AUSTRALIAN BROAD ACRE FARMING:

Attributes of successful investment

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Contents

Executive summary

The medium and long-term prospects for Australian agriculture are fundamentally positive, but the sector as a whole faces several key challenges in securing future prosperity.

A growing global population and increased demand for high-quality product creates a strong demand which we are well positioned to fill. Australian agriculture is highly efficient, and at present Australia has a comparative advantage in primary production. Low average returns disguise the reality that many farms are poorly run or minimally viable – the clear majority of total Australian agricultural output derives from a tiny minority of top-performing farms with excellent and reliable annual returns, which at scale is potentially highly attractive to international investors.

Like many human activities, agriculture contributes to global climate change. However more sustainable production techniques assist in mitigation of these effects. In the absence of a market price on carbon emissions and other environmental mismanagement, or of widespread adoption of international standards for sustainable development, the short-term interests of farmers are misaligned with medium- and long-term continued productivity growth. Given an increasing government and community focus on sustainability, future opportunities exist for lucrative public/private partnerships around natural resource management which have yet to be fully explored.

With shrinking rural populations, the availability of skilled labour is a potential limiting factor. This problem will be further exacerbated by the increased knowledge and skills threshold to engage with future agricultural technology, however operators are reluctant to invest in upskilling their often seasonal and temporary workforce, instead relying on temporary contractors to fulfil key roles. This 'hollowing out' issue is covalent with decreasing public sector investment in agricultural R&D and educational investment, leading to a decline in the renewal and growth of agricultural innovation and educational curricula and investment.

With most of the land suitable for broad acre farming already under production, future prosperity will derive from *embracing agricultural technology* and *sustainable development*, the two key areas the top performers are already embracing and heavily investing in. A lack of public spending in this area has been mitigated to an extent by increased private sector investment, but such investment is usually limited to refinement rather than 'blue sky' innovation.

It is likely that the key technologies behind future productivity increases will be:

1. Precision monitoring and information systems, enabling farmers to make smarter decisions faster;
2. Continuing the automation trend, driving up productivity and driving down expenses by freeing human operators from routine tasks;
3. Incorporating cutting-edge advancements in crop nutrition, bio genetics and selective breeding into routine farming operations, increasing yields with every generation; and

4. Tailoring machinery requirements and farm operations to each operation through bespoke hardware and software, driving increased productivity and enabling radical approaches to capturing all possible outputs for profit.

We conclude that successful investment in Australian broad acre agriculture should therefore have the following attributes:

1. Sufficient scale to maximise capital and process efficiency.
2. Be innovation driven through by integration of network based skills and technologies that are applied actively and developed quickly at micro farm level and then multiplied across the business.
3. Be sustainable, be in sync with community; and embrace of all potential opportunities for revenue generation offered by the land footprint occupied, including carbon, water and energy.
4. Actively embracing the opportunity to overcome the skills shortage in agriculture through repositioning food production and land management as an innovative and vital sector full of opportunity.

1: Australian agriculture in context

Australian agriculture is a sector of critical importance. In the 2014-15 financial year, the value of total farm exports exceeded AUD $43 billion, with a trend average yearly increase of 8.3% since 2010-11 and up 36.6% over the five-year period[1]. Over the economy as a whole, this places the sector second only to iron ore exports ($54 billion in 2014-15, down 27.1% since 2013-14)[2]. Reliable returns combined with medium- and long-term international trends combine to make Australian agriculture an attractive investment option.

1.1: International market forecasts

Global population, currently at approximately 7.3 billion people, is expected to increase to 8.5 billion by 2030 and 9.7 billion by 2050[3]. The vast majority of this increase is expected to occur in low and lower-middle-income countries, net and increasing importers of food, and by 2050 more than two-thirds of the global population is expected to be urbanized - 90% of this increase in urban dwellers will be concentrated in Asia and Africa, in many cases seeing an absolute decline in the rural/agrarian primary producing population[4].

This expansion in global population will require a large increase in global food production. To feed the 2050 global population to base acceptable nutrition levels will require a 70% increase in food production from 2007 levels, with cereal production growing by one billion tonnes and meat production by 200 million tonnes. Net cereal imports into developing countries will need to triple, and the adequacy of domestic production, while globally variable, will decrease in key market areas of Africa, the Near East and Asia, increasing reliance on food imports[5]. Together, the traditionally strong markets of the People's Republic of China (PRC; 43%) and India (13%) are expected to account for over half of this growth in demand[6].

Further, changing global demographics will also alter food consumption patterns. As a result of increased consumer income, the greatest projected increase in demand is for fruit, vegetables, broad acre cereal crops, fish and dairy[7]. In addition to bare calorific demand, therefore, markets are projected to have an increased appetite for higher-quality produce.

1.2: Land usage and efficiency

The simplest route to increased yields – placing more land under cultivation – is heavily qualified by economic and socio-political factors. By 2050, only an additional 5% of arable land is expected to be under cultivation. Rather, 90% of the growth in food production will derive from increased productivity[8].

[1] 'Value of Australian agricultural exports', *Agricultural Commodity Statistics 2015*, ABARES
[2] *Australia's Top 25 Exports, Goods and Services*, DFAT/ABS
[3] *World Population Prospects: 2015 Revision*, United Nations Department of Economic and Social Affairs (UNESA)
[4] *World Urbanization Prospects: 2014 Revision*, UNESA
[5] *High Level Expert Forum – How to Feed the World in 2050* Rome conference discussion paper, UNESA/UN Food and Agriculture Organization (UNFAO)
[6] *Food Demand to 2050: Opportunities for Australian Agriculture* (2012), Linehan, V et al., ABARES, Canberra
[7] *ibid*
[8] *How to Feed the World in 2050*, op cit.

Australia, as a major exporter of broad acre agricultural products, is currently internationally competitive. However, our successes in this area stem mostly from access to large areas of arable land, market proximity, favourable export and taxation policies, low sovereign risk, and a reliable workforce – factors tied to extent of land cultivated, not efficiency of usage[9]. For Australian agriculture in particular, increasing land under cultivation may simply not be an option – only about 6% of our total 400 million hectares of agricultural land is of sufficient quantity to support intensive cropping programs year-round[10].

This, combined with generally low soil fertility and highly variable rainfall, means that average Australian rain-fed total crop yields are less than a third of those in North America, Europe and the PRC[11]. Despite these lower total yields, Australian farmers ensure competitiveness through excellent efficiency and conservative cropping, leading the world in grain yield per fertiliser unit and per millimetre of growing season rainfall[12].

1.3: Farm productivity and yields

On average, the rate of return for Australian broad acre agriculture is low, averaging 1.1% (4.2% including capital appreciation) over the 20-year period to 2012-13[13], and in that year only 6% posted farm receipts of over $1 million, with 55% under $100,000[14]. However, these results mask much underlying variability, with top farms posting far superior results[15].

Australian agriculture is predominantly small-operator based, with 72% of farms covering less than 500,000 hectares and 36% of total farms occupying less than 50 hectares. As might be expected, the larger farms are far more efficient, with the top 20% of farms producing over 80% of total farm output and smaller farms deriving the majority of household income from off-farm sources[16]. A large number of Australian farms seem to be just 'getting by', or are run on a non-commercial/hobbyist basis – over half of total broad acre output derived from the top 25% performers, but the bottom quarter accounted for only 8%[17].

This huge disparity in farm performance may be related to scale and efficiency of operation – top performing farms were, on average, geographically twice as large and posted nearly three times higher total farm receipts than middle performing farms, as well as benefitting from significantly lower relative operating costs. These most successful operations also posted vastly higher capital investment – 64% of returns as opposed to 2% - than the bottom cohort.

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[9] *Optimising Australian agriculture's competitive advantage* (2014), Keogh, M., for Farm Management Institute Agriculture Forum, Sydney
[10] *ibid*
[11] *Australia's Agricultural Future: Returns, Resources and Risks* (2015), Grafton, R.Q et al, Australian Council of Learned Academies for Securing Australia's Future working group
[12] *ibid*
[13] *Agricultural Competitiveness Green Paper* (2014), Commonwealth of Australia
[14] 'Size of Australian Farm Business – 2011', *Australian Social Trends* (2012), ABS
[15] See also below at 2.1.
[16] *Australia's Agricultural Future*, op cit.; see 2.1 below on this issue.
[17] *ibid*

Again as a function of scale, top-performing farms had a higher gearing rate and greater debt, but spent a lower percentage of income on servicing interest – 8% as opposed to 11%[18].

While Australian yields are currently globally competitive, real gross value of production has stalled since the 1950s; starting at about $40 billion in 1953 on the back of the superphosphate boom and consistently hovering at about $45 billion (2013 dollars) ever since Productivity has increased at an average of 2.1% per annum over the total period – however, this disguises a pronounced slackening in the past two decades, with the growth rate until 1994 at 2.5% and only 0.7% since[19]. Consolidating farm holdings and intensifying production of existing areas under cultivation, while maintaining existing expertise in efficient cropping, thus presents a compelling opportunity to capture a greater share of the expanding international market.

1.4: Comparative advantage, total factor productivity and terms of trade

Total factor productivity (TFP) is the ratio of outputs to inputs. TFP growth occurs when the amount of outputs increases for a given amount of inputs. **Profitability** is the ratio of the growth in income to the growth in costs. It is tied to the **terms of trade** (ToT) available to farmers – the ratio of the prices received by for outputs relative to the prices paid for inputs.

Crudely, therefore, **profitability = ToT x TFP**, or, in other words, increased productivity will only result in increased profits if the terms of trade remain constant. TFP is obviously influenced by many factors including climate events, technological innovation, water availability and so on. ToT is similarly a result of many different variables, some of which can be manipulated by farmers and government (such as taxation policy capital works) but many of which cannot (market movements, climate change, global phosphate reserves, etc.).

Competitiveness in international markets is related not only to TFP and profitability, but also to the concept of **comparative advantage** – the extent to which a state's economy is more efficient at turning a given input of capital and labour into a particular output than another state; or in other words, the opportunity cost for a particular industry is lower. If Australia is more efficient at agriculture than, say, America, then even though the US may have the capacity to produce far more total agricultural output than we do, their economy will naturally prefer to allocate resources towards the industries at which the US is more efficient and import food from us – Australian agriculture has the comparative advantage.

Australia has retained this comparative advantage for many decades as a result of productivity growth in the agricultural sector outstripping growth in the rest of the economy. For the period 1975-99 agricultural productivity grew four times faster than any other sector, and twice that of other OECD nations[20]. As such, while other nations have higher TFP growth, we have maintained higher relative efficiency and hence a comparative advantage. A reduction in TFP growth, either absolute or relative, could threaten this position.

[18] *ibid*
[19] *ibid*; see also below at 3.2
[20] *Productivity growth in Australian agriculture: trends, sources, performance* (2007), Mullen, J.D; Crean, J, Australian Farm Institute

As indicated above, ToT is also critical to profitability. Historically, ToT has declined by about 2.1% per annum, although at a decreased rate since the 1990s, slightly outstripping average TFP growth[21]. This ongoing pressure on profitability has seen many smaller operators falling behind, with a relatively static real value of agricultural production being concentrated in the hands of higher-performing farms[22].

In summary, the profitability of agriculture depends on how efficiently it uses resources (TFP) and the relative price of agricultural outputs versus required inputs (ToT). Australia currently has a comparative advantage in many agricultural outputs as a result of the structure of our economy, which has allowed us to remain internationally competitive despite lower total outputs than other states. This position has declined in recent years, requiring a refocusing and reinvestment of resources in order to maintain our present lead.

1.5: International private investment – trends and experiences

Globally, investment in agriculture and primary production has dramatically increased in recent years. Since 2006, private equity funds have invested some AUD $2.8 billion in Europe alone[23]. Investment activities vary from case to case, but may range from purchasing equity in existing corporations, purchasing land direct and farming under contract, joint ventures, or linked activities such as storage, logistics and training. As most entities are private and unlisted, full data on investment figures and returns is unreliable or unavailable, however globally it is estimated there is around $30 billion in funds committed or targeted for investment in primary production from approximately 60 major institutional investors operating predominantly in the agricultural space[24].

While large in absolute terms, these investments represent only a tiny fraction of the possibilities open – these operations represent interests in less than 1% of globally available farmland[25], and the total $40-50 billion invested in agriculture to date falls far short of the estimated $1.35 trillion potential opportunities worldwide[26]. Australia is seen as a highly attractive investment destination, with approximately $3 billion worth of international investment in our primary agricultural production, second only to the US at $4.2 billion and more than double the next contender, South America, at $1.1 billion.

Returns on investments are highly variable. Following the 2006-2007 spike in agricultural commodity prices, a large number of funds quickly diversified into agricultural acquisitions which have proven to be more complicated to manage than initially estimated. However, competently managed properties are posting significant returns within short timeframes, in particular purchase/develop/sell investments – of companies willing to disclose results,

[21] *Australia's Agricultural Future*, op cit
[22] See above at 1.3.
[23] *Emerging investment trends in primary agriculture* (2013), Luyt, I et al; for UN FAO/European Bank for Reconstruction and Development
[24] *ibid*
[25] *Responsible investment in farmland – TIAA-CREF farmland sustainability report* (2012), for former Teachers Insurance and Annuity Association – College Retirement Equities Fund (now just TIAA)
[26] *Emerging investment trends in primary agriculture*, op cit

AdecoAgro posted a return on investment of 34%, while BrasilAgro managed 27%[27]. Of international funds buying in to the market after the 2006/07 price boom, and contemplating a longer returns period (in particular own/operate strategies) no major investments have yet reached maturity or been exited. Modelling released by funds indicates investment tenure period of around 10 years, with returns expected of between 8% and 25%, averaging around the high teens. In the USA, a register of farmland owned exclusively by tax-exempt foreign investors demonstrates that over the period 2003-2013 the average returns on investment are greater than 10% - since 2012, an annual return on cropland of around 17% (12.6% capital appreciation/4.4% income return)[28].

An analysis of existing market performance of major international investors working within Europe and Eurasia, while incomplete and reliant upon literature and marketing releases, combined with limited public data, yields some insights into the features of best-performing investments[29]:

1) Disciplined business model emphasising efficiency and performance over scale growth and quick returns;
2) Expansion from modest scale in manageable steps, recruiting local talent;
3) Ensuring capital was raised at manageable levels, based on yield performance of the land rather than expected gains in capital or land value; and
4) Aggressive improvement of capital and land to add value to the underlying production enterprise.

In summary, market fundamentals for agricultural commodities are positive and trend upwards over the mid-term, with some uncertainty over the long-term out to 2050. Key drivers of rates of return reward an approach that seeks to maximise the productivity of the land and the improvement of agricultural activities upon it, rather than a 'grab and sell' approach focusing on scale of acquisitions.

[27] *ibid*
[28] *ibid*
[29] *ibid*

2: Social, market and sovereign risk

Australian agriculture faces some unique challenges, including a changing rural population, shifting production patterns, and international market risks. Both industry and government action is required to ensure continued productivity and profitability in the sector. However, a growing space exists for sophisticated operators to secure a market leading position through early adoption of key practices designed to meet these challenges.

2.1: Rural demographics

The face of Australian agriculture now is much different to that of previous decades. As an employer the sector has seen a relative decline, dropping from 14% of the population in the 1970s to 3% today[30]. The faces on the farm have changed too, or to be more precise they have not – the median age of farmers has increased by nine years since the 1980s to the highest in any sector, with the percentage of farmers aged 55 years and over increasing from 26% to 47% and the percentage aged under 35 decreasing to just 13%[31]. The proportion of employers has fallen, as has the number of family members contributing to the business, raising succession as a major issue. Further, the proportion of farm families deriving income from off-farm sources has increased to nearly 50% since 1990, with the average earnings more than doubling to $33,500 per year[32]. The average farmer is now older, likely to be self-employed or a casual worker, likely to be poorly educated and poorly paid[33].

As discussed above[34], however, these averages can paint a slightly misleading picture of the overall state of health of the agricultural sector. While the overall trend in production-focused commercial-scale agriculture has been towards consolidation, expansion and intensification, a parallel trend has been the rise in 'hobby farms' or 'lifestyle properties'. Approximately 30% of all broad acre farms produce an average output of $100,000 or less. That 30% produce only approximately 4% of Australia's total agricultural output, and, crucially, derive over 90% of their total income from off-farm sources. Indeed, in bad years, off-farm income is relied upon to offset bad harvests and operating losses, with off-farm income as a percentage of total spiking to over 120% in 2007-2008[35].

Australian agriculture is therefore increasingly diverging into three camps:

1) hobbyists, producing a tiny percentage of all agricultural output, remaining on the land as a lifestyle decision, and for whom the economics of production are less relevant than the personal satisfaction of engaging in primary production;
2) existing 'family operators', farming as a commercial enterprise and producing a reasonable (but shrinking) proportion of total output but increasingly reliant upon off-farm sources of income; and

30 *Australia's Agricultural Future*, op cit
31 *Census of Population and Housing* (2011), ABS
32 *Trends in Australian Agriculture* (2005), Productivity Commission
33 *Australia's Agricultural Future*, op cit
34 See at 1.3
35 *Time to get rid of the average Australian farmer*, (2013), Keogh, M, Australian Farm Institute

3) larger 'commercial operators', producing the largest share of total agricultural output and increasingly responsible for profits in the sector.

2.2: Rural diaspora

Connected to this changing face of rural communities is a continual movement from rural Australia to urban centres, driven by greater work options, better support services, health outcomes and educational options. This diaspora has obvious consequences for the local availability of labour, particularly skilled labour[36], and the viability of regional communities[37]. As a sector, agriculture faces negative public perceptions about profitability, lifestyle options, working conditions, rural decline and an ageing workforce, discouraging new entrants and talent[38]. Further, the sector faces strong competition for labour from other industries, poor engagement of youth, women, migrants and Indigenous Australians, poor human resources planning and capacity and limited workforce development[39].

Compounding this problem is the role of the 'family farm' as a major source of population stability and growth in rural areas. With an increasing number of farmers struggling with succession issues, an increasing number of properties being bought for hobbyist or lifestyle purposes, and a drive towards consolidation and expansion of rural holdings by commercial enterprises, many traditional farming families are disappearing from rural communities. In particular, younger people are leaving rural communities and not returning, citing feelings of 'under valuing', poor accessibility, limited transportation, poor medical services, accommodation, information technology and communications infrastructure and limited career opportunities[40] - as noted above, a tiny minority of farmers are now under the age of 35, a 75% decline since the 1970s[41].

This population decline is also changing the nature of rural communities, further degrading their viability and 'liveability' and leading to a vicious cycle. Larger enterprises are less likely to purchase produce and machinery from local businesses, while a drive towards consolidation and larger holdings means fewer potential customers for non-farm inputs, meaning local businesses are forced to relocate, shut down or reduce services[42]. The increase in the number of 'hobbyist' farms has had only limited ability to slow or reduce this trend – most such farms tend to be peri-urban, located on the fringes of urban centres and within easy commuting distance and hence with little reason to form attachments to rural or local communities[43].

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[36] On this issue, see below at 4.3.
[37] *Australia and Food Security in a Changing World* (2010), Prime Minister's Science, Engineering and Innovation Council
[38] *Workforce, Training and Skills Issues in Agriculture* (2009), Primary Industries Ministerial Council
[39] *Australia's Agricultural Future,* op cit
[40] *Workforce, Training and Skills in Agriculture*, op cit
[41] See above at 2.1; *New entrants to Australian agricultural industries – Where are the young farmers?* (2014), Barr, N; for Rural Industries Research and Development Corporation
[42] *ibid*
[43] *Australia's Agricultural Future,* op cit

2.3: Sustainable production – market pull factors

Consumers of Australian agricultural output will have noticed that there has been a large increase in recent years of 'certified' product (RSPCA approved, Forestry Stewardship Council, WA Made, etc). Certification of this type is a global phenomenon, however the proliferation of Australian certification schemes, particularly those run by industry groups, has confused buyers and created suspicion amongst the public, and these schemes are poorly understood by international markets[44]. In particular, voluntary certification schemes which represent a genuine push towards more sustainable practices are at risk of being 'crowded out' by those (generally backed by industry bodies) which merely uphold existing standards[45].

Further, many of these schemes do not align with international standards, or have not been tested against them. Thus, Australian-only sustainability certified products face higher production costs for questionable benefits[46]. There appears to be a need for government support for international standards-based certification, or alternatively greater regulation of voluntary industry schemes, to address what is arguably a market failure in this area. If Australia is to continue our excellent reputation for food security[47] and secure a key position as a provider of high-quality produce to a growing international middle class, further work is required to better align the willingness of producers to seek accreditation towards those that are meaningful[48].

2.4: Market access – future challenges and opportunities

In pursuing international market opportunities, Australian farmers face additional challenges beyond those found in other OECD exporter nations.

As Australia exports a higher proportion of its agricultural produce than many other nations, and maintains relatively free and open access to its domestic markets, the fluctuating international market price has more of an impact on our farmers. Additionally, with a smaller relative domestic market, the potential consequences of market interference or distortion are commensurately more serious[49]. Many of our key crops (oilseeds, wheat and barley in particular) are subject to larger price variations than other products in international markets[50], and the lack of a price support scheme or domestic subsidy removes important cushions enjoyed by primary producers in other economies.

The recent conclusion of several free trade agreements (FTAs) with key nations such as the Republic of Korea, Japan and the PRC represent important developments in this area - the

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44 *Voluntary Australian land management certification systems* (2007), Gleeson, T, for Rural Industries Research and Development Corporation

45 *Ten Commitments Revisited: Securing Australia's Future Environment* (2014), McKenzie, F; Williams, J, ed Lindenmayer, DB et al, CSIRO publishing

46 *Private Food Standards as Responsive Regulation: The Role of National Legislation in the Implementation and Evolution of GLOBALG.A.P.* (2013) Lockis, S et al, *International Journal of Sociology of Agriculture and Food*, vol.20 no.2 pg275

47 See also below at 3.5.

48 *Australia's Agricultural Future*, op cit

49 *ibid*

50 *Managing Risk in Agriculture – a holistic approach – Highlights* (2009), OECD Publishing, Paris

opportunity to secure lower prices in these important and developing markets is obviously critical for the future of exports to these regions. However, further development may be needed on this front – in some cases, Australia has is merely 'catching up' to its competitors, such as New Zealand, and many staple food grains (particularly wheat and rice) are regularly left out of such agreements due to foreign concerns surrounding self-sufficiency[51]. With such grain crops steadily increasing as a share of domestic production[52] the implications for international trade over the long term are unclear.

2.5: Sovereign intervention

In addition to international trade policy, government and regulators can also provide key services to better serve the needs of the agricultural sector, reduce risk and encourage efficient and profitable production. The need for public intervention in the sector is generally low, and evidence suggests that private industry is usually more effective at providing a market-based solution for many difficulties facing farmers[53]. However, a case may be made for intervention to help manage catastrophic risk, or where exigencies and new developments in international markets (for example, a ban on live exports imposed by key nations) mean that while an underlying industry or usage remains economically viable temporary assistance is necessary (for example, retraining, negotiating exemptions or qualifications to import bans, or providing credit facilities). In other words, where market failure means that the consequences of government intervention will be less economically inefficient than inaction.

An example of the facilitative role of government may be found in the water markets in existence in many areas, which utilise market forces to ensure optimum production efficiency and are currently working well[54] - as discussed below[55], the efficiency of such markets was such that although total water extractions during the drought years fell by 70%, the gross value of irrigated product dipped only 1%[56].

Another initiative gaining ground in Australian agriculture is the adoption of regional resource management bodies, whereby authority for strategic land use zoning, catchment planning and management, regulatory and permitting functions and other government roles are devolved from central control to smaller regional bodies. Such groups are then able to operate at a scale small enough to capture local knowledge and stakeholder input, while remaining large enough to encompass the diverse needs of communities, both rural and urban, and manage the various pressures impacting on landscape use[57].

Governments may also provide risk-mitigation services through income or tax smoothing, whereby farmers may 'set aside' pre-tax income from good years to offset the risks of poor

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[51] *ibid*
[52] See also below at 4.2.
[53] *Managing Risk in agriculture – Policy assessment and design* (2011), OECD Publishing, Paris
[54] *Water Markets in the Murray-Darling Basin* (2014), Grafton, R.Q; Horne, J, *Agricultural Water Management*, vol 145 pg 61
[55] See at 3.3.
[56] *Sustainable irrigation: how did irrigated agriculture in Australia's Murray-Darling Basin adapt in the Millennium Drought?* (2014) Kirby, M, et al, *Agricultural Water Management* vol 145 pg 154
[57] *Blueprint for a Healthy Environment and Productive Economy* (2014), Wentworth Group of Concerned Scientists

returns in future years, however caused – an example in the drought relief context is the Farm Management Deposit Scheme. While such approaches face some criticism for ‘crowding out’ private risk management, there is essentially no cost to taxpayers and so this represents a low-hanging fruit of government intervention.

3: Resiliency and sustainability

Australian agriculture has developed a strong risk-management culture in the use of natural resources. Faced with some of the oldest and most weathered soils under cultivation anywhere on the planet, good land stewardship practices and significant investment in agricultural and bio-sciences has nonetheless ensured continued productivity across a range of resources. However, a range of new challenges posed by biosecurity hazards, climate change and changing environmental and especially hydrological conditions will require new techniques to overcome and prosper.

3.1: Competing incentives and public goods

Agricultural activities almost always result in both positive and negative side effects, or externalities, that are not fully reflected in the market price of inputs and the market value of outputs. As a simple example, good land stewardship and topsoil maintenance policies will have a positive impact on riverine and ecosystem health that provides great benefit to the surrounding community, while land clearing, over cropping and monoculture agriculture will have a net detriment to water table levels, soil salinity, and biological resiliency. While recent adventures in carbon pricing in the domestic political sphere and a push towards sustainable development as part of industry self-regulation have gone some way towards incentivising positive behaviour and penalising poor stewardship, the full extent of possible outcomes is not, and is incapable of being, fully captured in a pricing model.

Further complicating matters is that many of these externalities have the nature of a **public good** – that is, something which is both non-rivalrous (use of a resource by one party does not restrict another party from also using that resource) and non-excludable (one party cannot realistically prevent another from also using that resource). The classic example in agriculture would be utilising aquifer water supplies – one farmer sinking a bore does not stop another from doing the same, nor can they stop the second bore being sunk, or the third, until the aquifer pressure drops too low to be usable. This has two main consequences:

1) no party has an economic incentive to invest in maintaining the public good – the benefits of doing so cannot be enjoyed by them alone and so to do would be to allow others a 'free ride' at their expense; and

2) no party has an economic incentive for sustainable consumption – in fact, quite the opposite; as the usage of others cannot be restricted, every party has an incentive to grab what they can for their own benefit before the resource is exhausted.

In addition to competition for public goods within the agricultural sector, farmers also face competition from society more broadly. As above, while in recent decades some mechanisms have reduced this, a disparity still exists between the interests of local communities and that of farmers seeking to maximise efficiency, productivity and profits. Further, a form of 'market failure' can be seen to exist, whereby at least part of the decreasing productivity growth in agriculture can be attributed to degradation of natural resources because in the past there was no effective price penalty for poor stewardship[58].

Consequentially, any future measures to promote growth and efficiency in agricultural production will not be implemented in a vacuum. Public policy no longer accords agriculture a privileged position, despite its economic importance, and the efficiency benefits of any new measures will be balanced against the societal and wider community interest. Further, farmers themselves should be cognisant of and willing to price into their own calculus of interest the likely mid- and long-term consequences of their activities.

3.2: Climate variability

Intimately connected with the land and the changing seasons, agriculture is beholden to them, and a single good or bad season can have consequences on productivity and output that far outweigh any other single factor. As such, accounting for climate variability in undertaking any analysis of agricultural growth rate and productivity is critical.

As noted above, Australian agricultural TFP has since the 1970s increased at an average of about 2.5% per annum until the mid-90s, before dropping sharply to about 0.7% in the years since[59]. Accounting for climate variability, a somewhat clearer picture emerges – the average TFP growth for the period 1978-2008 drops to 1.53%, with TFP growth for the period 2000-2008 dropping even further to 0.24%[60]. As such, despite individual years of drought, it is evident that apparent steady gains in productivity over the recent decades in fact have more to do with generally good growing seasons.

The future Australian climate under the effects of global warming are difficult to predict, but generally the consensus seems to be that average temperatures will increase and rainfall patterns will shift unpredictably[61]. Under higher rainfall scenarios, TFP is predicted to increase for all aspects of agricultural production. Taking broadacre wheat production as an example, lower rainfall may see a TFP reduction over the period of 7.3% in WA and 4.2% in NSW by 2030 under a business-as-usual model. Farmers by adaptation may be able to reduce to this reduction to 3.6% in WA and 2.1% in NSW[62].

Accordingly, it is critical that TFP growth is maintained at at least historical averages in order to offset the potential impacts of climate variability on agricultural production. Adaptation is critical, and farmers must be prepared to shift production to suit the changing climate.

3.3: Water availability

As the driest inhabited continent with the most variable annual and seasonal rainfall patterns worldwide, the availability of water is obviously a key issue and a significant limiting factor in

[58] See eg discussion in *Australia's Agricultural Future*, op cit.
[59] See above at 1.3
[60] *Productivity Pathways: Climate adjusted production frontiers for the Australian broadacre cropping industry* (2011), Hughes, H et al, Research Report 11.05, ABARES
[61] *Climate change in Australia: agricultural impacts and adaptation* (2006), Kingwell, R., *Australasian Agribusiness Review* vol. 14
[62] *Adapting to climate change: issues and challenges in the agricultural sector* (2007), Heyhoe, E et al, *Australian Commodities* vol.14 no.1

agricultural production[63]. At approximately 60% of total water consumption economy-wide, agriculture accounts for the largest share of total water extraction[64], primarily in irrigated production. As might be expected, total usage varies from season to season, generally mirroring rainfall, but historically has stayed at approximately 12,000 gigalitres in non-drought years, dropping to a low of approximately 7,000 gigalitres in 2007-2008 at the peak of the millennial drought[65].

Interestingly, gross value of irrigated product and amount of water used are only slightly correlated over the short term. As noted above[66], Australian farmers are some of the most efficient users of water in agriculture worldwide – during the recent drought years of 2006-2012, gross value of irrigated product increased from approximately $10 billion to approximately $13 billion, while water usage remained at about 6,000 gigalitres below pre-drought levels[67].

Given the obvious importance of water to irrigated agriculture, it is likely that this lack of decline in total gross value instead represents the agile nature of irrigated industries and the efficiency of water market mechanisms. Irrigated industries generally have a degree of flexibility built in to their operations imposed by many years of variable water availability, and the operation of national water markets allows scarce resources to be allocated to those particular operations able to make most economic usage[68]. Of the major irrigated commodities, there exists a very large disparity between the gross value of the commodity produced and the amount of water required to produce it. As an example, in 2011-2012 rice production used approximately 1,140 gigalitres to produce a gross value of approximately $248 million, ($220,000 for each gigalitre), livestock grazing used 1,580 gigalitres for a value of approximately $3.15 billion ($1.9 million for each gigalitre), while vegetables used 0.37 gigalitres for a value of $2.6 billion, an efficiency of approximately $7 billion per gigalitre[69].

The geographic distribution of Australia's water supplies are also misaligned with much of our population base and historical irrigated agricultural areas. Approximately 45% of our total exploitable water yield occurs in the extreme north of the continent, followed by Tasmania at 25%, however the majority of irrigated agriculture occurs in the Murray-Darling basin, which captures only 6.1% of exploitable yield[70]. Existing infrastructure in these areas range from very good (Tasmania) to sporadic (northern Australia, with some notable exceptions such as the Ord River scheme).

Further preventing a straightforward expansion in irrigation in this area is the competing incentives of local communities and long-term sustainable resource management – in hydrological systems, no water is 'wasted water', with runoff into streams and oceans critical

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[63] *Australia's Agricultural Future*, op cit
[64] 'Inland water', Federal Department of Environment/Bureau of Meteorology
[65] 'Agricultural water use', ABS
[66] See above at 1.2
[67] *Australia's Agricultural Future*, op cit
[68] See also discussion above at 2.5.
[69] Derived from *Gross value of irrigated product* and *Volume of water applied* datasets, 2012, ABS
[70] *A continental scale assessment of Australia's potential for irrigation* (2010), Petheram, C.M et al, *Water Resources Management* vol. 24 pg 1791

for maintaining hydrological cycles and riverine health. Integrated land and water stewardship is essential to long-term sustainable development, and over-extraction can have extremely serious and expensive consequences for remediation, as seen in the Murray-Darling region where at last estimate approximately $12 billion will be required to implement the Murray-Darling Basin Plan.

Growth in this sector will thus require innovation, good land stewardship through exploration of techniques such as mosaic irrigation, increased efficiency of usage and regulatory and industry action to 'price in' the environmental costs of over extraction. Given the innate variability of the sector, industry will also need to retain flexibility of operations and the ability to scale output to available resources. Nonetheless, the large disparity between the current geographic concentration of irrigation activity and the location of underutilised resources presents irrigated agriculture as a significant potential growth area.

3.4: Soil utilisation and fertility

Agriculture uses an enormous percentage of Australia's total land mass – some 456 million hectares, or approximately 59% of the entire continent. Of this total usage, by far the largest single use is livestock grazing, with 429 million hectares, or 94% of total agricultural land use, set over to grazing on natural vegetation or modified pastures. Cropping (27 million hectares) and horticulture (500,000 hectares) come very distant second and third place[71]. In recent years there has been a slight reversal, with a total decrease of approximately 19 million hectares (likely representing the abandonment of marginal ventures and the transition towards forestry and native re-vegetation). The pattern of agricultural usage has also shifted over time, with a 6% decline in the area used for grazing and a 39% increase in cropping since the early 90s[72].

It is perhaps unsurprising that this widespread land usage has had an extreme impact on Australian flora through habitat degradation. Since European settlement, 99% of temperate lowland grasslands, 60% of coastal wetlands, 34% of low eucalypt woodland and approximately 30% each of mallee and eucalypt forest have been cleared[73]. This modification from natural equilibrium and intensification of usage has had consequences for soil quality and fertility, requiring careful management.

Good soil, and Australian soil in particular, has many qualities of a non-renewable resource. Australian soil is, in geological terms, extremely old, very weathered, and on average some of the least fertile in the world. As a result, it forms and regenerates very slowly, while degrading rapidly, particularly under intense use. While some soil around wetland areas, particularly black and brown cracking clay most commonly found in floodplains in NSW and Victoria, is highly productive, the majority of the remainder is of poor to fair quality.[74]

[71] National Land Usage 2005-2006 (2010), ABARE-BRS
[72] *Towards national reporting on agricultural land use change in Australia* (2013), Mewett, J et al, *Technical Report 13.06*, ABARES
[73] 'Loss, fragmentation and degradation of habitat', *Year Book Australia (2009-10): Australia's biodiversity*, ABS
[74] *Australia's Agricultural Future*, op cit

The primary issues facing Australian agriculture in maintaining soil quality and fertility are acidification, erosion, and loss of soil carbon. Further, managing soil quality requires a balancing of public, private and intergenerational interests, difficult to reconcile.

Acidification is primarily an issue where high nitrogen fertilisers are used, combined with a high degree of product removal, and hence is most an issue in WA, NSW and Victoria. Approximately 50 million hectares are already suffering from soil acidification, while current levels of soil liming are fundamentally inadequate. Without further adequate action, it is estimated that an additional 30-60 million hectares will drop to a pH level hostile to all but the most acid-tolerant plant species[75]. In an Australian context, the effects of increasing acidity have been somewhat masked by the selection of mostly acid-tolerant crops and grasses, particularly legumes, thereby slowing productivity loss due to poor soil management. Further, lime is used sparingly and infrequently in Australia, or not at all, and hence the local lime industry is small and product much more expensive than in the USA or Europe[76].

Erosion remains a significant problem in Australia, despite recent adoption of techniques such as revegetation, minimum tilling and contouring. Thanks to a varied landscape, different mechanisms of erosion apply to different operations, hillside (slipping, runoff), gully (flooding and surface water) or arid plain (dust storms) and thus differential management techniques are required. Unfortunately, most such techniques require a reduction in the total area under cultivation, or a lessening in intensity of existing usage, and thus perverse short-term incentives can apply to limit take-up of techniques that would benefit long-term sustainability. A second-order problem to which erosion further contributes is sediment and nutrient load delivery to rivers and estuarine systems, particularly in northern and south-eastern Australia. Nearly 19,000 tonnes of phosphorus and 141,000 tonnes of nitrogen from agriculture are exported to the coast annually[77], causing significant environmental damage to estuarine, riverine and marine ecosystems. In the absence of regulatory oversight, these costs are not usually 'priced in' to farm economics.

Salinity, despite entering the national consciousness in the early 2000s, has had less of an overall impact on agricultural production than previously feared; somewhat perversely thanks to other environmental disorders and mismanagement disguising its effects. First, the salinity process is mostly rainfall-driven, and so the Millennium Drought slowed the expression of dry land salinity. Second, overuse of aquifer resources has in areas lowered the water table, shrinking and in some cases halting saline discharge. Third, the altering of rainfall patters due to climate change tends to produce 'shorter, sharper' bursts of periodic higher than average rainfall, which can have the effect of 'washing' salinity out of soils and into river systems[78].

Despite these masking factors, overall salinity has continued to increase, particularly in water and river systems. Thus, while climate change and mismanagement may reduce the direct

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[75] *Managing Australia's Soils: A Policy Discussion Paper* (2008) Cambell, A., National Committee on Soil and Terrain/Natural Resource Management Ministerial Council
[76] *Australia's Agricultural Future*, op cit
[77] *Managing Australia's Soils*, op cit
[78] *The effects of global change on soil conditions in relation to plant growth and food production* (1996), Brinkman, R et al, UN FAO Land and Water division; *Australia's Agricultural Future*, op cit

exposure of agricultural land to salinity, the likely impacts on water quality are likely to get worse, reducing the utility of non-rainfall on-farm water sources and imposing downstream social and environmental costs.

3.5: Biosecurity and risk management

Thanks to our relative isolation as an island continent, Australia is both protected from and vulnerable to emerging pest and disease threats. As a result of strict biosecurity measures, many threats such as foot-and-mouth are unknown here, which has had a positive impact on both our total productivity and the perceived food safety of our products.

However, a lack of experience with several critical threats could lead to a lack of preparedness and slow response to future potential outbreaks, which would have the potential to cause widespread potential losses. The CSIRO has identified five 'megatrends' that raise implications for future biosecurity, as well as a number of 'megashocks' which could have a potential catastrophic impact on agricultural production[79].

Broadly the trends or risk factors include:

1) Increased agricultural production and exploration of new or niche products increase the risk of introducing new pests or diseases, while increase productivity places local ecosystems under more stress;
2) A growing shift from rural to urban areas has led to a disconnection from primary production and a lack of awareness of the importance of good biosecurity policy;
3) Increased movements of goods, people and vessels across borders creates additional vectors for disease, including particularly through the explosive growth in online retailing;
4) A loss of biodiversity through ecosystem destruction resulting from poor land stewardship reduces resiliency in the natural environment, while climate change tends to facilitate the movement of pests and diseases into new areas;
5) A lack of investment in the area, combined with an aging population and loss of skills, limits the ability of the industry to relate to biosecurity shocks.

Twelve potential 'megashocks' are identified by the report, and include such potential issues as a wheat rust epidemic, introduction of exotic fruit flies, foot and mouth or bluetongue outbreak, and a spike in antimicrobial resistance amongst microorganisms. The recommended response differs according to the threat, however common threads exist:

1) Returning research and development to previous levels to maintain skills and techniques needed to combat potential outbreaks;
2) Emphasising the potential benefits of Australian biosecurity, including the export of skills and knowledge and the branding benefits of 'disease free' status;
3) Recognising that mitigation and preparedness is just as important as prevention, requiring investment from industry and government alike.

[79] *Australia's biosecurity future: preparing for future biological challenges* (2014), Simpson, M et al, CSIRO

4) Co-opting industry expertise and knowledge into surveillance and reporting, rather than a culture of secrecy and top-down imposition of policy viewed as being anti-farmer.

3.6: Farms as environmental stewards

Farm operations cannot be easily divorced from the local ecosystem in which they are situated. This is true especially of ecological processes such as nutrient cycling, nitrogen fixation, hydrological and climate cycles, but also of some biological links, responsible for pest and parasite control, pollination, and other biological services often undervalued by farmers. Additionally, the off-farm impacts of unsustainable or harmful agricultural practices are significant, but are often not priced in to cost/benefit models. Australia has the dubious honour of having the largest documented decline in biodiversity of any continent for the past 200 years, and the highest rate of species decline in the OECD[80].

In addition to the social and off-farm costs, biodiversity loss and species decline can have significant impacts on farm productivity. While exact figures are difficult to quantify, native fauna can assist in seed entrapment, pest control, building soil nutrient stores, assist water penetration and storage, and build microbial activity, while flora are well-adjusted to our peculiar soils, controlling soil acidity and salinity, preventing erosion and promoting regular rainfall. Where native ecosystems have been replaced, significant costs are incurred in managing invasive species such as pigs, camels, buffalo, rabbits and goats, along with weeds – the cost of controlling weed species alone is in excess of $4 billion per year[81].

However, looking forwards, significant opportunities exist for agriculture to not only secure its future sustainability and therefore medium- and long-term profits, but also to profit from a growing movement towards sustainability. Global markets for carbon and other forms of environmental services have already attracted much interest from farmers, and public policy offers some support for the idea of viewing the agricultural community as environmental stewards, who should be paid accordingly[82]. Progress in this area will require further development of monitoring and reporting standards, along with regulatory clarity, as government seeks to avoid subsidising private benefit with public money and thereby reducing or distorting market drivers towards increased efficiency[83]. Future markets for public goods could see farming operations incorporating multiple land stewardship roles into their income stream; for example, in addition to selling wool and wheat, farming operations could derive income from carbon credits, be paid for better managing water quality and reducing salinity by a local catchment authority, receive government funding for a species conservation program, and sell to the local grid renewable energy produced from on-farm solar and hydro.

[80] 'Biodiversity decline in Australia', *Year Book Australia (2009-10): Australia's biodiversity*, ABS
[81] *Australia's Agricultural Future*, op cit
[82] *Blueprint for a Healthy Environment and Productive Economy* (2014), op cit
[83] *Targeting Payments for Environmental Services: The Role of Risk* (2003), Alix-Garcia, J et al, *Gianni Foundation of Agricultural Economics*

4: Efficient production - knowledge and skills investment

While Australian farmers have gained an excellent reputation for land management and cropping strategies, further room to improve exists in attaining maximum productivity. As already addressed, real gross production value has stalled in the sector, due to a range of factors[84]. To further increase yields, maintain current market leading position and drive future profitability, a range of new approaches will be required, both in the areas of technical proficiency and innovation, addressed in chapter 5, and through a range of possible efficiencies deriving from greater management expertise, skills and knowledge growth.

4.1: Farm yield and production frontier

In measuring efficiency, the production frontier represents the theoretical maximum output for a particular enterprise, taking into account existing best practice in land management, technological developments, employee training and so on, but also domestic political realities, market forces and access to capital. As farms become more efficient, farm yield approaches closer to the production frontier. For many years, Australian farmers have been relatively close to this theoretical maximal efficiency, however there has been a marked downwards trend in recent decades[85]. To address this decline will require a renewed drive towards efficient production, a new approach to technical challenges and human capital, and significant investment in agricultural R&D.

4.2: Efficiency – technical, scale and mix

Technical efficiency represents the difference in performance between top-performing farms and average farms – or, in other words, how efficient individual farms are at adopting and applying existing technical innovation, strategies and techniques. Australian farmers have a generally strong record of rapid adoption of technology directed towards efficiency benefits, continuing our historical accomplishments in this area[86]. A good example of technical efficiency is the modern concept of precision agriculture – using technologies such as GPS monitoring, geographic information systems, soil sensors and yield monitors to allow farmers to implement best-practice management techniques and juggle a number of variables to ensure maximum yield from minimal inputs[87]. While the benefits of such technology and techniques differ from farm to farm, in most cases initial capital outlay is fully recouped within 2-5 years and in the majority of farms within 2-3 years[88].

Much of agriculture presents a diminishing returns scenario. Scale efficiency represents the degree to which a particular farm is operating at the most efficient size and intensity of operations, taking into account such things as natural resource preservation (fallowing, crop

[84] See above at 1.3
[85] *Productivity Frontiers*, op cit; *Australia's Agricultural Future*, op cit.
[86] See above at 1.2.
[87] *Australia's Agricultural Future,* op cit
[88] *The economic benefits of precision agriculture: case studies from Australian grain farms* (2007), Robertson, M et al, for Grains Research & Development Corporation/CSIRO

rotation, salinity reduction strategies, etc.), degree of capital reinvestment, local supply and demand, labour costs and so on.

Mix efficiency represents the degree to which the chosen agricultural activities of a farm align with the maximum efficiency for that particular property, taking into account rainfall, soil type and quality, distance from grain handling terminals, livestock export ports, and so on. Mix efficiency is calculated on a sustainability basis and is highly dependent variables beyond mere land suitability – for example, one of the future challenges for agriculture is that a declining pool of skilled labour and the increased technical requirements of modern agricultural technique[89] have driven many operators to focus on one type of production.

As an example, the classic 'mixed farm' has seen a rapid decline, with the area of broad acre production devoted to grazing decreasing by 6% while land planted to crops increased by approximately 50% since the early 90s[90]. This lowers costs and allows for increased technical efficiency by allowing operators to narrow the skills and competencies required for on-farm operations, but may reduce scale and overall productivity, as well potentially endangering sustainability and leading to negative environmental impacts[91].

4.3: Skills base and acquisition

Traditionally, the agricultural industry has placed a low level of priority on education and training, with a perceived bias against 'book learning' and increased focus on on-the-job practical training. Over a third of farmers have no education beyond a Year 10 completion certificate (or below), while nearly 60% have no tertiary qualifications[92]. Historically, this disinterest may stem from a number of factors, including lack of access to good communications and technology infrastructure, the need to travel significant distances to attend training, a lack of available time, particularly during normal business hours, higher relative costs per student, and lower levels of literacy in the rural population[93].

A number of entrenched perceptions also present barriers. Traditionally low university entrance requirements paired with a lack of family encouragement and negative views of many teachers towards agricultural careers combine to create an impression that agricultural studies are for students of lower abilities, or are unrewarding or boring. As a result, the number of students studying agriculture at a tertiary level is declining, and well short of the estimated market requirement[94]. For example, for the period 2001-2006 there were

[89] For more on which, see 4.3, following.

[90] *Landscapes in transition: tracking land use change in Australia* (2011) Lesslie, R et al, *Science and Economic Insights,* pub ABARES, issue 2-2.

[91] *Trajectories of change in rural landscapes – the end of the mixed farm?*, McKenzie, F in *Rural Change in Australia* (2014) ed. Connel, J, Dufty-Jones, R, Ashgate Publishing Ltd

[92] *Employment Outlook for Agriculture, Forestry and Fishing – July 2008* (2008), Department of Employment, Education and Workplace Relations

[93] *Workforce, Training and Skills Issues in Agriculture,* op cit

[94] *Workforce Planning in Agriculture: Agricultural Education and Capacity Building at the Crossroads* (2008), Pratley, J, *Farm Policy Journal* vol 5(3) p 27

approximately 800 (trending downwards) graduate completions per annum, serving an estimated demand of approximately 2,000 positions for new graduates within the field[95].

Industry is also in many cases reluctant to participate. The majority of Australia farmers are still small operators, who are generally not able to afford for staff to take time off for training and lack the resources to pay for access to educational courses that are often based in urban centres[96]. Even for larger enterprises, perceptions are that formal training provides no immediate financial benefit to farmers, or that investment in training what are often seasonal or casual employees will not accrue financial benefit to farm management within the term of their employment. As a result, the focus shifts away from upskilling existing staff and towards the employment of contractors perceived to have the necessary skills[97].

This lack of replenishment has led to a situation where the specialist knowledge required to compete in modern agriculture is increasingly concentrated in a shrinking pool of experts. The number of 'family farms' has decreased by 30% since the mid 1980s, with the total number of farms shrinking by approximately 42,000 and the total number of employees shrinking rapidly, falling by 19% between 2001 and 2006[98].

A number of proposals have been put forwards to tackle these issues[99], broadly that:

1) Negative perceptions amongst educators and the general public should be addressed, through providing pertinent, clear information on agricultural career pathways and closer integration with secondary schools and industry;
2) Streamlining and adding flexibility to current vocational regimes, including by reducing focus on 'full package' courses and instead offering shorter, cheaper more specific courses offering only the competencies and skills needed for specific processes or industries;
3) Addressing lack of consistency in the mutual recognition of qualifications and training by universities and the vocational training system, to aid pathways to education; and
4) Encouraging a forward-looking attitude amongst industry that recognises the need for employee upskilling.

This declining knowledge and skills base, and more critically the potential decline of the institutions and pathways needed to upskill new workers into the future, has potential consequences for agricultural productivity. Modern agricultural practices are more intensive than ever before, both in terms of energy and inputs but also in terms of the knowledge and skills required to properly maintain such practices. Both cropping and grazing systems require specialised skills to manage not only machinery, technical and strategic elements, but also to

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[95] *Graduate Completions in Agriculture and Related Degrees from Australian Universities* (2008), Pratley, J, Copeland, L, *Farm Policy Journal* vol 5(3) p1
[96] *Reality check: Matching training to the needs of regional Australia* (2008), Gelade, S; Fox, T, National Centre for Vocational Education
[97] *Workforce, Training and Skills Issues in Agriculture,* op cit
[98] *Agriculture in Focus: Farming Families, Australia, 2006* (2008), ABS
[99] *ibid*; *Australia's Agricultural Future,* op cit

compete in a crowded marketplace in the arenas of sustainability, branding, market penetration and financial and succession planning[100].

4.4: Innovation and knowledge sharing

Distinct from invention, innovation represents the combination of existing knowledge from different sources to produce a novel beneficial outcome - in other words, doing more with what is currently known. Innovation is driven by knowledge exchange and information networking, as distinct from formal processes of inquiry or research. Further, innovation is (or should be) an ongoing process, rather than a one-off event, providing continuing low-level gains in efficiency or productivity. Such gains may be less impressive than one-off 'quantum leaps', but are nonetheless critical in maintaining positive growth trajectory - in a study of 270 WA broad acre farms from 2002-2011, the only factors to have a significant positive effect were farmer's preparedness and ability to utilise cropping innovations (such as minimum tillage, pasture phases, strategic seeding, etc.) already well understood within the industry, and their time management and organisational skills[101].

As such, interactions and developments at the farm level are as important, or more so, than universities, colleges, commercial labs and other institutions of learning, yet these processes are generally poorly understood and poorly supported by regulation and policy[102]. Innovation requires integration with local and industry partners, a certain degree of flexibility and access to capital, and trust and collaboration between partners, supported by governance structures that ensure equal value is derived by both parties to the relationship[103].

While both industry and government have a role to play in encouraging innovation, a key issue to overcome is to give farmers a greater voice. Knowledge generation in the agricultural space is often regarded as a top-down, high-end process, where researchers and corporations approach farmers with a fait accompli. While this is an important mechanism for knowledge dissemination, enabling infrastructure and connections between different parties is likely to have a greater effect, rather than seeking to impose defined interventions on primary producers[104]. Farmer-to-farmer networks, both formal and informal, are highly efficient at encouraging and enabling innovation, while a growing trend is developing where formalised grower's groups pair to partner in optimising their particular production mix.

4.5: Research extension

A related issue to knowledge and skills acquisition is research extension, or the dissemination of and take-up innovation and invention to farmers. The benefits of R&D are only realised

[100] *Harvesting productivity: ABARE-GRDC workshop on grains growth* (2010), ABARES; *Trajectories of change in rural landscapes – the end of the mixed farm?*, op cit

[101] *A deeper understanding of farm productivity* (2011), Kingell, R. et al, Australian Export Grains Innovation Centre/University of Western Australia

[102] *Farmer-driven Innovation in New South Wales, Australia* (2013), McKenzie, F, *Australian Geographer* vol.44, pg 81

[103] *Community-based, Regional Delivery of Natural Resource Management: Building system-wide capacities to motivate voluntary farmer adoption of conservation practices* (2008), Marshall, G.R; for Rural Industries Research and Development Corporation

[104] *Australia's Agricultural Future,* op cit

when farmers choose to put those new technologies, techniques or strategies into practice, which may require individual upskilling[105].

State and Territory governments have traditionally undertaken a major role in research extension, however funding has declined over time from approximately 24% of total public agricultural research expenditure in the 1950s to approximately 19% today[106]. Given shifting government priorities and budget pressures, this trend is unlikely to be reversed, with dissemination of information increasingly viewed as a private issue for individual operators to handle as a business expense[107]. Further, public-sector extension is likely to increasingly focus on sustainability and resource management policy for agriculture, rather than the previous emphasis on productivity and yield growth. As such, the public sector may not be able or willing to assist in serving the whole of the field[108].

To a certain extent, this slack has been taken up by private industry, grower's groups, input suppliers (in an attempt to create a market for their own product), and informal farmer-to-farmer contact[109]. Indeed, some private providers (such as consultants and industry conferences) are rated higher than CSIRO or State government bodies as a source of accurate, relevant information[110].

[105] On which topic, see above at 4.3.
[106] *Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian, broadacre productivity* (2011), Sheng, Y et al, ABARES research report 11.7
[107] *Public-sector agricultural extension – what should it look like in 10 years?* (2013), Pannel, D; Marsh, S, *Farm Institute Insights* February 2013, Australia Farm Institute/UWA School of Agricultural and Resource Economics
[108] *ibid*
[109] *The blueprint for Australian agriculture 2013-2020* (2013), National Farmers Federation
[110] *Are traditional extension methods still preferred? Farm Institute Insights* February 2013, Australia Farm Institute/UWA School of Agricultural and Resource Economics

5: Future farms – technology and innovation

As already noted[111], modern agricultural practices already require a degree of specialist knowledge. Farming employs a range of technologies and practice that require lifelong continued professional development and learning in a climate of expensive capital investment, volatile markets and social challenges[112]. As noted above[113], Australian agriculture, generally very efficient, already operates at or close to production frontiers. In recent decades, productivity growth has slowed to less than half historical averages and is continuing to trend downwards[114]. While many factors may have contributed to this, diminishing public and private investment in agricultural R&D is consistently identified by industry and researchers as a critical factor. Thus, to drive continuing productivity gains, operators will be forced to invest in new methods and explore new technological frontiers.

5.1: Future R&D

Australian agricultural research and development is largely unique in its use of statutory corporations funded by levies imposed on industry matched by government grants. This approach largely removes the free-rider problem[115], and historically, backed by adequate funding of research extension programmes[116], has been largely effective in ensuring Australian agricultural productivity and efficiency[117]. Concerns exist with the current conflict between government and private industry, each suggesting that the other should shoulder more of the burden. Government generally seeks to increase (or un-cap) the levies rendered on industry, while the long lag times between inception and the fruits of research coming to light mean many farmers feel that they receive no benefits in their working lives - although such arguments likely ignore the benefits accruing to the current generations that were paid by other farmers in the past[118].

As research and innovation cannot easily be divided into public- and private-sector benefits, and the knowledge and skills products of research in the sector have many public-good characteristics, the current structural approach on balance remains likely to best deliver future R&D outcomes. However, a decline in funding and a shrinking pool of researchers[119], combined with a change in focus for many institutions, will require a refocus and increased allocation of resources to maintain previous trend productivity growth and hence international competitiveness. To maintain TFP growth at or above 2%, needed to stay ahead

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111 See above at 4.3.

112 *The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations* (2010), Oreszczyn, S et al, *Journal of Rural Studies* vol 26 p404

113 See above at 4.1.

114 See above at 1.3.

115 See also above at 3.1.

116 See above at 4.5.

117 *Australia's Agricultural Future,* op cit

118 *ibid*

119 For more on which, see above at 4.3.

of trend decline in terms of trade, investment in agricultural R&D will need to be returned to historical levels at or about 3% of the gross value of agricultural product[120].

Much of current publicly-funded R&D in the agricultural space seeks not only to enhance productivity, but also to deliver better environmental outcomes, usually seeking to maintain current levels of productivity with less of an environmental cost[121]. As already noted[122], such benefits may not be 'priced' in a way which allows them to be easily assessed in considerations of TFP, but are nevertheless critical for future sustainable operation and balancing of public policy concerns. Further, much R&D is perhaps understandably focused on single systems or single enterprises, seeking to enhance a specific process, or overcome a particular challenge.

As a result, the interactions between systems have been less well studied[123], and the potential for realising efficiencies, linkages and potential future gains in mixed-use farms have been neglected. Notably, nearly half of the worlds food supply derives from mixed crop/livestock systems[124], and the current focus on single-output agricultural systems prevents realisation of mix efficiency and threatens sustainability[125]. An opportunity therefore exists for industry to potentially derive much of the needed increase in productivity and efficiency from pursuing mixed agriculture rather than increasing monoculture production.

5.2: The case for research

Investment in agricultural R&D brings with it a significant return on investment in terms of increasing productivity. While difficult to measure and decouple given the mixed public/private nature of our R&D system, the rate of return on Australian public spending in R&D has been estimated at about 30%[126]. Notably, these measures fail to reflect the entirety of the benefits stemming from R&D – as discussed above at 5.1, significant gains have been made in the areas of sustainability and mitigation of environmental impacts, which are currently not 'priced in' to rates of return. Further, as Australian industry pays only a capped share of the costs of R&D, the rate of return for industry (as opposed to public) spending is greater still.

Australia has not been alone in neglecting agricultural R&D. Since the 1960s, the share of public contributions to agricultural R&D by developed nations has decreased from 58% to 48% by 2009. Over the same period, the contributions from the Asia-Pacific region – notably

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[120] *Australia's Agricultural Future*, op cit
[121] *ibid*
[122] See above at 3.1.
[123] *Evidence of farm-level synergies in mixed-farming systems in the Australian Wheat-Sheep Zone* (2010), Villano, R et al, *Agricultural Systems* vol.103 issue 3
[124] *Smart investments in sustainable food production: revisiting mixed crop-livestock systems* (2010), Herrerro, M et al, *Science* magazine vol 327 pg 822
[125] See above at 4.2.
[126] *The returns from research in Australian broadacre agriculture* (1995), Mullen, J.D, Cox, T.L, *Australian Journal of Agricultural Economics* vol.39 no.2 p.105; *Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian broadacre productivity* (2011) Sheng, Y, et al, for ABARES Research Report 11.7

from India and China – have increased from 20% to 31% and continue to trend upwards[127]. Considering the long lag between public investment and benefits accruing to industry[128], if Australia wishes to remain competitive in the international marketplace over the medium and long term, this decline needs to be addressed in the near future.

5.3: Private investment

Driven partly by necessity caused by a declining public investment, purely private investment in agricultural R&D has been rising[129]. The majority of such investment is directed towards the 'practical end' of the spectrum – private activity in Australia is complementary to public R&D given our unique system[130] and relatively small market. The experience in the US, where private investment makes up 56% of total spending, similarly supports the view that private investment is more concerned with the implementation or monetisation of the more 'blue sky' projects supported by the public dollar. It is thus usually more directed towards the short term, and produces value increases primarily over that period rather than the sustained growth stemming from public sector involvement[131].

As foreshadowed above, agricultural research tends to have many public-good qualities. Thus, private agricultural R&D in Australia can, in addition to finessing and adapting the products of Australian public-sector R&D, 'free ride' off international developments to a certain extent. As an example, Australia private-sector breeders have capitalised on developments made by CIMMYT[132], with the overwhelming majority of Australian semi-dwarf wheat cultivars now either using CIMMYT lines as at least one parent ancestor and 98% of Australian wheat production sown to this ancestry[133].

While forecasting is an inherently imprecise exercise, there appears to be a general consensus amongst industry and private operators as to the technologies with the greatest potential impact over the medium and long term:

1) Better information, allowing smarter decisions to be made faster and enabling other technologies;
2) Increasing automation, increasing productivity and reducing labour requirements;
3) Continued refinement, suiting production to the land rather than trying to force marginal or unsustainable production; and
4) Exploring new frontiers and solving engineering challenges.

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[127] *Agriculture in the global economy* (2014), Alston, J.M; Pardey, P.G, *Journal of Economic Perspectives* vol.28(1) pg121

[128] Estimated historically at 35-50 years, although with decreasing lag times in modern context – *Australia's Agricultural Future,* op cit

[129] *ibid*

[130] *Private sector investment in agricultural research and development in Australia* (2010), Keogh, M; Potard, G, for *Australian Farm Institute*

[131] *Losing the plot? Agricultural research policy and the 2014 Farm Bill* (2014), Pardey, PG et al, *Choices* magazine (Agricultural and Applied Economics Association) 3rd quarter

[132] Centro Internacional de Mejoramiento de Maíz y Trigo / International Maize and Wheat Improvement Centre, El Batan, Mexico

[133] *Analysis of the Impact of CIMMYT Research on the Australian Wheat Industry* (2004), Brennan, J.P; Quade, K.J, economic research report no.25, for New South Wales Department of Primary Industries

5.4: Information revolution

Information is critical to farming. Without knowing what stock are where, their condition, the chance of rainfall, crop condition, disease status, breeding season, nitrogen levels, and the thousand and one other individual variables that can impact production, it is almost impossible for farmers to ensure adequate yields. Increasingly common as part of precision agricultural systems[134], monitoring and information systems can take many forms ranging from simple weather stations through to per-field soil sensors measuring everything from moisture levels and acidity to nitrogen, salinity and root penetration.

Monitoring systems are currently commercially available, in various forms, and it is likely that their usage will become increasingly ubiquitous. As the technology develops, the potential uses will also expand to allow even further gains in efficiency and productivity to be pursued. For example, researchers at the University of Bonn are pairing high-resolution 3D laser scanning of field topography before sowing with regular imaging of crops as they grow to provide accurate indications of plant dimensions and therefore biomass – allowing per-sector assessments of growth patterns. Differential light reflection from plant leaves can even signify the presence of nematodes or other parasites infesting crops, allowing rapid diagnosis and treatment without having to uproot growing crops[135]. In the livestock sector, 'smart' ear tags for cattle allow the collection of a wealth of data, including number of steps taken, jaw movement during rumination, body heat and other key signs of vitality that allow early detection of sick or distressed animals, remotely and long before human feedlot staff can detect distress by eye[136].

Ultimately, the biggest impact of better information will be to enable better decisions – particularly important in Australia, home to some of the most variable rainfall, soil and climate conditions in the world, conditions which will only become more variable as the global climate changes further. In the words of one dairy farmer:

> *"This is one of the worst seasons on record around here and the only thing that has made it survivable has been good, early planning...It was not a pretty plan. It was a survival plan in the teeth of a failed season...Central to our planning were the CSIRO's soil moisture maps and Pastures from Space. Combining the two tools, we could see that not only were our pastures not growing in the peak of Spring, there was little chance they could. The soil was powder dry all the way down to a couple of metres. That can only be fixed by weeks and weeks of rain. In other words, we knew we were stuffed early enough to do something about it, thanks to the CSIRO. It's survivable if we plan early, plan well and it doesn't happen too regularly."*[137]

[134] For more on which, see 4.2 above.

[135] University of Bonn Department of Photogrammetry/Institute of Geodesy and Geoinformation, www.ipb.uni-bonn.de/research

[136] *Technical note: accuracy of an ear-tag attached accelerometer to monitor rumination and feeding behaviour in feedlot cattle* (2015), Wolger, B et al; *Journal of Animal Science* vol.93 no.6 p3,164

[137] *Climate change has not been answered for farmers – we need more information, not less* (2016), MacDonald, M, *The Guardian* newspaper 9 February 2016

5.5: Agricultural automation

The process of mechanisation in agriculture has generally been to add 'force multipliers' to the manual labour input of a human operator – a smooth line from hand sowing and the sickle to multi-row tillers and combine harvesters. Current trends take this development even further by not merely aiding human input to existing systems but by removing it altogether – to move from mechanisation to automation, taking many rote decisions and routine responses off the shoulders of farmers and leaving human operators free to pursue higher-order strategy.

Automation of this kind is highly reliant upon better information, and hence is a natural progression from the development of advanced sensors and connected agricultural infrastructure. Australian farmers are experts in efficiency, deriving the greatest possible benefit from every drop of water and granule of fertiliser, however many of these decisions are simple cause/effect once sufficient information is available. For example, knowing the growth profile and needs of a particular wheat cultivar, together with the available soil moisture and nutrient levels, it becomes readily apparent what needs to be done to ensure maximum growth – there is no need for a human operator to be involved.

Armed with this data, therefore, agricultural robots – 'agbots' – can be programmed with the desired results and crop profile and autonomously apply inputs of fertiliser, water, lime or other soil additives exactly and only when needed. An example currently coming on to the market would be RowBot™[138], a joint venture between Carnegie Robotics and independent corn growers in the US, which is able to autonomously navigate between corn rows and side-dress in-season nitrogen only as and when needed, minimising usage and maximising efficiency and profit. In Australia, SwarmFarm has released its first commercial robot targeting grain production in Queensland, capable of conducting spraying operations around the clock completely autonomously, navigating around obstacles and recognising and precisely targeting weed growth, cutting herbicide use by 40%[139].

5.6: Adapt or perish

In addition to overcoming technical and production challenges, technology may also enable research and crop tailoring to move out of the lab and onto the farm. High-throughput plant phenotyping (HPTT) combines sensors, genetics and robotics to develop new lines of a crop, continually improving nutritive content, drought and pest tolerance. By automating the recording of physical characteristics – phenotypic traits such as fruiting location, stalk thickness, leaf number and so on – and comparing this to already-known characteristics and markers for the variety under cultivation, artificial selection can be sped up by several orders of magnitude over hand selection based on individual observations. Paired with the increasing sophistication of robot labour, farmers could rapidly select for the particular characteristics that suit their own unique soil, rainfall and climate conditions[140].

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[138] www.rowbot.com

[139] *Campbell's Comeback*, Courtney, P; *ABC Landline* broadcast 20 September 2015; www.swarmfarm.com

[140] *Lights, camera, action: high-throughput plant phenotyping is ready for a close-up* (2015), Fahlgren, N et al; *Current Opinion in Plant Biology* vol.24 p93

Farm productivity can also be increased by tailoring responses to pest and weed threats as well. Taking over crop monitoring duties from human labourers allows quicker and more rigorous inspection of existing characteristics used to indicate disease or distress, but also opens up the potential for new avenues of inspection – sampling airborne chemical pheromones or mould spores to detect insect infestation or wheat rust, monitoring high-frequency sounds to pinpoint rat infestations in silos, or, as above, observing differential light absorption from plant leaves to diagnose nematode infection[141]. From that data, a response tailored to the specific pest severity and makeup can be arrived at to suit the needs of that particular operation. Ultrasonics can deter mammalian pests and be fine-tuned to target invasive European species while leaving native fauna undisturbed, pinpoint UV application can selectively sterilise areas affected by mildew while limiting collateral damage, and artificial pheromones can deter pests such as fruit fly without needing recourse to pesticides[142].

5.7: Engineering the future

Continuing capital and engineering investments in agriculture will take new and different forms. In pursuit of increased efficiency, fleet management and rapid response is already part of many farming strategies through existing technologies such as John Deere's FarmSight™ or the Google-backed Farmer's Business Network in the USA, however concerns exist about the proprietary nature of vendor-driven technologies and the potential for users to become 'locked in'. Future capital investment in this area is likely to see increased uptake of autonomous agbots, responsive to human input but needing no human guidance for routine tasks, with farmers taking advantage of advance in 3D printing and small-run production manufacturing to 'roll their own' solutions, customising their fleets and developing their own software solutions, all scaled to their own individual needs[143].

The very mechanics of agriculture may change, too. All farming relies upon efficiency of inputs, however technology has allowed advances in 'closed loop' agriculture that radically increases input efficiency. Primarily seen in hydroponics setups, such systems view food production as a system with inputs and outputs; inputs with costs attached, outputs capable of being captured for profit. Productivity and profitability is therefore a matter of reducing the inputs to a minimum while capturing a maximum of outputs, with the ideal system one that is totally 'closed' – the only products being 'lost' to the system being the food products themselves.

While such concepts are more commonly seen in greenhouses and the relatively new concept of 'vertical farms', the principles are also capable of being applied to broadacre agriculture. As an example, dairy farms produce as outputs not only milk but also copious amounts of manure. In the USA, 98% of dairy farms are not capable of assimilating the quantity of manure produced back into the biological cycles on the land, and as such the remainder of the output

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[141] *Drones as common as tractors? Farm technology in 2025*, McConchie, R et al; *ABC Rural – Queensland Country Hour*, published 27 October 2015

[142] This last example already in commercial usage – see eg. www.semios.com

[143] *Technology is changing the face of northern Australian cattle farming*, Swain, D; *The Conversation* website, published 30 October 2014.

is wasted. A partnership between Fair Oaks Dairy and Bion Environmental Technologies in Indiana saw the excess manure produced by the 27,000 head of dairy cows collected and used in ethanol generation for biofuel, providing for all the energy needs of the cattle operation, while the cattle are fed on the wet distillers grains coproduced by the ethanol process[144].

144 www.fofarms.com