerships with research institutions and universities and the nurture of knowledge networks through innovation intermediaries can all be expected to be increasingly important to Australia's agriculture of the future. The traditional linear model for research, development and extension will continue to undergo transformation. Effort to foster the new networks of knowledge and facilitation of innovation will be of critical importance to increasing productivity. It will be important to explore new ways to attract new entrants to agriculture knowledge generation, dissemination and brokering, and fostering the dynamic knowledge networks in the farming communities and industry. Overall, knowledge delivery and intensive management systems will be an integral part of the farm business. Steps to foster farmer-driven innovations and knowledge-intensive agricultural systems will likely require new mechanisms involving greater subtlety and flexibility in ways that traditional research, development and extension support opportunistic diversification and sustainable intensification.

7. Risks

R. Quentin Grafton

This part of the report examines the key risks facing Australian agriculture, and how they might be managed. All businesses face hazards that can potentially affect the returns, costs, profitability or long-run viability of operations. Hazards are events that can potentially cause harm while the probability or likelihood of the harm occurring is, in common parlance, defined as ‘risk’. In the risk literature, however, risk is defined differently as the expected value of a hazard or an adverse event (Grafton and Keenan 2014), or simply as the probability or likelihood of a hazard multiplied by the consequence of event, usually defined in monetary units. Thus, risk represents *both* the likelihood of a hazard and the magnitude or consequence of the hazard and is the potential negative consequences as a result of a hazard (Hardaker et al. 2004).

7.1 Introduction

It is frequently assumed that there is a trade-off between the probability/likelihood of a hazard occurring and the magnitude of the adverse event, or its consequence. This is shown in Figure 29 with the curve R1 where every point along the curve represents the same level of risk prior to risk treatment such that a high probability of a low consequence event may generate the identical risk as a low probability event, but with a high consequence. In reality, the risk actually faced by individuals or organisations is affected by the level of ‘risk treatment’ or risk management before an event occurs that is intended to reduce the impact or consequence of an event.

We might expect that the ability of an individual or enterprise to manage a potential risk would decrease with the magnitude of the event. Thus, a high consequence event with a large negative impact, even if it has a low probability, may offer a lower opportunity for risk treatment than a low consequence event which might be managed within an enterprise in a straightforward way through its day-to-day operations. By contrast, a high consequence event may be impossible to fully insure against and could also pose challenges in terms of how proactively it can be managed as there would be very little experience, if any, about how to control or respond to a high consequence–low probability event.

To what extent a hazard actually causes harm, such as a loss in profits, depends on the vulnerability of the business to the hazard and also the risk treatment or risk management undertaken by the business prior to the hazard occurring, and when it occurs. To illustrate, we can consider a drought as a hazard that represents potential harm to farming enterprises. The probability of a drought of certain duration or magnitude occurring would, typically, be defined by historical weather records with a possible greater weighting of data in the more recent past if there is correlation between present weather events and weather events in the immediate future. If both the probability of hazards and their consequence increase over time then the potential risks would also rise.

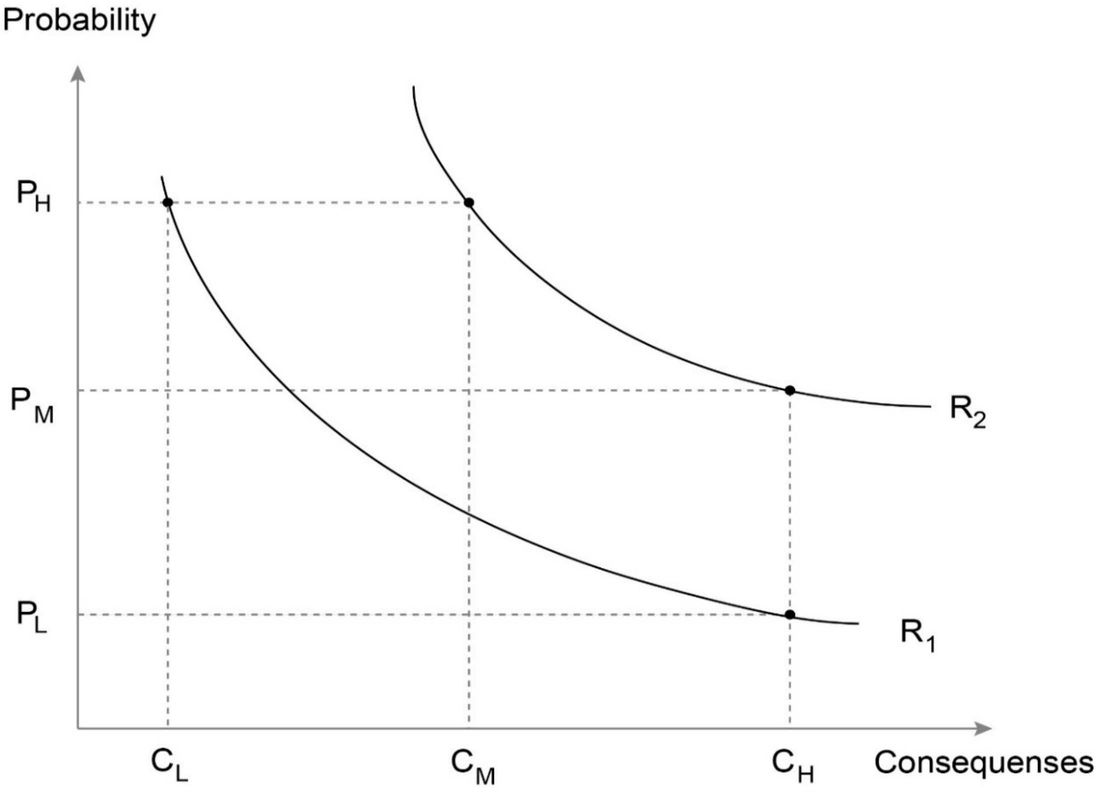


Figure 29: Risks: probabilities and consequences.
Source: Grafton (2010, page 607).

The actual harm of a drought is not equal across farming enterprises even if farmers were to be exposed to the same hazard, such as identical reduction in average rainfall during a drought. This is because factors both within (such as the choice of crops grown) and outside (such as soil type found on the farm) of the control of farmers determine the actual level of harm on a particular farm of any particular hazard.

Factors outside of a farmer's control can be referred to as the sensitivity of the landscape to a given hazard. Some landscapes are more sensitive than others such that with the same cropping patterns one farm may be severely affected by dryland salinity while another farm may suffer little or no damage. Sensitivity to hazards can also vary by farming practice and type. For instance, an irrigated farm in the early stages of a drought is likely to be less vulnerable in terms of reduced returns from lower than average rainfall, than a farm without irrigation because the irrigated farm has access to water stored in dams to water crops while the exclusively rain-fed farm does not.

Risk management decisions made before a hazard occurs can reduce the harm from a hazard regardless of the sensitivity of the landscape farming enterprise. These risk treatments are actions that determine the *actual* level of harm which is less than the *potential* level of harm in the absence of risk management. For example, a livestock farmer may choose to have a lower stocking rate than is possible in periods of normal rainfall so as to provide a 'buffer' in terms of feed in case of a drought. Similarly, an irrigator may choose to manage drought risk by owning higher rather than lower reliability water entitlements so as to ensure a greater likelihood that the full water allocation is available should there be a drought.

The risk treatment that farmers, or indeed any enterprise or organisation should use, is provided in Figure 30. The first step is to compile an information base, specify assumptions about risks and to engage, where appropriate, with stakeholders (Burgman 2005, p. 54). Risk management is an ongoing and circular process that includes: risk identification, prioritisation of risks, risk assessment, identification of risk management options, the selection of a risk management strategy, implementation of the strategy, and then monitoring and updating of the strategy.

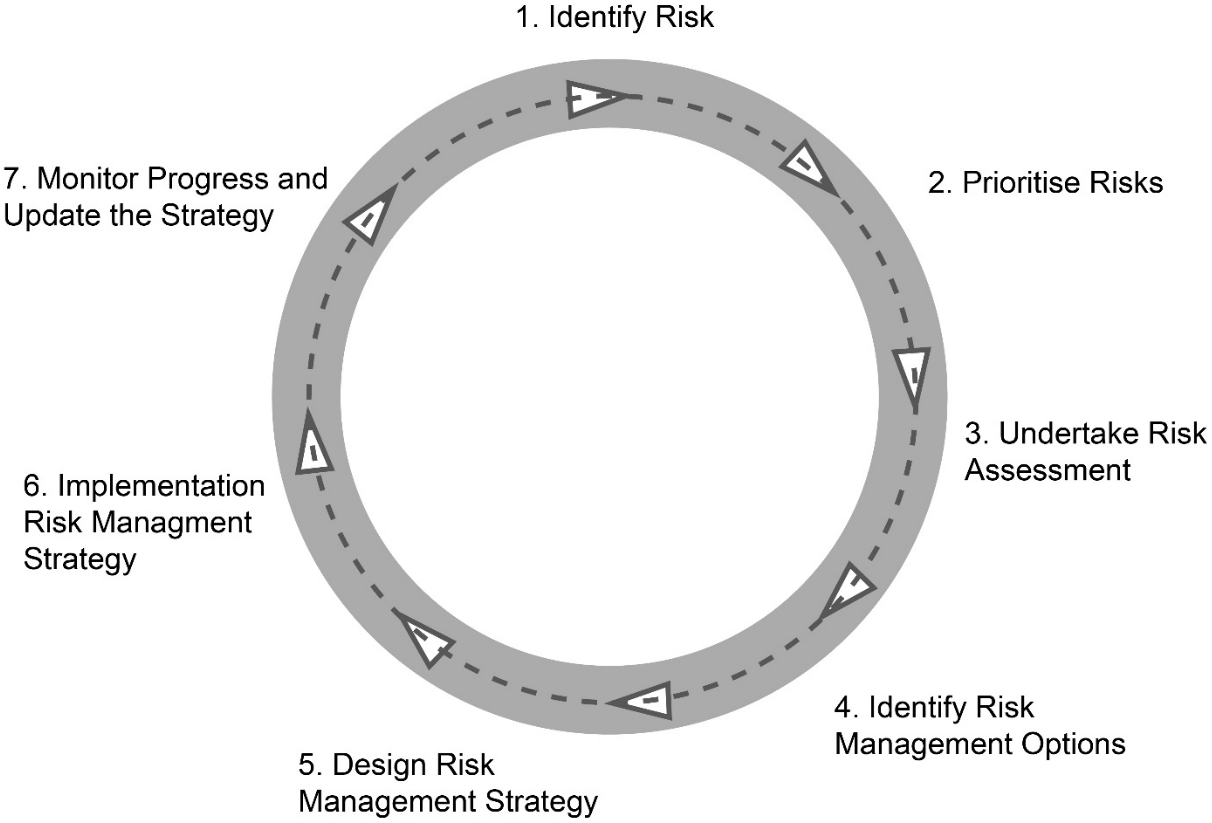


Figure 30: Risk management cycle.

The importance of the risk framework is not so much in the assignment of probabilities to hazards, or estimates of the potential consequences should a hazard arise, both of which can be difficult, if not impossible, to do with any accuracy for some hazards. Rather, it is evaluating what might be the possible hazards, prioritising for action across the possible hazards, and determining what actions can reduce the actual harm caused by the hazards so as to reduce the costs and to speed the recovery following a hazard (Australian Risk Policy Institute 2012).

The circular risk identification and management approach is applicable for a wide range of risks whether they be managed within the operations of a farming business, in what might be called 'normal' risk, 'transferable' risk that can be managed with financial and market instruments, including insurance, and also for 'catastrophic' risk (OECD 2011). Normal risk is characterised by typical or normal variations of a hazard, such as rainfall during a growing season, and can typically be managed within an enterprise by decisions made about input use and what outputs are produced. Transferable risk represents a hazard of sufficient magnitude or consequence that some form of insurance and/or borrowing or credit facility is required to help an enterprise respond, should the event occur. Both normal and transferable risks represent systematic risks in the sense that there is historical precedent and series of data that allows for systemic quantification and management of the risk.

Catastrophic risk involves hazards that may be difficult or impossible to insure against and would, typically, include events of such consequence and be sufficiently widespread that public assistance and response may be the only method to effectively manage the risk. Catastrophic risk is also characterised by the phenomenon of 'cascading risk' such that the size of the losses incurred by one enterprise affects the loss incurred by other enterprises. For example, with a catastrophic flood key agricultural service providers may suffer losses to their equipment such that they are no longer able to provide the previous level of service, or indeed any service, to farmers. This, in turn, raises the costs to farmers irrespective of whatever loss they may have incurred as a result of such a flood. Catastrophic risk may also be non-systematic in the sense there may be no pattern of probabilities that would allow for a reasonable quantitative assessment of its likelihood (Newberry and Stiglitz 1981).

7.2 Risks in agriculture

Farming, as with any business enterprise, faces a variety of risks. Many of these risks can be managed and are not unique to farming. Such risks include financial risks in terms of access to credit and personal or idiosyncratic risk in terms of the health of the owner-operator. The principal system risks that are much more pronounced in agriculture than in other market sectors include:

1. Market risks associated with access to output markets that can be affected by supply chains, and also rules of access.
2. Sovereign risks associated with state and national government policies in terms of taxes and subsidies and what farming practices are permitted.
3. Price risks in terms of the prices received for commodities as well as prices paid for key inputs, such as fuel and fertiliser.
4. Production risks in terms of the level of production that includes weather-related hazards such as insufficient water, but also by other factors such as pests and diseases that may change over time.

In general, Australian farmers suffer greater market, price and production risks than their counterparts in many other OECD countries. Market risk is greater because Australia exports a higher proportion of the value of its agricultural produce and, thus, is subject to greater potential interference in terms of access. Price risks, as measured by the variability of crop prices, are also larger for key crops such as wheat, barley and oilseeds (OECD 2009) because Australia has no price support scheme, has greater exposure to world markets than other OECD countries, and because of exchange rate fluctuations. Production risks are also greater in Australia in terms of key crops as a result of a more variable climate than most other countries. Overall, relative to other all industry average, Australian agriculture is about three times more variable as measured by its annual value of output (Keogh 2012).

Evidence from Australia, and other developed economies, is that farmers are highly effective at managing normal risks and also transferable risks provided that there exist competitive markets for key inputs (such as land and water) and outputs coupled with a well-functioning and competitive financial sector (OECD 2011). In the case of normal risks, risk management approaches by farmers typically involve adaptation or change to farm operations. This could be as straightforward as growing a less water-dependent crop during a drought or reducing the amount of inputs, such as the amount of fertiliser applied, when a hazard or adverse event occurs. Price risks, for instance, can be managed by buying price contingent contracts and hedging with the exchange rate while production risks, within limits, can be managed by farming practices and investments in infrastructure, such as irrigation.

Whatever the level of type of risk, effective risk management arises from good business practices and sensible, best practice on-farm management actions along with readily accessible historical data and forecasts on key risk variables (prices, rainfall, etc.). Critical to effective risk management is relevant experience, education, and the capabilities of farmers. In Australia, at least for normal and transferable risks, there are well-developed markets, and most farming operations are well-adapted to the Australian landscape to effectively manage most risks.

7.3 Role of Government

The case for public assistance in terms of managing risk in agriculture is in terms of catastrophic risks, especially in the context of either market risks or production risks. In terms of market risks, a justification for a public–private management of risk could include unexpected import bans of certain types of Australian agricultural exports, such as the live animal trade. In such a case, the agricultural sub-sector remains profitable, but for whatever reason there is temporary lack of market access. The public role in risk management would be to support measures to overturn the import bans, assist in market access to other markets and to provide, if required, lines of credit to cover the temporary loss of income.

A case may be made for market intervention in the event of catastrophic production risks brought about by invasive species, extremely rare weather-related events, or a large and unexpected hazard. For invasive species or pathogens, there is a justification for intervention to prevent further contagion with preventative measures that would otherwise be underprovided privately and, in the absence of some compensation, may be underreported. In terms of rare or first-time weather-related events, intervention may be justified if there are cascading risks where a lack of coordination in terms of overall risk management would result in an otherwise profitable business failing. Assistance is also justified if it hastens the recovery process in the community at large, and this has social and economic benefits.

The types of interventions available to governments include:

1. Establishing markets that promote risk management: such as the creation of water markets to allow farmers to better risk-manage droughts.
2. Risk smoothing: such as schemes that allow farmers to smooth their incomes by tax averaging over high- and low-income periods.
3. Risk management: such as providing historical data and up-to-date forecast of key risk variables and assistance and advice in risk management.
4. Risk reduction: such as the coordination of actions to monitor and contain pests and diseases and the building of infrastructure, such as levies, to reduce risks of flooding.

In all cases, the justification for intervention is the existence of a market failure whereby government action may generate a more economically-efficient outcome than in the absence of intervention.

Establishing markets and providing the institutional and regulatory support for markets is a key way governments can support risk management in agriculture. For example, comprehensive water markets developed by the Council of Australian Governments (COAG) from 1994 onwards, especially in the Murray–Darling Basin (Grafton and Horne 2014), were a critical factor in ensuring the nominal gross value of irrigated agriculture falling by just 1% between 2000–01 and 2006–7 despite a fall in water extractions of 70% (Kirby et al. 2014). The value of water entitlements and water allocations to these entitlements is that they allow farmers themselves to make their own decisions in terms of managing yield risks associated with reduced water availability.

Risk smoothing reduces tax liabilities in periods of low income. This allows farmers to share risk with other taxpayers, but without necessarily imposing a cost on other taxpayers. Given that information and knowledge is non-rival, but its acquisition imposes fixed costs, there is also a justification for reducing the costs of acquiring skills in risk management, especially if this helps to avoid cascading risks across farming enterprises.

Risk reduction, through coordinated action, is justified to overcome the ‘free rider’ problem of the provision of public goods and includes both ‘soft’, such as information provision, and ‘hard’ infrastructure, such as flood control. Further, effective risk reduction across Australia requires specialised skills and fixed costs of operations that benefit from a single-provider model. In terms of risk reduction, the delivery of information through CSIRO, the Bureau of Meteorology and ABARES and other knowledge-creating and brokering organisations would be underprovided in the absence of government support. The scale of operations of these research organisations also allows for strategic planning in terms of which knowledge is developed that, in turn, provides inter-temporal benefits in terms of risk reduction and the prioritisation of risks to be managed. In addition to knowledge generation and provision, government agencies such as Biosecurity Australia and the Australian Quarantine and Inspection Service can provide both the expertise and regulatory authority to reduce the likelihood of emerging plant and animal disease threats. As in the case of knowledge organisations, there are likely to be economies of scale in terms of monitoring and benefits from government-to-government data sharing which would likely be constrained should biosecurity services be provided privately.

Given the large range of risks facing Australian agriculture it is not possible to provide a comprehensive review of these risks. Instead, we highlight some of the key risks that include:

1. Production Risks: Drought
2. Production and Market Risks: Biosecurity
3. Market and Price Risks: Import controls and the social licence to export
4. Production Risks: Climate change

7.4 Production Risks: Drought

The most common production risk faced by Australian farmers is drought risk that arises when there is insufficient water to maintain 'normal' farming operations. Droughts are common place in most locations in Australia, but severe drought over an extended area and period of time may only be expected, say, once every couple of decades. The most recent severe drought, called the Millennium Drought, affected most of the Murray–Darling Basin, with varying degrees of severity, over the period 2002 to 2010. The only comparable drought, in terms of its severity, was the Federation Drought of 1895 to 1903 which resulted in very large stock losses at that time.

Farmers should be expected to manage short- to medium-term droughts given that periods of low rainfall and/or higher temperatures are a 'normal' feature of the Australian climate landscape (Kimura and Antón 2011). Thus, coping or managing with droughts that are expected to occur with a reasonable frequency, should be part of standard farming operations of Australian farmers. Nevertheless, a case may be made for drought assistance for catastrophic risk or exceptional circumstances, such as with a one in a 100 years drought, because it cannot be insured against nor can it be successfully managed within existing capacities of farming enterprises in what would otherwise be profitable farming operations.

Managing risk in farming must also recognise the biophysical realities. Large parts of Australia are simply not suitable for cropping due to insufficient rainfall and the inadequacy of the soils. In such places, farming enterprises must be adapted to the landscape and if there is a mismatch, drought risks may be intolerable. This 'matching' of farm production type to the land and climate scape, and the consequences of misalignment, is likely to become more pronounced with climate change.

One of the key reasons that irrigators in the Murray–Darling Basin were able to manage the adversities of the Millennium Drought was because they were able to trade water, a key input to their operations. This allowed water to move from lower to higher value uses benefiting both buyers and sellers (Grafton and Horne 2014). Access to credit, the ability to both borrow and save, and the existence of insurance markets are also important factors that allow farmers to manage risk in their operations.

Australian Governments have a long history of intervening and providing drought support for farmers in what has been called 'Exceptional Circumstances'. The framework for determining exceptional circumstances is based on several criteria including meteorological conditions, agronomic and stock conditions and farm income levels and, in theory, should be an event of more than 12 months in duration and be a one in 20- or 25-year event (ABARES 2012). Exceptional Circumstances Drought Relief was initially developed as part of the 1992 National Drought Policy that recognised that providing assistance in response to a drought as a 'national disaster' does not support good risk management practices by farmers. From 1997, assistance has been provided in terms of Exceptional Circumstances Interest Rate Subsidies, Exceptional Circumstances Relief Payments (for basic income support to meet living expenses) and a Farm Management Deposit Scheme (allows farmers to set aside pre-tax income in good years for use in low-income years) (ABARES 2012). The problem with such supports is that they can 'crowd out' private risk management and may even discourage farmers from developing off-farm income sources if this were to reduce the likelihood of them receiving interest rate subsidies.

A recognition that the Exceptional Circumstances Trigger for drought has not promoted good risk management was documented by the Productivity Commission in 2009. For instance, the trigger was declared in more than 5% of years, and in some locations for more than ten years over the period 1992–2008 (Kimura and Antón 2011). A commonly held view is that the frequency of droughts in southern Australia will likely increase with climate change (Hennessy et al. 2008). As a result of drought policy reviews and a drought reform pilot (Keogh et al. 2011), Australian Governments signed the *Intergovernmental Agreement on National Drought Program Reform* in 2013 to come into effect on 1 July 2014. Under this Agreement, all governments have agreed to encourage farmers to better prepare for droughts and manage their business risks. Further, Exceptional Circumstances Interest Rate Subsidies and also Relief Payments are to end. As part of the new package of support, governments will provide: (1) a Farm Household Allowance that provides assistance to farm families experiencing financial hardship, but without the need for Exceptional Circumstances declaration and an entitlement of up to three years of fortnightly income support; (2) Farm Management Deposits Scheme; and (3) Farm Business Training.

The key to judging whether the latest drought reforms are successful or not will be whether they are complemented or not by ad hoc income or other support measures (federal or state level) that allow farmers, who are unable or unwilling to bear normal or transferable risks, to remain in business in the absence of such support. Thus, the Drought Concessional Loans totalling $280 million that were committed to farmers by the Australian Government in February 2014 (Abbott and Joyce 2014) needs to be carefully evaluated as to what incentives it provides to farmers in terms of how to manage production risk as a result of droughts. Providing funds to farmers whose enterprises are misaligned to the land and climate scape increases production risks, augments the costs paid by taxpayers, and exacerbates social costs. Ultimately, such support is counterproductive if the aim is to promote a dynamic agricultural industry that is internationally competitive, and able to effectively manage risks.

7.5 Production and Market Risks: Biosecurity

Biosecurity refers to an integrated approach to managing risks to human, animal and plant life that is, typically, associated with the early recognition, containment and prevention of pest and disease threats. Australian agriculture is particularly vulnerable to emerging pest and disease threats because of its relative isolation as an island continent. As a result of this isolation, a number of pathogens and diseases that are found elsewhere in the world, such as foot-and-mouth disease, do not currently exist in Australia.

The public role in Australia in terms of biosecurity risk is a public–private partnership whereby farmers co-invest or cost share depending on the external effects of threats. For instance, in terms of livestock diseases, measures to prevent or control life-threatening diseases that can be transmitted from animals to humans (such as rabies), and that have a minimal impact on the livestock industry are 100% funded by governments and are called category 1 diseases. By contrast, diseases that are limited to livestock and that impose costs that are primarily incurred by the livestock industry are defined as category 4 diseases. For these diseases, the industry funds 80% of the control costs (Kimura and Antón 2011).

While Australian agriculture faces a number of existing threats from invasive species already in Australia, the greatest risks are in terms of hazards not currently found in Australia, but which exist in other countries, and have the potential to cause widespread costs and damages. CSIRO (2014) has identified what it calls ‘megashocks’ which would be capable of causing catastrophic risk for Australian agriculture in terms of biosecurity. In terms of crop, vegetable and fruit production these catastrophic risks include:

1. Wheat rust which could have a devastating effect on yields and ability to sell the most valuable agriculture grown in Australia.
2. High levels of morbidity and mortality of bees.
3. Introduction of a new, exotic fruit fly.

In terms of the livestock industry, the catastrophic biosecurity risks identified by CSIRO (2014) include:

1. Nationwide outbreak of foot-and-mouth disease; and
2. A ‘bluetongue’ outbreak in the principal sheep producing regions of Australia.

Foot-and-mouth disease, in particular, would impose very large costs in terms of loss of farm production and large social and economic costs to the community; but equally as important, it would likely trigger import bans for Australian livestock production until the disease was eradicated.

Given that the potential economic losses of catastrophic risk associated with biosecurity could be costs in the billions of dollars, Australia's agricultural future is dependent on effectively managing such risks. Biosecurity risk management must involve the whole Australian community from travellers to Australia, importers, farmers, scientists as well as those employed directly in monitoring and surveillance and undertaking risk analysis. It also involves complementary risks in the sense that climate change may increase the farm land vulnerable to outbreaks of pests and diseases, and may also increase the likelihood of the introduction of some invasive species.

Experience from both Australia and overseas indicates that effective biosecurity requires an integrative approach that includes veterinary and plant sciences, epidemiology, economics and social research (Gibbens 2013). The benefits of disease eradication will, typically, decline the more prevalent the disease as the area or population unaffected declines, while the costs of eradication increase the more widespread is the disease (Epanchin-Niell et al. 2010). Equally as important, is the finding that higher spending on control leads to lower animal disease losses, but the optimal level of control could be an intermediate level of control which is neither complete disease eradication nor is it a zero level of control (McInerney 1996).

7.6 Market and Price Risks: Import controls and the social licence to export

Market risk refers to possible hazards in the context of market access while price risk refers to factors that would either increase variability or reduce the average level of prices for Australian agricultural products. Market risks can arise from multiple causes, but the two principal factors identified in this report are: (1) embargoes that would prevent the export of Australian food or fibre commodities and processed food into export markets; and (2) constraints on market access and/or reductions in the price received for Australian agricultural products as a result of failures to meet agreed-to-societal-standards or norms.

Trade embargoes represent the most extreme form of import control and can arise from several factors. The most likely cause is from food contamination or the fear of disease contagion such as from the import of fresh meat if there were to be a foot-and-mouth outbreak in Australia. Food contamination risks arise infrequently, but can and do occur, and pose catastrophic risks. To illustrate, in 2013 Fonterra, the world's largest dairy exporter, announced that whey powder produced at one of its plants could contain *clostridium botulinum* which, if consumed by infants in infant formula, could be life threatening. This triggered a product recall by Fonterra, but also import bans by both Sri Lanka and Russia. Subsequent tests by the New Zealand Ministry for Primary Industries indicated there was no botulism in the milk products. The follow-up testing with a negative result allowed Fonterra to recover from the fall-out from the false positive test, but shows how market risk can arise suddenly and impose large economic costs. In some cases, import bans may be imposed even in the absence of evidence of contamination or contagion because some producers in countries that import food from Australia are keen to reduce competition and will utilise whatever information they can to support such bans.

Import bans can also arise from sovereign disputes. The most recent example is the decision by Russia to ban in August 2014 and, for one year, the import of beef, pork, fruit and vegetable produce, poultry, fish, cheese, milk and dairy products from the European Union, the United States, Canada, Norway and also Australia. According to the Russian Government, this was a retaliatory measure in response to sanctions imposed by these countries on Russia over its annexation of Crimea in March 2014, and Russian support for independent activists in Eastern Ukraine.

A lack of a social licence can pose both market and price risks to Australian agricultural producers, especially exporters. The most recent example is the live animal trade and the self-imposed export ban by Australia in June 2011 in response to concerns over the treatment of cattle exported to Indonesia. While the ban was subsequently lifted following an independent review and improvement in protocols and checks along the supply chain, the Australian ban resulted in a retaliatory import control response from Indonesia before live cattle exports from Australia were allowed to resume. The key point is that social acceptance of live animal exports is diminishing with a greater attention and awareness of animal welfare issues. Further, in terms of this issue, there are activists who do not support any live animal exports regardless of the safeguards or protocols in place and, thus, are actively campaigning against all live animal exports from Australia, and other countries. Similar 'social licence' risks may also arise in the future on other issues. For instance, some climate-change activists in the future may wish to target Australian food for boycotts or to prevent additional coal exports from Australia through or near to the Great Barrier Reef. Similarly, some governments may seek to impose additional import tariffs on Australian goods if they believe Australia's policies in the environmental dimension are providing an 'unfair' trade advantage.

Given the importance of exports to Australian farmers, the increasing use of social media and campaigns by activists to link government policies to consumer purchases, and also the willingness of overseas producers to support import bans, social activism represents a growing risk to Australian food exporters. This requires collective action by food producers, but also by governments, and proactive identification and management of these risks.

One possible risk management strategy is food and farm certification schemes that, to date, have not generated the hoped-for financial rewards for producers. Going forward, such certification schemes may be viewed as a necessary cost of doing business and risk management regardless of whether it generates a price premium. This is because sustainable certification may be necessary to ensure continued market access and to manage the possibility of consumer boycotts. On the upside, sustainable certification may increase opportunities for Australia in the high-quality markets in emerging economies. Should sustainable certification of Australian agricultural products be developed at a national level, it will require coordination and collective action by producers and global agribusiness, as well as the Australian Government, and will need to be internationally recognised and consistent with existing international standards.

7.7 Production Risks: Climate change

In the context of risk and agriculture, climate change can be interpreted as the change in the probability and the magnitude of hazards or climate-related events that increase production risks. For illustration purposes only, this can be represented by a shift in the risk curve in Figure 29 from R_1 under the present climate to R_2 under a changed climate. A sufficiently large enough change in the frequency of adverse climate-related events, such as floods, may also reduce the ability of farmers to manage production risks in terms of higher insurance premiums payable to cover losses to buildings and equipment.

The challenge for the agricultural sector is that while the overall trend with climate change is for higher surface temperatures, there is much uncertainty as to how fast temperatures will rise, and what their level will be at a point in time. Further, there is a great deal of uncertainty at a sufficiently small enough spatial scale as to what the effects of climate change might be in terms of rainfall, as localised effects may dominate regional or national trends. This uncertainty makes it difficult to manage risk with climate change, especially if the climate changes at a rapid rate.

Despite the high degree of uncertainty at a local or farm level, data already compiled on past weather-related events (Grafton and Keenan 2014), shows that both the number and economic losses (insured and overall) associated with weather-related events that cause catastrophic risks is growing over time (see Figures 31 and 32). Even these figures underrepresent the risks of climate change to the agricultural sector because droughts, typically, do not cause property damage and because farming enterprises are much more dependent on weather in terms of their production than other market sectors, such as manufacturing or the service sector. The upward trend in weather-related catastrophes is not only increasing globally, but is also true for Australia (Schuster 2011), and is consistent with climate-change model projections (CSIRO 2014).

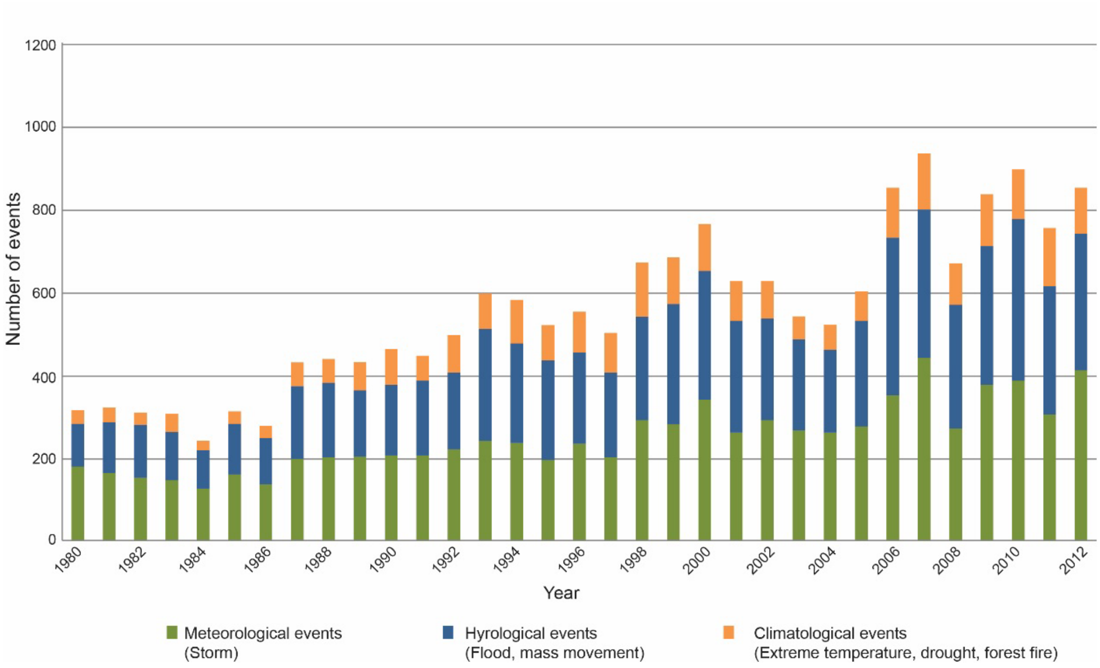


Figure 31: Number of global weather-related catastrophes 1980–2012.
Sourced from data at Muchener Ruckversicherungs-Gesellschaft, Geo Risk Research, NatCatSERVICE.

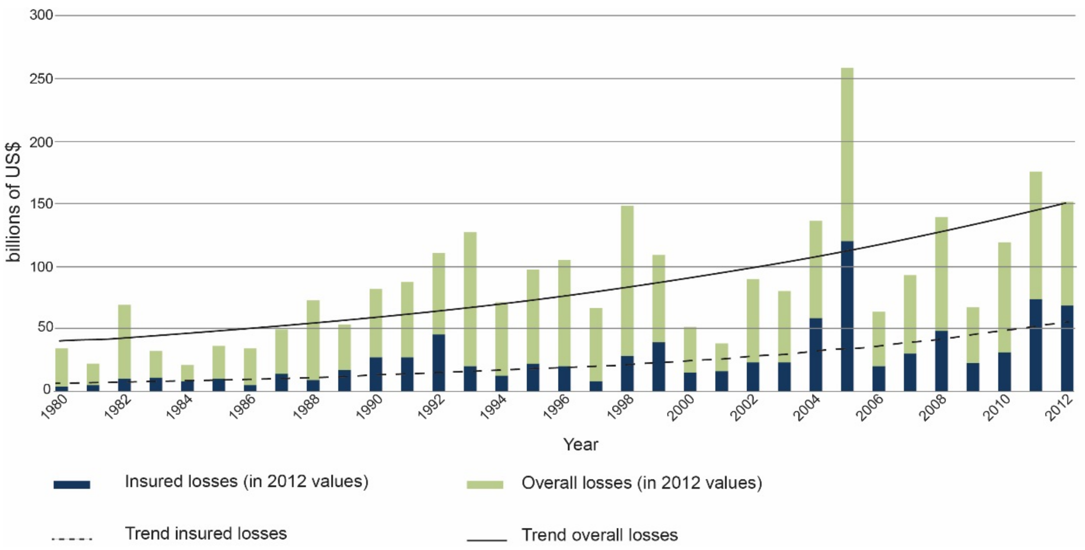


Figure 32: Economic losses (insured and overall) associated with global weather-related catastrophes 1980–2012 ($US billion).
Sourced from data at Muchener Ruckversicherungs-Gesellschaft, Geo Risk Research, NatCatSERVICE.

A recent review of the projected effects of climate change on Australian agriculture was undertaken by CSIRO (Stokes and Howden 2010). Their overall conclusion is that, at least in the short term, the most effective risk management approach by farmers is to enhance and to promote their existing capacity to respond to climate variability (Howden and Stokes 2010). Grafton and Keenan (2014) propose that there should be a national, state and regional risk register that provides a quantitative index of relative consequences and relative probabilities of all risks, including climate risks that would expand Australia's *National Adaptation Assessment Framework* (Commonwealth of Australia 2013).

Risk planning is integral to the effective implementation of Australia's Adaptation Framework that is intended to improve the future well-being of Australians. Risk planning and land-use planning are closely related because choosing where to farm, in terms of soil and climate, is arguably the most important factor in risk management with climate change.

As proposed by the Australian Government (CSIRO 2013), a National Adaptation Framework should include:

1. Assessment of Drivers: or the characterisation of those factors that promote effective adaptation and that include assessment of climate risks; governance and rules and regulations; markets and incentives for adaptation; and social acceptance of what changes are required.
2. Implementation of Activities: the actions that should be currently undertaken in terms of current climate risk, no- or low-regret actions that would provide positive net benefits even if climate change did not occur; long-term planning; and investment in building skills and the information base.

An Adaptation Framework is complementary to a National Security Assessment such as that undertaken in the United Kingdom and which is on a biennial cycle and 20-year planning horizon. If such a risk register were developed in Australia, it would provide a fit-for-purpose guide about present and future risks, and not just climate change, and give transparency over the prioritisation of risks, planned risk treatment and trade-offs across risk management.

In evaluating climate risk in Australia, Grafton and Keenan (2014) argue for ex-ante public–private partnerships in responding to climate risks so as to improve resilience that reduces the recovery time, following a hazard, and lowers the actual consequences of weather-related events. Such partnerships should enlarge the opportunity set available with climate adaptation and risk management, and reduce the consequences of weather-related events associated with climate change. This is illustrated in Figure 33 whereby effective climate adaptation increases opportunities and reduces risks while poor planning or maladaptation that does not consider future risks may even increase the consequences of climate change.

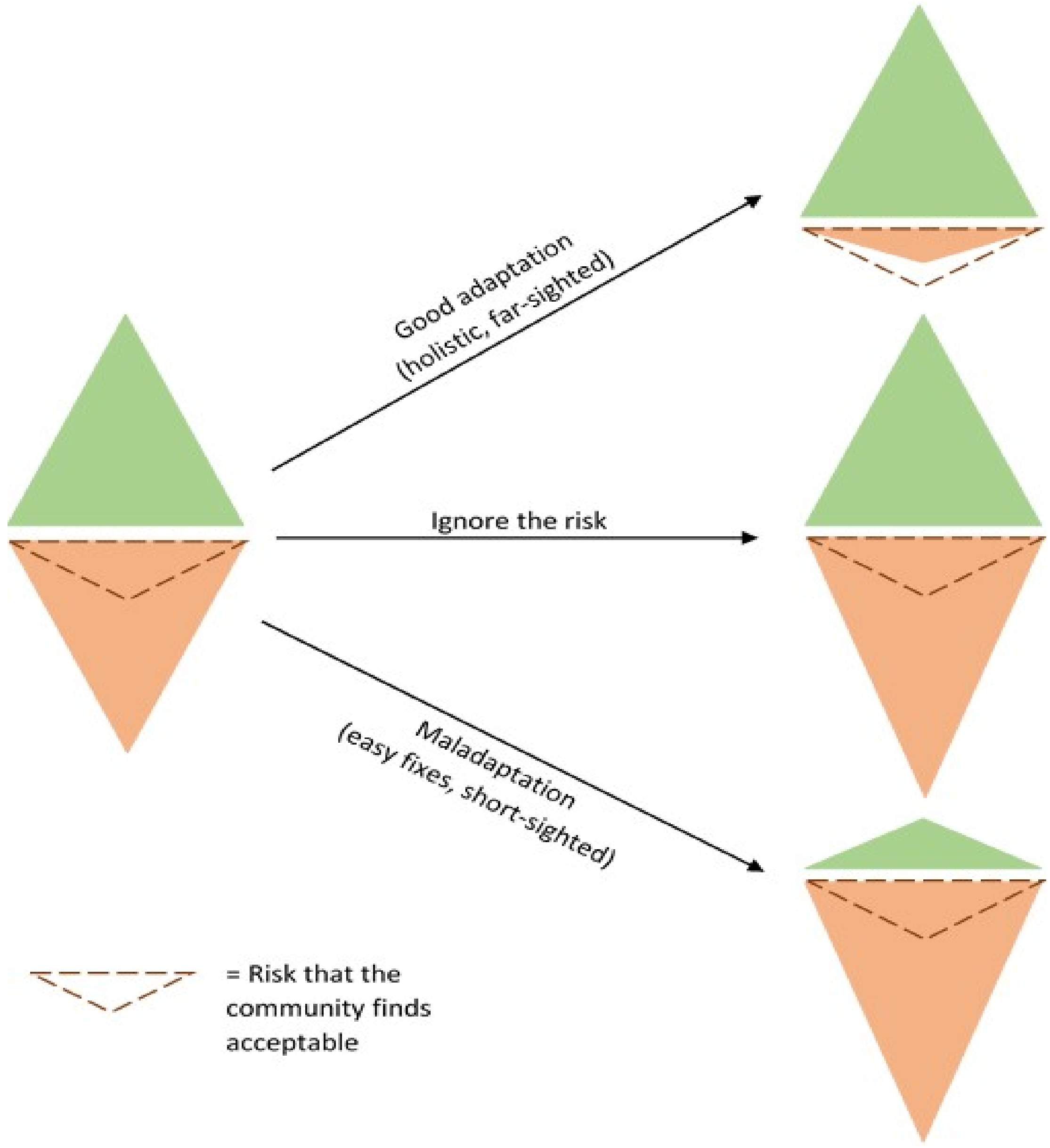


Figure 33: Risk management and climate adaptation: risks and opportunities.
Source: Commonwealth of Australia (2013, page 37).

An example of ex-post recovery assistance rather than adaptation or preparation for hazard events is *New Zealand's On-Farm Adverse Events Recovery Framework*. This is part of that country's disaster relief program and is intended to:

1. Speed up recovery of the rural economy following an adverse event; and
2. Minimise spillovers into the rest of the economy (OECD 2011).

This is achieved by setting, in advance, what are the prescribed assistance actions (clean-up assistance, tax relief, emergency unemployment benefits and special needs grants, exit grants, psychological recovery assistance), but the scale of assistance depends on the assessed consequences of the hazard after the event.

Relative to 1990, climate-change projections for Australia indicate that surface temperature by 2030 will increase by about 1.0 degree Celsius with 10th to 90th percentile range of between 0.6 and 1.5 degrees Celsius (Hennessy et al. 2010). The greatest projected warming is expected to occur in inland Australia with a more than 50% probability that warming will exceed 1.0 degree Celsius by 2030. Rainfall projections are highly uncertain and are expected to increase in some areas, but decline in others, with the expectation that rainfall will decrease in the southern parts of Australia. Further, the timing of rainfall may also change, even if the annual rainfall does not change, with the expectation that winter rainfall will likely decline in southern locations.

Overall, the projected and uncertain rainfall changes range from –10% to +5% in northern Australia to between –10% to no change in southern Australia by 2030, relative to 1990. If these projections prove correct, this could possibly result in reduced median projected streamflow by 2030 of 9% in the Murray–Darling Basin, 3% in Tasmania and 24% in south-west Australia (Commonwealth of Australia 2013, p. 91). Greater change in terms of surface temperature and rainfall are expected beyond 2030, but as to what these changes will be is highly dependent on future global greenhouse gas emissions over the coming decades.

The projected changes in average temperature and rainfall are within the current climate variability that farmers are already managing. Thus, the expectation is that farmers will be able to adapt and adjust to changes in average temperature and rainfall, but this will likely require adaptive measures (Howden et al. 2010; Stokes et al. 2010; Miller et al. 2010) that include: varietal changes (more thermally and/or drought tolerant), species change, planting time variation, and changes to crop and pasture management practices (nutrient management, irrigation, salinisation management, livestock heat stress, stocking rates, crop diversification, and weed and pest control management). On-farm adaptation will need to be supported by research such as the Australian Government's *Climate Change Research Program* which was established to test the responses of crops to higher temperature and also carbon dioxide, to examine ways to reduce heat stress in livestock, and to assess the viability of new forages. The present spread of agricultural research stations across a range of temperature and rainfall regimes should also be a source of adaptation strategies, even if past findings become more applicable further south.

As part of their risk management, farmers will shift where they grow crops as the climate changes. This adjustment is currently underway in terms of grape production as Australian grapes are ripening earlier and wine producers are shifting some of their production to cooler regions further south. For example, Treasury Wine Estates, the world's second-largest listed wine company, is developing vineyards in Tasmania (Commonwealth of Australia 2013). Similarly, winter cereal production now occurs in southern Victoria while in the past the prevailing climate was too wet to make such production financially viable. It is also possible that summer cropping options will increase in areas where formerly the climate was strictly Mediterranean.

Arguably, the greatest risk to agriculture from climate change is not changes in mean temperature or rainfall, but possibly increased frequency of hazards or extreme events, such as droughts and floods. In the absence of extreme events it is projected that, with adaptation, Australia can maintain its comparative advantage in grain production for export (Sanderson and Ahmadi-Esfahani 2011). Thus, the climate change challenge for Australian agriculture is to manage extreme weather-related events that have reduced agricultural output in the past such as in the 2002–03 and 2006-07 droughts, the 1994–95 drought, and the 1982–83 drought.

Severe droughts and extremely hot years occur about every 20 years in Australia and over the period 1900 to 2007 (Hennessy et al. 2008) and affected about 4.5% of the area of seven major agricultural regions, including the Murray–Darling Basin. Based on CSIRO climate modelling, the mean area affected in these seven regions increase between 60% and 95% over the period 2010–2040, depending on what is assumed about future greenhouse gas emissions. While these projections are highly uncertain, under the higher-end projections it is possible that the frequency of extremely hot years may increase to once every two years in these regions (Hennessy et al. 2010).

Given Australia's already high climate variability, and possible increase in frequency of extreme events with climate change, it would seem that Australian agriculture would be well-served by the development and support of practices that assist farms and landscapes to recover faster and maintain their inherent capacity to produce food, fibre and ecosystem services following such events. Many of these practices are already in use by farmers in response to current climate variability, but additional approaches are likely to be required and also to disseminate knowledge of best practices.

Collective action is required given there are market failures in the provision of information, and also in terms of regulations that would permit new financial instruments, such as climate derivatives, to allow farmers to better manage their risk. Whatever public or collective actions are chosen, all interventions must expressly avoid skewing market price signals (such as land values) that may be indicators of risk, or to subsidise infrastructure (such as water storage) that may encourage maladaptation and increase rather than reduce risks.

7.8 Risks and resilience

Resilience is the capacity of systems to respond to change and, in particular, their ability to respond to negative shocks and still retain their key characteristics and capacity (Holling 1973). Sometimes resilience refers to the time it takes for a system to 'bounce back' from a shock (Grafton et al. 2005). Resilient biophysical and socio-economic systems should be able to:

1. Recover from shocks and disturbance;
2. Adapt through learning; and
3. Undergo transformation, when necessary (PMSEIC 2010).

The relevance of resilience in terms of Australia's agricultural future and risk management is that both on-farm and off-farm decisions must account for the unintended consequences of short-term actions and possible risks across the food and water landscape. To illustrate why resilience matters in terms of agricultural risks, consider a drought in which there is an increased demand for irrigation water. In the absence of 'resilience thinking' (Walker and Salt 2007) and adequate water planning, this increased demand results in an absolute and proportional decline in the water available for environmental flows in streams and rivers (Grafton et al. 2013). The unintended consequence is reduced resilience of the landscape to cope with further droughts, or other hazards, because of, say, reduced groundwater recharge and the dieback of trees that would otherwise maintain soils stability, and other factors. In turn, reduced landscape and farm-scape resilience lowers crop yields or pasture production without the use of additional inputs, and increases production risks when the next drought arrives.

By adopting resilience thinking, decision-makers can reduce the risks of transitions that may push critically important water and environment systems toward thresholds that, once exceeded, could result in a catastrophic event (Scheffer 2009). Reducing the likelihood or diminishing the consequences of catastrophic risks embraces a landscape or a systems perspective where the health of the landscape is considered to support the ability of farming systems to provide food and fibre. For example, while the causes of the Honeybee Colony Collapse Disorder (CCD) in Europe and North America have not yet been determined, it is widely accepted that changes in the landscape and how bees are managed in that landscape have been contributing factors in colony collapses. This illustrates that services provided by the landscape are valuable and need to be maintained if the productivity of food production is to be sustained.

Proactive and ex-ante actions at the farm level, supported by collective action to risk manage catastrophic risks, can reduce the actual impact and also speed recovery following catastrophic events. This is illustrated in Figure 34 where the area beneath the lower dashed line refers to risks that can, and should, be managed by farmers themselves with the help of markets to transfer risks. The area between the lower dashed line and the upper dashed line represent risks where it is appropriate for market intervention and public–private partnerships to manage catastrophic risks. The area above the upper dashed line are risks for which there is no currently adequate approaches to managing catastrophic risks. Actions to promote resilience in landscapes are shown to increase the set of risks that are 'manageable' or recoverable and that allow farming systems, and the landscapes in which they reside, to 'bounce back' from catastrophic events, be it a severe drought or an outbreak of an invasive species.

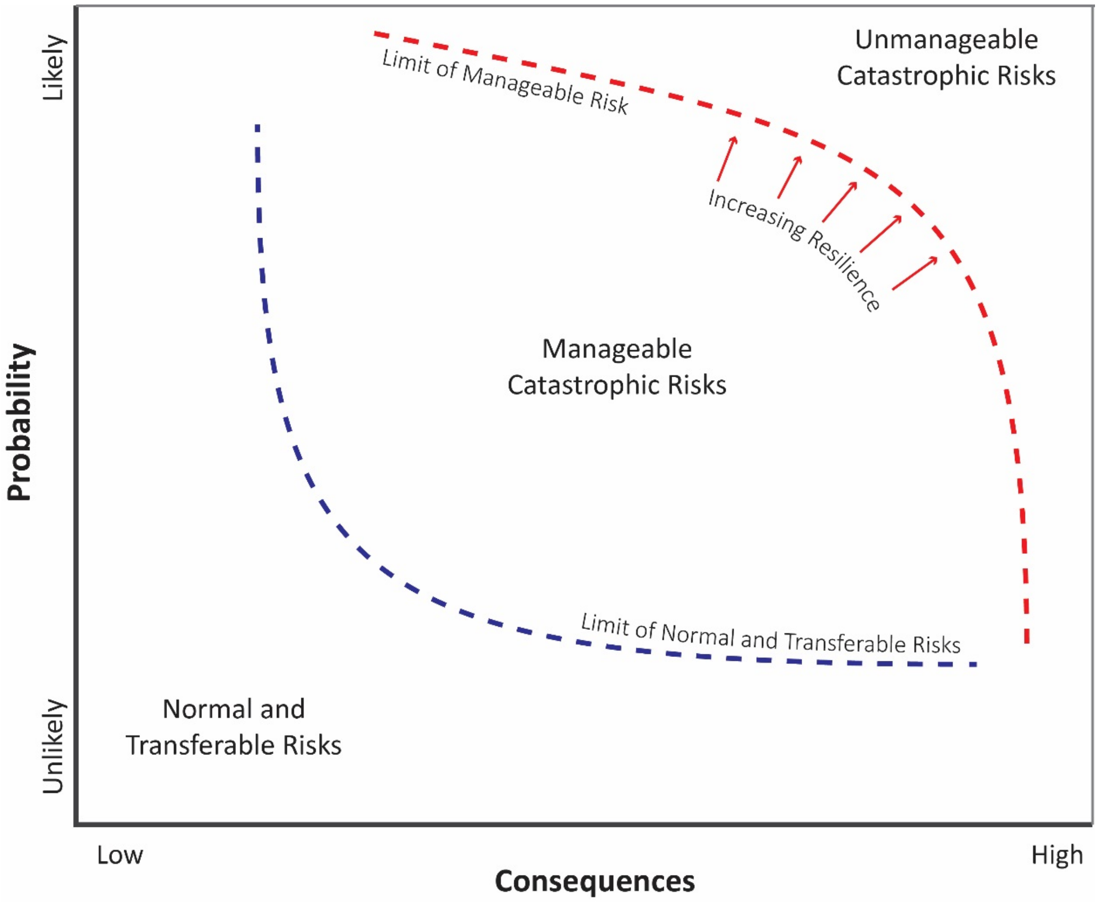


Figure 34: Resilience and normal, transferable and catastrophic (manageable and unmanageable) risks. Adapted from Dow et al. (2013, page 388).

While there is no 'recipe book' to follow in terms of promoting resilient landscapes and to better manage catastrophic risks, the following actions are likely to be valuable key steps:

1. Implementation of a holistic approach to risk management (OECD 2011) that considers multiple risks, complementary risks and cascading risks to food and water systems and the landscape, and includes strategic environmental and resource planning (PMSEIC 2010; Wentworth Group 2014).

2. Identification and prioritisation of catastrophic risks (OECD 2011) and ways to better manage and respond to catastrophic risks, preferably in partnerships between governments and farmers. Possible outcomes from this identification and prioritisation process include: diversification of farming systems; opportunistic farming that takes advantage of 'good' years and reduces vulnerability in 'bad' years; linking of land and water governance systems to make integrated decisions about landscapes; regionalisation of resource planning to ensure decisions are made by people with good understanding of landscape function; and adequate support for information and measurement of key landscape measures of health (Wentworth Group 2014).

3. Adaptation to climate change. Actions may include: relocating what types of agriculture is practised and where; adapting agriculture to a changing climate-scape through

innovation; avoiding 'lock-in' in terms of public investments that prevent flexible farm responses; and support for innovative experiments at local scales (PMSEIC 2010).

4. System mapping and measurement of the biophysical and socio-economic systems, and the connections between them (Grafton 2010). Such 'mapping' and measurement allows assessment over time of landscape changes, the identification of 'linkages' that may need to be strengthened (such as transport and communications links within and across communities) to promote resilient landscapes, and linkages that may need to be removed, such as support for marginal farmers to remain on landscapes which are ill-suited.

7.9 Conclusions

In summary, Australian agriculture faces many risks, some of which may grow over time. Fortunately, Australian farmers are well-equipped to manage risks and many of their practices are adapted to opportunistically diversify their operations while accounting for the landscape in which they operate.

Looking to the future, the Australian agricultural sector and rural communities will likely need assistance to adapt to climate change, and also to risk manage weather-related, biosecurity, and market access catastrophic events. This government assistance should augment rather than replace farmer-initiated risk management actions. Such public assistance must, at all costs, avoid 'crowding out' of individual risk management. Instead, public–private partnerships should create incentives for farmers and their communities to adapt in ways that reduce the ability of the landscape to recover from catastrophic events.

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