Farming Smarter, Not Harder:

Securing our agricultural economy

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About this report

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The Sustainable Economy Program aims to identify options for Australia to flourish while bringing our economy within environmental limits. Australia has tremendous opportunity to leverage our natural resources and skills in innovation to build a fair, sustainable and prosperous economy – one that provides a secure future for all of us. Yet to do so, we need policies to support a rapid economic transition.

Farming Smarter, Not Harder is the second in a series of reports looking at how different sectors of Australia's economy can benefit from policies to preserve the environment and resources that sustain them. CPD would like to thank the Ian Potter Foundation for their funding of this report.

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Main points

Australia is ranked in the top 5 exporters of commodities like wheat, beef, dairy, mutton and lamb. Farm products account for over 10 per cent of our exports, worth $35.9 billion. By 2050, rising global food demand and higher prices may present big opportunities for countries who are net exporters of food.

Winners of the food boom will be countries with less fossil-fuel intensive agriculture, more reliable production, and access to healthy land and soils. Australia will need to use farm inputs more efficiently than our competitors, as many of our soils are low in nutrients and are vulnerable to degradation. Every year we continue to lose soil faster than it can be replaced. How we manage our land and soils will be key to turning projections of an extra $16.4 billion in food commodity exports by 2050 into reality.[i]

This report finds that Australian agriculture can build a lasting competitive advantage through innovation that raises agricultural productivity, minimises dependence on fuel and fertilizer use, and preserves the environment and resources it draws on. To achieve this, we need to:

- Look after land and soil assets to raise agricultural production and maintain long-term viability. Acting now to improve soil condition could increase wheat production by up to $2.1 billion per year. It could also improve the efficiency of fertilizer and water use by crops.
- Support farmers to diversify their revenue sources to reduce financial risk, and ensure more reliable farm incomes. New carbon farming and biodiversity initiatives may present opportunities to diversify farm incomes.
- Act now to prepare for future risks, particularly more frequent droughts under climate change. Without action to adapt to more variable and extreme weather, by 2050 Australia could lose $6.5 billion per year in wheat, beef, mutton, lamb and dairy production.

Leading Australian farmers are already taking action to improve soil condition, with tangible benefits. Government policies need to support all agricultural industries to develop and implement innovative sustainable farming practices and business models.

Rising global demand and prices present challenges and opportunities

Globally, food demand is predicted to rise 60 per cent by 2050, assuming continued economic growth and increased meat consumption. Most of the extra demand is expected from rising populations and incomes in Asia.

While global production is likely to increase to meet demand, there will be winners and losers due to the uneven distribution of land, water and economic wealth. Demographic pressures and climate change may add to food insecurity, particularly in Africa and Asia.

Looking forward, food prices are likely to be both higher and more volatile. Farm input costs are also likely to rise. This means that countries with less fossil-fuel intensive agriculture, and more reliable production, will better placed to benefit from times of high prices.

[i] This projection is in 2007 dollars, before considering inflation or changes in international commodity prices or exchange rates.

Australia has greater opportunities, but similar challenges to the rest of the world

Australia can build a lasting advantage in smart, input-efficient farming which preserves the environment and resources that it draws on. Our agricultural industries rely on land and soil in good condition. Our farming practices compare well to the fossil fuel intensive agriculture of some other major exporters. While we lack comprehensive information to measure how sustainable our land and soil management is, Australian farmers have a strong track record of adopting new practices and investing in natural capital.

However, there are challenges to increasing production. Every year we continue to lose soil faster than it can be replaced. There are natural limits to the further expansion of agricultural land and water use. Agricultural productivity growth has slowed due to poor weather and slower investment in innovation. Australia is projected to be as exposed to climate change as many developing countries.

Australia's challenge is to increase productivity per hectare, without raising farm input costs through higher fertilizer and fuel use. Maintaining strong farm finances is essential to allow farmers to invest in new farming practices, and stewardship of natural capital.

Farming smarter, not harder, can sustainably increase production

Australian agriculture will need to apply a wide range of innovations to expand production despite more variable weather. Farming smarter can raise production levels, improve input-efficiency and provide the flexibility to match production to variable weather conditions.

Many Australian farmers have already increased input-efficiency and productivity by improving the condition of their soil. Investment in research and development is essential to adjust existing smart farming practices to local needs, and to find even more efficient and productive ways of farming.

It pays to invest in natural capital

Maintaining healthy ecosystems is important for long term agricultural viability. Native grasses and other vegetation can protect agricultural soils from erosion and severe degradation during drought periods. They also offer habitat for bee populations that provide $1.8 billion each year in pollination services.

Investment to keep land and vegetation in good condition insures against risks to long-term production. Early action is essential as reversing damage is more expensive than preventing it, and is sometimes impossible.

Regional level co-ordination of individual land-holders' actions to maintain or improve natural capital is crucial. This is because many benefits can only be gained when action is taken across a number of farms, and may be difficult to predict ahead of time.

Farmers' stewardship of the land is essential, and deserves support

Australian farmers are active stewards of our land and soils. Australia has made some good progress by putting in place policies that support farmers in that role.

However, given the size of the opportunities and some of the challenges ahead, there are four key areas where policies need to be scaled up, streamlined or resourced with far more consistency than in the past.

Recommendations:

Increase investment in knowledge

- We need to ensure farming communities are equipped with the best possible knowledge to maintain long-term agricultural productivity, by strengthening the connection between local knowledge and agricultural research.
- Government funding for research and development should be significantly increased; at a rate of up to 7 per cent a year to match investment through the 1950s to 1970s. Additional funds could come from savings due to more effective drought policies, or revenue set aside from mining taxes and royalties. Additional investment should be directed toward increasing the input-efficiency of current practices and developing new farming systems to improve long-term land and soil condition.
- The Commonwealth Government should implement the Productivity Commission's recommendation to establish a new research institution (Rural Research Australia) to sponsor a broad rural research agenda including soils management.
- The National Soil Health Strategy should be funded through an endowment sufficient to support ongoing research and monitoring for at least 20 years. This requires a minimum $25-50 million per year by the Commonwealth Government, and matching investment from State and Territory governments.[ii]
- Government and industry should increase funding for effective extension programs, to increase the rate of adoption of practices that preserve land and soil condition.

Provide more stable funding for regional natural resource management

- Natural Resource Management Networks are essential for supporting farming communities to coordinate and facilitate landscape-wide investment to maintain or improve the condition of land, soils and other natural capital.
- Federal and State governments should commit to a 10-year agreement to provide stable long-term funding for regional Natural Resource Management (NRM) bodies to co-ordinate government funding and land-holder actions to improve natural capital.
- Regional NRM bodies should also be given specific, stable funding to monitor long term trends in natural resource condition, and the environmental outcomes of land-holder actions and government programs to improve it.

[ii] Based on estimates by Dr Neil McKenzie, 2009, Managing Australia's soil and landscape assets: national challenges for soil science, CSIRO Land and Water, Canberra.

Enable accountable community governance of land and soil management

- Farming communities need mechanisms to develop a shared understanding of, and promote, land management practices matched to farms' land and soil capability. For individual land-holders, knowledge shared over time and across landscapes is an essential guide to achieving economic and environmental sustainability. For regional communities, agreement on standards of stewardship can reduce the risk of 'free riding' by a minority of landholders with little direct interest in, or limited ability to, maintain productive agricultural landscapes over the long term.
- Farming communities should be supported to develop stewardship standards based on a shared understanding of appropriate management practices for different land and soil types, and projected drought frequencies. Stewardship standards could draw on Best Management Practice guides already developed by some NRM bodies.
- Regular independent expert reviews will be required to maintain the community's trust in, and promotion of, agreed stewardship standards.

Align financial incentives with the long-term needs of sustainable farming communities

- In addition to current moves to reform drought and exceptional circumstances policy in the context of a changing climate, Australia's drought assistance policies need to support regional communities to take a lead in preparations for more frequent and severe droughts.
- Federal Government assistance for drought preparation should be linked to community stewardship standards. Drought preparation assistance should be available only to farm businesses that develop and implement farm action plans that a) are informed by agreed community stewardship standards, and b) prepare to maintain economic viability under projected drought frequencies.
- The Federal Government should consider additional taxation benefits for Farm Management Deposits to assist with drought preparedness, for businesses which develop and implement farm management plans.
- The Federal Government should consider income contingent loans, or other financial assistance, for farm businesses which take a risk on management practices that go beyond agreed community stewardship standards to enhance farm and landscape resilience. This could include trialling innovative new farming practices, developing new enterprises to access payments for ecosystem services, and investing in natural resource management that delivers clear and lasting public benefits.
- The Federal Government should set up an innovation fund for joint public and private investment in near-commercial projects to develop profitable enterprise models that draw income from carbon offsets under the Carbon Farming Initiative. Public funding should focus on opportunities which could diversify farm income streams, raise productivity and improve land and soil condition.
- As an important complement to drought preparation measures, income safety nets and social support services should be modelled on recent trials in Western Australia. These trials provided a) an income safety net assessed by individual circumstances, rather than geographic location, and b) more permanent social support services for farmers.

If implemented well, these measures can strengthen Australia's agricultural economy and the health of the environment and resources that it depends on.

"The future of farming is serious business for all Australians."

Introduction

Introduction

"In my travels I have seen wonderful examples of individuals regenerating the landscape through various 'innovative' practices. Through good soil and water management, they shine like beacons as stunning examples of what can be, and to my mind, must be done to meet the challenges of the future. But, for all sorts of reasons, their work in successfully managing the paddock is not being widely adopted nor quickly enough." [iii]

Michael Jeffery AC, former Governor General, now Australia's first 'Advocate for Soils'

Global populations are growing and food prices are rising, which creates new market opportunities for Australian agriculture. Recent estimates are that exports could double or treble by 2050. This report looks at how to support farmers dealing with the practical challenges of seizing this opportunity, in the context of land degradation and rising input costs. It demonstrates some of the economic advantages of an agricultural sector that can learn to flourish within environmental limits.

The primary focus of this report is on agricultural land and soils as essential assets that underpin agricultural productivity. However, many of the issues and ideas raised here are relevant to the management of other environmental assets, such as water, vegetation and biodiversity.

The near-term challenge for sustainable agriculture in Australia is to increase production per hectare without relying on greater use of expensive fertilizer and fossil fuel inputs, or running up against the environment's capacity to absorb runoff, nutrients or greenhouse gas emissions. Improving input efficiency can quickly deliver economic and environmental benefits from acting early to avoid resource constraints.

Over the longer term, we need to guard against risks to agricultural production. These include more volatile weather due to climate change, long-term degradation of soils, depletion of phosphorus fertilizers, and the loss of natural capital which provides free ecosystem services such as protection from floods and habitats for pollinators.

We need to take actions now that prepare for responses over three different timeframes. In the near term, this means improving the input-efficiency and reliability of agricultural production using currently available technology and farming systems.

It also means investing now in research and development of more resilient crop varieties and knowledge-intensive farming systems. In the medium term, this should deliver highly productive agricultural systems that balance inputs with outputs, to maintain soil productivity and natural capital.

Preparation for long-term risks also needs to start now. For example, experiments with closed-loop systems can recycle nutrients from plate to paddock. Maintaining diverse forms of farming is important for learning about alternative agricultural systems. Keeping a diverse food distribution chain can provide insurance against supply shocks. Repairing natural capital by stabilising riverbanks, or replanting trees for flood mitigation and habitat, can provide insurance against weather and other shocks.

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iii Soils for Life, 'Innovations for Regenerative Landscape Management: Case studies of regenerative land management in practice', 2012

Many of these actions require policy measures which are not covered in this report, which focuses primarily on near-term actions to maintain agriculturally productive land and soils.

Australian farmers have the energy and ideas needed to make our agriculture an inspiration to the world and a prosperous legacy for future generations Australia's farmers are committed to their role as stewards of healthy landscapes, and many are going beyond the call of duty to restore or conserve the land. Unfortunately, despite these significant efforts, landscape degradation is still a serious problem; one that threatens to derail the bright future ahead for farming if it is not dealt with rapidly and effectively.

Australia's farmers deserve to be supported with policies that are better tailored to the unique nature of agriculture as an industry, and better resourced in recognition of farmers' role as landscape stewards. Australian agriculture is diverse, as are those in the agriculture business. We refer to 'farmers' throughout this report where we should really be referring to farmers, graziers, horticulturalists, viticulturalists and dairy farmers. We hope readers will forgive us for using the colloquial shorthand!

The future of farming is serious business for all Australians. We hope this report stimulates public discussion and essential policy debates on how to make that future a vibrant one.

"Demand for food is predicted to rise 60 per cent globally by 2050."

Rising global demand and prices present challenges and opportunities

Rising global demand and prices present challenges and opportunities

To understand Australia's opportunity and responsibility to help meet rising global food demand, it is important to look at what is happening in world agriculture.

Globally, food demand is predicted to rise 60 per cent by 2050, assuming continued GDP growth and increased meat consumption.[1] While global production is likely to increase to meet demand, winners and losers will emerge due to the uneven distribution of land, water and economic wealth. Historically, unsustainable farming practices and unfair trade policies increased the gap in agricultural production between developing and developed countries. Climate change is projected to exacerbate this disparity.

Higher prices for food and the escalating costs of farm inputs mean that countries with less fossil-fuel intensive agriculture will be better placed to gain from export opportunities. Greater food price volatility means that countries with more reliable agricultural production will benefit from the upside of high prices, while minimising the downside of low production due to poor weather.

Looking forward, demographic pressures and climate change may increase food insecurity, particularly in Africa and Asia.

Key facts

- Over the past 50 years, the world's agricultural system has expanded to feed 7 billion people by doubling or tripling food production, with only a 12 per cent increase in cultivated land.[2] Overall, the world produced more food than was needed.
- Increased food production was driven by a 7-fold increase in inputs of nitrogen fertilizer, a 3.5-fold increase in inputs of phosphorus, comparable increases in pesticides, a 70 per cent increase in irrigated land, and higher fossil fuel use.[3]
- Greater food production came at the cost of reduced soil fertility, increased water pollution and biodiversity loss. One quarter of the world's land is now highly degraded, based on the first global assessment of land resources[iv].[4]
- Demand for food is predicted to rise 60 per cent globally by 2050, relative to 2005-2007 levels, assuming continued GDP growth.[5] Most of the extra demand is due to rising populations and incomes in Asia.[6]
- Globally, crop yield growth has halved.[7,8] During the 1960s crop yields were rising by 3 to 6 per cent a year. Now they are rising by only 1 to 2 per cent a year. In poor countries yields are flat.
- Average food prices are expected to be 20 to 30 per cent higher over the next decade compared to the last decade.[9]

[iv] The United Nations Food and Agriculture Organisation define land degradation as a low status and negative trend in the capacity of land to provide ecosystem services, based on the following indicators: soil health, biomass, water resources, biodiversity, and economic productivity.

- International food prices have spiked three times in the past 5 years, with extreme weather being a driver each time.[10] Further price spikes are expected, with weather conditions representing the most frequent and significant driver of price volatility.[11]
- The food price spikes of the late 2000s pushed an additional 80 million people into hunger.[12] Over 1 billion people, or one sixth of the world's population, now go to bed hungry every night.[13]
- Climate change is projected to hit agricultural production hardest in developing countries. By 2050, agricultural productivity may decline 18 per cent in the least developed countries and 25 per cent in India.[14] With the exception of Australia, projected impacts on developed countries are much less severe.[15]

By 2050, global food demand is predicted to rise by 60 per cent

By 2050, the world population is projected to be 9.1 billion, up 32 per cent from 2010.[16] In absolute terms, the world's population is expected to grow by 2.2 billion.[17] Over 85 per cent of population growth is expected in large urban centres and mega-cities in developing countries.[18] Of those additional people, almost one billion will live in Africa.[19] Asia's population will increase by more than one billion, including 400 million more people in India. In comparison, China's slowing and ensuing negative growth will add only 63 million people.[20]

Demand for food is predicted to rise 60 per cent globally by 2050, relative to 2009 levels.[21] Such a prediction assumes continuing GDP growth, rising incomes and increased meat consumption per capita. The majority of extra food demand is anticipated to reflect rising population and incomes in Asia.[22] Rising incomes in China are predicted to be a major driver of this demand, accounting for 43 per cent of the global increase.[23] India accounts for 13 per cent.[24]

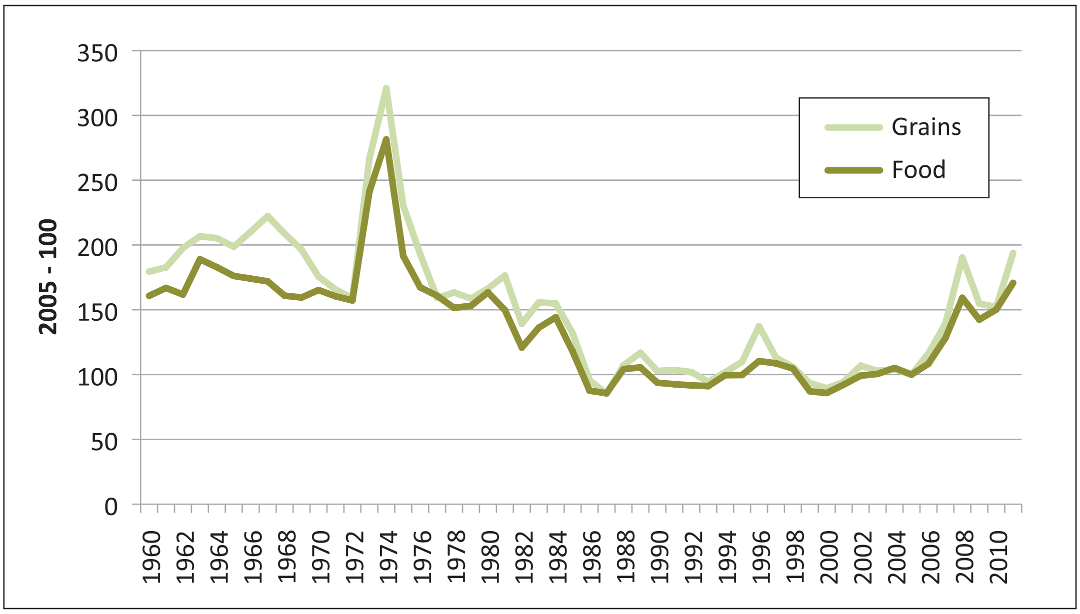
Reducing food wastage may partially alleviate the pressure of rising demand. Roughly one-third of food produced for human consumption is wasted globally.[25] More food is lost per capita in industrialised countries, with significant waste at the consumption stage. In developing countries, per capita losses are lower, and most wastage is at the early or middle stage of food supply chains. While some food waste may be utilized for fertilizers, or feed for animals, there remains a significant opportunity to use available food products more efficiently.

The era of cheap food may be over

Between 1961 and 2008, food supply grew faster than population. Food production grew by 179 per cent while the world population grew by 117 per cent.[26] This period corresponds to the 'Green Revolution', which relied on high-yielding varieties of cereal grains, irrigation and the expansion of fertilizer and pesticide use to increase global agricultural production. Overall, the world produced more food than was needed, although the benefits were not evenly distributed.

During this period, agricultural prices declined in real terms. Figure 1 shows a consistent decline in average agricultural commodity prices from 1970 through to the mid 1980s, once the effects of inflation are removed. From the mid 1980s to 2000, prices fluctuated around a relatively flat baseline.

Figure 1: Long-run food and grain price indices (real terms, 2005 dollars)



Source: World Bank, 2012[27]

Production growth is now slowing. Global agricultural production is expected to grow at 1.7 per cent a year, compared to 2.6 per cent per year in the past decade, according to the Organisation for Economic Co-operation and Development (OECD) and the United Nations Food and Agriculture Organisation (FAO).[28]

A new era of higher average prices is expected. Over ten years to 2020, average prices are likely to be 20 to 30 per cent higher than in the decade to 2010, according to the OECD and FAO[v].[29] These projections do not consider the impacts of climate change on agricultural production. For example, more frequent floods or droughts in key export regions have not been factored into forecasts for average prices.[30]

By 2050, climate change could drive average prices even higher. Projections of climate impacts vary widely, and many different factors influence average prices. However, some estimations envision wheat prices in 2050 that are double those of price projections without climate change.[31] Maize used for animal feed could be up to 55 per cent more expensive, with rice prices up to 37 per cent higher.[32] Beef prices could be 20 per cent higher than otherwise.[33]

These projections assume that the world continues to rely on fossil fuels, although with a slower rate of greenhouse gas emissions than at present[vi]. While such estimates do not account for possible increases in some crop yields due to higher levels of carbon dioxide in the atmosphere[vii], neither do they consider how the increased frequency of extreme droughts and floods may impact crop production.[34, 35]

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v In real terms, cereal prices are anticipated to average 20 per cent higher for maize and 30 per cent higher for poultry meat, compared to the period 2000 to 2010.

vi Projections use the 'A2' scenario from the IPCC's Special Report on Emissions Scenarios, 2007. Global emissions are currently closer to the more extreme A1FI scenario. (For details see notes 31 & 47)

vii Some studies (see endnote 34) suggest higher levels of carbon dioxide in the air can increase crop yields. This is known as the 'carbon fertilisation effect'. Its actual impact on crop yields is uncertain. While studies conducted in the 1980s suggested positive impacts could offset increased temperatures and decreased soil moisture, they measured crops in enclosed areas. More recent, large-scale, trials in the open air achieved only half the benefits seen in enclosed trials. (For more details see note 34)

Box 1: Food price spikes – a growing problem?

Food prices had been declining or stable from the 1970s until the early 2000s.[40] However, from 2006 they rose rapidly, and by mid 2008 they reached their highest level in 30 years. In 2010, prices surged again. By February 2011, they reached the highest level recorded since the Food and Agriculture Organisation of the United Nations started measuring food prices in 1990.

Many factors combined to drive the food price spikes of the late 2000s.[41] These factors included long-term trends in supply and demand as well as short-term variability in other drivers of food prices.

Long-term trends

- Slowing supply growth. From 1960 to 2000, the growth rate of cereal yields dropped by half, following 30 years of under-investment in agriculture.
- Continuing growth in the demand for food. Looking forward to 2050, demand is forecast to grow at 1.0 per cent a year.[42]
- Biofuels substituting for food production or consumption. Production of biofuels has tripled since 2000.[43] Between 2005 and 2007, higher demand for feed stocks accounted for around half the global increase in cereal use.[44]
- Declining food stocks. In 2007, global stocks were at their lowest level in decades. Government-run buffer stocks transferred to private operators were administered on a 'just-in-time' basis, with more reliance on imports to make up annual variations in domestic production.[45, 46]

Short-term shocks

- Poor harvests in major producing countries due to extreme weather events. In late 2010 drought reduced the grain harvest in Russia and the Ukraine by a third. Floods in Australia and the United States further reduced food production and internationally-traded supply.
- High oil and energy prices raised the cost of fertilizers, irrigation and transport.
- Speculative transactions. Commercial traders used agricultural commodity futures markets to hedge food prices[viii]. Such speculative trades, based on the belief that food prices would continue to rise, became a self-fulfilling prophecy and drove prices up even higher.[ix]
- Export restrictions led to hoarding and panic buying.

[viii] Some smaller traders also built up stores of agricultural products, as physical insurance for speculative trades.

[ix] Speculation involves trading any valuable financial instrument in an attempt to profit from fluctuations in its price, regardless of its underlying value. All trading in commodity futures involves speculation, as the investor has no capital at risk and their return does not depend on the actual value of the commodity. Short-selling, or entering a contract to sell an asset without actually owning or ever buying that asset, is also speculation.

Price volatility may be here to stay

More volatile prices are likely in the future. Between 2007 and 2012, the world experienced three international food price spikes. At the time, each of these crises seemed to be perfect storms; high prices driven by the unexpected coincidence of short-term shocks compounded by long-term trends (see Box 1). However, none of the factors driving high and volatile prices have disappeared. In fact, some short-term factors are likely to become more frequent drivers of price volatility.

The OECD and FAO expect that price volatility will be driven by an increasing number of factors. [36]

- Weather conditions are now the most frequent and significant factor causing price volatility. Climate change is altering weather patterns, with unpredictable impacts on extreme meteorological events. Global supplies increasingly come from regions with highly variable production, such as the wheat fields of the Russian Federation and Ukraine.
- Energy and agricultural markets and prices are becoming more closely linked to each other. Oil price volatility is being transmitted to agricultural markets through supply pressures (as the cost of fertilisers and transport vary), and through demand pressures for biofuel feedstocks. According to the OECD and FAO, each 25 per cent increase in crude oil prices drives coarse grain prices up by 5 per cent.[37]
- Food demand will become less responsive to higher prices as per capita incomes are expected to rise by up to 50 per cent in many poor countries.
- Demand for biofuels is expected to double again in the next decade, consuming 13 per cent of global grain production, 15 per cent of vegetable oils and 30 per cent of sugar cane production by 2020. Higher oil prices would raise demand for alternative fuels to replace fossil based fuels.[38]
- Speculation in financial derivatives based on food commodities can amplify price volatility. Some commentators believe that the activities of large, powerful institutional investors (since the deregulation of commodity derivative markets in 2000) have led to speculative bubbles in food prices.[39]

Continuing high and volatile commodity prices will benefit some farmers and countries, but disadvantage others. Countries which are net exporters may benefit at times of high prices. Those with less fossil fuel intensive agriculture, and where farmers are able to adapt production to more variable weather, will be best placed to profit. Other producers may see profits squeezed as costs for fertilizers, fuel and grain-based animal feed rise. Poorer farmers in particular may lack savings or insurance to survive large swings in annual income.

Box 2: Global climate change – implications for food production

Climate change is altering weather patterns around the world. The most recent report from the Intergovernmental Panel on Climate Change suggests that changes in weather have already been observed. Such changes include widespread changes in rainfall patterns, wind patterns, and types of extreme weather including droughts, heavy rain, heat waves, and the intensity of tropical cyclones.[47]

By 2050, higher temperatures and more variable weather are predicted.

- Global mean surface temperatures are projected to be 1.4°C to 3°C higher by 2050, relative to 1961 to 1990.[48]
- Changes in rainfall patterns will vary regionally. Rainfall is forecast to increase in the tropics and higher latitudes, and decrease in the semi-arid to arid mid-latitudes, as well as in the interior of large continents.[49]
- Droughts and floods are expected to become more severe and frequent. More intense rainfall is expected with longer dry periods between extremely wet seasons.[50] The intensity of tropical cyclones is expected to increase.[51]

Climate change is projected to increase the gap in agricultural production between developing and developed countries. In developing countries agricultural production capacity is projected to decline by 9 to 21 per cent by 2080, due to a reduction in the area and potential productivity of crop land as weather patterns change.[52,53] With the exception of Australia, most developed countries are less likely to be impacted, with effects ranging from a 6 per cent decline to an 8 per cent increase[x].[54]

- Africa is likely to be particularly hard hit, as cereal yields are expected to decline and land suitable for wheat may almost disappear.[55]
- Sub-Saharan Africa, already one of the poorest regions in the world, is likely to be the most adversely impacted. The number of hungry people could rise from 24 per cent to between 40 and 50 per cent by 2050.[56]
- India and South Asia may see agricultural production decline by as much as 25 per cent by 2050, compared to a baseline without climate change.[57]
- Australia may see production decline by 13 to 19 per cent by 2050, without action to mitigate or manage climate risks.[58] This is greater than for any other developed country, and greater than for many developing countries.

The greatest impacts on global agricultural production and prices may come from extreme weather. Periods of price volatility have recently coincided with droughts and floods in major supply regions, with extreme weather a driver of each of three price spikes in the last 5 years.[59] Changes in weather patterns will also increase the pressure of weeds, pests and disease on agricultural production.[60]

x The low end of range assumes higher carbon dioxide levels have a positive effect on crop yields. The high end of the range assumes no positive effect on crop yields.

More frequent extreme events could drive ongoing price volatility. Agricultural commodity prices have always been volatile, as supply depends on natural weather variability, while demand is relatively rigid. However, current price forecasts have not considered the impact of a potential shift in the frequency of extreme events on regional production or on global prices. [61]

There is evidence that more frequent high temperatures are already appearing. Globally, 10 times as much land now suffers extremely hot seasons compared to 1951 - 1980.[62] Hot summers, wildfires and droughts are now much less unusual events. The European heat wave of 2003, the Russian heat wave of 2010 and US droughts in 2011 were all amplified by climate change.[63]

Early action will be necessary to reduce the risk of price spikes. Effective mitigation and adaptation policies, including measures to improve the ability to cope with extreme weather shocks, need to be put in place.[64] If the current rate of greenhouse gas emissions continues, beyond 2050 it will be much more difficult to adapt agriculture to manage and minimise the risks of climate change.[65] So it is critical to slow emissions growth today to avoid a highly challenging post-2050 future.[66]

Food insecurity is rising

In the late 2000s, the world woke up to a food crisis as prices soared to the highest levels ever recorded. With global food stocks at their lowest in 30 years, many countries scrambled in vain to secure enough food to feed their populations. By 2009 an additional 80 million people were pushed into hunger – leaving over 1 billion people, or around one sixth of the world population, going to bed hungry each night. [67] In the future, food insecurity is likely to remain a global challenge.

Food demand is expected to rise faster in low-income countries compared to the global average. By 2050, demand could be up to 100 per cent higher in developing countries, compared to a 70 per cent global rise relative to 1990 levels.[68] High and volatile food prices reduce the food security of poor households in developing countries. Such volatility particularly affects the urban poor, landless and female-headed households, who may already spend up to three-quarters of their income on food.[69] In the least-developed countries, most of the food-insecure population are small-holder farmers.[70]

These countries face a tension between the short-term objective of importing food for people living in poverty, and the long-term objective of increasing domestic food production to limit exposure to price spikes.[71] When global prices are low, local farmers are often unable to compete with cheap imports, and so struggle to maintain access to local markets, potentially ending up having to leave farming altogether.

Particularly in Africa, farmers are financially disadvantaged compared to global exporters. African farmers pay three to five times the world market price for fertilizer, and receive only 30 to 60 per cent of the market value for their products.[72] This disparity is due in part to high transport costs and distance from markets, but also to policies that support urban populations while putting implicit taxes on agriculture.[73] Since it usually does not pay for such farmers to apply fertilizer, they try to maintain production levels by increasing labour inputs: the intensity of cropping or grazing. Without breaks between crops or grazing, there is no time for soil organisms, organic carbon and nutrients to rebuild.[74] Such farming practices lead to a downward spiral of falling yields and declining soil condition.

Resource scarcity and climate change also disadvantage countries that will need to produce more food in the future. Per capita land availability in low-income countries is less than half that of high-income countries.[75] Many low-income countries have crop yields of less than half their achievable potential. [76] Poor crop yields are due to low soil fertility and carbon content in tropical soils, as well as unpredictable rainfall in the dry tropics and sub-tropics. Climate change is predicted to further reduce crop yields in developing countries. [77]

To improve food security, small-scale producers need support to raise productivity, while being shielded from the negative impact of cheap, imported food products arriving in local markets. [78] If successful, this could create markets for secondary and tertiary industries in rural areas, leading to the development of local economies. [79] This model assumes the rural population will buy locally produced goods and locally provided services, and that improved yields can meet increased demand.[80]

Developing food systems that deliver food where it is most needed will require sustained global and local leadership. Globally, price distortions due to agricultural subsidies need to be removed, and drivers of price volatility need to be managed or minimized. Locally, leaders in developing countries will need to balance support for small-scale rural producers with the needs of rapidly urbanizing populations.

Box 3: Food security, food sufficiency, or food self-sufficiency – what is the difference?

Food security, food sufficiency and food self-sufficiency are frequently confused and incorrectly used terms. While they refer to overlapping issues, there are distinct differences.

Food security is a major global issue. The World Health Organisation defines food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life".[81]

Food sufficiency is both a global and national issue. Food sufficiency refers to the ability of agriculture to produce sufficient food to meet demands. At a national level, food sufficiency can be achieved through domestic production or food imports. Food sufficiency in a developed country means that a sufficient quantity and variety of foods is available to reliably meet consumer demands and preferences over the long term.[82] For developing countries, meeting basic needs in the short term is often a higher priority.[83]

Food self-sufficiency may be a national policy objective. Countries aiming for food self-sufficiency target the ability to meet food demand through domestic production alone. Policies aimed at self-sufficiency can provide secure access to food, improved current account balances, insulation from price shocks, and more stable rural economies and communities. However, where domestic production is inefficient, unsustainable, or expensive due to labour shortages or long transport distances, such policies may impose high costs on consumers and the environment.

Increasing production won't be as easy as in the past

Past agricultural production put pressure on ecosystems

Past agricultural production has put pressure on the ability of nature to provide the ecosystem services – such as healthy soils, water, and a safe climate– that support food production. About half of globally usable land is already in pastoral or intensive agriculture, significantly reducing the number of intact and fully functioning ecosystems. [84]

Historical clearing of land for agriculture reduces the ability of ecosystems to provide many regulating services – such as minimizing flooding, purifying water and reducing erosion, salinisation and acidification of soils. Poor agricultural practices can also reduce the ability of managed ecosystems to provide goods and services.[85]

One quarter of the world's land is now highly degraded due to soil erosion, water degradation and biodiversity loss[xi,xii].[86] Both land clearing and, to a lesser extent, agricultural practices increase the level of greenhouse gas in the atmosphere, thus increasing the risk of climate change[xiii].[87,88]

The 'Green Revolution' relied on more intensive use of resources

Over the past 50 years, the world's agricultural system has expanded to feed 7 billion people by doubling or trebling of food production with only a 12 per cent increase in cultivated land[xiv].[89] About half of this yield increase was achieved through increased use of water and fertilizers, and about half through new crops.[90]

The new agricultural technologies that supported this are often called the Green Revolution. By substituting resources and technology for the expansion of agricultural land, the Green Revolution spared many natural ecosystems from conversion to agriculture. However, the benefits were not evenly distributed. The Green Revolution largely bypassed Africa and most non-irrigated cropland in Asia and Latin America.[91] Poor socio-economic conditions and transport costs limit access to fertilizers, while low water availability limits irrigated agriculture.[92]

The increase in global cereal and meat production was associated with increased use of fertilizers, irrigation and total pesticide production. This involved a 7-fold and 3.5 fold increase in inputs of nitrogen and phosphorus fertilizers, comparable increases in pesticides, a 70 per cent increase in irrigated land and increased fossil fuel consumption for energy.[93]

Such intensive industrial agriculture decouples production from natural soil fertility at a significant cost. Excess nutrients, pesticides and animal wastes have resulted in pollution of soil and water resources.[94] This caused health hazards for human and animal populations, loss of biodiversity and contamination of rivers, coastal waters and lakes.[95]

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xi The United Nations Food and Agriculture Organisation define land degradation as a low status and negative trend in the capacity of land to provide ecosystem services, based on the following indicators: soil health, biomass, water resources, biodiversity, and economic productivity.

xii A further 8 per cent is moderately degraded, 36 per cent is slightly degraded or stable, ten per cent is improving in quality and the remaining 20 per cent is bare or covered by water.

xiii Overall contribution of agricultural operations to greenhouse gas emissions is relatively small at 10 – 12 per cent of emissions in 2005 (Smith et al, 2005). However, clearing of native ecosystems for agricultural use in thetropics is the largest non-fossil fuel source of greenhouse gas emissions to the atmosphere (Vlek, 2012)

xiv Agricultural production grew between 2.5 and 3 times, thanks to significant increase in the yield of major crops.

Global food production is now more vulnerable to pest or disease outbreaks. World food supplies rely on an increasingly narrow range of genetic resources.[xv] Just 30 percent of available crop varieties dominate global agriculture. These, together with 14 animal species provide 90 per cent of total calories consumed worldwide. Industrial-scale monocultures of countries like the United States are more vulnerable than more diverse farming systems. Since 1945 the use of synthetic pesticides in the US has grown 33-fold, yet crop loss to pests continues to increase.

Looking forward, the world faces a significant challenge to feed a projected 9 billion people by 2050. Global demand for grain is predicted to double due to increased incomes and more meat consumption. Ramping up 20th Century agricultural practices to meet this demand would require doubling or tripling fertilizer and pesticide use, doubling irrigated land area, and converting over 10 billion hectares of natural ecosystems to agriculture.[96] The resulting large-scale damage to ecosystems – through soil degradation, water pollution, habitat destruction and unprecedented species extinctions – would leave the global agricultural system even more exposed to shocks such as extreme weather and invasive pests.

Productivity growth is slowing

The gains of the Green Revolution appear to be fading. Global agricultural productivity growth has halved, with crop yields rising only 1 to 2 per cent a year compared to 3 to 6 per cent a year in the 1960's.[97,98] In poorer countries they are flat.[99]

One of the causes of decreased productivity is slower research and development investment. Globally, growth in public spending on agricultural research and development (R&D) has declined by 51 per cent in real terms in the two decades since the 1980s.[100] The world has a 30-year deficit in research and development investment.

Returns from investment in industrial agricultural technologies are often short lived.[101] Weeds develop herbicide resistance within one or two decades of new herbicides being introduced.[102] Insects evolve resistance to new insecticides within a decade. Resistant bacteria appear within 1 to 3 years of the release of many antibiotics.[103]

Resource constraints are significant in some regions

Constraints to the expansion of agriculture are highest in some of the poorest areas of the world. Low-income countries have less than half the average available cultivated land per capita of high-income countries.[104] By 2050, without new policies, over 40 per cent of the global population is projected to be living in river basins under severe water stress.[105]

Worldwide the area of land under rain-fed crops is projected to expand by 5 per cent by 2050, or 70 million hectares.[106,107] In theory, the world has around 1.4 billion hectares of prime land that could be used for cultivation.[108] However, transitioning this land-base would involve significant conversion from pastures to crops and substantial investment.[109]

Most arable areas are in just a few Latin American and sub-Saharan African countries where lack of access and infrastructure make agricultural production uneconomic.[110] In other countries and regions with fast growing populations, land constraints may be severe.[111]

[xv] For discussion of these issues, see C. Nellemann et al., eds., The Environmental Food Crisis - The Environment's Role in Averting Future Food Crises (United Nations Environment Program, 2009), http://www.grida.no/publications/rr/food-crisis/.

Some developing countries have natural limits to expanding irrigated agriculture. Currently, almost three quarters of irrigated land is in developing countries, where it supports 60 per cent of rice and 40 per cent of the wheat grown worldwide.[112] While water resources are globally abundant, they are extremely scarce in the Near East and North Africa, and in northern China, where they are most needed.[113]

Globally, rising prices for fertilizers could impact agricultural production, farmers' profits and food prices. Nitrogen and phosphorus are critical nutrients for plant growth. Resource scarcity may drive up their costs for agricultural use.

Nitrogen fertilizer costs are likely to rise over time. Natural gas is the main feedstock for nitrogen fertilizers. While the world has large reserves of natural gas, prices are currently at their lowest in ten years, and demand is rising.[114] Most analysts predict that prices will rise to double current levels.[115]

Phosphorus fertilizer costs are also likely to rise over time. Phosphate rock is the only source of new phosphorus entering the food supply chain. Concerns about 'peak phosphorus' were raised when estimates suggested that supplies of high-grade phosphorus for fertilizers may run out in the next 50 to 100 years, with production likely to peak by 2070.[116] Recent upward revisions to global reserves suggest that current production could be maintained for 300 to 400 years.[117] However, prices could rise well before then, as the cheapest reserves are depleted first. Price spikes may also become a source of international tension as over 80 per cent of phosphate rock reserves are held by just four countries.[118]

Box 4: The global land grab

Demand for agricultural land rose in response to recent food price spikes. Global expansion of agricultural land was less than 4 million hectares per year before 2008. In 2009 approximately 56 million hectares of large-scale farmland deals were announced.[119]

Land acquisitions have been concentrated in Africa, where over half the world's apparently available rainfed cropland is located in just 10 countries.[120] Countries such as Ethiopia, Mozambique and Sudan have transferred millions of hectares to investors in recent years.[121]

Foreign investment in agricultural land in Australia has increased since the mid-1980s. In December 2011, 11.3 per cent of agricultural land was foreign or part-foreign owned.[122] The figure was 5.9 per cent in March 1984.[123]

Around the world, many plans to develop land are being scaled back as risks become apparent. These include unrealistic objectives, price changes, inadequate infrastructure, technology and institutions. By 2011, only 21 per cent of the announced deals had actually started farming.[124]

Declining soil condition hits hardest in poor areas

Declining soil condition is one of the most significant contributors to land degradation. In less populated areas, soil erosion is an issue.[125] In more populated areas, depletion of soil fertility and soil pollution are more common.[126]

In 1996, soil degradation affected an estimated 15 per cent of the world's land. Figure 2 shows the results of the global assessment of human induced soil erosion (GLASOD). A lack of reliable quantitative data has limited the ability of global studies to identify the exact location and ultimate causes of declining soil condition. GLASOD is possibly still the most comprehensive survey specifically focused on soils.

Different types of soil degradation affect different types of soils, and may interact. Whether or not degradation occurs can depend on the amount of vegetation cover, and the management practices used by farmers.[127] The most common types of soil degradation are:

» Soil erosion – surface soil and its nutrients are carried away by wind, water, chemical weathering or tilling land with a plough.[128]

» Soil salinity – build up of salt limits crop yields and may lead to agricultural land being abandoned. There are two kinds of salinity; both dryland (from rising underground watertables) and irrigated land salinity.[129]

» Soil acidity – Soils naturally acidify as they weather over millions of years.[130] Most agricultural systems increase the rate of acidification by removing alkaline products or increasing the level of nitrogen (in the form of acidic nitrates) in the soil. [131] Acidic surface soils reduce the efficiency of nutrient use, which can reduce yields. Acidic sub-surface soils can have toxic levels of metals, which reduce crop root growth, leading to lower nutrient uptake, less efficient water-use and lower crop yields.

» Soil compaction - refers to the increased 'bulk density' or densification of soil.[132] It is usually caused by machinery or trampling from livestock.[133] Compaction can reduce yields by restricting the growth of plant roots, and the movement of water and air through the soil.[134]

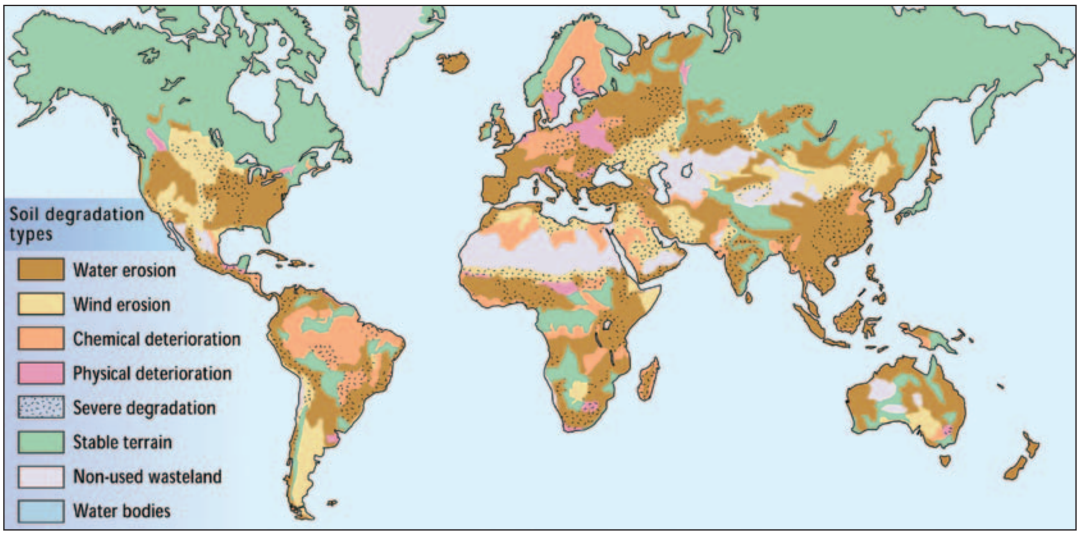
» Soil carbon decline – soil carbon makes up to 40-60% of soil organic matter by mass (SOM).[135] The loss of soil carbon and SOM is accompanied by the loss of soil nutrients; increased soil bulk density; loss of structure, decreased water holding capacity; reduced ability to provide nutrients to plants; increased erosion; and leaching and decreased biological activity.[136] Soil carbon decline ultimately leads to reduced crop yields and quality.

» Soil fertility depletion – refers to a combination of the loss of soil nutrients, soil acidification, loss of organic matter or reduced cation exchange capacity (CEC).[137] CEC is an indicator measuring the soil's ability to provide the three important plant nutrients calcium, magnesium and potassium.[138] Soil fertility decline may also be associated with an increase in toxic elements.[139]

There are hidden costs to declining soil condition. Since decline often occurs gradually, farmers may not notice slowly declining yields or increased use of nutrients and energy-intensive inputs. Agricultural practices that degrade soil increase the need for fertilizer, pesticides, irrigation and energy to maintain productivity.[140]

The economic impacts of this hit hardest in the poorest areas of the world. In tropical areas, low soil fertility and carbon content, combined with low rainfall, keep crop yields below their potential in many low income countries.[141] In many tropical soils, agricultural production declines exponentially as soil is lost due to erosion.[142] Soil salinity and water-logging has led to significant yield declines in developing countries on 15 million hectares, or almost 9 per of total global irrigated land.[143] The risk of soil salinity is a problem for at least a further 2 million hectares per year.[144]

Figure 2: Human-induced soil degradation



Source: FAO[145]

Farming harder will only increase fossil-fuel dependence

Agricultural production is increasingly dependent on fossil fuel energy. Sunshine provides around 90 per cent of total energy inputs to agriculture, through the process of photosynthesis. However, since the 1960s there has been augmentation of solar energy with fossil fuel energy to increase agricultural productivity.[146] In 2007, food production at the farm level used 2 to 5 per cent of commercial energy in almost all countries, regardless of their level of development.[147] Of this, up to 70 per cent is for the production and use of chemical fertilizers[xvi].[148]

Modern agricultural techniques increase productivity per hectare through chemical fertilizers, and productivity per worker through fuel-driven equipment. Such techniques increase production from available sunshine and water, and reduce reliance on both the nutrient cycling capacity of soils and the availability of workers. However, as agricultural systems become more intensive, their energy efficiency decreases. Each calorie of on-farm fossil fuel energy input produces 1.1 calories of food output in the United States, and 1.7 calories in Europe. This ratio is nearly 1:5 in developing countries.[149]

[xvi] This figure is for developing countries. A lower percentage of on-farm energy use is likely in developed countries, where a greater amount of fuel is used for machinery.

Rising meat consumption will accelerate the fuel intensity of farm production. Meat from livestock requires 2.5-10 times as much energy and 4-7.5 times as much water to produce the same amount of calories and protein as grains.[150] Currently one-third of the world's grain cereal supply is used for animal feed.[151]

When off-farm energy use is considered, food production and supply is even more energy dependent. In urbanised societies, post-harvest processing, distribution, packaging and home preparation generally uses 3 to 5 calories of fossil fuel for every calorie used producing food at the farm level.[152] Food losses and wastage between field and fork also increase energy dependence. Globally, around 50 per cent of edible calories are lost through inefficiency as crops are converted to food for consumption[xvii].[153]

Instead, we need a sustainable intensification of agriculture

In the simplest terms, agricultural systems are sustainable in the long term only if the outputs of all products harvested are balanced by inputs back into the system.[154] This means balancing carbon and nutrients taken up by crops or animals with inputs back into the soil. For acidic soils, it can also mean applying alkaline lime or other soil amendments to neutralise acidity. Unsustainable agricultural systems lead to declining soil condition over time, with reduced crop yields or growth of pasture.[155] An increased need for fertilizers and other inputs to maintain agricultural production levels is symptomatic of unsustainable agriculture.

In a broader sense, agricultural systems also rely on a range of ecosystem services for their long-term viability. Ecosystem services are flows of goods or services provided free by nature, with benefits to humans that may not be priced. Services provided by land assets include regulation of floods by trees and other vegetation, creation and regeneration of fertile soils, degradation of plant litter and animal wastes, purifying water and recharging streams.[156] Many of these services flow from interactions between vegetation, and the movement of water and soils through the landscape. Others flow from interactions between soil carbon, nutrients and animals, plants and fungi.

Sustainable intensification of agriculture means producing more food from the same land area with the same or lower inputs, while maintaining or enhancing soil condition and the ability of land to provide ecosystem services.

Restoring soil fertility is important to raising yields in many developing countries. These nations often have low soil fertility, little land to spare, unreliable rainfall and limited access to affordable fertilizers.[157] Most degraded and depleted agricultural soils have lower soil organic carbon than before they were cleared for agriculture.[158] Restoring soil fertility by increasing soil organic carbon can dramatically improve crop yields.[159] Increasing soil carbon means maintaining a positive nutrient balance, which can require addition of nitrogen through manure, growing legumes or using fertilizers.[160] Positive synergies build over time, as increasing soil carbon improves soil water storage and retention of nutrients.[161] However, while improved land and nutrient management can result in higher yields, such enhancements can prove difficult to sustain if rainfall is unreliable.[162]

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xvii Sources of loss and wastage include inefficient harvesting, transport, storage, packaging, as well as food processing at wholesale, retail and household levels. However, not all the energy in agricultural products that are harvested but not eaten are lost, they may be used for feed, bio-energy and soil management.

Maintaining or enhancing soil condition is also important for developed countries. Improved soils reduce the cost of lost agricultural production, or the cost of increasingly expensive fertilizers and other agricultural inputs. More efficient use of fertilizers and pesticides can also reduce the environmental costs of water and soil pollution, excess nutrient runoff into rivers and estuaries, and the loss of biodiversity.[163]

To be successful, sustainable intensification of agriculture needs to provide economic and environmental benefits, while increasing global production.[164] Given the risk of increasing food-insecurity, increasing global production is an important goal to keep in mind. A number of estimates contend that 30 to 50 per cent of crop yields are attributable to nutrient inputs from commercial fertilizers.[165] In some countries, increased fertilizer use may be essential to increase soil organic carbon, before higher crop yields can be achieved. In other countries, far more input-efficient farming practices will need to be developed to manage overall fertilizer use.

Sustainable agricultural intensification is knowledge intensive. Highly productive agriculture requires a sophisticated balancing of inputs and outputs, based on sound understanding of how agricultural ecosystems function.

For highly degraded soils, relatively well-known farming practices such as no-till farming, maintaining crop residues as a mulch, applying manure, planting legumes to capture nitrogen and matching nutrient inputs to plant requirements, should lead to improved agricultural production.[166] Sustainable intensification could also lead to new agricultural systems that are designed to focus production on the most viable areas of land in a farm, leaving other areas for conservation, or for tree plantations generating carbon credits or timber production. The critical point is to match farming practices and agricultural systems to soil and ecological conditions. Practical local knowledge is essential, in combination with scientific expertise.

A significant global investment in science, technology and agricultural practices is needed to increase agricultural yields, nutrient-use efficiency, water-use efficiency, soil fertility; and to manage diseases and pests.[167] Recent estimates suggest a $160 billion investment in land protection and development, soil conservation and flood control; and $1 trillion for irrigation water management is needed by 2050 for developing countries alone.[168]

"Australia can build a lasting advantage in smart, input-efficient farming which preserves the environment and resources that it draws on."

Australia has greater opportunities but similar challenges to the rest of the world

Australia has greater opportunities but similar challenges to the rest of the world

Australia is amongst the top 5 exporters of wheat and coarse grains, beef, sheep meat, dairy and wool. Projected rising food demand in Asia may present big opportunities through to 2050. However, there are natural limits to the further expansion of agricultural land and water use. Australia's challenge is to increase productivity per hectare, without raising farm input costs through higher fertilizer and fuel use.

Australia can build a lasting advantage in smart, input-efficient farming which preserves the environment and resources that it draws on. Our agricultural industries rely on land and soil in good condition, and our farming practices compare well to the fossil fuel intensive agriculture of some other major exporters. While we lack comprehensive information to measure how sustainable our land and soil management is, Australian farmers have a strong track record of adopting new practices and investing in natural capital.

One of the biggest challenges for Australian agriculture is the fact that our soils are low in nutrients and are particularly vulnerable to degradation. Despite the best efforts of many farmers, every year we continue to lose soil faster than it can be replaced. How we manage our land and soils will be a major factor in whether we capture the benefits of higher global food prices.

Acting early to avoid rising resource costs and climate change impacts will help Australia sustain a flourishing agricultural economy over the long term. However, if uncertainty leads to inaction, by 2050 Australian agriculture may be highly vulnerable to climate change.

Key facts

- Agriculture produces over 10 per cent of Australia's exports, worth $35.9 billion in 2010-11[xviii].[169] It produced around 2 per cent of GDP and provided 307,000 jobs. [170]
- Australian exports provide around 2 per cent of global wheat, sugar and beef consumption.[171]
- Australian wheat and flour is around 11 per cent of total world exports, sugar around 6 per cent of global trade, and beef around 15 per cent. [172]
- Australia is ranked in the top 5 exporters of wheat, beef, dairy, etc and is the world's largest exporter of wool.
- By 2050, the projected export value of beef, wheat, dairy products, sheep meat and sugar could be $16.4 billion higher than in 2007, before considering inflation, changes in international commodity prices or changes in exchange rates[xix].[173]
- This would require over an 80 per cent increase in the volume of production of our main food based agricultural commodities.[174] Annual production growth rates of 1.4 to 2.1 per cent would need to be sustained for almost 40 years.

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xviii Not all these exports are used for food products.

xix Projections are in 2007 A$, converted from the 2007 US$ used in the source document. These projections provide an assessment of a plausible scenario for growth in global food demand, conditional on a set of assumptions as explained in the Appendix.

- Australia's population may rise from 22.5 million in 2011 to 30.9–42.5 million by 2056. [175,176] Unless diets change, food consumption would rise by 37 to 89 per cent.
- Agricultural productivity growth has slowed from an average 2.2 per cent to 0.4 per cent a year in broadacre cropping and grazing since 1993-94[xx].[177] Inputs of materials and services have increased while land, labour and capital input has decreased[xxi].[178]
- Energy and energy-dependent inputs average 34 per cent of farmers' input costs across all cropping and grazing industries.[179]
- In 2001-2002 as many as 20 million hectares of soil were affected by acidity, which reduces the ability of plants to take up water.[180] In the same year, 40 million hectares had unsustainable rates of erosion.[181] Agriculture occupies 457 million hectares.
- Australia's soils have lost 40 to 60 per cent of their organic carbon since land was cleared for agriculture.[182] One of the most important benefits of high organic carbon levels is to provide soil moisture when plants need it.[183]
- Improving soil condition presents a $1.1–2.1 billion opportunity to lift wheat production per year.[184] While upfront investment is required, the value of recovering lost production is likely to rise over time.
- Australian farmers spent almost $3 billion to prevent or manage weeds, pests, and land or soil problems in 2006-07.[185] Of this, $305 million was on soil conditioners.
- Climate change may see Australia's agricultural production decline by 13 to 19 per cent by 2050, without action to adapt agriculture to changes in weather.[186]
- The area of land exposed to extremely hot years has doubled over the last 40 years.[xxii] By 2030, years with extremely low soil moisture could occur twice as often.[xxiii]
- In the two drought years during the 2000s, crop production was equivalent to the consumption of 25 million Australians, compared to almost 60 million in 2010-2011.[187]
- Without adaptation, Australia could lose $6.5 billion a year in production of wheat, beef, sheep meat and dairy by 2050, if greenhouse gases are not reduced to safe levels.[188]

Agriculture is an important industry for Australia

Agriculture makes an important contribution to Australia's economy. It produces over 10 per cent of Australia's exports and over 2 per cent of GDP.1[89] In 2010-11, exports of farm products were worth $35.9 billion.[190] In the same year, the gross value of agricultural (farm) production was $47.7 billion.191 Table 1 shows the range of products that make up Australia's agricultural industry.

Agriculture forms the backbone of Australia's rural economies. For more than 40 years, at least 85 per cent of rural jobs have been in agriculture[xxiv].[192] In 2010-11, agriculture provided 307,000 people with jobs.[193]

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xx Figures are 2.2 per cent a year from 1952-53 to 1993-94, and 0.4 per cent a year from 1993-94 to 2006-07.

xxi Over the period 1977-78 to 2008-09

xxii Exceptionally hot years typically occurred over 10 to 12 per cent of Australia between 1968 and 2007, compared to a long term average of 5 per cent.

xxiii Highest 10 per cent of predicted results for a 50 year period centred on 2030, compared to 1957 to 2006.

xxiv Defined as jobs in agriculture, fisheries and forestry

Table 1: Gross value of agricultural production, 2010-2011

Product	Gross value of agricultural production ($billions)
Beef (including live cattle)	7.8
Wheat	7.1
Horticulture (largely fruit and vegetables)	8.3
Dairy products	3.9
Sheep meat (including live sheep)	2.9
Other food products	3.6
Grains and oilseeds (other than wheat)	5.1
Industrial crops (cotton products, sugar, wine grapes)	4.6
Wool	2.7
Other crops	1.7
Total agricultural commodities	**47.7**

Source: ABARES, 2012[194]

Internationally, Australia is one of a handful of large exporters of agricultural commodities. Australian wheat and flour is around 11 per cent of total world exports, sugar around 6 per cent of global trade, and beef around 15 per cent. [195] Australia is ranked in the top 5 exporters of wheat, beef, dairy, etc and is the world's largest exporter of wool, as Table 2 shows.

Table 2: Australia's rank in world trade of agricultural products

Commodity	Australia's rank	Australia's market share
Wool	1	43%
Sheep	2	32%
Beef	2	18%
Wheat	3	15%
Milk	4	8%
Coarse grains	5	5%

Source: ABARES, 2011[196]*; IWTO, 2011*[197]*; Dairy Australia, 2011*[198]*; FAO, 2010*[199]

In terms of global consumption, Australia's role is much less significant. Australian exports provide 2 per cent of wheat and sugar, and 1.5 per cent of beef consumption.[200] Asia is the main export market for Australian food products, taking 59 per cent of Australian agricultural food exports in 2010-11.[201]

Australia is currently a net exporter of food products. This includes raw agricultural food products as well as processed food and beverages. In 2010-11, Australia exported $26 billion and imported $9.3 billion worth of food products.[202] Around 90 per cent of imports are processed foods and beverages, such as alcohol, soft drinks, confectionary, and canned fruit and vegetables.[203]

Demand for Australian food products could more than double by 2050

Rising demand from Asia could more than double demand for exports of Australian food commodities. Recent projections are for the real value (in 2007 dollars) of Australia's five fastest growing agricultural food exports to be around 130 per cent higher in 2050 than in 2007.[204] China is projected to be the largest source of increased demand, as rising incomes are expected to increase per capita consumption, particularly of meat.

By 2050, the projected export value of beef, wheat, dairy products, sheep meat and sugar could be $16.4 billion higher than in 2007, before considering inflation, changes in international commodity prices or changes in exchange rates[xxv].[205] This assumes no changes in productivity growth, no changes in land and water availability, and full adaptation to any marginal changes in farming conditions.

Table 3: Projected increase in export value of selected Australian agricultural food commodities

Commodity	2007 value of exports (2007 A$bn)	2050 value of exports (2007 A$bn)	Increase (2007 A$bn)	Percentage change
Beef	5.7	13.2	7.5	131%
Wheat	3.4	7.3	3.9	115%
Dairy products	1.6	4.4	2.8	169%
Sheep meat	0.6	2.3	1.6	260%
Sugar	1.0	1.6	0.6	63%
Total	**12.4**	**28.8**	**16.4**	**133%**

Note: This table includes only the five food based agricultural commodities for which the largest increase in exports were projected. The source publication included other food products, such as fish.

Source: Linehan et. al., 2012[207]. Values were published using n 2007 US $. These have been converted to 2007 A$ using the average exchange rate for 12 months ending June 2007.

[xxv] Projections are in 2007 A$, converted from the 2007 US$ used in the source document. These projections provide an assessment of a plausible scenario for growth in global food demand, conditional on a set of assumptions as explained in Appendix 2.

Australia could benefit from over an 80 per cent increase in the real value of production of agricultural food commodities, if over an 80 per cent increase in the volume of production can be achieved. (see Table 4) Projections used prices from 2007 to value production in real terms, using 2007 dollars. For each individual commodity, a change in the real value of production implies the same percentage change in production volume. As Table 4 shows, the largest predicted increases in production value are for beef, wheat and dairy products. The production volume of each of these commodities would need to increase by over 80 per cent by 2050, compared to 2007.

Table 4: Projected increase in production value of selected Australian agricultural food based commodities

Commodity	2007 value of production (2007 A$bn)	2050 value of production (2007 A$bn)	Increase (2007 A$bn)	Percentage change
Beef	9.9	18.1	8.2	83%
Wheat	4.8	8.9	4.0	84%
Dairy products	4.3	8.3	4.0	94%
Fruit	2.9	4.2	1.3	43%
Sheep meat	1.1	2.8	1.6	144%

Note: This table covers only the five food based agricultural commodities for which the greatest increase in production was projected. The source publication included other food products, such as sugar and fish.

Source: Linehan et. al., 2012[207] *Values were published using n 2007 US $. These have been converted to 2007 A$ using the average exchange rate for 12 months ending June 2007.*

At the same time, Australia's population may double from the current 22.5 million people[xxvi].[208] If present trends continue, a population of 35.5 million people is likely by 2056.[209] The actual number could be higher or lower, depending on the levels of fertility, life expectancy and immigration.[210] Official forecasts range from 30.9 to 42.5 million people.[211] Unless Australian diets change, domestic food demand will rise by 37 to 89 per cent. The potential for export growth should be considered alongside a likely increase in domestic demand

Australia is better placed than many countries to realise this opportunity

Australia has developed a comparative advantage in 'extensive' agricultural production, which relies on large areas of land and limited inputs of labour.[212] Australia has 2.15 hectares of arable land per capita[xxvii], more than ten times the global average of 0.2 hectares per capita[xxviii]. [213,214] Many Australian farms are large and managed by a small number of farmers. Only Canada has fewer farmers per hectare of arable land than Australia[xxix].[215]

[xxvi] Estimate at December 2011, by the Australian Bureau of Statistics.

[xxvii] Average over 2007 to 2011, defined as land under temporary crops, temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow.

[xxviii] As of 2008.

[xxix] In 2003, Australia had approximately 110 hectares per farmer. All other main producers had less than 60 hectares per farmer, except for Canada with just over 140 hectares per farmer.

Australia is somewhat ahead of many other countries in agricultural sustainability. Innovation has significantly improved land management practices. No-till cropping practices, developed to reduce soil erosion, have been widely adopted. Precision agriculture techniques are increasingly used to improve the efficiency of use of fertilizers and pesticides (see the next chapter for a description of precision agriculture).

Australian agriculture is more energy and nutrient-efficient than other major exporters.[216] Despite having relatively poor soils, Australian agriculture makes extensive use of ecosystem services provided by nature. For example, livestock production on native pastures converts low-quality grasses into meat, rather than relying on energy intensive grain as feed. In grain production, break crops, such as canola, are used to reduce outbreaks of diseases and insect pests, rather than relying solely on pesticides and fungicides.

Australian farmers are also more financially stable than those of other countries. In general farms are diversified, with high equity, have adopted new technologies and are strongly market focused.[217] Australian farmers have a long history of investing their own financial capital in both equipment and natural resources.[218,219]

Box 5: Australia and food security

As a major global food exporter, Australia has an opportunity and responsibility to help improve global food security. While domestic food security is not an issue for most Australians, rising and volatile global food prices could be a serious equity issue for Australia's poorest citizens.

Australia can contribute to global food security in three ways. First, promote fair trade principles in international negotiations. This will help level the playing field for farmers in developing countries who currently suffer from unfairly priced foreign imports, as well as for Australian farmers who are among the least subsidised in the Western world.

Second, enhance the stability of Australian agricultural production in the face of extreme weather. This will help to reduce global price volatility in the markets in which we are a significant exporter like wheat and coarse grains.

Third, invest in research and development to develop simple, resource-efficient, farming systems and select crops with greater resistance to heat, drought and floods. Since Australia is at the front-line of climate change, it has an opportunity to make a big difference to global food security by developing and sharing simple technologies that will be viable for hard-hit areas like Africa. In the process we may well develop lucrative products and services for export to the countries that can afford it.

For Australia, food sufficiency can be an issue for low-income families. Low income families need to spend twice as much of their income as an average family to maintain a healthy diet.[220] The cost of meeting Australian health recommendations for diet requires about 40% of the disposable income of welfare-dependent families. Families earning an average income would spend only 20% of their disposable income to buy the same healthy food.

However, Australia's farmers are not immune to the pressures and constraints facing the rest of the world

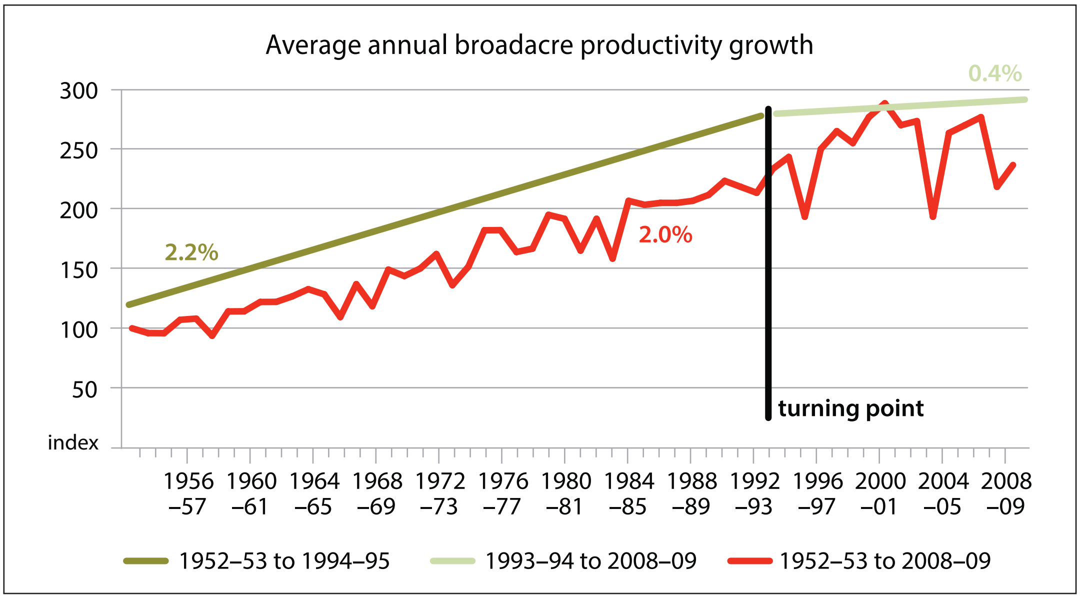
Productivity growth has slowed

Australian investment in agricultural innovation increased significantly from the early 1950s to the late 1970s, at a rate of around 7 per cent a year. In the late 1970s investment began to plateau, and since that point the average increase has been less than 1 per cent in real terms.[221] Although the Productivity Commission has noted that data on funding is deficient in that there may be some double counting and some relevant funding excluded,[222] such a clear trend makes it likely that real funding increases have significantly slowed.

There is evidence that this plateau in research funding has had a significant, but delayed, effect on agricultural productivity. Sheng et al. (2010) identified a turning point in the mid 90s after which productivity in broadacre agriculture grew at a significantly slower rate than in previous years, and showed that this was primarily due to climate effects and the slowing of growth in innovation funding.[223] There have been criticisms of this analysis, including the point that this may not be true of agricultural production as a whole.[224] However, there is ample evidence that research on agriculture delivers significant returns in increased productivity,[225] so it seems highly likely that a levelling-off in research funding would have had a corresponding effect on productivity.

An important point to keep in mind is that the relationship between research on innovation and productivity involves a significant time lag. Uptake of the results of research is minimal in early years. The rate of uptake then rises to a peak and tapers off as it is superseded by later research. Evidence indicates that this peak can take two or even three decades to occur.[226] This means that despite ambitious objectives in agricultural research in recent years,[227] dramatic improvements in productivity due to innovation are unlikely to be seen in the short-term.

Figure 3: Broadacre productivity growth has slowed



Source: Gray et. al., 2011[228]

Farmers are exposed to rising input costs

Australian farmers are likely to be exposed to the rising cost of fertilizers and fuel. While higher prices for agricultural commodities present opportunities, rising input costs will keep pressure on farmers' terms of trade (the relationship between input costs and output prices). Australian farmers have faced relentlessly declining terms of trade for decades (see Figure 4). In other words, the cost of inputs to farming has risen faster than the prices received for farm products.

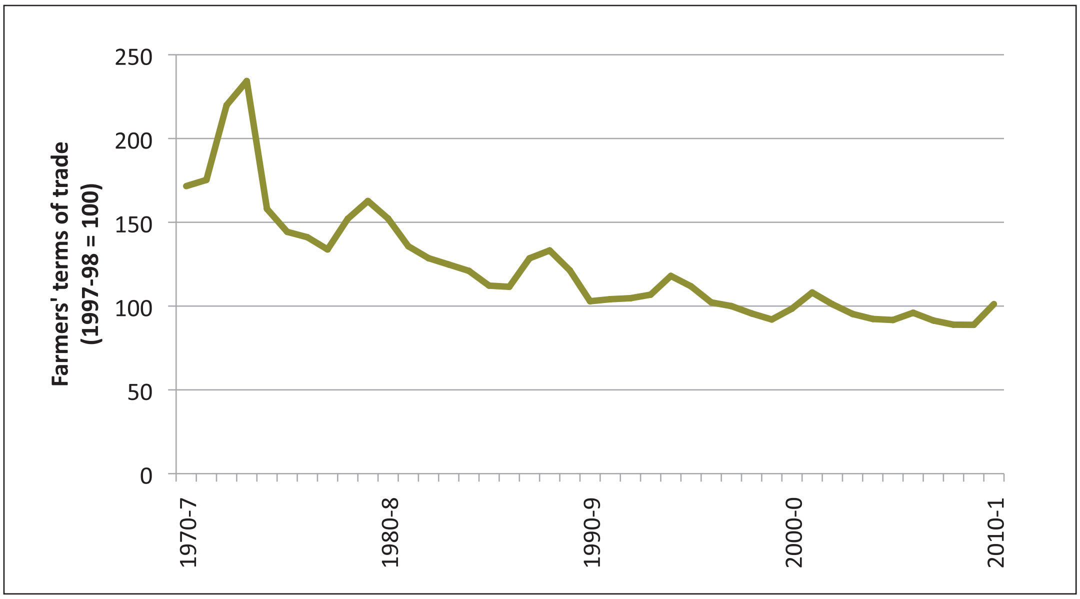
Australian agriculture is very vulnerable to rising oil costs. Australia depends on imports for half of the oil we consume.[229] Energy and energy dependent inputs are up to 50 per cent of farmers' input costs, for wheat and cropping farms.[230] The average across all cropping and grazing industries is 34 per cent.[231]

Australian crop farmers will be hard hit if fertilizer prices rise. Most Australian soils are naturally infertile, with low levels of nitrogen and phosphorus. A further problem is that the nature of Australian soils leads to inefficient use of phosphorus fertilizers. Only 25 to 50 per cent of phosphorus applied to Australian soils is available for crops or pastures.[232] This is because the soils hold onto phosphorus, rather than releasing it for plants to use.

Australia's cattle industry may also suffer from rising international grain prices. One way to increase production is to transfer pasture cattle to grain feedlots to increase their weight before sale. In 2011 a new Australian record was set with almost 35 per cent of all cattle (for domestic and export markets) finished on grain.[233] Producer margins on grain-fed beef are likely to be squeezed when grain prices are high.

Australian agriculture has recently intensified. More intensive cropping areas have expanded at the cost of pastoral grazing, due to the higher productivity growth of crops.[234] As Australian consumers acquired a taste for grain-fed beef, the proportion of cattle finished in feedlots for the domestic market doubled between the mid and late 1990s.[235]

Figure 4: Australian farmers' terms of trade, 1970-71 to 2010-11



Source: ABARES, 2011 [236]

Soil degradation limits production in some areas

Healthy, fertile soils are vital for growing crops and sustaining pastures. Soils in good condition provide essential nitrogen and phosphorus nutrients to plants. They support strong plant roots and provide reliable soil moisture over the course of the growing season.

Many Australian soils have suffered degradation that reduces the yield of crops and pastures. Many Australian soils are geologically old, with low levels of nitrogen and phosphorus. Some are particularly vulnerable to acidification. Since clearing for agriculture, Australia's soils have lost 40 to 60 per cent of their organic carbon.[237] One of the most important benefits of high soil carbon is the ability to provide soil moisture when plants need it.[238] Every year we continue to lose soils faster than they can be replaced.[239]

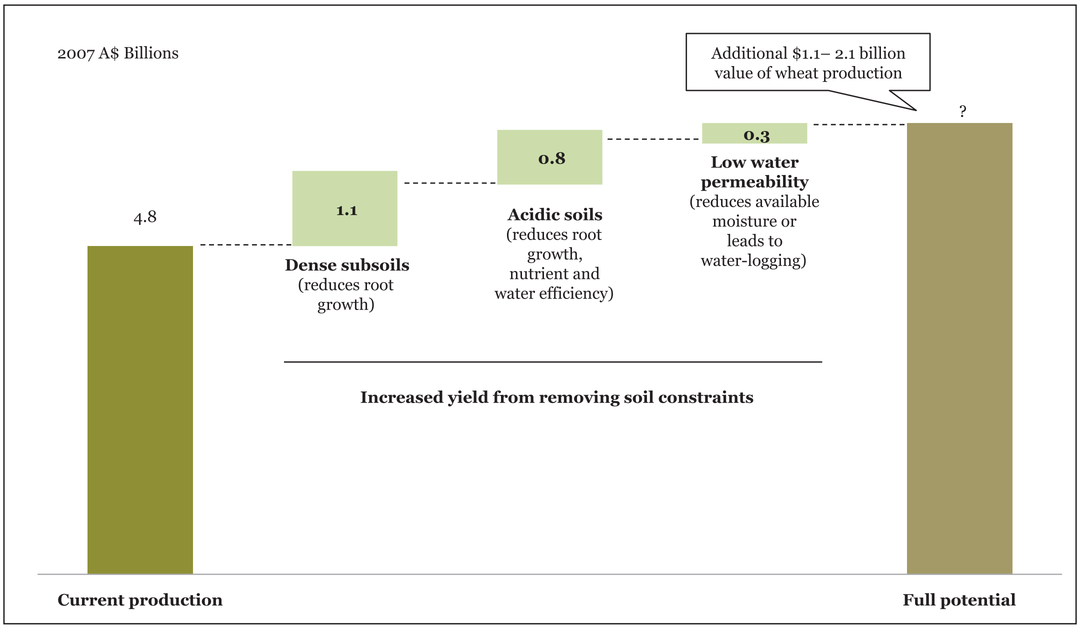
Land management practices to address this have improved significantly over recent decades. In 2006-07, Australian farmers spent $305 million on soil conditioners to improve the health of their soils.[240] However, there is little current information on the extent of soil degradation and the rate of changes in soil condition.

In 2000-2001, of the 457 million hectares of agricultural land in Australia, over 20 million hectares were affected by soil acidity, which reduces the ability of roots to take up water and nutrients.[241] Over 3 million hectares suffered soil salinity.[242] Low water permeability due to sodic soils affected over 100 million hectares, or 24 per cent of agricultural land.[243] Sodic soils have high levels of sodium ions, which limits their ability to absorb water. This can reduce the yield of irrigated agricultural production. Unsustainable rates of erosion affected almost 40 million hectares in river basins with intensive agriculture.[244]

Soil degradation has hidden costs. Replacing nitrogen and phosphorus nutrients lost through erosion with artificial fertilizers raises farmers' input costs. Lower nutrient efficiency and water efficiency reduces farm profitability, and may lead to nutrient pollution of streams through runoff. Soil constraints to yields reduce farm incomes, and in the long-term may lead to land being abandoned for agriculture or converted to other uses.

Reversing soil degradation can offer big gains in agricultural production. As Figure 5 shows, improving soil condition presents a $1.1–2.1 billion opportunity to lift wheat production per year.[245] While upfront investment is required, the value of recovering lost production is likely to rise over time due to higher prices for agricultural products. Rising costs for farm inputs would also improve the returns on investments in soil condition to improve resource efficiency. Currently marginal investments may provide commercially favourable short-term returns in the future, even without considering their longer-term benefits.

Figure 5: Soil investment opportunity



Source: CPD analysis based on Beeston et al, 2005, and Linehan et al, 2012

However, without action, the costs of soil degradation are likely to rise over time. The opportunity cost of yields lost to soil degradation will increase as long as soil erosion, acidity and salinity continue. Where soil degradation reduces input efficiency, the cost of additional farm inputs such as fertilizer, fuels and possibly irrigation water are likely to rise if resources become scarce.

Western Australia is an example of a region particularly impacted by soil degradation. The South-West of the state is Australia's largest wheat exporting region.[246] In 2010 it produced $1.8 billion of wheat, equivalent to 38 per cent of Australia's total crop.[247] At least 80 per cent of surface soil is acidic, based on recent surveys of the main wheat producing areas.[248,249] The opportunity cost of lost production (the value of the wheat that could have been produced but wasn't due to acidity) was estimated at $0.5 billion in 2009.[250] Without adequate application of agricultural lime, worsening acidity will further reduce crop yields.

There are natural limits to the further expansion of rainfed agriculture

Australian agriculture cannot continue expanding by moving onto new land. Areas with enough water for rainfed agriculture have already been developed. Historically, the most productive land was cleared first. So the remaining land has either unreliable rainfall, or poor soils, or both. More recently, urbanisation and mining threaten to encroach onto existing prime agricultural land (see Box 6).

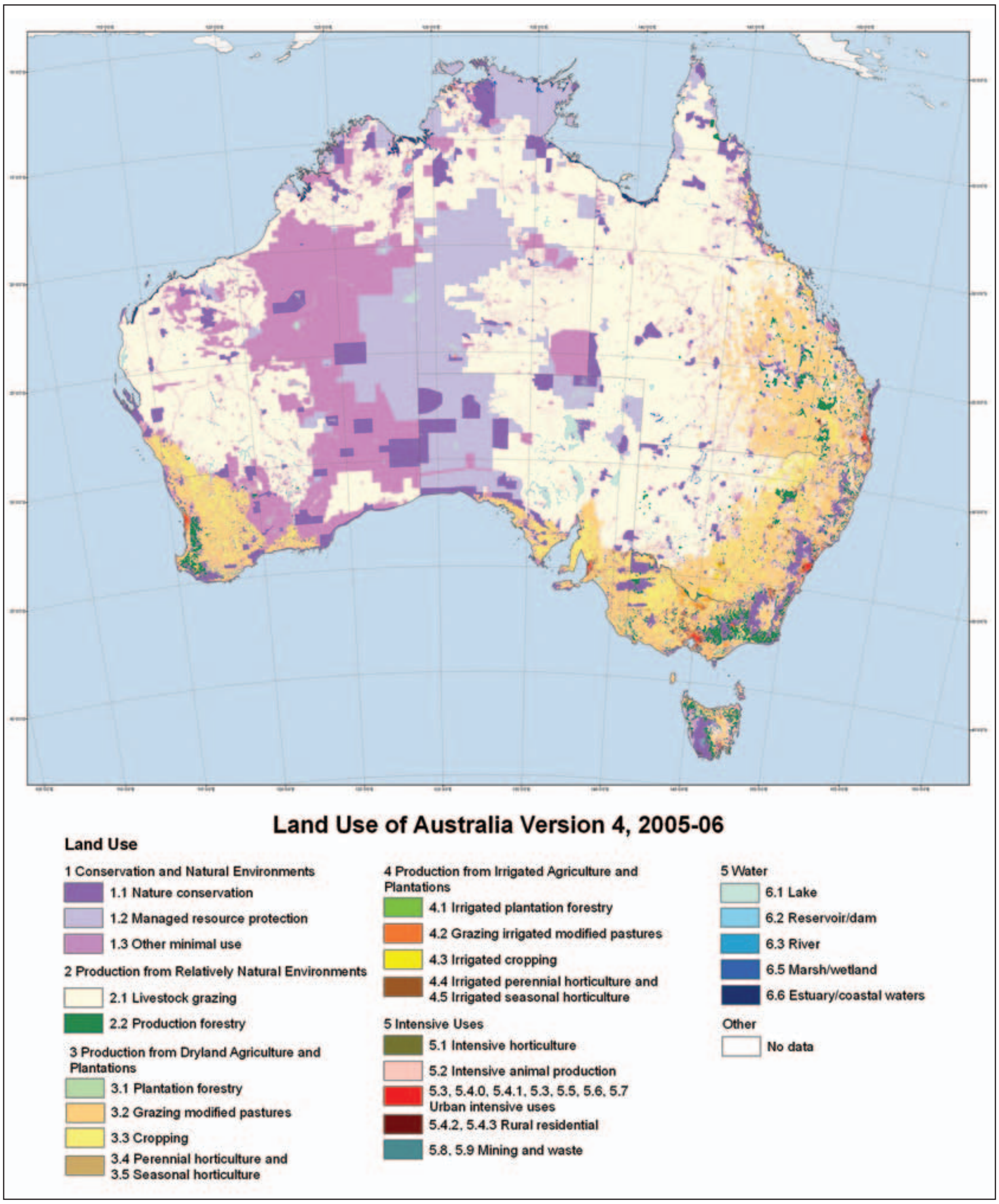
In 2005-2006, agriculture occupied 457 million hectares, or 59 per cent of Australia's land area (Figure 6). Extensive grazing of livestock on native pastures (light yellow) dominates the vast dry inland, but only where groundwater is available. Between the dry interior and the coast, 14 per cent of Australia has enough reliable rainfall to grow crops and modified pastures (light orange interspersed with yellow). This area produces almost all of Australia's cereal grains, and most farms also raise livestock. Only 6 per cent of Australia, a narrow strip along the coast, has enough rainfall for fruit, vegetables, dairy and sugar cane, with beef also raised on sown pastures.

Historically, agriculture progressively expanded onto lands with soils less suited to agriculture. The development of the wheat industry illustrates this trend. In 1890, relatively fertile red-brown soils in South Australia and Victoria produced more than 80 per cent of Australia's wheat crop.[251] However, by that time yields in these states were already falling as soil fertility declined and the wheat-producing frontier moved onto poorer soils.[252]

By 1911, NSW dominated Australian wheat production, as railways extended to the South-Western slopes with similar fertile red-brown soils to Victoria.[253] Australia first became a wheat exporter as NSW production exceeded demand.[254]

Western Australian wheat production did not expand significantly until the 1950s and 1960s.[255] More than half the land with the right climate for wheat has very infertile, sandy soils.[256] Producing wheat in these conditions required the development of new technologies utilising fertilizers and trace elements.[257] While the Western Australian wheat belt now dominates Australian exports, yields per hectare remain below those in NSW.[258]

Figure 6: Australian agricultural land use



Source: World Bank, 2012[259]

Box 6: Managing conflicting demands for farmland

Agriculture exists in competition with other potential uses of the same arable land, such as mining and coal-seam gas extraction (CSG), expanding towns and cities, and to some extent tourism and conservation. Some competing uses can co-exist with ease, adding valuable diversity to local economies and critical mass to local populations. Others can make for uncomfortable neighbours, particularly during times of rapid change, or where there is conflict over common resources – such as water resources in the case of farming and CSG.

Australia is currently dealing with the pressures of two fast-growing sources of competition for arable land:

» At the same time as pushing up demand for food and other agricultural exports, the growth in the size and wealth of the global population is pushing up demand for fuel and minerals, resulting in a massive expansion of mining and CSG. Capital expenditure in major resource projects has reached record levels. As of April 2012, the federal governments' official list of approved projects had a total value of $261 billion. In comparison, at the height of the resources boom in the 2000s there were $70 billion worth of projects.[xxx] It has been estimated that water extraction by the CSG industry could be in the range of 300 gigalitres per year, which compares to current total extraction from the Great Artesian Basin of around 540 gigalitres per year.[xxxi]

» Domestically, Australia's accelerating urbanisation is encroaching upon the valuable agricultural land that surrounds many of our cities. Australia is already highly urbanised, with 68% of the population living in major cities in 2006,[xxxii] and it is anticipated that over 93% of all Australians will live within an urban community before 2050.[xxxiii]

Free-market purists argue that an unfettered market in land will result in land being put to its highest-value use, while others argue that landscapes are part of the social fabric and that social values should therefore be considered, especially when rapid transformations are underway.

Different policy approaches to managing land-use conflict can be placed on a spectrum from 'who pays wins' to 'command and control'. An individual or group's position on that spectrum will often shift depending on context. A farmer looking to sell up and retire might be opposed to a command and control approach to minimum property sizes, while welcoming a bit of top-down regulation on coal-seam gas mining. A city-dweller might like the idea of command and control approaches to the foreign acquisition of farmland while preferring a free-market approach on urban sprawl in the hope that it could keep house prices down.

[xxx] Cleary, Paul. Mine-Field: The Dark Side of Australia's Resources Rush. (Canberra, Black Inc: 2012) p 9. (citing Bureau of Resource and Energy Economics. Mining Industry Major Projects. Canberra, Australian government: April 2012.)

[xxxi] National Water Commission, Coal Seam Gas Update, June 2012.

[xxxii] Australian Bureau of Statistics, "Population Distribution," 4102.0 Australian Social Trends 2008.

[xxxiii] United Nations, World Urbanization Prospects: The 2009 Revision Highlights, Prospects, 2010.

If conflicts over land-use are to be resolved without resorting to a battle over who can shout the loudest or lobby the longest, a strategic approach is required. Good strategy is impossible without access to good information, so measures such as the bio-regional assessments to be undertaken by the 'Interim Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining' are essential.

Where good information is available on the cumulative impacts of different land uses across a region, decision-making should be informed by:

- The community's social goals;
- Economic assessments which take in the full costs and benefits of different development pathways – including the local and nation-wide positive and negative social and environmental externalities of different options;
- The potential for future productive re-use of the land following the decommissioning of any land use;
- Awareness of the underlying drivers of land-use transformation, and the potential for rapid changes in these drivers (such as house prices, food prices, mineral and fuel prices, etc).

There is minimal potential for increasing irrigated agriculture

Over the 45 years to 2001, the area of irrigated land quadrupled to over 2 million hectares, accounting for 1% of agricultural land.[260] Irrigated agriculture uses 65 per cent of all water in Australia, and produced almost 30 per cent of the gross value of Australian agriculture in 2009-2010.[261, 262]

Australia has limited potential to increase the area of irrigated land. If all planned irrigation in Tasmania is developed, total irrigated land area in Australia could increase by 10 per cent.[263] Careful development of groundwater irrigation in northern Australia could add another 1–2 per cent to the total irrigated land area.[264]

However, new developments could be prone to soil degradation and downstream pollution, unless they are exceptionally well managed. For example, most soils in northern Australia are 100 to 500 times as vulnerable to erosion as soils in the south of Australia.[265] Without the protective cover of native grasses and other vegetation, high wet season rainfall and frequent cyclones would lead to rapid soil loss.

The Murray Darling Basin demonstrates some of the problems that arise when water resources are over-developed. The Murray Darling Basin (MDB) is Australia's largest irrigation area. It produces over 30 per cent of Australia's gross value of irrigated agriculture and over 10 per cent of the gross value of all agriculture.[266] Agriculture in the MDB uses 60 per cent of all irrigation water in Australia.[267]

The MDB is home to around two million people.[268] It is also home to some 30,000 wetlands.[269] While most are on private land, they rely on public water from floods and groundwater to support wildlife.[270] The MDB's wetlands are valued by Australians for their beauty and biodiversity. They also have a significant economic value. For example, maintaining the lower Murray dairy swamps in South Australia has a filtration value of $1,180 to $12,700 per hectare per year.

Over-development has significantly reduced downstream river flows. By 2000, surface water use had expanded to more than half the natural river flow, just short of 100 per cent of the natural flow to the sea.[271] The river now ceases to flow into the sea 40 per cent of the time, compared to 1 per cent before water resource development.[272] Six of Australia's 10 most water stressed rivers are in the MDB[xxxiv].[273] Dredging at the Murray mouth costs $36 million a year.[274]

Groundwater resources are also over-used. Groundwater accounts for 16 per cent of total water use in the MDB, but could increase to one-quarter of total use by 2030.[275] Current groundwater use is unsustainable in 7 of 20 high-use regions in the MDB.[276]

Climate change is predicted to put further pressure on water resources in the basin. By 2030 average climate predictions are for water diverted to irrigation in the driest years to fall by more than 10 percent in most regions of New South Wales, by around 20 percent in the Murrumbidgee and Murray regions, and by around 35 to over 50 percent in the Victorian regions.[277]

Changing weather patterns make yields less predictable

Australia's agricultural sector, native plants and animals have to cope with widely variable weather. Year-to-year and decade-to-decade variability is an intrinsic part of Australia's harsh climate – Dorothea Mackellar called it the land of droughts and flooding rains for a reason.

Australian farmers therefore have experience in managing a more highly variable climate than most other regions of the world, and may well find growing international demand for their expertise in dealing with such conditions as weather patterns change in other countries. However, coping with historic variability in a stationary climate is a different challenge to adapting to continuous change.

Climate change is altering traditional weather patterns.[278] Average temperatures have risen by 0.9°C between 1910 and 2011.[279] Each decade has been warmer than the last, with the last decade being the warmest[xxxv].[280] The warming around Australia is consistent with the global pattern and cannot be explained by natural variability alone.[281]

As change becomes the new normal, weather extremes will move beyond the coping range of many agricultural systems. This will reduce the odds of good returns, shifting some industries to locations with more reliable rainfall, and leading to either transformation or rapid decline in others. Capital investments in farming will be riskier, as buying new cropping gear or additional farming land is conditional on good seasons. Fewer good years may also reduce farmers' and graziers' financial liquidity, making it harder for them to adopt new farming practices.[282]

Impacts are already occurring in Australia. Dairy production has shifted south due to shortages of water.[283] Poor weather in the decade from 2000 reduced the output of cropping farms by 13 per cent, compared to 1997-1978 to 1999-2000.[284] The high-input, high-yield cropping systems developed in the 1980s and 1990s proved vulnerable to the drier and more variable weather in the 2000s.[285]

[xxxiv] This assessment is based on average flows over the last 15 to 20 years, with current levels of water development and management regimes. Reductions in flows due to climate change and climate variability were not considered.

[xxxv] This is despite two cool years due to consecutive la Nina events.

Extreme temperatures are becoming more frequent:

- » The area over which exceptionally hot years have occurred has doubled over the last 40 years, covering 10–12% of the area of Australia[xxxvi].[286, 287]
- » Extremely high temperatures are now likely every 1 to 2 years, compared to a long-term average of once every 22 years[xxxvii].[288]
- » Lower rainfall is likely to also contribute to more frequent agricultural droughts:
- » Years with exceptionally low rainfall may occur twice as often, and over twice as large an area by 2040[xxxviii].[289]
- » Years with exceptionally low soil moisture may occur twice as often by 2030[xxxix].[290]

The largest impacts will come from extreme weather, rather than changes to average conditions. A warmer climate is expected to make droughts more severe, and increase the risk of fires.[291,292] Changes in rainfall will vary across Australia.

Droughts are likely to be more severe because water evaporates faster in warmer weather, so it takes more rainfall to break a drought. While droughts are triggered by low rainfall, the level of soil moisture determines the impact on agriculture.[293] The combination of drying and increased evaporation means soil moisture is likely to decline over much of southern Australia.[294] Hotter and drier months are also expected to lead to an increase in fire risk, especially in South-East Australia.[295]

Southern wheat producing regions are projected to receive less of the winter and spring rainfall needed for wheat crops.[296] In the North, intense rainfall events are likely to become more extreme, due to a warmer, wetter atmosphere.[297]

The impacts of changing weather patterns on agriculture are difficult to predict precisely. They depend on the extent and timing of changes, the vulnerability of particular crops or animals, and the way in which farmers adapt. However, poor weather conditions generally slow agricultural productivity growth over time.[298] Some early research suggested the yields of some crops may increase with rising temperatures and CO2 concentrations. However, extreme changes such as increased frequency of high temperature events and longer droughts would offset those benefits.[299]

By 2050, climate change has the potential to reduce Australian beef production by 19 per cent, wheat production by 13 per cent, and dairy production by 18 per cent below a baseline with no climate change.[300] Impacts on South-West WA may be particularly severe, with poor growing years likely to occur four times as often, over four times the area[xl].[301]

Climate change threatens losses of $6.5 billion in beef, wheat, dairy and sheep production by 2050, without significant investment in research, development and extension to adapt to more variable and extreme weather.[302]

So research and development into more resilient crop varieties, farming practices and possibly entirely new business models is essential to reduce and adapt to the impacts of climate change.

[xxxvi] Exceptionally hot years typically occurred over 10 to 12 per cent of Australia between 1968 and 2007, compared to a long term average of 5 per cent.

[xxxvii] Average prediction for 2010 to 2040 based on 13 climate models using mid-range emissions scenarios (IPCC A1b and A2). The long term average is for 1900 to 2007.

[xxxviii] Highest 10 per cent of predicted results for 2010 to 2040, compared to 1900 to 2007.

[xxxix] Highest 10 per cent of predicted results for a 50 year period centred on 2030, compared to 1957 to 2006.

[xl] Highest 10 per cent of predicted results for 2010 to 2040, compared to 1900 to 2007.

Box 7: How much does Australian agricultural production vary year to year?

Australia's agricultural production varies highly from year to year, due to our widely variable weather. Thinking about how many people Australia feeds in a drought year, compared to a more typical year is one way to picture how large this variation can be.

Table 5 shows the results of a rough estimate of the variation in agricultural production. This suggests Australian grains can feed 59 million people in a good year, compared to 25 million in a drought year.

To estimate the number of people Australia feeds, we compared total cereal production with current Australian per capita consumption of cereal for all uses. This assumes all cereal consumed in Australia is either for human consumption, or to feed cattle for meat consumed by Australians. We used 2010-11 production as an example of a typical year. As an example of drought conditions, we used the average of production for 2002-2003 and 2006-2007.

Obviously this is a simplification. Some cereal consumed in Australia feeds cattle that are exported, and some cereal is used by industrial processes. However, Australian diets also include imported meat, fed on grain which is not reflected in average Australian cereal consumption figures. It is likely that grain consumed for Australian meat exports roughly nets out against grain used overseas to produce Australian meat imports. The fact that Australian grain consumption for all uses (700 kg per capita) is close to the average for industrial countries (592 – 641 kg per capita) confirms this is a reasonable assumption.[303]

Table 5: Australia feeds 59 million in a good year, 25 million in a drought year

	Typical year	Drought year
Volume of cereal and rice produced (million tonnes)[304]	41.0	17.6
Average Australian cereal consumption for all uses (kg/capita) [305]	700	700
Number of people fed	59 million	25 million

Source: CPD analysis

Drought years could become more common by 2050. Without adaptation to reduce the impacts of climate change on agricultural production, Australia may produce less grain than needed for our projected population in 2050.

We need to learn to farm smarter, not harder, to capture future opportunities

To maintain a competitive export position, Australian agriculture needs to learn to farm smarter, not harder. The challenge for Australia is to increase production per hectare, without raising farm input costs through higher fertilizer and fuel use. This means preserving soil and land assets, increasing input efficiency to produce more food with fewer resources, and developing new farming practices and systems to make production more reliable in the face of increasingly variable weather.

Many farmers and graziers are already benefitting from maintaining and improving soil condition by using technology and farming systems that are currently available. Soil in good condition provides production flexibility and reliability. Where soil condition is a constraint to agricultural production, reversing soil degradation or decline can improve the input- efficiency of water and fertilizers. See Chapter 4 for examples and their benefits.

However, we need to ramp up investment in research and development of new farming practices and systems now, to maintain productivity growth in the medium term. Without additional public investment, productivity growth will continue to slow. Since 1980, public investment in agricultural R & D has grown at only 0.6 per cent a year, a decline in real terms.[306] As it can take up to 35 years to see the full benefits of research, investment in resource-efficient and climate-adapted agriculture needs to be made now.

Research programs should focus on developing climate resilient crops and pastures, and knowledge-intensive, sustainable farming systems. A more active exchange of information between scientists and farmers will be essential to reduce the time lag between development and implementation of more sustainable agricultural practices. Sustainable agricultural practices and technologies need to be locally adapted and fitted to place.[307] This requires a high level of scientific knowledge, and land managers with the skills, information and a long enough time-frame to see the benefits of more sustainable agricultural practices and systems.

Encouraging larger farms, on its own, is unlikely to overcome slowing productivity growth. Aggregation of farms has previously led to improvements in productivity as more efficient operators took over from those who were less efficient.[308] Over the past two decades, the bottom 25 per cent of broadacre farms has struggled to generate positive farm cash flows[xli].[309] However, land prices have run ahead of returns per hectare in the past decade. The ratio of average land prices to cash receipts more than doubled between 2001-02 and 2009-10.[310] This suggests that land-holders will look for improved returns from current land, before investing in additional land.

Preparation for longer-term risks also needs to start now. Alternative farming systems - such as agro-forestry, organic farming and closed-loop farming – are real-world experiments that are generating solutions for future challenges. Agro-forestry combines agriculture and growing trees to produce commercial returns from both agriculture and tree products.[311] Organic farming is based on practices that reduce reliance on external inputs. Fertilisers and chemicals are limited

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xli Farms were ranked by a moving average rate of return to capital, excluding capital appreciation of land or other investments.

or excluded, soil health is carefully managed, and weeds are suppressed rather than being eliminated.[312] Demand for organic products is growing at an estimated 20 per cent each year.[313] Closed-loop farming recycles nutrients from organic waste as an input to farming, to tighten or close the resource loop. A recent survey suggests that 29 per cent of nitrogen, 24 per cent of phosphorus and 100 per cent of potassium used by Australia's grains industry could be supplied by organic waste from nearby intensive animal and meat production systems.[314]

If climate change or resource constraints become severe, land use planning and competition policy should prepare for impacts on food production. There is a strong risk management argument for protecting the most productive land and ensuring diverse food supply chains. For example, maintaining enough productive agricultural land around cities and towns to provide local food to a decentralised population could be a socially important goal if it provides insurance against rapidly rising transport fuel costs. Similarly, maintaining a diverse number of competitors in food supply chains can insure against their disruption by weather related disasters.

If we prepare now, Australia will be well placed to benefit from times of high international commodity prices, even if input costs rise. However, if we don't act now, Australian farmers may be squeezed between rising input costs and lower production levels.

We need to build up farm capital to manage risks

Australian farmers will need to manage risk well, to realise long-term benefits in a more volatile international market. Higher and more volatile agricultural prices will be driven by both increasing demand and supply side shocks. Like other exporters, Australian producers will be exposed to production risks, such as extreme weather, pests and diseases. Financial, price and production risks need to be managed and minimised, so that the upside from times of high prices outweighs the downside of periods of lower production.

The insurance market fails to cover the most common agricultural production risks, such as drought. Insurance is available for fire and hail damage. However, there are limited options for agriculture to insure against other production risks in Australia.[315] This means farmers must essentially self-insure against the impacts of drought or other extreme events on agricultural production.

Managing risks requires three types of farm capital. Financial capital provides liquidity to ride out droughts. Natural capital, such as healthy soil and land, provides the flexibility to shift the production mix to make the most of market prices and variable weather. Knowledge capital is needed to manage farm finances and production levels to ensure long-term economic sustainability.

Of the three, financial capital arguably comes first. Without it, farms risk being stuck in a cycle of deepening financial debt, declining natural resources, and lower productivity. Maintaining financial liquidity is essential for sustainable natural resource management. Australian farmers spent almost $3 billion to prevent or manage weeds, pests, and land or soil problems in 2006-07.[316] Despite the strong culture of natural resource stewardship, farmers can't be green unless they are in the black.

On average, farms which received drought support in the past decade had twice the debt and less than half the liquid assets of nearby farms[xlii].[317] They also had lower yields per hectare, and more stock per hectare and higher animal feed costs. This could be due to poorer soil condition, less management knowledge, or both. Either way, the financial strain of future droughts would increase the pressure to farm harder, potentially at the cost of soil condition and long-term agricultural productivity.

On the other hand, most Australian farmers have a strong track record of financial management and independence. Anecdotally, most of the capital for equipment and other on-farm investment has come from within the farm business or bank credit for the majority of farms which are family owned.[318] Only a small number of larger company-owned farms have access to equity capital, and only a small proportion of these can tap overseas capital.[319]

The payoff from early investment in natural capital and knowledge capital to support more sustainable agriculture is likely to increase over time, as weather variability increases. The following chapter titled 'It pays to invest in natural capital' consider some of these benefits. The chapter titled 'Communities of sustainability' looks at the idea of using the 'catchment care principle' as a useful rule of thumb when deciding how the costs of investment in natural capital should be shared.

[xlii] Based on farms receiving the Exceptional Circumstances (EC) interest rate subsidy compared to non-recipients in EC areas.

> "Savvy farmers are already implementing more sustainable agricultural practices."

Farming smarter, not harder, can sustainably increase production

Farming smarter, not harder, can sustainably increase production

Australian agriculture will need to apply a wide range of innovations to expand production despite more variable weather. Farming smarter can raise production levels, improve input-efficiency and provide the flexibility to match production to variable weather conditions.

Many farmers are already using practices that raise input-efficiency and productivity, by improving soil condition. Soil in good condition can allow farmers take advantage of more favourable seasons in a variable climate. This can ensure more reliable production levels and financial returns over time.

Investment in research and development is essential to fit existing smarter farming practices to local needs, and to find even more efficient and productive ways of farming.

Sustainable agricultural practices can benefit farmers and the environment

Australian agricultural industries are already developing and implementing agricultural practices that are better matched to our soils and climate. Some have been widely implemented, such as conservation agriculture. Others are not yet as widespread. Others are still at the experimental stage. Table 6 provides some examples of such practices, and their benefits.

For Australia to expand production to meet growing export opportunities, and adapt to more variable weather, agriculture will need to apply a mix of innovations to:

1. Match the level of inputs, agricultural products and practices to the variable soil and climate conditions within each paddock, farm, or catchment.
2. Enable crops and livestock to take advantage of more favourable seasons in a variable climate.

Innovations that capitalise on variations in soil condition between paddocks may increase agricultural production and input efficiency, while reducing degradation of soil and the environmental impacts of fertilizer and pesticide runoff. Precision agriculture is one such example.

Matching agricultural products to variable soil and climate conditions could allow less productive land to be used for carbon storage or biodiversity plantings, with an appropriate carbon price or payments for ecosystem services. Access to such payments is likely to be very valuable to farmers looking to diversify their incomes. Mosaic farming may offer potential for this, where perennials such as trees or shrubs are interspersed with annual crops.

Table 6: Examples of more sustainable agricultural practices for cropping and grazing

Practice	Explanation	Potential Benefits
Cropping		
Conservation Agriculture	A suite of management processes that reduce soil disturbance through minimum tillage, maintenance of crop residue in the soil following harvest, and crop rotation.	Reduces erosion through increased groundcover and minimised damage to soil structure. Improves soil moisture and nutrient retention. Lowers machinery, labour, and maintenance costs.[320]
Controlled Traffic Farming	A group of management practices that reduce the impact of farm machinery on soils by restricting wheeled equipment to particular routes and maintaining consistent traffic patterns.[321]	Avoids widespread soil compaction, and allows water to penetrate the soil more easily. Can allow for re-planting right after harvesting and double cropping.[322]
Precision Agriculture	Using knowledge of differences between paddocks in crop yields, soil surface cover, elevation, and other characteristics to determine most efficient management practices (i.e. selective fertilizer and herbicide application).[323]	Reduces input costs as well as fertilizer and chemical use while improving profits and reducing environmental impact.[324] One recent study suggests that matching rates of application of nitrogen fertilizer to soil depth could increase gross margins from wheat production by 1 per cent in an 'average year', but up to 11 per cent in a year with poor weather (in comparison to applying fertilizer uniformly).[325]
Integrated Pest Management	An economically sound group of selective pest management practices that are informed by the life cycle and biology of pests and minimize environmental damage.[326]	Reduces the need to use pesticides by promoting natural enemies, slows the development of pesticide resistance, and lessens the environmental impact of traditional pest management approaches.[327]

Practice	Explanation	Potential Benefits
Intercropping	The cultivation of two or more crops in the same place, grown together for most of their life cycle.[328]	More ground cover, which prevents soil loss and its associated costs. Use of legumes promotes nitrogen fixation and improves soil fertility. Growing crops with different root depths and nutrient requirements promotes efficient use of resources.[329]
Mosaic Farming	The practice of incorporating deep-rooted perennials within an annual cropping system in a pattern informed by variations in soil properties and yields between paddocks.[330]	Potential for reduced erosion, improved nutrient cycling, less nutrient waste and leaching.[331]
Mixed cropping and grazing		
Perennial Cropping/ Grazing	Crops produced from the same root structures over two or more years.[332]	Perennials have large root systems that decrease erosion, use and store water efficiently, and prevent salinisation of soil.[333] Can provide year-round nutritional feed for livestock or both feed and grain for harvesting in a mixed system.[334]
Grazing		
Rotational Grazing	Rotating livestock through a series of paddocks so that plants are grazed at the most nutritional phase of their lifecycles and allowed to regenerate in between grazing.[335]	Rest periods allow perennials to regrow roots, reducing erosion and allowing them to better endure dry periods.[336] Potentially longer grazing season with more even distribution of grazing than continuous grazing.[337]
Cell Grazing	Time-controlled grazing method involving stocking and rotational practices that are fine-tuned to plant life cycles.[338] Small paddocks enable short grazing periods with heavy stocking rates.[339]	Potential for high stocking numbers while allowing for soil recovery. Promotes growth of perennial native pastures which can use soil nutrients more effectively than annual grasses.[340] Cell grazing is an improvement over a fixed stocking rate, but even better results may be possible using observation and expertise to decide when pastures are ready for grazing.

Savvy farmers are already implementing more sustainable agricultural practices

The following examples highlight the benefits to farmers of implementing more sustainable agricultural practices. These practices offer benefits from some combination of:

- Reducing input costs by increasing the efficiency of fertilizer and pesticide use
- Optimising soil carbon to improve water retention and nutrient levels
- Managing ground cover to reduce soil erosion and maintain soil carbon levels
- Managing soil acidity and other soil constraints to improve crop yields.

Broadacre cropping

Broadacre cropping is an important agricultural sector for Australia. Major crops include cereals such as wheat and barley, pulses such as lupins and chick peas, and oilseeds such as canola and sunflower.[341]

Where nutrient availability is not a constraint for crop production, increasing soil carbon to keep soil moisture high when conditions are right for planting can directly increase crop yields.[342]

Reducing soil acidity can significantly increase the water-use and nutrient-use efficiency of crop production. Recent research suggests that access to information remains a key barrier to sufficient application of lime to overcome soil acidity.[343]

Conventional agricultural systems used before the 1970s tilled the soil, which destroyed the soil structure and increased vulnerability to wind and water erosion.[344] When combined with the use of clover to fix nitrogen and superphosphate fertilizers, tilling also lead to soil acidification.[345]

Since the 1970s, conservation agriculture has sought to maintain soil structure and fertility by leaving crop residues on or near the surface. Conservation agriculture can increase agricultural production, reduce soil loss through wind and water erosion, lower greenhouse gas emissions and improve water use efficiency.

Conservation tillage is a key part of conservation agriculture. Conservation tillage involves no-till or minimal till practices, combined with direct drill seeding techniques. This leaves crop residues on or near the surface, reducing soil erosion, improving water-use efficiency and maintaining or increasing agricultural production.

Across Australia, 76 per cent of cropped land is now managed with no cultivation, apart from when seeds are sown.[346] Achieving this level of adoption took over 15 years. The risk of adopting new practices probably contributed to this slow uptake. It may also have been due to the relatively small increase in commercial returns from conservation tillage compared to conventional agriculture over a 5 year timeframe.[347] Over a 20 year timeframe however, conventional agriculture has been found to lead to rapidly declining crop yields and quality. [348] So the longer-term returns from switching to conservation agriculture may be much higher than over a 5 year timeframe.

Growing grains in Western Australia

Farming 2,800 hectares at Miling and another 2,200 hectares at Nambung Station in WA, Tony White says that land management practices based on a better understanding of soils and better use efficiency have increased his yields while reducing input requirements. Tony has combined new grain varieties of wheat, barley, and canola with no-till sowing and rotations that are in tune with soil condition.

The rotations are varied but generally involve canola, a cereal, and a legume or pasture. Rotation with new crop varieties allows Tony to sow earlier and achieve higher yields. Grazing crops on the Milling property as part of regular rotation provides excellent weed control.

He says that adopting no-tillage farming has had the most impact on production. “The use of knife points and discs has enabled us to use water better and control weeds. The concept has made us more attentive to details such as rotations, soil constraints, fertilisers and now soil carbon,” he says. No-tillage provides an effective means to control disease, soil moisture, and weeds.

Source: GRDC [349]

Dryland cropping in NSW

Employing several environmentally sensitive land management practices has not only increased soil carbon and the productivity of Anne Williams’ dryland cropping operation, it has increased her gross margins nine-fold. Over the 20 years she has used techniques like no tillage and crop rotations, she’s seen wheat yields rise from an average 1.9 tonnes a hectare to 3.7 tonnes a hectare.

Anne’s farm includes a mix of cereals, oilseed and pulses. She has found that planting different varieties of wheat, canola and chickpeas that are particularly suited to the regional climate and soil type helps bolster yields.

Practicing no-till and employing a careful crop rotation strategy ensures that sufficient organic matter is left in the soil. It also decreases the nutrients lost to wind erosion by alleviating the dust storms that were once a problem during dry seasons.

Well-researched pest management strategies, including careful observations and proper timing of insecticides, along with the addition of beneficial insects, help protect her high yields. Taken together, these sorts of practices have allowed Anne to take advantage of high rainfall and increased soil moisture and optimize production in the area.

Source: GRDC [350]
Photo provided by: Porter Novelli, http://www.porternovelli.com.au

Grazing

Much of Australia's beef grazing industry relies on native pastures.[351] Sheep grazing for meat and wool is also an important industry, especially in southern states.

Particularly in dry areas, over-grazing leads to loss of groundcover and soil degradation. If this occurs through repeated drought cycles, the number of stock the land can carry may fall to unprofitable levels.[352]

Episodes of severe degradation occur when stocking rates remain high during droughts and groundcover declines due to over-grazing[xliii]. This decline is essentially permanent. While partial recovery of groundcover can occur during periods of higher rainfall, this requires even lower stocking rates than usual and may be unprofitable.

Keeping groundcover in place, by matching stock levels to available pasture, can avoid these problems and maintain the long-term carrying capacity of the land.

Preserving native grasses on grazing land can provide slightly higher and more stable cash returns and much less risk of negative returns over 25 years compared to pasture in a deteriorated state.[353] Keeping groundcover intact through droughts by using moderate stocking rates can reduce soil degradation and maintain forage for stock.[354]

Cell grazing and native pasture sowing on the Margaret River, WA

The Henwoods' Fossil Downs property encompasses over 400,000 hectares within the West Kimberley region of Western Australia. Being a 4th generation farmer, the Henwoods have seen it all; from droughts to destructive flooding. However over the past decade Fossil Downs has been subject to several major floods, with the worst seeing over 5,000 cattle lost, extensive damage to the homestead and precious soil resources being drained into the Margaret River.

In response to these destructive flooding events, the Henwoods have implemented a range of erosion control measures like strategically placing fences and building flat, wide roads that reduce surface runoff. By adopting these measures, Fossil Downs has reduced its soil erosion and has more soil moisture.

The Henwoods have also adopted cell grazing and cattle rotation, initially to limit stock losses during flood events. In doing so, they have discovered the benefits of reduced weed invasion and a substantial increase in the number of native vegetation species.

The latter has proved vital for Fossil Downs. By resting paddocks, three key native species have been allowed to establish so that they can be used for feed: the Blue Bush (*Chenopodium)*, Ruby Salt Bush *(Aucroco-num)* and Mulla Mulla *(Pilotus Exaltatus)*.

Importantly these natives have allowed herd weight to be stabilized even during exceptionally dry periods. John Henwood, together with agronomist Bob MacDonald, has attributed this success to the ability of native species' to retain protein levels year round unlike traditional pasture species.

[xliii] A common pattern of decline in ground cover and soil condition following over-stocking during droughts has occurred in seven major episodes of land degradation since 1898.

In addition these natives are better adapted to the harsh Australian climate and thus require fewer inputs than comparable non-native species.

The result for Fossil Downs is that herd weight is maintained even through exceptionally dry periods. The implementation of these practices has allowed improved environmental outcomes, securing these benefits for the long term. In fact the Fossil Downs site is now home to some of the healthiest pools along the entire river. By doing well through smarter farming practices, the Henwoods enjoy considerable success whilst supporting the natural environment.

Source: MLA[355]

Rotational grazing in Queensland

Conservative planned stocking rates and rotational grazing have resulted in a 7-fold profit increase since 2001 for the properties John Burnett owns and manages in the Fitzroy and Burdekin catchments in Queensland. Rather than maximizing stocking levels of cattle in the short term, John and Jan Burnett manage for optimal land condition over the long term.

The Burnetts carefully adjust stock numbers to seasonal conditions and practice wet season ‘spelling’: allowing the land a rest period for vegetation to regenerate. They keep stocks at approximately 75 per cent of the long-term carrying capacity of the land, which maintains groundcover and feedstocks. Rotational grazing ensures that the land will be rested, promoting the growth of perennials.

John says that wet-season resting for approximately 2 months dramatically improves land condition and as a result bolsters feedstocks and profits. Spelling regimes for most of the properties are dependent on paddock and herd size. Smaller paddocks are rotated regularly, while larger ones are given a wet season off at least every 5 years. In addition to allowing for resting, John says that rotational grazing makes basic farm management easier. For example, he moves cattle that are soon to be sold into paddocks closer to the truck yards as they gain more weight.

Healthy soils ensure that John’s land is resilient in the face of changes in seasonal weather patterns. With healthy land, he sees pasture growth in response to almost any amount of rainfall. He says that he hopes financial systems can be improved to allow farmers to focus on long-term viability ahead of short-term profits.

Source: DEEDI[356]
Photo provided by: Paula Heenan, www.paulaheelanphotojournalism.com

Irrigated horticulture

Horticulture is Australia's third largest agricultural sector. Irrigation is an important contributor to horticultural production, accounting for over 70 per cent of the gross value of production in 2009-2010.[357]

However, many Australian soils harden under irrigation and can restrict the growth of tree roots and their ability to take up water. In general, this is due to the age of Australian irrigated soils.[358]

The opportunity costs of reduced crop yields due to poor soil condition can be high. Australian horticultural crops grown on poor soil types can average as low as 10 tonnes per hectare, while those grown on the best soils can achieve yields of 50 tonnes per hectare.[359]

Soils with high organic matter are thought to be less likely to have this problem.[360]

Horticulture in the Goulburn-Broken Catchment (Murray-Darling Basin)

Adopting techniques that improved the health of his soils allowed James Cornish to grow larger and higher quality fruit on his Murray Valley orchard. He said that "we are running a more productive orchard," after investing in soil natural capital. His aim is to double or triple yields of his peaches, pears, apples, and lemons while improving soil quality.

Changes in James' practices protect fragile soil structure and thereby promote the growth of quality fruit. He uses a modified ripper that opens soil without deteriorating its structure and irrigation sprinklers that are in tune with soil permeability. This, along with reducing traffic on tree lines, reduces soil compaction. Avoiding herbicides in autumn promotes the growth of winter grasses, which prevents soil drying during the winter and maintains soil carbon levels.

James has seen improvements in soil texture and irrigation efficiency. Building banks of earth around fruit trees creates high-quality top soil that allows trees to develop roots and increase the potential for high yields. He says that water now penetrates the soil better when irrigating. Additionally, fewer tractor hours means less pollution and fuel costs. Increased yields of marketable products bring in increased revenue.

Source: National Program for Sustainable Irrigation[361]
Photo thanks to SapienSolutions

"Healthy, functioning ecosystems can provide tangible benefits to farmers."

It pays to invest in natural capital

It pays to invest in natural capital

Just as there are economic advantages to be gained from investing directly in the health of the soil on which farming and grazing takes place, maintaining the broader health of farming landscapes is also an important investment for the long-term viability of Australia's agriculture. Healthy, functioning ecosystems can provide a number of tangible benefits,[362] such as:

- Native grasses that can protect agricultural soils from severe degradation through drought and flood cycles
- Native paddock trees that provide similar benefits, as well as shade for livestock
- Bee populations that provide $1.8 billion each year in pollination services
- Biodiversity that provides a 'genetic library' for the development of new agricultural products.

The health of the ecosystems in which farming takes place also has an insurance value over and above the direct benefits noted above. Diverse landscapes are more resilient in the face of climate change. Maintaining land and vegetation in good condition can avoid 'tipping points' which lead to reduced agricultural production, such as widespread soil acidity. Early preventive action can prove much cheaper in the long run than attempting to make a landscape fit for farming again after it has shifted into a heavily degraded state.

Various kinds of investments are required to preserve or enhance the benefits of healthy agricultural landscapes, such as the adoption of alternative grazing strategies to preserve and regenerate paddock trees, or the cultivation of habitat for native bee populations.

Some of the benefits of investment to keep land and vegetation in good condition spread well beyond the individual farm, and many benefits are realised only when action is taken across a number of farms. These long-term benefits may also be difficult to predict ahead of time. In some cases there are trade-offs between short-term profitability at a farm level and the long-term viability of agricultural production at a catchment level. In addition, the costs to agriculture from landscape-wide damage are often hidden, and may only be recognised after tipping points have been passed.

The uncertainty, complexity, and long timeframes involved in maintaining ecosystem health makes regional coordination of individual land-holders' actions necessary to achieve benefits across a landscape. A case for strong, stable investment in Natural Resource Management institutions to foster such coordination is made in the next chapter.

Of course, there are also non-financial values associated with what the United Nations Convention on Biological Diversity defines as "the variability among living organisms…and the ecological complexes of which they are part…diversity within species, between species and of ecosystems." Diverse ecosystems are rich in cultural and spiritual meaning, as well as what economists call 'amenity value' (otherwise known as 'a nice place to live'). This kind of value can also translate into economic value – such as higher land prices in areas that appeal to retirees. The beauty of Australia's landscapes probably also plays a large part in many farmers' willingness to stay in a risky business in difficult circumstances.

The difficulty of distinguishing public and private benefits makes for vexed conversations over who should foot the bill. The next chapter looks at the idea of using the 'catchment care principle' as a useful rule of thumb for deciding how the costs of investment in natural capital should be allocated.

The value of paddock trees in grazing areas

The ability of trees and other vegetation to support the viability of agricultural production in the face of increasing weather variability can operate across an entire catchment or region. For example, maintaining water table levels to avoid soil salinity in times of heavy rainfall requires deep-rooted vegetation, such as trees, to be spread across a wide area.

Since European settlement, *Eucalyptus* box woodlands have been substantially modified by agricultural practices, and in many areas in southern Australia are now restricted to scattered or clumped trees.[363] Such scattered trees, including solitary paddock trees, provide ecosystem services such as enhanced water filtration, local biodiversity, and shade for livestock.[364]

An important function of such trees is regulating the run-off of water during heavy rains. On fine textured soils, areas under trees can absorb or capture approximately five times as much rainfall as areas with grassy slopes or annual crops.[365] This can moderate inflow to regional groundwater tables, reducing the risk of salinity. It can also reduce the risk of soil erosion. Erosion due to drought-breaking rain can make up 90 per cent of the total soil loss in a 20–30 year cycle.[366] If the frequency of droughts increases due to climate change, scattered areas of trees could be an important buffer against fast-flowing surface water that would otherwise erode soils.

NSW's Upper Lachlan Catchment includes an 800,000 hectare area dominated by livestock grazing, with some mixed grazing and cropping farms. This region is representative of both the south-eastern temperate grazing zone for beef; and is an internationally recognized endangered eco-region of grassy *Eucalyptus* woodlands and dry forests.[367]

Yet most remaining paddock trees are old, and are not being replaced by new trees due to both grazing pressure and high soil nutrients from use of fertilizers to promote the growth of pastures.[368] Without replacement, large areas of the Upper Lachlan Catchment and south-eastern temperate grazing zone could be treeless within decades.[369]

Alternative grazing strategies can allow trees to regenerate, but require upfront investment by farmers and have slightly lower financial returns compared to conventional grazing.[370] These involve setting aside some areas of the farm specifically for biodiversity, while intensively grazing other areas.[371]

Therefore, investment to maintain and replace paddock trees needs to consider the long-term benefits to maintaining agricultural productivity in the region, and environmental benefits that are valued by the broader community. Private investment to maintain paddock trees for their ability to moderate erosion and salinity could be partially supported by public payments for ecosystem services, as paddock trees are an important habitat for birds and other biodiversity.

Benefits of the birds and the bees: the need for a diverse set of pollinators

Pollination services in Australia are vital to sustaining the yields of many crops including apples, cucumbers, and avocados. Currently 65 per cent of Australian agricultural production is reliant, in some way, on pollination by European honeybees.[372, 373] This service is worth $1.8 billion to Australian agricultural production each year[374] and the bees that provide it also feed on native flowers.[375]

Australian farmers have relied heavily on the healthy populations of feral European honeybees to pollinate their crops. However, projected demand for pollination services will soon outstrip supply.[376]Australia is also the only nation not yet affected by the exotic Varroa mite, which has decimated bee populations across the world. While vigilant enforcement of quarantine regulations should be maintained, in the long run the introduction of the mite is considered to be inevitable, with all our trading partners and neighbours infested.

It is obviously very dangerous to rely on one species, a monoculture, to provide the lion's share of pollination services to the Australian agricultural industry. Investing today to build up commercial pollination services, like beekeeping, is necessary. We also need to remove the European honeybee's monopoly of the pollination market. Native bees can also provide valuable pollination services and farmers may be able to reduce their exposure to risk by enhancing and promoting nesting sites for native bees and insects on their properties.[377] Conservation and restoration of natural resources on farms can increase access to this "free" and essential service, while protecting Australia's 200,000 unique insect species.[378]

Rolling in the Hay: biodiversity as a 'genetic library'

As well as the possible economic benefit to existing agricultural industries, landscapes with enhanced biodiversity are a stock for future innovation. [379,380] Research has shown that native and biodiverse perennial grasses could be converted into second-generation biofuels, which have advantages over petroluem-based fuels as they are renewable and have lower emissions.[381] Second-generation biofuels are also at an advantage over first-generation biofuels such as corn grain ethanol or soybean biodiesel, as low-input high-diversity native perennial grasses can provide more usable energy, less greenhouse gas emissions, and less agricultural pollution per hectare.[382] The advantage increases over time, with monoculture biofuels producing 238 per cent less fuel than diverse native grasses after a decade - due to the damage done to soil biology from monoculture cropping.[383] The CSIRO has researched the potential for a biofuel industry in Australia and has found that it could be developed to have minimum interference with food production. 15 per cent of the grasslands around the Tropic of Capricorn in Queensland, currently primarily used for grazing, were found to have the technical ability to supply 54 per cent of Australia's liquid fuel needs.[384] This biodiverse, low-input, low-polluting, and renewable energy source has significant potential.

Weeding out pests

Currently there are 160 weeds considered threats to Australian biodiversity.[385] Weed infestations are known to adversely affect the hydrology, fire regimes, and nutrient cycling of native species and landscapes.[386] Weeds also represent a major economic problem for Australian agribusiness, with costs calculated at 10 per cent of the gross value of total agricultural production in 2000-2001.[387] However, the cost is likely to be even higher than this. $1.2 billion was spent in 2010-2011 on herbicides alone - $400 million more than was spent a decade ago.[388] The calculation also doesn't take into account the cost to farmers of the revenue they could have made had production not been constrained by weeds, what economists call an 'opportunity cost'. In 1998-1999 the opportunity cost of weed infestations was calculated at around $1.3 billion.[389]

A number of measures are needed to effectively control weeds on Australian farms. This includes site-specific weed management, in order to halt the wasteful practice of broadcast distribution of herbicides on land that is not necessarily infested.[390] Actions to increase biodiversity on the farm have also been shown to reduce total weed density. It is known that intercropping with certain legumes can reduce the total weed density in a field and thus reduce a farmer's herbicide expenditure.[391] Farmers must also be supported to identify and manage weed outbreaks early, in order to prevent major infestations. This requires adequate information, and coordination between land managers, pest management professionals, and property owners.[392]

A similar principle has been applied to reduce the damage done by pests. The 'push-pull' technique has shown to repel damaging insects and pests, by planting certain species of legumes and grasses with a maize crop. The aromas from the legumes planted in a perimeter around the field push away pests, while the grasses produce a scent that pulls in the insects so they lay their eggs on them rather than on the maize.[393]

Biodiverse landscapes are more robust

Enhanced biodiversity has been shown to increase ecosystem services, with a range of benefits to agricultural productivity, as well as acting as a buffer against the effects of climate change.[394, 395] It is known that some species react differently to others under different conditions and at different times, thus if one species is observed as being redundant to the productive capacity of an ecosystem at one time it is often a contributing member under a different set of conditions - an important attribute in the face of variable weather patterns. Because of this, even rare species have been observed as promoting the healthy functioning of an ecosystem[396]. Biodiversity across a landscape can therefore be viewed as an insurance policy against the variable climate of the future[397]. Although more research is always needed to properly understand how plants and animals interact over time, space and differing weather conditions across different parts of Australia, it is known that how we use the land impacts these relationships. This, in turn, affects their ability to promote productivity and buffer against climate change.[398, 399]

A stitch in time: why it pays to steer clear of tipping points

Once the ecological integrity of a landscape has been damaged beyond a certain point, repair can become difficult, expensive, or impossible.[400] The impacts of clearing for agricultural land use and historical land management practices have reduced the productivity of land in some parts of Australia. Clearing of native vegetation exposed soil to erosion and other forms of degradation. Some regions have seen significantly reduced capacities for supporting agriculture and dealing with uncertain weather.

The damaging effects of land clearing can easily be seen in Goulburn-Broken, where high salinity has stifled plant growth. In the 1970s, heavy rains caused water tables to rise to the surface in many parts of the Goulburn-Broken catchment.[401] Native vegetation probably could have buffered against such fluctuations in weather patterns. However, as a result of the removal of most of the deep-rooted woody vegetation in the region, responsible for maintaining underground water levels, heavy rains easily disrupted the tenuous hydrological balance[402]. When ground water rose to the root zone, it brought high salt levels along with it, stunting plant growth and resulting in significantly decreased soil fertility.[403]

In Western Australia, rapid clearing on what was already poor quality soil resulted in acidity and erosion problems for much of the area. Land clearing in WA took place over just a third of the time span of many other regions.[404] This rapid removal of vegetation caused severe wind erosion, compaction, and reduced the ability of some soils take up water.[405] The fact that the WA soils are sandy and particularly vulnerable to wind compounded these problems.[406] Subsequent agricultural practices also depleted soils of potassium, nitrogen, and phosphorous, which are essential nutrients for plant growth.[407]

In the rangelands in the centre of the continent, loss of perennial grasses due to over-grazing during droughts has led to severe soil degradation. Degraded soils lose the organic carbon, nutrients and structure needed to support perennial grasses on which stock graze.[408] The capacity for long-term stocking rates can be reduced to as little as 40 per cent of the average before degradation.[409] Where soil condition is too poor to support the regrowth of perennial native grasses, even with good rainfall, the land may need to be retired unless farmers can afford fertilizers to grow introduced pastures.[410]

> "Farmers' stewardship of the land is essential, and deserves support."

Communities of sustainability: policies to support the future of rural communities

Communities of sustainability: policies to support the future of rural communities

Farmers' stewardship of the land is essential, and deserves support

Australian farmers are active stewards of our land and soils. From millennia-old indigenous fire management to twenty-first century agricultural techniques, the Australian landscape has been shaped by human activities. Any discussion of how best to take care of the land must include, as a primary consideration, the actions of communities that exist within it. Farmers have a dominant role in managing the Australian environment: 59 per cent of Australian land is in their hands, and 52 per cent of Australian water use is for agriculture.[411]

None of this is news to farmers, and the majority see stewardship of the land as part of their identity. Over 90 per cent undertake natural resource management activities such as controlling introduced weeds and pests, and taking care of soils.[412] Much of this is simply good business practice for a farm, but many farmers will go beyond what is required for short-term productivity; for example, 52 per cent conduct activities to protect native vegetation, and collectively farmers have set aside 9.2 million hectares of their land for conservation.[413] It's clear that Australian farming communities have a strong culture of stewardship that drives sustainable land management practices.

Australia has made progress putting in place policies that support farmers in that role. Amongst others, these include the Landcare movement which started in the 1990s, Caring for Our Country, and the more recent Carbon Farming Initiative and Biodiversity Fund.

However, despite the significant efforts of many farmers, the time and money invested in natural resource management activities has not been enough to reverse the historic trend of landscape degradation, or avoid all the impacts of current land management practices. As was pointed out in Chapter 2, degradation issues such as erosion, acidity and salinity continue to affect Australia's soils, and other environmental problems such as biodiversity loss and declining river health are widespread and severe. So as well as acknowledging the work that farmers already do to take care of the land, we also need to recognise that more needs to be done.

Given the culture of stewardship amongst farmers, it is likely that many would wish to do more. So we need to look at how Australia can best support further stewardship activities by its farmers and farming communities.

To achieve this, there are four key areas where policies need to be scaled up, streamlined or resourced with far more consistency than in the past:

» **Increase investment in knowledge.** We need to ensure that farming communities are equipped with the best possible knowledge to maintain long-term agricultural productivity, by strengthening the connection between local knowledge and agricultural research.

» **Provide more stable funding for regional natural resource management.** Natural Resource Management Networks are essential for supporting farming communities to coordinate and facilitate landscape-wide investment to maintain or improve the condition of land, and need more stable funding.

» **Enable accountable community governance of land and soil management.** Farming communities need mechanisms to develop a shared understanding of, and promote, land management practices matched to farms' land and soil capability.

  For individual land-holders, knowledge shared over time and across landscapes is an essential guide to avoiding degradation of land and soils, and a cycle of deepening debt and lower productivity.

  For regional communities, agreement on standards of stewardship can reduce the risk of 'free riding' by a minority of landholders with little direct interest in, or limited ability to, maintain productive agricultural landscapes over the long-term.

» **Align financial incentives with the long-term needs of sustainable farming communities.** A range of reforms could match financial support and incentives more closely with the requirements of sustainable and productive landscapes and the needs of the people who depend on them.

This chapter discusses each of these areas in turn. A summary of the policy implications, and recommended policy tools to address them, is provided at the end of each section.

Who pays?

The risks and opportunities outlined in this report have direct implications for farmers and graziers, and indirect implications for Australian society as a whole. The costs and benefits of actions to manage these risks and make the most of the opportunities should be distributed fairly. Decisions about who pays for what actions, as well as the timing and manner of payment, should be based on a thorough understanding of the obstacles faced by managers of agricultural businesses when shifting to more sustainable practices.

Australians' shared awareness of the importance of sustainable agriculture often descends into stand-offs when it comes to question of who pays. Should the 'polluter pays' principle apply as it does for urban air pollution, implying that farmers should, for example, bear the full costs of eliminating run-off and erosion? Should those who benefit pay, implying that downstream farmers should contribute to the costs of upstream farmers' actions to maintain healthy rivers, or that the broader public should pay for the benefit of preserving unique endangered species?

This tension plays out in debates over the role and funding of regional Natural Resource Management networks and institutions. Should they be focusing on maintaining the landscape for agricultural productivity? Or maintaining the landscape in line with the expectations of the broader community?

Many attempts have been made to answer these questions. In 2003 the Victorian government set out the following three principles:

> *"Firstly, that rural land, managed well, provides a range of valued public good services in terms of environmental management and landscape amenity. Secondly, that the provision of these services is best achieved by maintaining the presence of people in the rural landscape. Thirdly, that the provision of services beyond the 'duty of care' should be paid for by society at large."*[414]

In its 2004 report on the impacts of native vegetation and biodiversity regulations, the Productivity Commission put it this way:

> *"It is reasonable to expect land-holders to bear the costs of actions that largely benefit them individually or as a group…they should not be expected to meet the costs of supplying public-good environmental services that are demanded by, and largely benefit, the whole community."*[415]

The Wentworth Group of Concerned Scientists has put forward the 'catchment care principle' as a way of resolving the tension between the 'polluter pays' and 'beneficiary pays' approaches to natural resource management and investment in sustainable landscapes:

> *"Each farmer has a responsibility to avoid damaging the long term interests of the farming community."*[416]

In other words, farmers have a responsibility that extends beyond the farm gate to the broader farming community, but not as far as general national benefits or 'public goods'.

In practice, this means costs are shared as follows:

» Costs of maintaining productive agricultural landscapes are shared by land-holders
» Transitional assistance is provided to repair historical damage, and meet above average costs of achieving 'public good' conservation
» Financial incentives are provided for voluntary conservation that goes above and beyond general 'public goods'

The catchment care principle draws on the evidence that farmers and graziers have a shared long-term interest in maintaining "fully functioning and productive landscapes" to protect the "the long-term interests of rural industries."[417] It also acknowledges that, as discussed in the previous chapter, no farm is an island – maintaining the landscape for agriculture requires actions by many farmers, with benefits that won't be bounded by fences.

The catchment care principle has a number of advantages. Firstly, the cost of improving environmental outcomes can be equitably shared between land-users and the public, as the full cost of increases in environmental outcomes are not carried by individual land-users.[418] Public funding can be more efficiently used, as the principle implies that taxpayers' funds will be used only for genuine public benefit. Secondly, the principle identifies the shared interest of different stakeholders in maintaining ecosystem integrity. This supports improved negotiations and can lead to environmental issues being solved with better social outcomes.[419] Finally, the principle more closely aligns the incentives of individuals and the public, by discouraging individual actions which damage ecosystem integrity and by requiring broader environmental goals be translated to ground-level management practices.

Choosing the right policies for the job

Good policy emerges from a well-informed and collaborative search for measures that combine equity, efficiency and effectiveness:

- Equity: Do people in the same circumstances bear the same costs or receive the same benefits? Is effort rewarded fairly? Does the policy give those in difficult circumstances a chance to improve their prospects? Is the growth in inequality kept in check?
- Efficiency: Could the same resources achieve a better outcome if invested in a different way? Is the effort proportionate to the result?
- Effectiveness: Does it work? Will it deliver real improvements on what came before? Is it on track to solve the problem?

These aims are often mutually supportive, but they can sometimes be in tension. For example, it might appear efficient to cut down on the funding of agricultural extension officers, with the assumption that farmers can or should make the effort to find out about opportunities for sustainable productivity gains without assistance. However, if extension officers are an effective way of achieving progress towards the shared social goal of sustainable agriculture, that would be a counterproductive policy. Likewise, it might appear efficient to impose a top-down national regulation requiring all farmers to, say, increase their soil carbon, but it would probably be ineffective given the difficulty of monitoring and enforcing such a policy, and the variation across Australian landscapes.

Different policy tools will deliver different combinations of equity, efficiency and effectiveness in different circumstances, and each tool has advantages and disadvantages.

The selection and design of policy tools should be underpinned by a strong understanding of the unique nature of agriculture as an industry:

- Farming sustainably is knowledge intensive, and requires practical experience mixed with scientific expertise. As a result there is a need for strong connections between farmers and agricultural researchers.
- No farm is an island, entire of itself. The benefits of investment to maintain or improve the condition of land, soils and other natural capital are greater when action is co-ordinated across the landscape.
- Most farmers are active stewards of land and soils, but they often cannot observe enough on their own farm, or in their own working life, to determine the best land management practices to use. Knowledge needs to be shared over time and across landscapes so farming communities can maintain productive land, soils and agricultural landscapes.
- Farming is a risky business. Success is often measured as the number of good years in each five or 10 years. Farmers' willingness to take a chance on new practices often depends on demonstrated benefits for agricultural productivity. Where this is uncertain and broader benefits are likely to accrue to the rest of the farming community or Australia, there is a strong case for transitional assistance.

Knowledge: Connections between agricultural science and agricultural communities

Farming sustainably is knowledge intensive, and requires practical experience mixed with scientific expertise. As a result there is a need for strong connections between farmers and agricultural researchers.

> *"If we survive the drought, we would wish to continue with various workshops and education projects to help us continue improving our farming practices. The Whole Farm Planning… [through a locally provided] programme revitalized our farming enterprise and probably has sustained us to cope with the pressures we are now under with this once in a lifetime drought." (Participant in land stewardship workshop, 2003)*[420]

It's common for researchers to call for more investment in information – in this case however more knowledge is not a luxury, but a precious resource that has the potential to make a tangible difference to the lives of everyone who depends on healthy farming landscapes.

Australian farmers tend to share the knowledge they acquire through experience about what works on their farm; this can be seen in the fact that an important predictor of whether farmers will adopt a novel technique or technology is its use by other members of their community.[421] As a result, agricultural communities have a great deal of understanding about the practical effects of a range of agricultural practices and how they interact with conditions on a farm. However, this knowledge tends to be about 'fast' variables such as rainfall and paddock production, not 'slow' variables such as long-term climatic cycles and pasture condition.[422] For example, a climatic cycle that occurs over two decades is too long a period for most farm managers to build up repeated experience of the changes.

A further challenge for agriculturalists relying on community experience is that increasing climatic variability from climate change means that conditions in the future may be significantly different from the past. Changes are also occurring, both domestically and in global markets, in attitudes on what is required of agriculture. Consumers and the broader community are becoming more concerned about issues such as land clearing, water use, and livestock carbon emissions. The combination of climate change and attitude shifts could create pressure as well as support for transformational change at the farm level. Knowledge based on past experience will not always be applicable, and while most Australian farmers are successful, the majority do not have the excess profit margin to spend on experimentation.

Farming smarter will be knowledge intensive, and as a result there is a need for collaboration between farmers and agricultural researchers. This collaboration should involve information flowing in both directions during research, and in implementation. As the research is being designed and conducted, such communication will help ensure that the relevant fast and slow changes in land, soil and climate conditions are taken into account. In implementation, traditional extension programs (where information about innovations and their advantages is disseminated in order to increase their uptake) will aid farmers in choosing best practice, but researchers will also need to draw on farmers' expertise on implementation difficulties and practical possibilities for overcoming them.

Such collaboration should not be difficult since it is clear that Australian farmers are open to new techniques and technologies arising from scientific research and that agricultural scientists are keen to work with farmers.[423, 424] However, the complexity, travel costs and long time-frames involved in this type of research makes it expensive. Funding for agricultural research in Australia levelled off decades ago, and has become focussed on shorter-term projects, reducing the abilities of researchers to develop productive working relationships with farmers. Funding for extension has likewise levelled off.[425]

In this situation there is a clear case for increased public funding of research and extension. Improved agricultural practices and technologies have been demonstrated to have a number of flow-on benefits to the wider community, including cheaper and better quality food, rural communities that are more able to adapt to changing circumstances (with decreased costs to the welfare system), and a healthier environment. A recent Productivity Commission report acknowledged this saying:[426]

> *"The benefits of investment in rural R&D have been extensively investigated. While hard to quantify with any precision, there is little doubt that the overall payoff for both producers and the community from past investments has been significant."*

Given the evidence of continuing environmental degradation outlined in Chapter 2, the fact that the majority of Australian land is farmland, and the demonstrated ability of agricultural research to improve environmental outcomes, as well as deliver a host of other benefits, the need for increased research activity is obvious.

However, it is essential to ensure than any increase in funding actually produces research that addresses the challenges being faced. The scale of environmental challenges, including climate change, soil degradation and resource scarcity, means that new farming practices and systems will be required. Such change has not occurred quickly in the past. Change can be accelerated to a degree by effective extension programs, but there is an urgent need to start on the required research programs. Improvements to current techniques and technologies can 'buy time' by increasing resource efficiency. However, there must be parallel research on the new farming practices and systems needed for agriculture to flourish within environmental and resource limits, as well as on incremental efficiency improvements that delay reaching these limits. Both must be supported by effective extension to speed implementation.

Stable funding for research institutions working with farmers

Just as farmers will be better able to engage in sustainability initiatives if they are financially secure, researchers will do their best work with the correct financial arrangements. The critical aspect of research funding arrangements is that they are on long timeframes.

Stable funding over a number of years is necessary for a number of reasons: Research on alternative farming systems is a long-term process, and researchers are more likely to engage in this work if they have time to make a significant contribution. Also, because sustainability challenges often involve 'wicked problems', with multiple interacting factors and substantial knowledge gaps, research projects addressing these problems will need to time to build up group expertise and understanding before progress can be made. Lastly, both the transformational research and work on incremental improvements will progress faster if they provide an attractive career.

Short-term projects create inefficiencies because the researchers hired must spend time coming up to speed on the particular area of work. This expertise is lost when the project ends as the researchers move to other projects, or leave the industry entirely. In addition the prospect of stable employment is more attractive and attracts a higher calibre of applicant.

So the same amount of funding delivered through long-term agreements will be more effective than if provided through a series of short-term projects, because it allows research institutions to build up and retain substantial expertise in sustainable agriculture.

Of course, long-term projects will require robust accountability procedures to ensure that adequate progress is being made. Such procedures will need to strike a balance between clear objectives, and flexibility. The wickedness of the problems means that there must be room for changes in focus as knowledge gaps are filled.

Australia has number of research institutions with highly effective departments or divisions devoted to agricultural research, such as the CSIRO and several of our universities, as well as specialist institutions such as the Rural Research and Development Corporations. Increases in funding should be directed towards those institutions with a track record of working effectively with farmers and delivering sustainability and production improvements.

In addition, there is a need for a research institution specifically focussed on the sustainability of Australia's productive agricultural landscapes. This was the charter of Land and Water Australia (LWA) until it was defunded in 2009. There is widespread agreement that LWA's research provided a valuable contribution linking productivity, sustainability, and natural resource management on farms; and many feel that its abolition left a critical gap.

The Productivity Commission recently proposed the creation of an entity to fill this gap, Rural Research Australia (RRA). This body would not simply be a reincarnation of LWA. While it would have parallels and provide many of the same contributions, the research remit envisioned by the Productivity Commission is broader:

- a broad research agenda including soils management,
- an eventual annual budget of at least $50 million (progressively build up), and
- a board with Commonwealth and State government and Rural Research and Development Corporation representatives, complemented by members with specific research knowledge and funding and management expertise.

The creation of such a body could be of substantial benefit to the sustainability of Australian farms.

Smart Extension

By conserving our soil assets we can preserve an opportunity to benefit from future food price rises. So it is important that resource efficiency improvements, such as better liming practices or techniques for increasing soil carbon, are adopted as quickly as possible. This will make it easier for farmers to stay ahead of declining terms of trade and survive through the low points of increasingly volatile global markets, meaning there will be less pressure to generate short-term production gains which could come at the expense of long-term productive assets such as soil.

Also, the challenges posed by increasingly variable climate and resource scarcity will likely require new farming practices and systems. The development and refinement of alternate systems is a long-term task, meaning that rapid adoption may be necessary in order that alternatives are feasible before these challenges become too great.

Increasing the rate of adoption can be achieved by effective extension. There has been a significant amount of research on what constitutes effective extension. Much of it has been summarised in a paper by Pannell and others.[428] The key points from this body of research are:

- There is a need to build the credibility and trust in extension officers by avoiding: short-term funding, rapid staff turnovers, and staff that are inexperienced or lack technical farming expertise.
- High-calibre personnel on the ground will be needed because extension agents should ideally:
  - have authority and technical expertise,
  - be perceived by farmers as similar to them,
  - have a local profile,
  - posses good communication skills,
  - have personal relationships with landholders,
  - and be able to acknowledge and empathise with the problems and circumstances of landholders
- The use of multiple methods, e.g. print articles, verbal presentations, group extension, advertisements, enhances effectiveness.
- Although group extension work useful, one-on-one on-farm advice is critical.
- Counselling assistance may aid extension in some circumstances because some farmers, such as those experiencing severe financial hardship due to drought, may be too overwhelmed by their current difficulties to even think about adopting new techniques. Those in the most difficulty are also often reluctant to seek help. So counselling programs should not rely on self-initiated contacts. Integration with extension programs may help identify those in need of assistance.
- Where there are positive spillovers from adoption, extension work can increase the possibility of reciprocal spillover benefits by building trust within the group or community.

Pannell et al. emphasise that extension will not aid the adoption of techniques or technologies that are not in farmer's interests.[429] Thus the primary role for extension is to speed up the rate of adoption, not to raise the ultimate level of adoption.[xliv]

It should be noted that farmers' interests are not purely financial. Some conservation practices that have primarily off-site productivity benefits have been widely adopted. An example of this is the fencing of remnant vegetation, this maintains local biodiversity, which as outlined in Chapter 4, underpins agricultural productivity in the region. However, the practices are usually small-scale so the costs are small in comparison to the scale of the farm.

The fact that adoption of sustainability improvements will often only occur where they are financially feasible highlights the need for research funding. Where practices with primarily off-site agricultural benefits are substantially uneconomic for the individual farms on which they need to take place, research is required to provide alternatives or improvements that are less costly or more profitable – or to establish the case for public intervention to account for the public benefits of such practices.

[xliv] An exception to this is where innovations are difficult to trial due to factors such as high up-front costs. In these cases extension can provide sufficient information that farmers may be willing to take the risk of trialling the innovation, and this can lead to the adoption of a practice that would otherwise have failed to disseminate.

Interestingly the adoption of conservation practices with upfront costs is associated with membership of Landcare.[430] This indicates that there is an important role that NRM networks, discussed further below, can play in addition to extension by encouraging conservation practices motivated by an ethic of stewardship. Also, as mentioned above, farmers are more likely to adopt an improved technique or technology once they see it being used by those in their community. So community based programs such as Landcare also play an important part in the uptake of all innovations, and should be a key part of a move to more sustainable agriculture with regional productivity benefits.

Funding sources

The need for, and value of, investment in research and extension for sustainable agriculture is clear. However, this still leaves the question of where the funds should come from. The Productivity Commission, in the same report in which it recommended setting up 'Rural Research Australia', proposed reducing funds to the Rural Research and Development Corporations. The argument for this was made on the basis of lack of additionality, i.e. that government funds were replacing industry contributions to research rather than encouraging them. This argument fails to take into account the urgency of the need for sustainable agriculture research. This context affects the argument in two ways: Firstly, the argument is a prediction that the private sector will put in funds as government takes them out. If this prediction turns out to be wrong, the sector will lose research funding when there is critical need to increase it. Secondly, even if the prediction were to prove correct in the long run, there will almost certainly be a lag in private take up of the burden. Even a staggered decrease would still probably result in lags at each stage. Again this would mean a loss of total funding when an increase is needed.

Further discussion is necessary to identify sources of funds for increased investment in sustainable agricultural research. Three potential options are:

- Fund the increase from general revenue, recognising a) the substantial dividends which are likely to accrue to farming communities and all Australians who want to see a flourishing agricultural sector underpinned by healthy landscapes and b) the likely savings to taxpayers from lower welfare and drought assistance payments if farming profitability can be stabilised
- Revenue could be set aside from mining taxes and royalties. This effectively means that dividends from the mining sector would be used to help secure the future of the farming sector - one of the promising export industries which could help soften the end of the resource boom.
- At the state level, any savings from a change in exceptional circumstances policy to focus on resilience rather than large drought assistance payments could be directed towards agricultural research.

Policy implications:

We need to ensure that farming communities are equipped with the best possible sustainability expertise by strengthening the connection between local knowledge and agricultural research.

Research funding must also be long-term so research institutions can build up and retain substantial expertise in sustainable agriculture.

Recommendations

- Government funding for research and development should be significantly increased; at a rate of up to 7 per cent a year to match investment through the 1950s to 1970s. Additional funds could come from savings due to more effective drought policies, or revenue set aside from the mining taxes and royalties. Additional investment should be directed toward increasing the input-efficiency of current practices and developing new farming systems to improve long-term land and soil condition.
- The Commonwealth Government should implement the Productivity Commission's recommendation to establish a new research institution (Rural Research Australia) to sponsor a broad rural research agenda including soils management.
- The National Soil Health Strategy should be funded through an endowment sufficient to support ongoing research and monitoring for at least 20 years. This requires a minimum $25-50 million per year by the Commonwealth Government, and matching investment from State and Territory governments.
- Government and industry should increase funding for effective extension programs, to increase the rate of adoption of practices that preserve land and soil condition. The new requirement for Rural Research and Development Corporations to plan for and report on extension makes sense. To be effective, long-term, adequately funded programs will be required, staffed by experienced extension officers with technical farming expertise.

NRM networks: Co-ordination of landscape-wide investment

No farm is an island, entire of itself. The benefits of investment to maintain or improve the condition of land, soils and other natural capital are greater when action is co-ordinated across the landscape.

NRM networks include regional NRM institutions (such as Regional NRM Bodies), NRM groups and organisations (most notably Landcare), and industry bodies implementing best-practice management programs (including those representing dairy, rice and cotton). There are three main reasons why such networks are necessary for sustainability outcomes. Firstly, as has already been discussed above, they have a vital role in sharing knowledge. Secondly, there is a need for efforts to be coordinated at the landscape scale. While the work of many NRM activities takes place on farms or other properties (including national parks), it often needs to be part of a wider effort. So, for example, weed eradication is substantially less effective on individual properties than when undertaken by all local land-holders in a co-ordinated approach. Also, a landscape-scale perspective can help individual farmers identify what work is a priority. Thirdly, some NRM activities are essential for the health of a region, but must be undertaken on public lands such as roadsides and reserves. Such work will likely involve collaboration between local farmers, often with local councils and Landcare groups - and such collaboration requires a co-ordinating body. A final point worth noting is that the experience of farmers has been that natural resource management programs work best in regions where there are NRM networks.[431]

There has been a strong movement in Australia to give these networks primary on-ground responsibility for NRM and the health of local environments. However, some have argued that they have reached the limit of what they can do, and that alternate models are needed.[432] This judgement is premature. Many of these networks were originally intended to serve a social learning purpose, not to deliver environmental outcomes directly. NRM networks are moving towards ensuring that environmental outcomes occur, but so far there is very little evidence either way about their ability to produce positive environmental outcomes.[433] However, there has been a significant amount of research on their process and social outcomes, and the achievements have been good.[434] In addition there has been some research on environmental outputs and this also promising.[435] Given these positive indications, before embarking of structural reforms, the NRM networks should give networks chance to demonstrate their effectiveness on this front before structural reforms are pursued.

A further argument for continuing with the current structure of local NRM is that it is firmly grounded in the principle of subsidiarity - that decisions should be made at the closest possible level to where actions are taken. This is an internationally acknowledged principle of good governance and should not lightly be abandoned.

So funding to these bodies should be continued, with the requirement to monitor environmental outcomes and additional funding to cover this task. As with research institutions, attracting high-calibre staff and avoiding the inefficiency of high turnover requires long-term funding with appropriate accountability arrangements. These arrangements must take into account that there can be a significant lag between environmental activities and changes in environmental outcomes, and that due to knowledge gaps NRM networks will require the flexibility to refocus efforts in the light of new information gathered in the course of operations. Therefore accountability should be based on outputs, but there must be a requirement to consider any available information on outcomes when reviewing and planning activities.

Despite the demonstrated benefits of biodiversity to agricultural productivity and profitability, many farmers express concerns that production is severely affected by conservation.[436] Natural Resource Management (NRM) organisers have the potential to be powerful agents of change in the challenge to reverse on-farm biodiversity loss. However, in order for farmers to build a meaningful and trusting relationship with the organisers, funding to NRMs must be consistent and adequate. This way maintaining organisers in the community over the long-term is possible. As well as assisting in kick-starting biodiverse agricultural techniques on farms, a longer-term strategic approach to NRM institutions will allow for long-term evaluations of outcomes achieved by projects. This will enable follow up work where needed and will contribute to the building of knowledge and capacity of Australian farmers.

Policy implications:

Natural Resource Management Networks are essential for supporting farming communities to coordinate and facilitate landscape-wide investment to maintain or improve the condition of land, and need more stable funding.

Recommendations:

- Federal and State governments should commit to a 10-year agreement to provide stable long-term funding for regional Natural Resource Management (NRM) bodies to co-ordinate government funding and land-holder actions to improve natural capital beyond regional benchmarks.
- Regional NRM bodies should also be given specific, stable funding to monitor long term trends in natural resource condition, and the environmental outcomes of land-holder actions and government programs to improve it.

Accountable community governance: Stewardship standards

Most farmers are active stewards of land and soils, but they often cannot observe enough on their own farm, or in their own working life, to determine the best land management practices to use. Knowledge needs to be shared over time and across landscapes so farming communities can maintain productive land, soils and agricultural landscapes.

Landscapes are complicated – it takes time and effort to discover the impacts of the actions taken by previous landowners on present landowners, and even more time and effort to gauge the likely impact of present actions on future generations of farmers. It also takes a lot of effort to find out the impact that one farmer's action has on a neighbour's land and vice versa.

The hard work undertaken by a farming community to invest in a healthy and productive landscape can easily be undermined if the pressures pushing in the opposite direction remain unchecked. Such pressures include:

- The drive to cut corners 'just this once', for example at the end of a drought in times of particular financial hardship;[437]
- The 'tyranny of small decisions' – the cumulative impact of a large number of apparently insignificant actions can result in unwelcome and costly landscape-wide changes;[438]
- 'Free riding' by a minority of landholders that undertake no stewardship activities and rely on the work of others to keep the local area or catchment healthy and productive. The problem of free riding is discussed further below.

Landholders who do not undertake stewardship activities are not only a dead weight in sustainability efforts, they can undo work that has been done; for example by providing havens for weeds. Also, the existence of free riders undermines community support for sustainability work. If landholders see others doing no stewardship, and yet profiting from the common benefits delivered by the community's work, it creates resentment and can reduce the motivation to uphold the 'catchment care principle' – the responsibility of each farmer or grazier to avoid damaging the long term interests of the farming community. It can also create financial pressure for others to follow suit, as farmers compete on input costs as well as output prices.[439]

At present the number of landholders not undertaking stewardship activities is very small. However, there are three factors that may increase this number in future. Firstly, cuts to national park staff by some state governments.[440] National parks cover 4% of Australia's land[441] so the state government departments charged with managing them are significant landholders. Decreases in staff could well mean that less NRM activities will take place, turning these government departments into free riders. Secondly, increasing numbers of farmers are relying on off-farm income.[442] This means less time spent on the farm and potentially less of a financial stake in the health of the land. Thirdly, the level of corporate ownership of farms is increasing.[443] Indications from studies in the US are that farmers who do not own the land are less likely to adopt conservation practices.[444] Particularly where the corporate purchase of a farm is simply for short-term investment purposes, the landlord may have little interest in the long-term health of the land, or in the health of the local area and community.

Farming communities should be supported to develop stewardship standards to protect themselves from free riding. However, effective stewardship standards must be created in a way that recognises the unique nature of agriculture as an industry. Previous attempts at standard setting, such as native vegetation clearing laws, have suffered from an overly simplistic approach, assuming that the same rules can be applied to very different areas, and that the support of farmers is not necessary.

It is essential that stewardship standards are developed through a shared community understanding of how land management practices can be matched to individual farms' land and soil capability. Regional tailoring is essential as suitable practices will vary according to the needs, strengths and vulnerabilities of different areas. Regional farming communities are best placed to agree on what practical land management practices are needed to maintain the long-term productivity of agricultural landscapes, and avoid negative impacts on other land-holders. They are also best placed to promote the adoption of stewardship standards on farms in their region by demonstrating the benefits of maintaining long-term agricultural productivity on individual farms and across the landscape.

This combination of factors suggests that accountable community governance will be the most equitable, efficient and effective policy tool to enable sustainable agricultural communities to protect themselves from free-riding and related pressures.

This kind of governance will require extensive regional public debate, most likely facilitated by NRM bodies, and drawing heavily on information provided through Rural Research Australia. This will support regional communities to develop stewardship standards using a combination of scientific knowledge and landholders' local expertise on the particular needs and resilience of the area. It will also bring out community concerns, allowing them to be addressed. Some agricultural communities may place greater emphasis on issues such as grazing practices in their baseline stewardship standards, others may focus on irrigation practices, while others may decide that practices such as weed management and run-off control are more important for maintaining productive agricultural landscapes over the long term. Stewardship standards could draw on Best Management Practice guides already developed by some NRM bodies.

Policy implications:

Farming communities need mechanisms to develop a shared understanding of, and promote, land management practices matched to farms' land and soil capability.

For individual land-holders, knowledge shared over time and across landscapes is an essential guide to achieving economic and environmental sustainability.

For regional communities, agreement on standards of stewardship can reduce the risk of 'free riding' by a minority of landholders with little direct interest in, or limited ability to, maintain productive agricultural landscapes over the long-term.

Recommendations

- Farming communities should be supported to develop stewardship standards based on a shared understanding of appropriate management practices for different land and soil types, and projected drought frequencies. Stewardship standards could draw on Best Management Practice guides already developed by some NRM bodies.
- Regular independent expert reviews will be required to maintain the community's trust in, and promotion of, agreed stewardship standards.

Finances: Farmers can't be green unless they are in the black

Farming is a risky business. Success is often measured as the number of good years in each five or 10 years. Farmers' willingness to take a chance on new practices often depends on demonstrated benefits for agricultural productivity. Where this is uncertain and broader benefits are likely to accrue to the rest of the farming community or Australia, there is a strong case for transitional assistance.

Contrary to the usual representations in the popular press, where farmers seem always to be struggling, the majority of Australian farmers run successful businesses. However, there are a significant minority who are under pressure from declining terms of trade, and this pressure is likely to continue.

Changing weather patterns and market prices for various agricultural products will lead to shifts in the locations where different agricultural industries are economically viable. As the chapter titled 'Australia has greater opportunities, but similar challenges to the rest of the world' notes, some industries have already seen shifts in location or profitability due to dry weather.

Changes are also occurring, both domestically and in global markets, in attitudes on what is required of agriculture. Consumers and the broader community are becoming more concerned about issues such as land clearing, water use, and livestock carbon emissions. The combination of climate change and attitude shifts could create pressure as well as support for new farming systems and enterprises. Knowledge based on past experience will not always be applicable, and while most Australian farmers are successful, the majority do not have the excess profit margin to spend on experimentation.

Such changes could have implications for farming communities, as well as individual farmers. It has been observed that "farmers can't be green if they're not in the black"; farmers under financial pressure are less likely to be able to carry out stewardship activities. Farmers under pressure are also more likely to exit from farming (either by selling, or by spending more time generating off-farm income), and a shrinking farming community means higher costs for those who remain; for example the local agricultural mechanic may no longer have a viable business, meaning that remaining farmers have to spend time and/or money dealing with much more distant mechanics. These extra costs mean more farmers in the community are under pressure, leading to more exits and greater costs again. This can create a tipping point for farming communities where a relatively small financial downturn can have a disproportionate and lasting effect.

Although financial support would circumvent the problems caused by communities reaching a tipping point, there are major problems with providing such support in the form of subsidies.[445] In general, Australia has pursued a policy since the 1980s of avoiding farming subsidies. Despite the fact that this has meant Australian farmers competing largely unsubsidised against heavily subsidised sectors such as those in the US and Europe, this approach has been successful in that it has produced a flexible and resilient industry that draws far less on the public purse than most nations with a significant farming sector, such as the US.[446] Nationally the average income of farming families is as high as that of families in urban areas, (although average figures of course obscure the large variations between families and over time). Exposure to competition has given farming communities experience at meeting external challenges and adjusting autonomously when required. The absence of government subsidies also avoids the potential inequities from certain groups being able to access more support due to political influence, which would then cause division within farming communities.

The highly resilient and independent farming industry in Australia can be contrasted with the subsidy-dependant United States and European farms. These have not only had perverse affects on the national industries, they have also been unfair to farmers in developing countries. (The European subsidies are at least designed to create valuable social dividends, but it's likely that these dividends could be secured through other policies without such perverse affects.)

In this context the distinction needs to be made between subsidies, and transitional assistance. Subsidies are payments that help maintain current practices during periods where they are economically unfeasible. In doing so they provide a disincentive to efficiency, make communities dependant on subsidies and less practiced at adapting to change, and foster division between those who receive the support and those who don't. Transitional assistance may come in the form of payments, but can also be other forms of support; the primary aim is to facilitate change to a situation where support is no longer required. They are less likely to create inefficiency or foster division, and they can actively enhance communities' independence and adaptability.

Two examples of transitional assistance schemes that are being developed in Australia are given below. Both currently have rectifiable flaws, which will be discussed, but the advantage they provide for the viability of sustainable farming, by providing support without dependence, make them useful models for future policy reform.

Exceptional Circumstances (Drought Support) Policy Reform

Since the 1980s Australia has developed an economic liberalist approach in its agricultural policies, preferring market-oriented strategies that target Australia's international competitiveness rather than policy interventions such as tariffs, subsidies and price regulation.[448] However, there has historically been intervention in form of support during severe droughts. Drought support, now more generally framed as 'Exceptional Circumstances' policy, was developed to provide short term support to farmers who were experiencing exceptional circumstances that couldn't have been foreseen. Applications for a region to be declared in exceptional circumstances were assessed against a pre-defined checklist on the rarity and severity of the event, its impact on farm income, and whether or not it was predictable or part of a structural adjustment.[449] If so declared, farmers within the area were eligible for income support payments for up to 24 months (with the possibility for the declaration to be renewed).

There has been widespread agreement on the need to reform Exceptional Circumstances policy, so in 2008-2009 a national review was conducted. The review looked at economic,[450] social[451] and climatic[452] factors, and identified a number of flaws in the current arrangements:

- The payments and subsidies were inequitable and ineffective at encouraging improved management and self-reliance;
- The social assistance came too late and needed to focus on preparation and early intervention; and
- A changing climate, particularly an increased frequency and severity of droughts, meant that farmers needed access to information and that the current definition of exceptional circumstances was out of date.

In response to these criticisms, a different approach was embodied in a pilot policy of a set of programs, recently implemented in WA, which was designed to help farmers cope with extreme climate conditions. It contains no exceptional circumstances trigger, but instead comprised a basic financial safety net and social support services for all farm families, with farm resilience encouraged by providing training, (see Environmental Management Training, below), offering grants for resilience improvement activities (see Assistance to Improve Farm Resilience and Income Contingent Loans, below), and exit support for those on unviable farms.

Last year a review panel, chaired by Mick Keogh of the Australian Farm Institute, produced a report on the pilot programs. This review, while suggesting a number of improvements, was generally in support of the set of programs. The pilot has produced some important lessons for how Australian policy ought to respond to the possibility of increased droughts and other exceptional circumstances in a world with increasing climatic variability.

There are four areas of the pilot review's recommendations in which further conclusions can be drawn, outlined below.

Environmental Management Training

Within the farm planning program, the pilot review noted that the managing environments module was criticised by participants for focusing too much on providing evidence of climate change and not enough information on practical steps for improved on-farm environmental outcomes. There is clearly an opportunity here to provide training in sustainable farming techniques, which could be an important part of extension efforts (as discussed above in this chapter).

Assistance to Improve Farm Resilience

The pilot review panel recommended that the Building Farm Businesses program should not be continued. However, they did not rule out all assistance to improve farm resilience, and noted that future assistance could be better targeted to encourage activities that not only improve individual farm resilience, but also provide broader benefits for farming communities or Australia in general. Such activities could include:[453]

- "trialling innovations that draw on research and development"
- "help farmers to access alternative income streams, such as payments for ecosystem services"
- "natural resource management activities that are closely aligned with state and national priorities and programs, and deliver clear and lasting public benefits"

Assistance for trialling innovations drawing on research and development could be a good means of encouraging collaborative research discussed above, it would provide a means of offsetting the risk of trialling alternative farming systems and compensating farmers for time spent working with researchers.

Assistance to help farmers access payments for ecosystem services would provide further incentives to participate in carbon farming, helping to grow this important market, as discussed below. This could involve joint public and private investment in near-commercial projects, to demonstrate how profitable enterprise models can be set up using revenue from carbon offsets.

On the final point, one method to ensure that on-farm activities are aligned with landscape-scale needs is to draw on principles of adaptive governance. Nelson et al have proposed the idea of creating regional governance systems, co-designed by government and communities and supported by scientific monitoring, that set out standards of farm and environmental management linked to level of access to drought assistance.[454] These would allow farming communities to select the level of assistance available to them by choosing the level of natural capital management practices, including drought preparedness, they will implement. Having communities take the lead in preparedness would also mean that assistance for improving farm resilience would also foster practices in line with the local requirements for maintaining a sustainable and productive landscape.

This concept has strong parallels with the community stewardship standards discussed above, and could be combined with them. Governments could have input to developing and reviewing community stewardship standards by communicating the level of assistance available, based on how adequate these standards are to manage land within its capacity to maintain long-term agricultural production in face of shocks such as drought. Farm management plans demonstrating alignment with community stewardship standards would then allow farm access to the assistance available.

Income Contingent Loans to Improve Farm Sustainability

It is worth noting the option of income-contingent loans for drought preparation as an alternative to grants to improve farm sustainability, an idea supported by the National Farmers Federation as part of an integrated agricultural policy. The Productivity Commission has argued against this on the basis that commercial loans to increase farm viability are available and that current farmer decisions about levels of debt are rational.[455]

This is a reasonable argument from a narrow economic perspective, but there are two further points that should be considered. Firstly, where the broader social benefits of increased adoption of sustainable farming techniques out-weigh the risks of increased debt, income contingent loans to support the transition to such techniques may be desirable. As with assistance payments for improving resilience, the level of access to income contingent loans could be determined jointly by government and communities in the process of determining baseline stewardship standards. Secondly, as pointed out by Nelson et al, there is clearly a deep concern held by Australian society for rural communities affected by drought.[456] The availability of income contingent loans to reduce vulnerability to drought helps satisfy the political desire to support farmers in a way that is far less problematic than many other methods that have been used in the past and might be proposed again, such as interest-rate subsidies.

Farm Management Deposits

Although not part of the WA pilot trial, the review panel regarded Farm Management Deposits (FMDs) as an important complementary measure. They recommended retaining the scheme in its current form, a view that was also expressed by the Productivity commission. While FMDs are effective at improving farm resilience, but the uptake has not been high. Less than 40,000 primary producers hold FMD accounts,[457] out of a national pool of over 300,000 primary producers.[458] Further incentives to participate might be worthwhile, for example farmers in difficult times (perhaps assessed by eligibility for Farm Family Support) who have exhausted a previously held FMD account, and can demonstrate compliance with certain levels of environmental management benchmarks, might be able to apply for additional amounts to be added to the account. This would reward farmers who have genuinely attempted to prepare for future difficulties, but have been caught out by particularly tough circumstances.

Carbon Farming Initiative

The Carbon Farming Initiative (CFI) is an example of transitional assistance that is not a direct payment. In this case the support given through two mechanisms designed to facilitate Australian farms entering a new market, the global carbon market. The first mechanism is a monitoring institution, the Carbon Credits Administrator, which reduces the uncertainties of operating in this new market by applying standards to the carbon credits offered. The second mechanism is assistance with the creation of methodologies, the Methodology Development Program, along with independent assessment by the Domestic Offsets Integrity Committee. This reduces the burden of the innovation required to enter the market, and also provides certainty through providing objective assessment of the methodologies.

These supports are not entirely transitional assistance in that some elements will be ongoing; the Carbon Credits Administrator and the Domestic Offsets Integrity Committee are likely to continue. However, the work that these institutions do will change over time. A great deal of their early work will become less necessary one markets are up and running. For example, as a set of standard methodologies are established, the Domestic Offsets Integrity Committee will review variations on these, but the work of reviewing whole new methodologies will be less and less frequent.

Most comments on the CFI have been positive about the broad idea, and acknowledged its potential to encourage low-carbon land use and sequestration. However, a number of analyses have argued that there are serious flaws in the scheme:

- a likely lack of demand for credits[459]
- “leakage” possibilities (where emission reductions in one project mean that emissions increase elsewhere) and perverse outcomes for other environmental issues[460]
- potential inability to quantify additionality and verify effectiveness, and inadequate measures to discourage impermanence[461]
- inability to generate co-benefits, e.g. biodiversity, without supplementary payments[462]

It should be noted that the scheme has undergone revision and a number of the criticisms were written in regards to previous variations of the CFI, and so may not be relevant. So, for example, concern about lack of demand has been somewhat answered by putting a price on carbon (though controversy exists over whether this will create adequate levels of demand).[463]

A more recent critique by Andrew Macintosh and Lauren Waugh points out that the CFI now has many administrative provisions to deal with the problems of leakage, perverse outcomes, additionality, verification, and permanence.[464] However, the paper notes that the point is made that the effectiveness of these measures will depend on administrative powers being exercised correctly. The authors also point out the possibility of poor participation due to lack of information, cultural barriers, low carbon prices and wariness over markets prospects. The experience gained through initial involvement would reduce many of these barriers. As mentioned above, assistance for increasing farm resilience, if aligned with CFI requirements, could help overcome this by providing a further incentive to become involved in this market.

The issue of maximising environmental co-benefits is important, but is probably best dealt with through separate ecosystem service payment schemes such as the biodiversity fund. This could also be seen as transitional assistance if it improves the resilience of regional landscapes to shocks such as more frequent and extreme droughts. Because such schemes would be more contentious than the CFI due to a range of factors, such as the need to find direct funding from general government revenue, it makes sense to consider them separately.

We need a carbon market initially for offset and eventually for drawing down excess atmospheric carbon dioxide (and continuing offsets for any residual carbon pollution that can't be avoided). The CFI is useful contribution in this context as it has the potential to finance beneficial land management changes and give many farmers a chance to gain experience in the carbon farming market. This will have long-term benefits both to the land and the finances of farming communities.

Policy implications

Financial support and incentives need to be matched more closely with the requirements of sustainable and productive landscapes and the needs of the people who depend on them.

In addition to current moves to reform drought and exceptional circumstances policy in the context of a changing climate, Australia's drought assistance policies need to support regional communities to take a lead in preparations for more frequent and severe droughts.

Recommendations

» Federal Government assistance for drought preparation should be linked to community stewardship standards. Drought preparation assistance should be available only to farm businesses that develop and implement farm action plans that a) are informed by agreed community stewardship standards, and b) prepare to maintain economic viability under projected drought frequencies.

» The Federal Government should consider additional taxation benefits for Farm Management Deposits to assist with drought preparedness, for businesses that develop and implement farm management plans.

» The Federal Government should consider income contingent loans, or other financial assistance, for farm businesses that take a risk on management practices that go beyond agreed community stewardship standards to enhance farm and landscape resilience. This could include trialling innovative new farming practices, developing new enterprises to access payments for ecosystem services, and investing in natural resource management that delivers clear and lasting public benefits.

- The Federal Government should set up an innovation fund for joint public and private investment in near-commercial projects to develop profitable enterprise models that draw income from carbon offsets under the Carbon Farming Initiative. Public funding should focus on opportunities that could diversify farm income streams, raise productivity and improve land and soil condition.
- As an important complement to drought preparation measures, income safety nets and social support services should be modelled on recent trials in Western Australia. These trials provided a) an income safety net assessed by individual circumstances, rather than geographic location, and b) more permanent social support services for farmers.

Conclusion

> *"Today, there are thousands of farmers who want to restore our damaged rivers and landscapes and create a new model of sustainability that would become the envy of other nations.*
>
> *These people have energy, commitment and ideas, but they lack resources and scientific advice and are disempowered by the existing bureaucratic environment."*[465]

Implementing these principles and recommendations could provide Australia with a range of benefits: the ability to take full advantage of the market opportunities from a growing international food market, an agricultural sector largely unaffected by increasing field treatment costs, agricultural produce internationally valued for its sustainability, and landscape productivity robust to the effects of a variable and changing climate.

We'll know that Australia's agricultural and natural resource management policies are working well if they enable farmers and farming communities to:

- Preserve and enhance farm productivity and profitability while ensuring the provision of food and ecosystem services on a sustainable basis;
- Reduce any negative side-effects of farming and grazing (such as run-off, biodiversity loss, and carbon pollution) and increase positive externalities (such as the provision of good-quality jobs in rural communities and the maintenance of healthy landscapes);
- Rebuild the natural assets on which agriculture depends (such as soil health, water resources and biodiversity).[466]

This will require greater investment of resources by the general population as well as agricultural communities to build up stocks of natural capital, and institutional, knowledge, and social capital. Support for such investment is likely to come from a growing awareness of the private and public benefits of more sustainable farming and grazing, a culture of good stewardship in Australian agriculture and widespread willingness to pay for the preservation of healthy landscapes and thriving agricultural communities.

Appendix: Methodology

To estimate the future value of agricultural production, we applied the findings of two separate economic studies to recent baseline projections of production under business-as-usual conditions. The method and assumptions for the baseline and two scenarios are outlined below.

Baseline: business-as-usual

A 2012 projection by Linehan et. al. estimated the real value Australian production of agricultural food products covered in their analysis to be 77 per cent higher in 2050 than in 2007. This represents an annual average increase of 1.3 per cent.

Table A 1 shows a selection of the agricultural food products covered by Linehan et. al. Prices from 2007 were used to value 2050 production in real terms. Projections were originally reported in 2007 US dollars, and have been converted to 2007 Australian dollars using the average exchange rate for the 12 months ending June 2007.

In 2007 Australian dollar terms, in 2050 the value production for the products listed in Table A 1 is estimated to be $19.2 billion higher than 2007.

Table A1: Projected increase in value of beef, wheat, dairy, fruit and sheep production A$19.2 billion

Real 2007 A$

Commodity	2007 value of production (2007 A$bn)	2050 value of production (2007 A$bn)	Increase (2007 A$bn)
Beef	9.9	18.1	8.2
Wheat	4.8	8.9	4.0
Dairy products	4.3	8.3	4.0
Fruit	2.9	4.2	1.3
Sheep meat	1.1	2.8	1.6
Total	**23.0**	**42.2**	**19.2**

Note: The increases in value for each agricultural food product were calculated by CPD, as were the totals for the selected agricultural food products. These figures were not reported by Linhehan et. al.

Source: Linehan et. al., 2012.

The projections are intended as a baseline for analysing the sensitivity of Australia's agricultural food commodities to a range of variables. They rely on a set of assumptions about continued macro-economic growth, elasticity of supply and demand, and the rate of change in agricultural technology.

As such, they assume no significant or sudden changes in productivity growth. They also make the broad assumption that current land and water availability and climate conditions will continue, and that farmers will fully adapt to any marginal changes in these conditions.

Linehan et. al. note that ongoing investment in research and development will be increasingly important to maintain productivity growth in the face of land and water constraints.

Scenario 1: Soil investment opportunity

A 2005 study for the Grains Research and Development Corporation estimated likely gains in production if soil constraints to crop growth were completely removed. The efficiency of water use by crops could be increased if problems of soil acidity, highly dense subsoils and low water permeability are removed.

Using wheat as a reference crop, Beeston et. al. estimated an extra 3.1 - 6.2 million tonnes p.a. could be produced if all three constraints were removed.[xlv] By comparison, 20 million tonnes of wheat were produced in an average year over the decade to 2011.[467]

Table A2: Scenario 1 – Opportunity to increase value of wheat production A$1.1 - $2.1 billion

Real 2007 A$

Soil constraint removed	Increased volume of wheat production (million tonnes)	Increased value of wheat production (A$bn)
Dense subsoils	3.1	1.1
Soil acidity	2.1	0.8
Low water permeability	0.8	0.3
Total	**3.1 – 6.0**	**1.1 - 2.1**

Source: CPD analysis

To compare these figures to the baseline case, we converted them to dollar values in 2007 A$ terms. We estimated the potential percentage increase in production volume in 2007 by dividing Beeston et. al.'s estimates by actual production volumes for the year ending June 2008 (a relatively low production year). We then multiplied this percentage by Linehan et. al.'s 2007 figure for the value of Australian wheat production.

The opportunity to increase the value of wheat production could be US$0.9 - $1.7 billion, based on current levels of soil degradation. Estimating the cost to remove soil constraints is difficult, as it is likely to depend on individual farm conditions. While it may not be economically attractive for farmers to remove all soil constraints today, this may change if wheat prices rise sufficiently, or declining soil condition causes larger production losses.[xlvi]

[xlv] This is because the constraints may occur by themselves, or in combination. Where two or more constraints occur together, the increased production may be additive, or limited to only the most significant constrain.

[xlvi] Over time, declining soil condition can cause crop losses to rise significantly. For example, unless acidic surface soils are treated with enough lime subsurface soil acidity can become an enduring constraint to cropping. Treatment of subsurface soil acidity is more expensive and technically difficult than applying surface lime.

Scenario 2: Climate threat

A 2007 study by Gunasekera et. al. estimated that by 2050, climate change has the potential to constrain Australian beef production by 19 per cent, wheat production to 13 per cent, dairy production by 18 per cent and sheep meat by 14 per cent, below a baseline with no climate change.[468]

These estimates assume a mid-range climate scenario[xlvii], while emissions are currently tracking above the highest scenarios modelled by the Intergovernmental Panel on Climate Change.[469] They also assume there is no planned adaptation of agriculture to expected changes in climate.[470]

By 2050 climate shifts will require a transformation in farming systems. Some early adaptation will happen naturally as farmers apply existing strategies of changing the mix of existing crops and inputs in response to more variable weather. However, climate change is likely to significantly increase average temperatures, and drive more frequent extreme high temperatures and weather events. Successful adaptation to climate change will involve new crops and agricultural technologies. A significant investment in research, development and extension will be needed to manage and reduce the costs of climate change by 2050.

To estimate the potential size of this adaptation challenge, we applied Gunasekera's forecast yield reductions to the baseline scenario for 2050. We included beef, wheat, dairy and sheep farming, but not fruit as this sector was not covered by Gunasekera et. al.

Table A3: Scenario 3 – Potential threat to beef, wheat, dairy and sheep value of production A$6.5 billion by 2050

Real 2007 A$

Commodity	Business as usual - 2050 production value (2007 A$bn)	Climate impacted future - 2050 production value (2007 A$bn)	Threat without adaptation (2007 A$bn)
Beef	18.1	14.6	3.4
Wheat	8.9	7.7	1.2
Dairy	8.3	6.8	1.5
Sheep meat	2.8	2.4	0.4
Total for selected commodities	**38.1**	**31.6**	**6.5**

Note: Business-as-usual production values for individual commodities are from Linehan et. al. All other figures are from CPD analysis and were not reported by Linehan et. al.

Sources: Linehan et. al.; CPD analysis

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