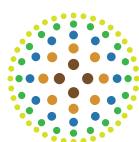


RURAL INDUSTRY FUTURES

Megatrends impacting Australian agriculture
over the coming twenty years

By Stefan Hajkowitz and Sandra Eady
July 2015



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Photographs

Photographs used in this report are sourced from CSIRO: www.scienceimage.csiro.au

Foreword

Resilient, profitable and competitive agricultural and rural industries need to actively consider what is coming and be well placed to respond.

This collaborative project between the Rural Industries Research and Development Corporation (RIRDC) and the CSIRO aims to draw out longer-term trends that might impact rural industries over the 20 year horizon. These trends could create opportunities or challenges and being aware of them should help businesses, industries and governments actively plan and be well positioned for possible changes.

RIRDC's National Rural Issues program delivers independent and trusted advice to industries and governments in areas that cover multiple industries and are nationally relevant. This research project is the first foresighting study conducted under the National Rural Issues program, it lays the foundation for further exploration and insights into future trends, themes and insights. RIRDC intends to build on this work to regularly provide knowledge to support agricultural and rural industry decision making.

This project was undertaken by CSIRO in collaboration with RIRDC. The CSIRO has highly regarded techniques to identify future trends and this paired with expertise in the CSIRO Agricultural Flagship was invaluable for this foundational study. The collaborative approach has been valued and I believe the product developed will be a useful resource over the coming years.

Both the CSIRO and RIRDC encourage you to consider the set of five interlinked megatrends presented in this report for planning and positioning your business, industry, regional community at national and local levels.

This report is an addition to RIRDC's diverse range of over 2000 research publications. Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns

Managing Director
Rural Industries Research and Development Corporation

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Executive summary

Australia's rural industries will be impacted by significant change at global, national and local levels over the coming decades. This will create opportunities and challenges for small and large farm businesses. It will have an impact on rural lifestyles, agricultural landscapes and Australia's society and economy in general. In order to better understand forthcoming change, RIRDC and CSIRO have completed a foresight study of Australian agriculture and rural industries. The narrative of the future is told through a set of interlinked megatrends impacting Australia over the coming 20 years (Figure 1). The aim is to help communities, individuals, companies and governments make informed and strategic choices to secure better outcomes.

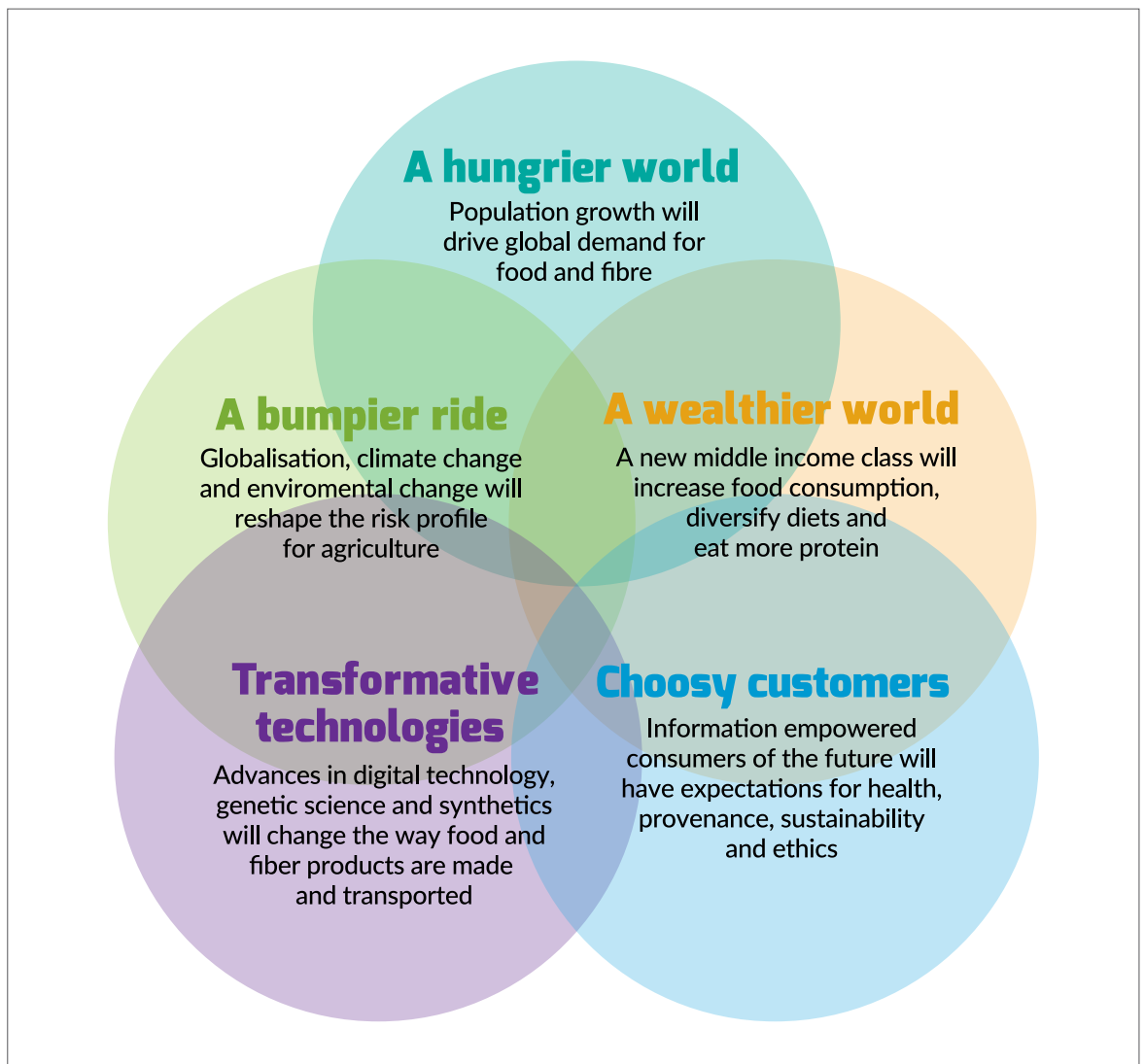


Figure 1: Megatrends impacting Australian rural industries.

A megatrend is a trajectory of change that will have profound implications for industry and society. A megatrend occurs at the intersection of multiple trends which relate to more specific patterns of change. Trends may be classified as geopolitical, economic, environmental, social or technological (GEEST). Researchers at CSIRO have developed techniques to identify trends via horizon scanning, and to synthesise the results into megatrends [4]. The five rural industry megatrends are shown here in an interlinked Venn diagram. Each area of overlap represents a unique story about the future calling for a strategic response.

Rural industry megatrends cover both domestic and global change because Australian agriculture is an export-oriented industry which sells around two-thirds of its produce offshore. Whilst domestic markets will remain important, the big growth opportunities are in emerging markets, especially in Asia, which have doubled or trebled their food and fibre imports in recent years and are set for continued and rapid growth. The megatrends are also focused on rural industries and the forces which have an impact on commodity markets and production costs. Each megatrend has supply-side and demand-side implications for industry.

A hungrier world

The world is getting hungrier because it needs more food. However, that doesn't mean the world can't be fed. Innovation in agricultural production systems, supply chains and governance can supply the required food output. The 'hungrier world' megatrend analysis tells the story of a rising world population and increasing food consumption accompanied by a shrinking global agricultural land area, water scarcity and spiraling energy demand. According to the United Nations Food and Agriculture Organization (FAO), the world must increase agricultural output by 70 per cent to feed its growing population by the year 2050 [5]. However, the world is estimated to be losing 12 million hectares of agricultural land each year to desertification and urbanisation [6]. In addition to this are the challenges of climate change and water scarcity. Australian agriculture has a vital role to play in supplying world food markets and in improving food security. Australia is also well placed to export agricultural expertise and know-how to emerging economies as they seek to develop their own agricultural sectors.

The implication of this megatrend for Australian rural industries is an opportunity to increase exports into expanding global food and fibre markets. As the world wants more food Australia is well positioned—both in terms of geography and comparative advantage—to supply overseas markets. Whilst Australia can't hope to feed Asia or the world it can increase production and increase exports.

A wealthier world

In the second megatrend, '*A wealthier world*', we explore the impact of domestic and international income growth on global commodity markets and on Australia's rural industries. In the developing Asia region alone, some 1.02 billion people will cross an income threshold and move out of poverty and into the middle classes. Average annual incomes are forecast to rise from US\$12,000 per person to US\$44,000 per person by the year 2060 in current dollars [7]. Rising wealth is having an impact on commodity markets. People are increasing their average daily calorie intake which means more food will be demanded. People are moving out of subsistence production and are more reliant on markets for food. Diets are shifting from being solely based on staple foods (for example, rice and grains) towards high-protein foods such as dairy, fish, meat and eggs. Boutique foods such as wine, tropical fruits and nuts are also seeing pockets of strong demand growth in emerging economies—a trend likely to persist into the future. This creates opportunities for Australian agriculture to diversify and to supply new and expanding markets.

The implication of this megatrend for Australian rural industries is an opportunity to diversify exports and grow new markets. The evidence presented here suggests a new wealthy Asian and emerging-economy customer will have a much more diverse and westernised diet. This represents an opportunity for Australian rural industries to identify the new food types and to connect to new markets. A diversified rural export base is likely to be more resilient to within-market supply-and-demand shocks.

Choosy customers

The consumer of the future will be increasingly empowered and motivated to choose food and fibre products with specialised characteristics. Today's consumer has different tastes, preferences and concerns to the consumer of 20 years ago. Organic certification, free-range eggs, health labels and fair trade logos were much harder to find in the supermarket of 1985; farmers' markets were rare events. However, in supermarkets of the year 2015, these labels are commonplace. Farmers' markets occur at multiple locations on a weekly basis in most large cities. The future consumer is likely to have new and stronger preferences. Health is likely to become a particularly prominent driver of food choice and consumption patterns, which has impacts both within and beyond the farm gate. Information technology will increasingly enable the consumer to selectively access, share and validate information about products along the whole farm-to-fork supply chain.

The implication of this megatrend is that Australian rural industries have an opportunity to increase market share by communicating the provenance, ethics, environmental performance and healthiness of their crop and livestock products. Social media and information technology will facilitate the communication of product information.

Transformative technologies

Advances in technology within the fields of digital, genetics and materials science will change the way food and fibre products are created and transported. Genetic technology will allow crop and pasture yields to improve and become more resistant to weeds, pests and climate risks. Advanced sensory systems and data analytics will permit advanced and highly integrated farm-to-fork supply chains. Customers will be able to readily trace food and fibre products from their origins, and supermarkets will have increased tools for quality assurance. Satellite and other remote-monitoring technologies will allow governments and ‘the crowd’ to access information about farm condition and management practices at low cost. Lastly, the world of synthetics is likely to advance rapidly as breakthroughs occur in the fields of advanced materials science and food manufacturing. Cotton, wool, leather and natural fibres are likely to experience increased competition as manufacturers improve the performance qualities of synthetic clothing and footwear. Advances in food manufacturing are likely to see the emergence of more synthetic substitutes for meat and dairy products. Lab-grown, or cultured, meat has already been demonstrated as technically feasible and scientists could improve the technology so it becomes commercially feasible.

A key implication of this megatrend for Australian rural industries is that farmers will have sophisticated tools to assist with decision-making. Big data systems and digital technologies will bring better risk management approaches to Australian agriculture; weather and yields will be much more predictable.

A bumpier ride

Risk is an ever-present characteristic of Australian agriculture. However, the coming decades will see changes in the global climate, environmental systems and world economy which will create new and potentially deeper risks for farmers. This is largely due to the interconnectedness of worldwide environmental and socio-economic systems. The risk profile is set to change. Climate change is elevating the frequency and severity of extreme weather (for example, droughts, floods, bushfires). The globalisation of supply chains, which provide agriculture’s critical inputs (for example, fertilisers, fuel, chemicals), increase the number of links in the production system—and therefore, the risk of supply-chain breakdowns. Weed and pest resistance to herbicides and pesticides is reducing their effectiveness. Biosecurity risk is increasing due to greater movement of people and goods across national borders. However, Australian agriculture has demonstrated an amazing capacity to adapt and respond to risks in the past. With today’s innovative technologies and deeper knowledge base, Australian agriculture is well positioned to respond to risks of the future.

The implication of this megatrend is that the risk profile for Australian rural industries will change into the future. This will call for new and deeper levels of resilience to withstand shocks associated with climate change, environmental change and globalisation.

01

INTRODUCTION



Agriculture has been practised in Australia for many thousands of years. In the early times, Indigenous Australians used systems of ‘fire stick farming’ and foraging strategies to secure a stable and reliable food source [8]. Following European arrival in the late 18th century, new techniques of agriculture were introduced. After an initial period of struggling to escape starvation, the first colony soon developed effective farming practices. In the space of a generation, midway through the 19th century, Australia had hundreds of thousands of hectares of cropland and millions of livestock animals supplying both domestic needs and export markets.

For the 100-year period from 1850 to 1950 Australia’s economy was said to be ‘riding on the sheep’s back’ [9]. We became a dominant producer, selling sheep (wool) and grain products into global markets. This fuelled job creation and economic growth and built the foundations for an advanced and prosperous economy. The history of Australian agriculture is a story of resilience, adaptation and innovation in the face of environmental, economic and social change. Today, agriculture is a mainstay of the economy, underpinning many other industries and providing a significant portion of Australia’s export earnings.

However, this outcome was far from assured in the early years of the industry and at times the existence of the industry may have appeared imperilled. The rural sector persevered through severe and prolonged droughts in the late 1800s and early 1900s which saw sheep numbers decline by 50 percent, cattle numbers decline by 40 per cent and wheat yields decline by 70 per cent [9]. Rural industries navigated economic recessions and depressions which saw commodity prices plummet and unemployment reach unthinkable highs of 30 percent in the 1930s. The agricultural sector continued to expand amidst the turbulence of two world wars, major structural adjustment and declining terms of trade in the latter part of the 20th century.

The Australian agricultural sector also demonstrated a capacity to identify and seize opportunities for growth and to develop new and innovative ways of making food and fibre more efficiently from both economic and environmental perspectives. The history of Australian wheat production reveals continual improvements in yield (often measured as tonnes per hectare) as farmers adopted improved soil-management techniques and agronomic practices. At the time of Federation in 1901, average wheat yields were 0.5 tonnes per hectare; in 1950 they were 1.2 tonnes per hectare; and in the year 2000 they were 1.8 tonnes per hectare—more than three times greater than 100 years previously [10]. A similar story exists for crop, pasture and livestock yields in just about every industry. In more recent times, science is finding ways to retain nutrients and soil on farm paddocks, thereby decreasing the environmental impact. Significant advances are being made in the management of soil degradation, on-farm biodiversity, greenhouse gas emissions and water pollution in agricultural landscapes.

As we become more deeply immersed in the 21st century, more change lies ahead. By many accounts this change is accelerating due to the combined forces of exponential technology growth and rapid expansion of global trade. Global trade matters, because 60 per cent of farm produce made in Australia is sold to other countries. The remainder meets 93 per cent of domestic needs [11]. Technology matters, because it will create new business models, supply chains, synthetic products and sensory systems.

In the context of demographic and social change, the rural sector is set to experience significant shifts in the coming two decades. Existing markets may be extinguished and new markets may emerge. History has shown us that the trajectory of change may be gradual at first but eventually reaches a point where existing models unravel and a new competitive landscape emerges. Those businesses, governments and community groups prepared for the new landscape are likely to achieve better outcomes. In order to help Australia's rural industries anticipate and plan for change, the Rural Industries Research and Development Corporation (RIRDC) has partnered with CSIRO to conduct a strategic foresight exercise on the future of agriculture. The time-frame for the analysis is the coming 20 years – roughly out to the year 2035. However, some of the change described is already occurring and much will still be happening into the more distant future.

This report presents a narrative of the future for Australia's rural industries. The narrative is built upon a set of interconnected trends and megatrends. A 'trend' is a pattern change, projected into the future, with implications for present-day choices. Trends typically have temporal and spatial definition. Trends also relate to a relatively specific issue or topic. Trends may be classified as geopolitical, economic, environmental, social or technological (GEEST). A trend is distinct from a 'background issue' because it has directionality of change over time with either positive or negative impacts on an industry, region, organisation or society. A 'megatrend' occurs at the intersection of multiple trends and describes a more significant and deep-set trajectory of change with profound implications. The megatrend analyses will describe plausible futures to help decision makers working in rural industries to make wiser choices. They have been identified through a strategic foresight process developed by CSIRO.

The description of each megatrend concludes with an examination of the implications for innovation within rural industries. Science, research and technology, in multiple fields spanning engineering, physical sciences and socio-economic sciences, are vital mechanisms for ensuring continued productivity growth and expanding global market shares for Australia's agricultural industries. However, in the area of innovation policy, and all other policy arenas, this document is descriptive rather than prescriptive: it does not attempt to make recommendations about what businesses, governments or communities should, or ought, to do in relation to rural industries. Instead this document seeks to describe forthcoming change in order to inform and catalyse important choices and actions taken by others. The report commences with a brief description of the current profile and structure of Australia's rural industries. The megatrends are then presented with a final section briefly describing the methods.

Strategic foresight process

Strategic foresight is a cross-disciplinary field of study which aims to explore plausible futures and help people make wiser choices. Over the past six years, CSIRO has developed a generic strategic foresight process pioneered through multiple megatrends, scenario planning and strategy projects delivered in diverse industry sectors. This process has been applied in the current study.

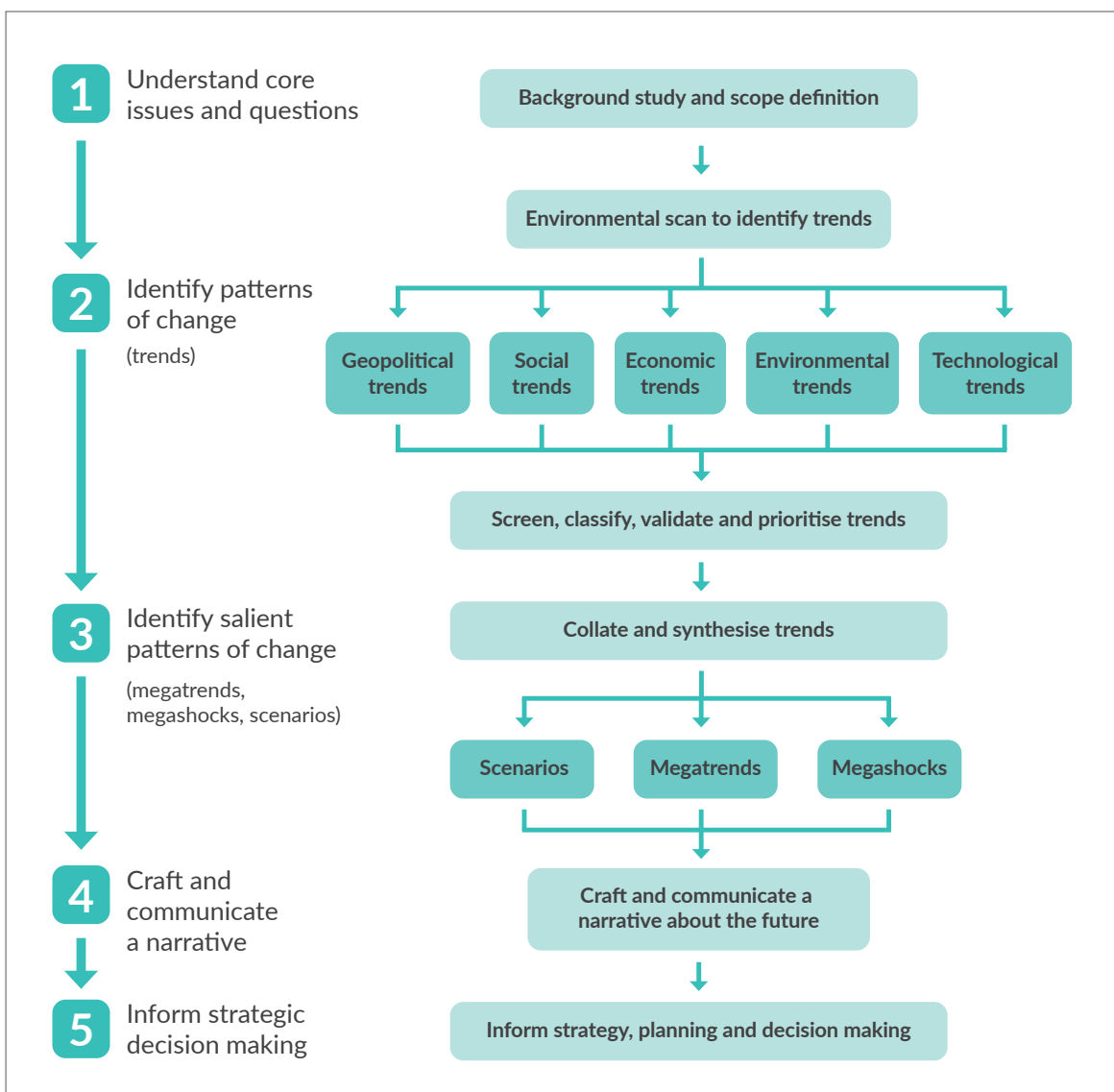


Figure 2: Generic foresight process developed by CSIRO.

The generic process is designed to be adaptable to meet the specific needs of a client. The approach draws on concepts developed by the Shell scenario planning team (which has been in operation for over 40 years) [170, 171]; on the concept of ‘megatrends’ as developed by John Naisbit [172] in the 1980s; on work by The Boston Consulting Group [173]; and on more recent academic publications in the Elsevier journals *Futures* and *Foresight* [174]. The result is a process with five main stages and numerous building blocks (Figure 2).

In the first stage the process commences with a background study and scope definition. The background study documents the current conditions, size, structure, opportunities and challenges within the industry, region or societal grouping being studied. Unlike the forthcoming stages, the background study is concerned with the current status and historic conditions. It does not attempt to look into the future. The scope defines the stakeholder groups, timeframe and issues to be considered throughout the remainder of the project.

In the second stage, trends are identified by horizon-scanning processes. This casts a wide net over all patterns of change which are potentially relevant to the organisation. The environmental scan errs on the side of being overly inclusive rather than exclusive. The trends are typically grouped as geopolitical, social, economic, environmental and technological. However, an alternative and tailored nomenclature can be designed to classify the trends based on the unique needs of the organisation.

Processes of validation and screening are used at a secondary stage to remove any ‘by-catch’ (that is, trends which are unsubstantiated or irrelevant). The screening and validation process checks to ensure trends pass two tests:

- evidence that the pattern of change is actually occurring and likely to continue occurring into the future, and
- evidence that it matters to the organisation.

The process of validation often involves checking the proposed trend against datasets, expert opinions and research findings published in journals to ensure accuracy. Sometimes evidence is found both supporting and undermining the trend and the foresight team needs to make a difficult judgement call about where the weight of evidence lies and whether the trend should be included.

In the third stage the trends are collated and synthesised to identify more salient patterns of change and possible future events which hold significant implications for decision makers. These are captured as building blocks: scenarios, megatrends and megashocks. These building blocks are not necessarily mutually exclusive and a foresight study may use one, some or all in developing a narrative about the future. The final two stages involve crafting and communicating a narrative about the future and then injecting that narrative into strategic decision making processes. The narrative captures all of the relevant building blocks and describes the methods and information sources so that the audience has confidence in the results.

Futurespeak: key terms

Trend: A pattern of social, economic, environmental, technological or geopolitical change that will impact an organization over years or decades.

Megatrend: A more important trajectory of change expressing itself over a decadal period, with far-reaching implications for the organisation occurring at the intersection of multiple trends.

Shock: A sudden and hard-to-predict but known possible event that has a chance of occurring over coming years and decades with either positive or negative impact on the organization.

Megashock: A more important sudden event resulting from multiple trends and shocks with far-reaching implications for the organization leading to irreversible change.

Scenario: A plausible and evidenced-based narrative about the future, at a set point in time, incorporating both trends and shocks, with implications for contemporary decision-making.

Weak signal: A weak signal is a pattern of change which is not widely known, and may be hard to discern amongst signal-to-noise issues, but could impact the organization. Correctly identifying and describing weak signals is key to gaining competitive advantage.

Wild card: A wild card is a 'left-of-field' event that is well outside the commonly considered range of risks before an organization, although it can have a significant impact via indirect pathways.

Signpost: A signpost provides information about a decision that will need to be taken in the imminent future based on trends, shocks and other foresight analyses.

Adapted from [3] Hajkowicz SA, Roy C (2013) Forecasting the future. *Superfunds Magazine* 385

OR

RURAL INDUSTRIES

*And days went by on dancing feet,
With harvest-hopes immense,
And laughing eyes beheld the wheat
Nid-nodding o'er the fence.*

- FROM THE POEM 'SAID HANRAHAN' BY JOHN O'BRIEN

What are the rural industries?

According to the Australian and New Zealand Standard Industrial Classification [1], rural industries ('Agriculture') are broken into the following classes:

- ◀ Agriculture, Forestry and Fishing
 - ◀ Agriculture
 - ◀ Nursery and Floriculture Production
 - ◀ Mushroom and Vegetable Growing
 - ◀ Fruit and Tree Nut Growing
 - ◀ Sheep, Beef Cattle and Grain Farming
 - ◀ Other Crop Growing
 - ◀ Dairy Cattle Farming
 - ◀ Poultry Farming
 - ◀ Deer Farming
 - ◀ Other Livestock Farming
 - ◀ Agriculture support services (e.g. sheep shearing, crop harvesting)

This report also examines future trends for farm forestry and aquaculture as they can be contributors to primary production income and food delivery.

Before embarking on a narrative of the coming 20 years, it is worth setting the stage by describing the current profile of Australian rural industries. Rural industries may be defined as 'a collection of farm businesses, and their employees, using plant and animal production systems to create food and fibre products for human consumption'.

A classification of rural industry types can be drawn from the Australian and New Zealand Standard Industrial Classification (ANZSIC) system, a formal and widely used classification of all industry types. It is regularly updated to accommodate changes in technology, economic activity and new products entering the market. Under ANZSIC, rural industries are grouped within Division A: Agriculture, Forestry and Fishing (see Textbox 1). In addition to these categories, farm forestry and aquaculture can be considered part of 'rural industries' and are given coverage in this report.

Production

Australian farms supply 93 per cent of the food needs of the nation [11]. In financial year 2012/13 Australian agriculture produced food and fibre commodities worth A\$48 billion. Some of the major commodities included beef cattle (A\$7.7 billion), wheat (A\$7.2 billion), vegetables (A\$3.8 billion), dairy products (A\$3.7 billion), fruit and nuts (A\$3.7 billion) and wool (A\$2.5 billion). Collectively, these six commodities accounted for 60 per cent of total agricultural production [12]. Australia's rural industries contribute 3 per cent of Australia's gross domestic product. However, an analysis by a peak industry association, the National Farmers' Federation, found that when the value-adding processes which occur beyond the farm gate and the broader sphere of economic activity associated with production are accounted for, agriculture's contribution to gross domestic product is around 12 per cent (or A\$155 billion) [13]. When adjusted for inflation and expressed in current prices, the gross value of agricultural output in Australia has increased slightly over the past 40 years. During this time, farmers' terms of trade (the ratio of prices paid to prices received) have fallen substantially (Figure 3). The fact that farmers have increased output despite declining terms of trade attests to the adaptability and innovation of the rural sector.

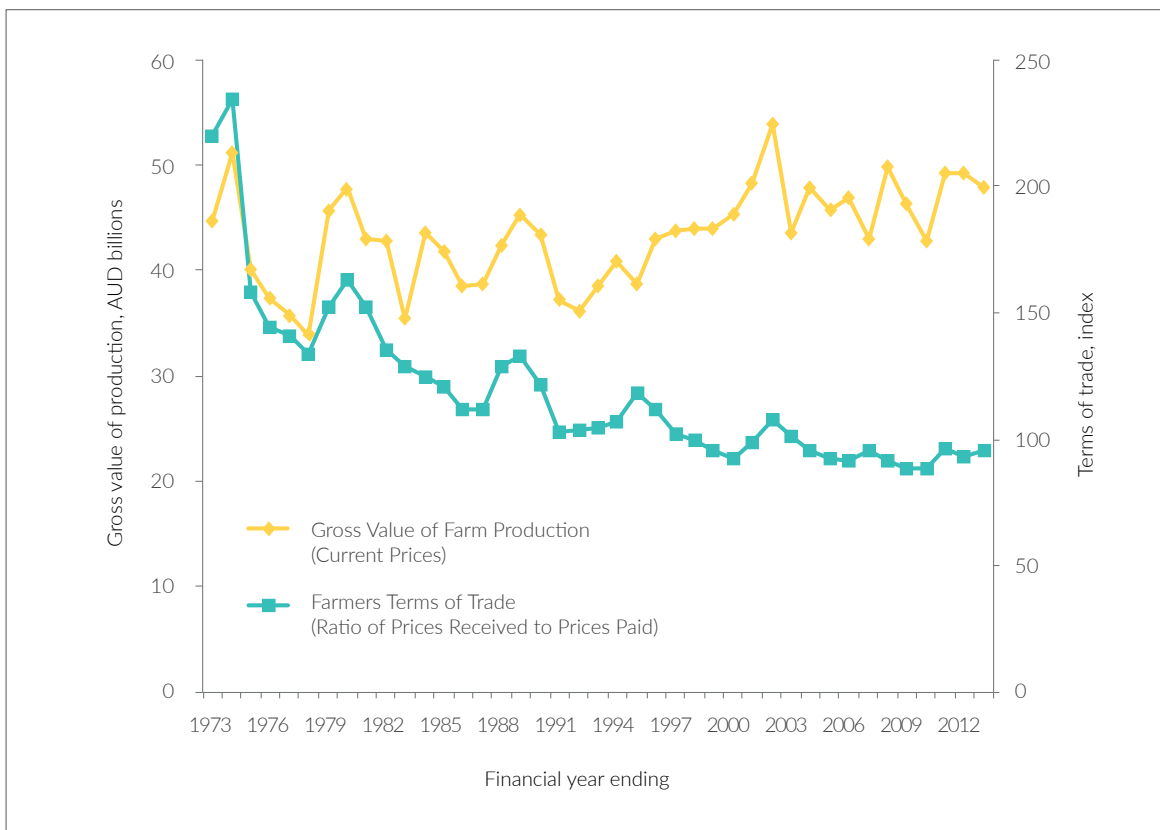


Figure 3: Gross value of farm production and terms of trade

Source: Australian Government Department of Agriculture [14]

The area of land used for farming in Australia has declined gradually since the 1970s. In the year 1973 Australia had some 500 million hectares (65 per cent of the country’s total land area) used for farming. This has fallen to 400 million hectares today. However the area used for wheat and other forms of cropping has substantially increased—from 7.6 million to 12.8 million hectares (wheat) and from 4.6 to 11.4 million hectares (other crops). Over the same period, beef cattle numbers have remained relatively stable, hovering around 25 million head. In comparison, dairy cattle and sheep numbers have fallen substantially from the early 1970s to today. Over this period, dairy cattle numbers decreased from 4 million to just under 3 million and sheep numbers roughly halved from 140 million to 74 million [14].

Exports

Australian agriculture is an export-oriented industry and is impacted by movements in global markets. Around 60 per cent of what we produce is sold offshore [13]. In the financial year ending 2013, the Australian agricultural sector generated total exports of A\$38 billion, which represents 13 per cent of Australia’s A\$300 billion in total goods and services export earnings for the year [15]. When viewed as a time series, the dataset on agricultural

exports reveals strong and rapid growth (Figure 4). When expressed in current prices (that is, with inflationary effects removed), Australia's total export earnings for agriculture have increased from A\$3.4 billion in 1973 to A\$40.3 billion today. In the last three years, as the world moved out of the Global Financial Crisis (which saw all economic activity plummet), agricultural exports have achieved average annual year-on-year growth of 10 percent. The main export earners are cereals/grains, sugar, meat and wool. However, during the 1990s exports diversified into many other rural industries. Today the 'other' category is by far the most dominant and contains farm, forest and fisheries products, including wine; paper and paperboard; and fish transhipped at sea or captured under joint venture agreements, which are not included in rural exports by the Australian Bureau of Statistics.

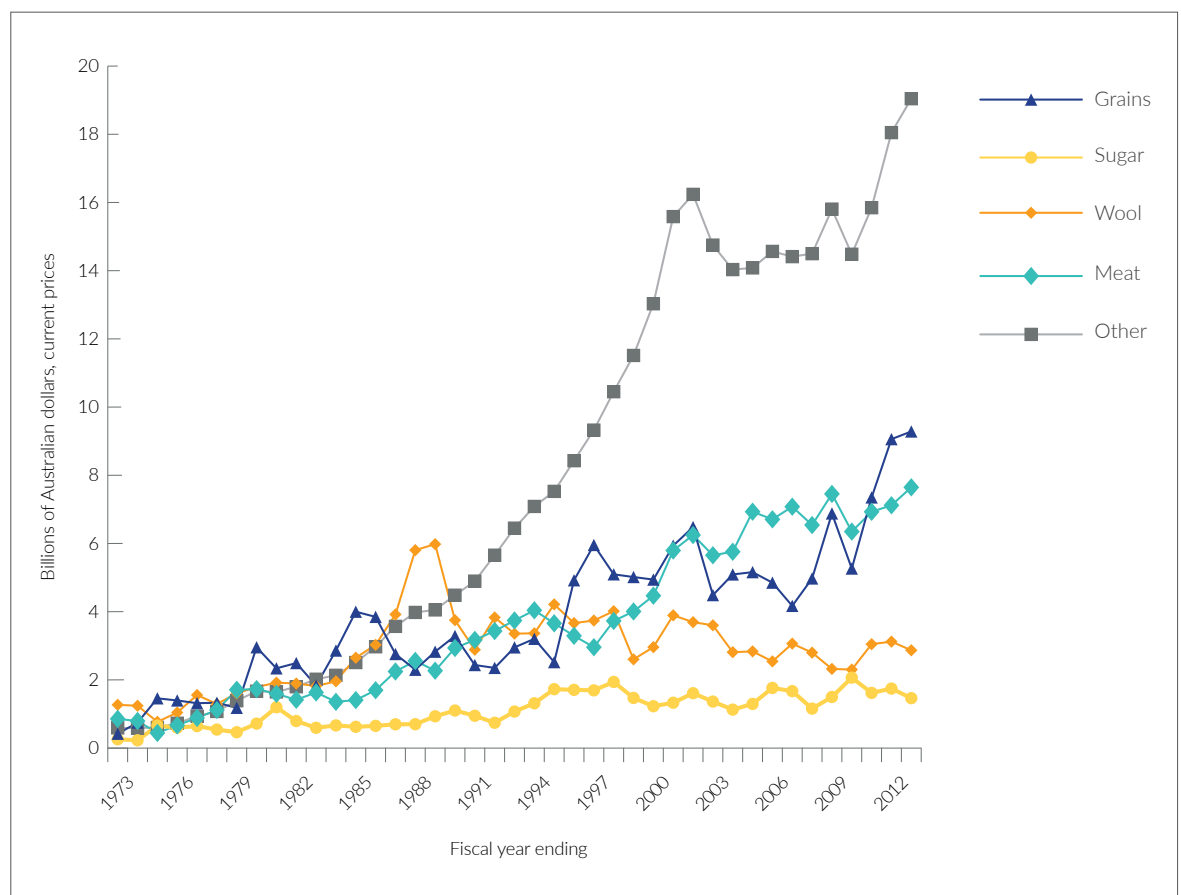


Figure 4: Rapid growth and diversification of Australian agricultural exports (current prices)

Source: Australian Government Department of Agriculture [14]

One of the important reasons Australian agricultural exports have risen so sharply is demand from emerging economies in Asia and, to a lesser extent, Africa. Exports of rural produce to Europe, the Americas and the Oceania region have remained relatively stable with slight increases or (in the case of some countries within these regions) slight decreases. However, the North Asia and Southeast Asia regions have shown very strong growth. For example, China has more than doubled its imports of Australian agricultural produce over an eight-year period, from A\$2.9 billion in the fiscal year ending 2006 up to A\$7.8 billion in the fiscal year ending 2013. Indonesia, Malaysia, the Philippines, the Republic of Korea and Singapore have also grown their imports. One exception in the Asian region is Japan, which has slightly contracted its total imports of Australian farm produce, from J\$4.9 to J\$4.3 billion, over an eight-year period leading up to the current time.

Liberalisation of global trade, particularly for agricultural products which are highly protected in many economies, has been slow. However, there has been an increase in bilateral and regional free-trade agreements which have yielded benefits for Australian agriculture. Equally, Australia has benefited from operating in a business environment with low levels of protection, as this has driven significant improvements in productivity [16]. Trade liberalisation is likely to have a large impact on Australia's ability to export into the region and a free trade agreement with China and our participation in the Trans-Pacific Partnership will be key drivers for future export growth.

Overall, these data reveal that global markets are an important and dominant source of growth for Australian agricultural industries. Domestic markets are obviously important and will remain so. However, they are less likely to be where the really strong growth opportunities lie. These datasets also reveal the power of emerging market economies within our direct region.

Demographic and industry structure

The demographic structure of Australia's rural industries reveals a shrinking workforce, a declining number of farm businesses and an ageing workforce (Figure 5). Compared to other wealthy economies, Australian agriculture receives relatively small subsidies. Much of the current industry structure is documented in a recent publication by the Australian Bureau of Statistics [11]. The results are summarised in this section.

According to data from the Australian Government Department of Agriculture [14], the rural workforce has shrunk considerably over the last decade. In many cases farmers have retired and their children have chosen to take up jobs in towns and cities, which eventually leads to sale of the family farm. In other cases, farmers have opted for jobs in different industries.

Much of the reduction has happened in the last 10–15 years. In 1970 there were 450,000 Australians who identified themselves as farmers. In 1980 this had fallen to 414,000, but by 1990 it had risen to 432,000 and remained level until the year 2000. The agricultural workforce then started to contract, shedding 110,000 jobs and reaching a total population of 321,000 today. Data reported by the National Farmers' Federation indicate that the 'farm dependent economy' workforce is much larger, at 1.6 million people (17.2 per cent of the total Australian labour force).

As workforce numbers have decreased, labour productivity has increased—which is essential to maintain and grow industry output. ‘Labour productivity’ is the industry output divided by the number of workers and is a measure of the efficiency with which workers convert raw inputs into the final consumable products of a particular industry (food and fibre in the case of agriculture). Productivity improves over time due to innovation and to the discovery of new ways to make more product with the same or fewer inputs.

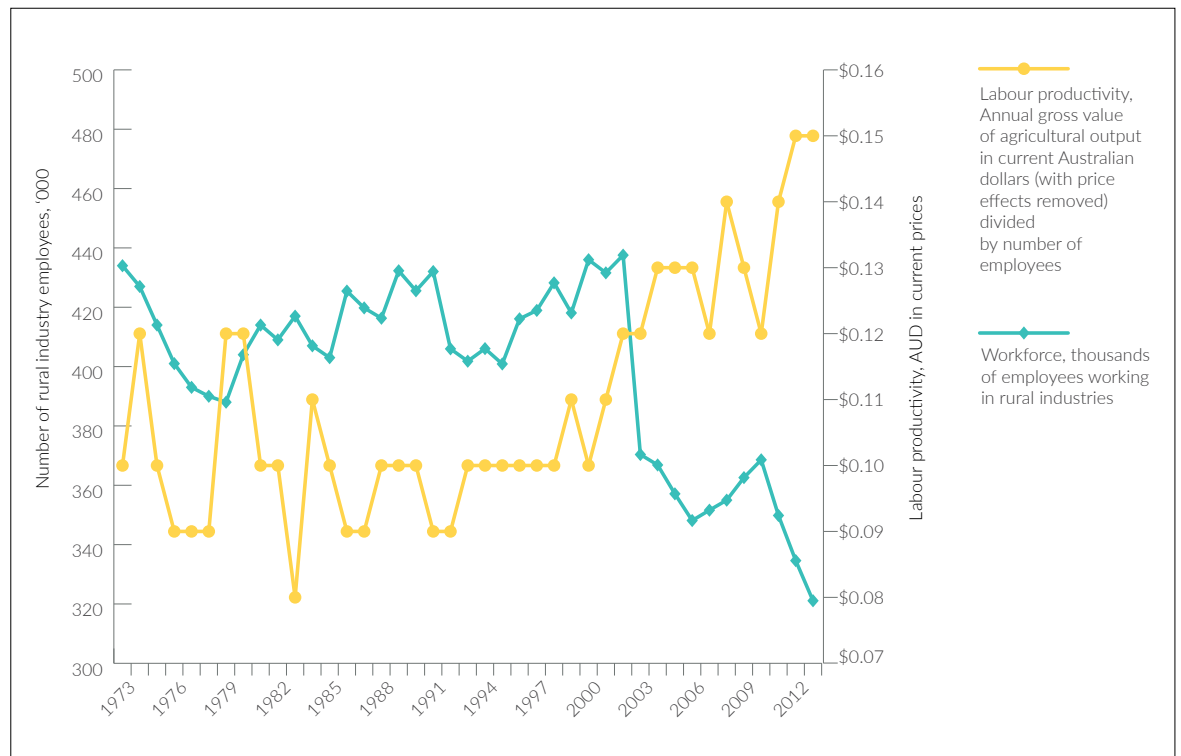


Figure 5: Declining workforce and increasing labour productivity in Australian agriculture

Source: Australian Government Department of Agriculture [14]

In 1970, Australia had 192,550 farm establishments. This number has fallen each year since then and today there are 135,692 farm establishments [14]. The trend has been towards amalgamation and increased size of operations. Despite the shift towards larger farms, the majority (55 per cent) remain relatively small enterprises with a value of operations below A\$100,000 per year. A small number of farms (7700 or 6 per cent of the total) have operations which exceed A\$1 million per year. The land area occupied by farm establishments shows a similar skewed distribution, with 72 per cent having less than 500 hectares. The nation has 100 super-sized farms which cover over 500,000 hectares each. Beef cattle farming is the largest category for Australian farm businesses (28 per cent), with the next most common categories being mixed grain, sheep or beef grazing (18 per cent).

Australian agriculture is distinct because it receives relatively low government (public sector) subsidies compared to other countries (Figure 6). Subsidies occur when a government uses taxation revenue to make payments, either directly or indirectly, to businesses working in a given industry. According to data from the Organisation for Economic Cooperation and Development (OECD), Australian farm subsidies are 4 per cent of gross receipts, compared to an average across all OECD nations of 22 percent. In Korea, Iceland, Switzerland and Norway, subsidies are over 50 per cent of gross receipts [17]. Global agricultural markets in which Australia competes are subject to many other forms of policies with an impact on trade, including import and export restrictions and tariffs.

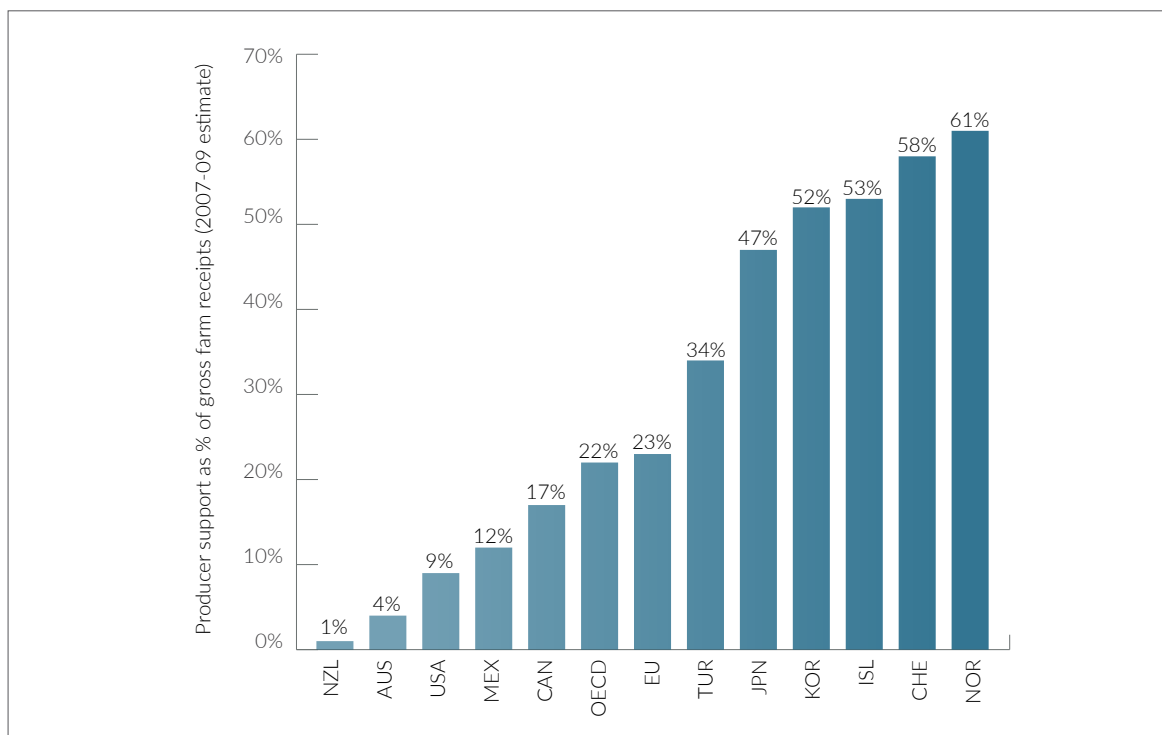


Figure 6: Producer support as a percentage of gross receipts (2007-09 estimate)

Source: The Organisation for Economic Cooperation and Development (OECD) [17]

Innovation and R&D

Australian rural industries have achieved strong productivity growth due the development and adoption of technology. According to the Australian Productivity Commission, real agricultural output has more than doubled over the 40 year period leading up to 2004 and agricultural exports have tripled. Furthermore, the rural sector has achieved remarkable productivity growth during the 30-year period from 1975 to 2004, with 2.8 per cent year-on-year growth. This has continued to occur through commodity price cycles and three droughts and commodity price cycles.

This growth is partly the result of development and adopting science, research and technology products. A study by the Australian Government Department of Agriculture [18] found that public sector investments in broadacre R&D have generated internal rates of return of between 28 and 47 per cent per year, making them high-performing investments. The same report notes total factor productivity (TFP) growth of broadacre cropping has increased at the rates of 0.33 per cent from R&D and 0.27 per cent per year from extension (processes to encourage adoption of technologies and practices) (0.6 per cent per year in total).

Australian expertise in agriculture is highly sought across the globe. Whilst the mining industry has begun to document and describe the size of the mining, engineering, technology and services (METS) sector, comparatively less is known about the current or potential future size of Australia's agricultural 'know-how' sector. However, centuries of R&D which has been tested and proven in practice is likely to have built a diverse and valuable agricultural knowledge industry.



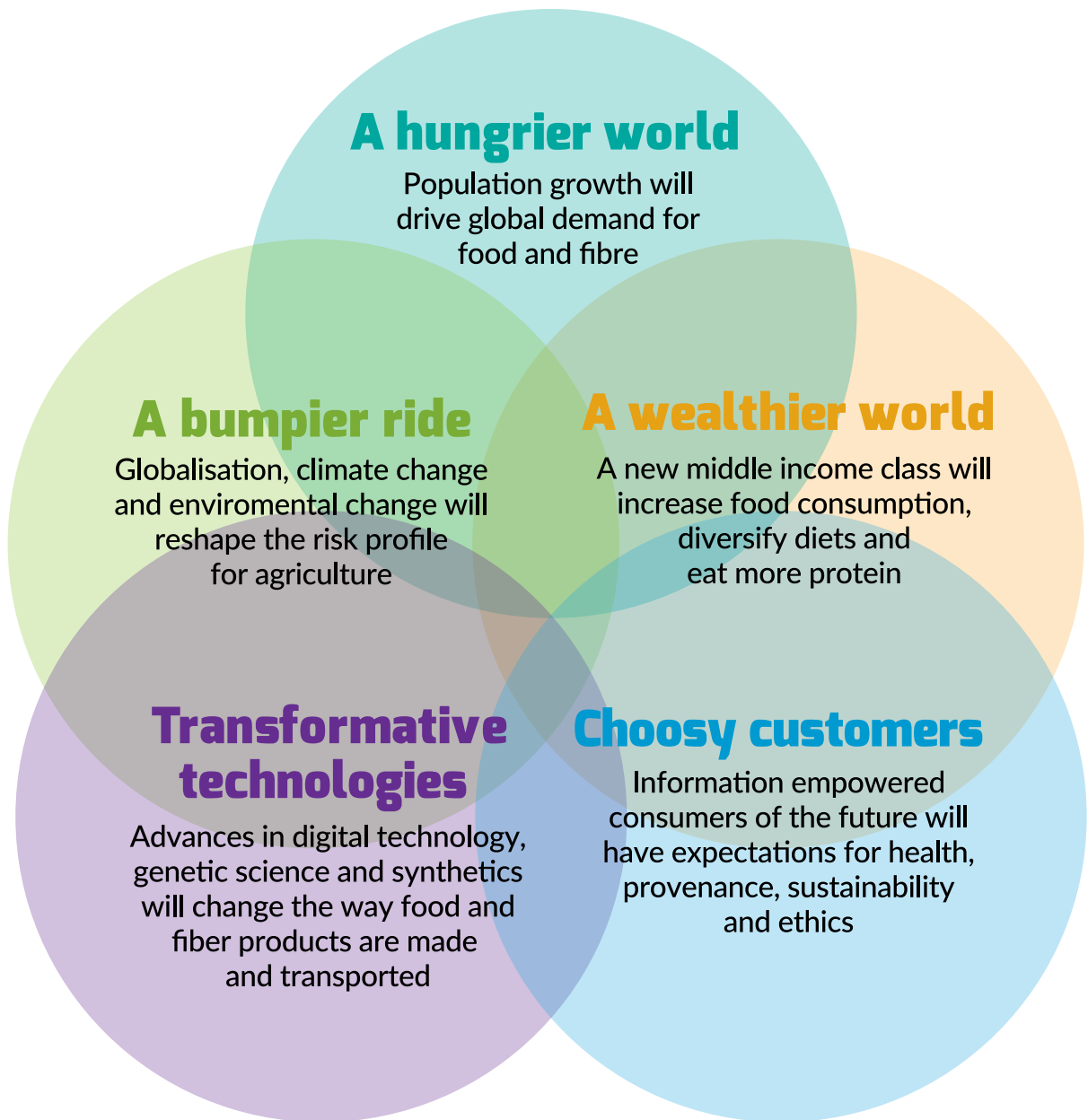
Summary of industry challenges

Based on this snapshot of Australian rural industries, several themes emerge which represent key opportunities and challenges for the industry at the current time:

- Continued productivity gains (including labour productivity) are required to deal with competitive terms of trade and an ageing labour force in agriculture
- Australian agriculture is predominantly export-oriented, a sector with real comparative advantage and a crucial part of the economy now and in the future. This export orientation means the sector benefits from, and is reliant on, the performance of these global markets
- Variability in returns to agriculture has increased significantly due to increased climate variability, volatile exchange rates and fluctuations in market demand. Skills and systems to effectively anticipate and manage these increasing risks are a crucial component of the future for the sector.
- The trend to fewer, larger farms continues in response to the need for improved competitiveness. While new business models are emerging, the family farm remains the most common ownership structure and it increasingly faces pressure to grow and to maintain efficiency.
- Rural industries must continually grow and diversify exports in response to structural change in emerging economies [19]. As more people (in the Asian region especially) join the middle-income classes, there will be a stronger demand for conventional products and for a more diverse range of food and fibre products.
- Access to quality production resources (arable land, reliable water) and proximity to markets remain major factors in planning for increased production capacity.

The following sections of this report explore the future for the food and agriculture sector through the lens of these megatrends. The findings suggest a continuation of some longstanding and well-understood trends, as well as shifts that will potentially change the 'playing field' and open up both opportunities and challenges for the future.

MEGATRENDS
IMPACTING
AUSTRALIAN
RURAL
INDUSTRIES



OB

A HUNGRIER WORLD

*“We have the means to do it.
We can banish hunger from
the face of the earth.”*

- HUBERT H HUMPHREY, VICE PRESIDENT OF THE UNITED STATES

The world as a whole will be consuming substantially more food in 20 years, and substantially more again in 50 years, than it does today. This is due to rapid population growth and increasing per-person food-consumption rates. The result is a large increase in global demand for food and fibre products. Australia's rural industries, along with rural industries from many other countries, have an opportunity to respond to this demand growth.

Although the world is 'hungrier' for more food, there is much reason to be optimistic that hunger will be increasingly alleviated. Innovations in agricultural production systems and improved supply chains have the potential to meet and exceed global food demand. The United Nations Millennium Development Goal of halving the number of people who suffer hunger between 1990 and 2015 is on track to be met. Whilst the vital challenge of ending hunger is enormous, the world's agricultural system is equal to this task; a world where everybody has enough to eat is within reach.

The 'hungrier world' megatrend analysis examines the issues of supply and demand for agricultural products on a global scale. As the world wants more food there is an opportunity to increase the quantity and diversity of food and fibre exports. Demand growth creates an opportunity for Australian agriculture to supply new and growing markets and, at the same time, to improve food security.

World population growth. Population growth is a key factor in global food supply-and-demand dynamics. Based on population growth trends, there will be about 2.3 to 2.4 billion more people on earth by the year 2050. This is an increase of almost 10 billion [5]. Most of this increase will be in developing countries—those with the lowest per-capita gross domestic product (GDP) and currently a sub-maintenance-level food consumption. There is also uncertainty about the magnitude of the increase in developing nations, where the increased population will reside, and the risk of hunger is amplified as these are the countries least able to respond. Revisions of population growth have been most dramatic for countries like Zambia, where the population was predicted to grow from 12 million in 2005–07 to 29 million in 2050, but this has now been revised to 45 million in 2050 [5].

When does population growth stop (or reverse)? Predictions are that populations in developed countries will start to decline from the mid-2040s—a trend that is already evident in Russia and Japan but unlikely to manifest in Australia due to its immigration policy [20, 21]. East Asia (largely influenced by China) will have negative growth from the early 2040s; Latin America in the early 2060s; and South-Asia in the mid-2060s. Growth will be asymptotic in the Near East and North Africa in the mid-2080s. After 2080 the only region with still growing population will be the sub-Saharan Africa [22]. Population growth in Africa is predicted to be high for longer because of a rapid decline in infant and child mortality, whilst female fertility remains high. Whilst family planning services have been able to reduce fertility by about one child per woman, it is economic and social development that will have the largest impact on population growth [23].

How much more food is needed? Using 2005 as a baseline, about 60–70 per cent more food will be required to meet demand by 2050 [5]. The projected increase is based on both predicted population growth (making up 70 per cent of the growth in food demand) and predicted income growth (30 per cent of food demand). It is significant to note that the required growth rate of global production will be lower than in the past [5], so the task of feeding a burgeoning population is not a new one for agriculture. Past improvements have lifted available food to 2770 kcal per person per day [5], which is adequate to ensure a well-fed population. But the distribution of this food remains problematic, with a third of the world's population currently existing on 1840 kcal per person per day, a less-than-maintenance energy intake [24]. Improvements in food consumption have generally followed an increase in GDP, with the exception of India (an anomaly for which there is no ready explanation) [5]. Split into meat and cereals, the relative growth required to meet demand in 2050 is about 46 per cent for staple grains and 76 per cent for animal protein. While these increases lead to an overall improvement in nutritional standard in most countries, this would still leave 320 million people (3.5 per cent of the population) poorly fed by 2050 (a considerable improvement in terms of the percentage of hungry people but a far lesser improvement in absolute numbers, as the world's population grows).

Food supply and the power of innovation. Across the ages there have been strong views put forward that uncontrolled population growth will lead to a collapse in society brought about by natural limits to food and energy. Early proponents were Thomas Robert Malthus with his *Essay on the Principle of Population*, followed with more recent entreaties such as Paul Ehrlich's *Population Bomb* and the predictions of the Club of Rome. However, a cataclysmic collapse in human population has not come to bear, largely due to the ability of food producers to respond to increased demand through innovation. The 'Green Revolution'—where the world saw widespread application of improved plant varieties, increased water and nutrient inputs, and farm mechanisation—allowed growth in food production to outstrip demand during the latter quarter of the 20th Century [5]. The world's agricultural producers are well positioned to meet food demand in the coming decades, as they have in the past. However, there are considerable challenges on the path ahead: much more food is needed.

More food from croplands. Although improvement in crop yields in most countries has slowed over the past decade, yield improvement is still the major contributor to growth in global food output. Going forward it is expected that 80–90 per cent of the increase in crop production required will come from improved yields. This includes yield growth of over 70 per cent in developing countries and close to 100 per cent in developed countries [5, 25]. If yields improve globally by 1 per cent per annum, which appears to be a realistic target [25, 26] given recent trends and yield gaps, this increase would provide the 46 per cent growth required to meet global demand without the need for further expansion of land area under cropping. But given there will be increased demand for gains for livestock production, it is anticipated that additional land will be required for arable use. In addition to this, there may be unforeseen demand for land resources for biofuel production and carbon sequestration; when coupled with the adverse impact of climate change on crop production, there will be mounting pressure to bring more land into production to avoid a grain deficit.

There has been an expansion in cropping area, largely in South America, Asia and Africa, but globally the harvested area of land has been relatively stable since 1960 [5]. A significant part of the increase in global trade in grain has been the result of nations changing their export profile, with countries such as the Russian Federation and the Ukraine growing significantly as grain exporters [5] as open market forces have come into play following the structural changes from the break-up of the USSR [27].

More food from livestock. Increased output in the order of 1.4 per cent per annum would be required to meet consumer demand for meat products by 2050. This is unlikely to be achieved in grazing systems in developing countries without significant technological advances and industry development. However, the Australian northern beef industry achieved 1.8 per cent and dairy 1.4 per cent growth in output over the last 2-3 decades [28, 29]. The projections for meat production show that the increase in livestock numbers will remain significant, but less so than in the past. Higher carcass weights will play a more important role in beef and sheep meat production, while higher off-take rates (shorter production cycles) will be more important in pig and poultry meat production [5]. Increased demand for animal protein will be across-the-board but more so for chicken and small ruminants [5, 30]. Additional requirements for stock feed (up to 14 per cent of grain production) will put increasing pressure on supplies and may require new land to come into production. Demand for stock feed will be increasingly driven by developing countries, rising from the current level of 42 per cent to 56 per cent of coarse grains by 2050, reflecting the strong growth trend since the early 1990s [5]. There is strong trend for larger-scale livestock producers to show the greatest improvement in total factor productivity; hence we can expect to see increasing pressure for building scale in these industries [29].

The potential for continued yield growth. 'Yield' is the quantity of output product (for example, tonnes of wheat) as a ratio of inputs (for example, hectares of land). 'Yield gaps' (Table 1) are the difference between potential yield and actual farm yield. The presence of a yield gap indicates that crop production can be increased through the adoption of improved technologies and practices [25, 31]. Yield gaps are currently largest in developing countries where technology adoption is lower [25]. Some countries do have 'spare' land [5, 32] (including Australia) and the quickest way to get extra production into the market is to expand the area, by bringing new land into arable production or swapping land to the more profitable crop. Even though there will be some increase in land under cultivation, increases in yield, which have been critical in the past, will continue to be the major source of expanded food production. To achieve these yield advances, investment in research and development to address technical constraints and to lift yield potential is essential [31]—as well as investment in system capacity, from farmer skills through to transport and reliability of markets [25]. The yield gap for livestock can be viewed in a slightly different context. Improved livestock production can be driven by intensification, as seen in the poultry industry and with cattle feedlots, and is not constrained by water and land resources directly. However, it manifests itself as an increased demand for grain, so the yield gap in cropping productivity is important in determining overall availability of animal protein. Overall there is considerable opportunity to increase food production by using technology and improved production practices to close the yield gap.

Table 1: Global estimate of growth in farm yield and current yield gap (difference between potential yield and farm yield as a percentage of farm yield) for major crops

Crop	Yield growth p.a. (linear slope expressed as a per cent of 2009/2010 farm yield)	Yield gap percent (Potential Yield-Farm Yield)/Farm Yield
Wheat	1 percent	48 percent
Rice	1 percent	57 percent irrigated, 123 percent rain fed
Maize	1.5 percent	36 percent US, 96 percent China, 400 percent eastern Africa
Soybean	1.0 percent	30 percent
Canola, oil palm, sugar beet, cowpea	>1.5 percent	<50 percent in developed countries, >100 percent in developing countries
Sorghum and pulses	Close to zero	<50 percent in developed countries, >100 percent in developing countries

Source: Adapted from data produced by the Australian Centre for International Agricultural Research [25]

More land can be converted to agriculture. An assessment of 'spare' land at a global level shows that 1.4 billion hectares could be converted to rain-fed arable agriculture [5]. Estimates of growth in crop area are in the order of 10–20 per cent [5, 25]. Converting spare land to arable production would largely be at the expense of pastures, increasing the pressure on livestock industries to intensify. Future competition for land will come from other sectors such as urban development, biofuels, mining and conservation for socio-environmental purposes. Queensland recently completed a 'land audit' [32] which shows the level of expansion that would be possible if the market drivers existed for food production (Table). Without drawing on protected or reserved areas, the potential expansion for horticulture (150 to 400 fold) was substantial, while sugar had the potential to expand 12-fold and broad acre cropping 3-fold. This expansion would be at the cost of pasture land. However, there was only a small (5 percent) potential for grazing expansion into new land.

Table 2: Land use change for expanded food production for Queensland (extracted from [32]).

Queensland land use	Current land use		Potential land use	
	Area (ha)	Percentage of state	Area (ha)	Percentage of state
Broadacre cropping	3,547,778	2.06	10,921,561	6.34
Sugar cane	565,162	0.33	6,997,216	4.06
Perennial horticulture	87,829	0.05	12,827,225	7.45
Annual horticulture	47,166	0.03	21,848,591	12.68
Grazing	147,926,860	85.87	155,729,682	90.39

Irrigation water and production increases. The potential to increase production through more irrigation (on existing or new arable land) is minor, estimated at some 22 million hectares globally [5]. This is because most of the unallocated renewable water resources (located in China and India predominately [5]) are not located where there is water scarcity and arable land that would respond to irrigation. The potential for expansion is even more uncertain, given the current use of non-renewable water sources (fossil water in underground aquifers) and the effect of higher global temperatures on plant water demand and rainfall patterns. Demand management will play an important role in improving water use efficiency in water scarce regions; the need is not for new water but for better management of existing water stocks.

The impact of trade on global food systems. To meet food global food demands the global trading system will continue to expand and dominate supply [5, 25]. Developing countries are predicted to greatly expand the amount of food they trade, both exports and imports; hence a dependable market for food is essential. This includes not only the removal of trade distortions but also a global system that can avoid price shocks as seen in 2008 and 2011. Progress towards free and fair trade is slow but measurable, and measures have been put in place to better monitor global production of staple foods [33] so that shortages can be anticipated and appropriate resources factored into supply management to avoid humanitarian crises. This will see a trend towards international collaboration to apply advanced technologies such as earth observation systems to collect and validate production (for example, GEOGLAM) [34]. Some trends in global food trade will be predictable—such as growth in trade for developing countries outstripping that for developed countries [5]. But patterns of trade may be less predictable, as externalities such as more extreme weather events (such as Australia’s Millennium drought); geo-political tensions (for example, trade sanctions with Russia) and trade agreements influence particular markets on a short–medium term basis.

Access to capital. Capital investment is a critical enabler for growth in any sector. To meet future food demand, the United Nations Food and Agriculture Organization has estimated that an additional investment of \$83 billion annually will be required in developing countries to allow them to meet food needs by 2050 [35]. Financing these improvements requires functioning capital markets and incentives for both farmers and the private sector to invest. Capital for agricultural development is predicted to come from a number of sources [36]:

- Private equity via structured agricultural investment funds (which assist in mitigating the risk associated with the agricultural sector by diversifying investments)
- Growth of a new investment class termed microfinance investment vehicles
- Public–private partnerships with public money (both national and provided by donors) facilitating investment with high national interest
- Sovereign investment by countries (for example, China and Saudi Arabia).

As well as direct investment in agriculture, there needs to be a corresponding investment in improving enabling infrastructure such as roads, rail, airports and port facilities and in human capacity, through investment in education and health.

Investing in agricultural research and development. Improvements in productivity rely on a strong innovation system, which has historically yielded high returns for agriculture with benefit-cost ratios of 8–12 [37] under Australian conditions, with similarly high ratios, albeit more variable, for investment in developing countries [38]. The lag period for returns can be substantial, with periods of 30–35 years often considered typical for agriculture [39]. Despite the favourable relationship with research, development and extension, the trend for investment has shown a distinct decline over the last 10 years [25], and coupled with the decline in improvement in productivity, this has been mooted as a possible cause. If productivity increments are to supply the majority of the increase in food production required, then continued investment in R&D is critical to ensure that ‘potential’ food turns into ‘real’ food on the ground.

Agriculture, energy demand and biofuel production. As food demand grows there may be a corresponding increase in demand for land to meet the burgeoning market for renewable energy and to achieve greenhouse gas mitigation targets. This will be driven by national, regional and international policy on climate change. Currently there are a mix of policy instruments being used internationally to curb greenhouse gas emissions [40]—emissions trading schemes, carbon taxes and direct action through regulation or incentive schemes such as renewable energy targets, caps on industrial emissions, and the Australian Government Carbon Farming Initiative. Internationally, political resolve is strengthening to see action on climate change, as evidenced by the US-China joint announcement in November 2014 on climate change and clean energy cooperation. Biofuels currently use 16 per cent of the US maize crop, 54 per cent of the Brazilian sugar crop and 9 million tonnes of vegetable oils. This represents marked growth over the last decade [5]. These values are predicted to grow over the next decade at a similar rate, to 12 per cent, 28 per cent and 14 per cent of world coarse grains, sugar cane and vegetable oil used for biofuel production [41].

A change in energy policies could impact markets. Most projections of biofuel production are for current global policies. However, if there is a shift away from fossil fuels, the demand for feedstock and land will escalate. Biofuel prices will also be determined by policy—both policy that is directly related to greenhouse gas mitigation (and hence a rise in competitiveness compared to fossil fuels), as well as specific policy governing biofuel targets and the required greenhouse gas ‘savings’ that need to be demonstrated by feedstock [42]. These latter policies may serve to temper the flow of food into the biofuels supply chain, as increasing concern regarding the ethics of the industry play out [43]. However, many second-generation biofuels also rely on land for production and, unlike food, which has a natural bound on its demand, the energy market will continue to grow with GDP. Energy markets are large compared to food markets.

Agriculture and carbon sinks. To date the conversion of agricultural land to carbon farming of trees has largely operated in the voluntary market with little pressure created to convert land. The rate at which the market for carbon offsets will grow is uncertain. Growth in this market hinges on the targets for mitigation set by national policies and international agreements. From these targets will flow an implied price for carbon to achieve the required level of abatement. Prices in the order of A\$50 to A\$65 would trigger a sharp increase in the area of land being devoted to carbon plantings, which would create significant competition for resources between land use for biofuels, carbon and food [44]. Predictions that there will be enough food to meet world demand are premised on a modest increase in the use of food for biofuel and with little regard to carbon plantings. If there is increased competition for land, the cost of commodities will go up, as more productive farm land is brought into biofuel or carbon storage. This could impact food supply and demand balances.

Global demand growth and export markets. Currently the majority of Australian farm exports are to countries in Asia. China is our largest and fastest-growing customer, taking 14 per cent of the value of agricultural exports. China is closely followed by Japan at 13 per cent, the Middle East at 10 per cent and the European Union, United States and Indonesia at around 7–8 per cent [45]. The ongoing role that Australia plays in global markets will be diverse, selling basic food commodities to developing nations and higher-value niche products (such as wine, dairy and prime beef) into more affluent sectors. The growth of Australia's agricultural exports will partly depend on how competitive we remain compared to the lower cost structures of countries operating in the same sectors. The cost-price squeeze so familiar to Australian farmers, where input costs increase at a greater rate than prices, indicates that demand is less than supply in global commodity markets [29] and low-cost producers are servicing the bulk of increased demand. Overall demand growth from the world does not guarantee Australia a boost in export earnings.

Productivity growth in Australia—how much more food can we make? Some rural industries are demonstrating growth in overall output. For example, the Australian dairy and the northern beef industries have shown consistent output growth over the last 20 years. This has been driven by industry structural changes, such as dairy readjustment schemes [28] and the demand for lighter live-export cattle in northern Australia [29]. The adoption of improved genetics, husbandry and nutrition have also played an important role. However, there are disconcerting trends for productivity in Australian broadacre agriculture. Although productivity has grown at the reasonable level of 1 per annum for broadacre farming over the last 20 years, output growth only contributed 0.1 per cent of the total [28]. Slower growth rates in broadacre production have been attributed to extreme weather events and to decreased investment in agricultural research and development [28].

Capital investment in Australian agriculture. Increasing agricultural production in Australia will partly depend on securing new capital investment. The trend for capital investment (excluding land purchases) in the Australian agriculture, fisheries and forestry sector is positive, showing an average of 1.1 per cent per annum increase over the period from 1990 to 2013, with most of the increase occurring since 2003. In recent years, this was a higher annual growth rate than in the services and manufacturing sectors, but lower than in mining [46]. Private investment may be an important source of capital [47]. For example, the construction of two meatworks in northern Australia, near Broome and Darwin, were privately funded. These facilities will open up opportunities for beef cattle producers in northern Australia.

Securing food supply chains offshore. Around the world, the bulk of food consumed is produced locally, with only 19 per cent of world production entering international trade [5]; most food will be produced in a country where it is consumed. International trade will continue to be an important path for securing food deficits. Countries with scarce land and water resources but with financial reserves will outsource agricultural production by buying resources on the global market. In addition, there will be an increasing trend for foreign investment in countries rich with agricultural resources of land and water [35]: an example of this can be seen in northern Australia where there has been investment by Indonesian businesses in cattle properties so as to secure supply chain certainty [48]. The 'Land Matrix' is a global land monitoring initiative aiming to increase the efficiency and transparency of offshore agricultural land investments. Data from the Land Matrix, reported in a United Nations Food and Agriculture Organization (FAO) report [49], identifies 1217 overseas agricultural land deals covering 83 million hectares during the period 2000 to 2012. The top five investor countries are identified as the USA, Malaysia, Singapore, United Arab Emirates and the United Kingdom. The top five target countries are identified as Papua New Guinea, Indonesia, South Sudan, the Democratic Republic of the Congo and Mozambique [50]. The future is likely to see growth of direct foreign investment in agricultural land. Whether this is for financial objectives or securing food supply chains for sovereign food security is debated [51].

Selling agricultural know-how. Given that over 90 per cent of the food needs will be met by in-country production, perhaps an important contribution Australia can make to feeding a hungry world is in the export of our expertise, innovation and services to countries with high population growth and growing demand for specific food groups. This can be approached through two avenues: business investment and official development assistance. Foreign investment in agricultural expertise in the Chinese agricultural sector has shown a strong growth trend since liberalisation of capital markets commenced in the 1990s [52]. Examples of this type of investment across the region are Fonterra's investment in the Chinese dairy industry and Elders' investment in beef feedlots in Indonesia. In many countries with the fastest-growing populations, such as Africa, there has also been a significant upward trend for foreign investment, but the majority of this has flowed to extractive resource industries [53]. Small-scale agriculture is likely to require a significant level of public and private development aid but the trend for greater global investment of this nature over the last decade (a 6 per cent increase in 2013) has not flowed through to the neediest region of sub-Saharan Africa, which has had a falling share of the global (and Australian) aid budget [54].

Opportunities for northern Australia. Northern Australia offers some opportunity for growth in food production: the proximity to major Asian markets and to areas of underdeveloped water and land resources for both grazing and intensive agriculture [47]. However, there are significant barriers including high inter-annual climate variability, constraints on the viability of surface water storages, access to labour and the liveability of the region. Expansion in the north would require significant investment in infrastructure and institutional capacity-building to improve planning, governance and service delivery. Capital inflows will only occur once there is clear land title and reliable access to water. Markets for produce need to be built as production expands, as seasonal overproduction of perishable food like fruit and vegetables can disrupt domestic markets and contribute to economic stress and risk in such industries [55]. The most successful agricultural production across northern Australia has been grass-fed beef cattle, with niche industries to support live export such as irrigated fodder. There may be room for expansion in livestock numbers in some regions, with further property development in the form of fencing and watering points [56].

Implications for Rural Industry Innovation

1. Expert Growth

As the world seeks larger quantities of higher-quality food, Australia has the opportunity to supply these strongly growing but competitive markets, especially regionally. Given the scale of the demand from these markets, Australia cannot hope to feed Asia or the world—however it could substantially increase production and exports. There are considerable opportunities to develop new land and water resources within Australia. Much of the nation's resources could also be used more efficiently, as the variation in performance of producers is substantial. To fully realise this potential, an expansion of the production base, ongoing efficiency improvements and significant adjustment will be needed. This can be achieved with increased access to new or under-utilised land and water resources and highly productive farming systems focussed on contemporary market needs. A significant, ongoing innovation effort (RD&E) to improve productivity, profitability and environmental sustainability is also essential.

2. A requirement to understand the geographic distribution of demand.

The character and scale of demand for food and fibre products will vary considerably between markets. Understanding the nuances of global and regional growth and their particular market requirements will help target the export growth effort.

3. The importance of removing trade barriers.

Despite recent successes, the food sector in many countries remains highly subsidised and considerable trade barriers exist for Australian exports. The recent free trade agreement with China and other countries will provide growth opportunities for a number of industries, in particular the dairy industry. Ongoing efforts for further reform are vitally important, as progress will continue to enhance Australia's competitiveness and market opportunities. The National Farmers' Federation identifies trade liberalisation as a priority issue, saying that:

A successful outcome from the multilateral negotiations in the WTO [World Trade Organization] remains the NFF's number one trade policy priority, and has the potential to result in billions of dollars in extra income for rural and regional Australia [57].

Emerging questions

- Are there other countries better positioned to respond to growing global demand (in terms of products, price and supply) with the potential to out-compete Australian products in our domestic and exports markets?
- Will the Australian agricultural industries' supply chains be able to scale up production and performance to meet this competitive challenge?
- Will the policy context support or hinder this growth?
- What is the role for innovation (RD&E), at what level, and how should it be funded and structured?
- If the capacity of the Australian food and agriculture sector is constrained by capital does it matter where overseas investment comes from, particularly if it brings with it market access advantages?



04

A WEALTHIER WORLD

*“After all those years in Asia,
I don’t have to do promotion
anymore. We just release
a Jackie Chan movie and
— Boom! — people go.”*

Throughout history, the world economy has demonstrated a resilient capacity for growth. Despite two world wars, the Great Depression (1930s), the Great Recession (2008–2009), numerous regional conflicts, pandemics and natural disasters, the world's economy has continued to grow at an average rate 2.2 per cent per year over the last century [59]. Most forecasts suggest continued rates of growth will occur during the 21st century. However, growth rates will be considerably varied across regions and countries. Emerging economies within East Asia, Latin America and the Middle East are expected grow more rapidly in the short-to-medium term. Countries in these regions are growing at rates two to three times faster than advanced economies.

As billions of people in these regions move into the middle-income bracket, and many people move further beyond, new agricultural export markets will emerge. This is already occurring. There has been impressive growth in grains, sugar, meat and wool commodity exports in recent years, which are the traditional and longstanding export earners of Australian agriculture. However, by far the largest growth—in both percentage and absolute terms—comes from the 'other' category, which contains a diverse range of boutique and specialised products. In the coming 20 years, rising incomes in emerging economies present a major growth opportunity for Australia's rural industries, for both traditional commodity exports and for many new food and fibre products not yet mass produced.

This megatrend is about the food and fibre products demanded by a wealthier world. The focus is on emerging economies in Asia, which are becoming increasingly significant trade partners. That's where the growth curves are steepest and the opportunities are most intense. Australia's rural industries won't be the only supplier competing to gain market share, but there are many points of comparative advantage and natural differentiation for Australian agricultural products in world markets.

Rapid income growth in emerging economies. According to data from the Organisation for Economic Cooperation and Development (OECD), the average income for a world citizen—measured as GDP per capita (the world’s total economic output divided by the number of people)—is currently US\$14,000 per year. This is forecast to grow to US\$17,000 by the year 2020; to US\$22,000 by the year 2030 and US\$28,000 by the year 2040 [7]. Therefore, on aggregate, people across the world will be earning double their current income by the year 2040. Rates of income growth are fastest in Asian countries including China, India and Indonesia. In reality, income is unevenly distributed and GDP per capita is an average measure across the whole economy; a measure of median income would be different. Nevertheless, average income growth does mean that, year-by-year, the world is likely to have much greater buying power. For people who are already wealthy, this won’t have much impact on their food and fibre purchasing decisions. However, poor households in emerging economies who escape poverty and join the middle-income classes are likely to diversify their diets and increase food consumption. Income growth in emerging economies is the underlying driver of increased demand and diversity for agricultural products.

Rising calorie intake. The world will demand substantially more food into the future for two main reasons. The first is population growth: more people will need to eat more food. The second is income growth. As people become wealthier they also increase daily food consumption, which means per capita kilojoule consumption is also on the rise. The world of the future will contain more people who, on average, eat more food. The United Nations Food and Agriculture Organization (FAO) [60] estimates that per capita kilojoule consumption will increase from 2358 kcal per person in the year 1966 to 2940 kcal per person by the year 2015 and 3050 kcal per person by the year 2030. In the world’s advanced economies such as Australia, Western Europe and North America there’s not much change between now and the year 2050 (an additional 60 kcal per person per day). However, the world’s developing countries will increase daily food consumption by over double that amount with an additional 130 kcal per person per day.

The relationship between income growth and food consumption. A comparison between national income (measured as gross domestic product per capita) and food consumption (measured as kilocalories per person per day) reveals a positive and logarithmic association (Figure 7). This means that income-growth at the lower end of the scale is associated with larger jumps in daily food consumption compared to income-growth at the higher end of the scale. In other words, when low income earners receive a pay rise they put a much greater portion of their additional income into buying food. As over one billion people in emerging economies cross into the middle-income bracket, they are likely to substantially increase food intake over coming decades. We are about to see a big jump in daily food intake, which will be the key underlying driver of future demand for Australian agricultural produce.

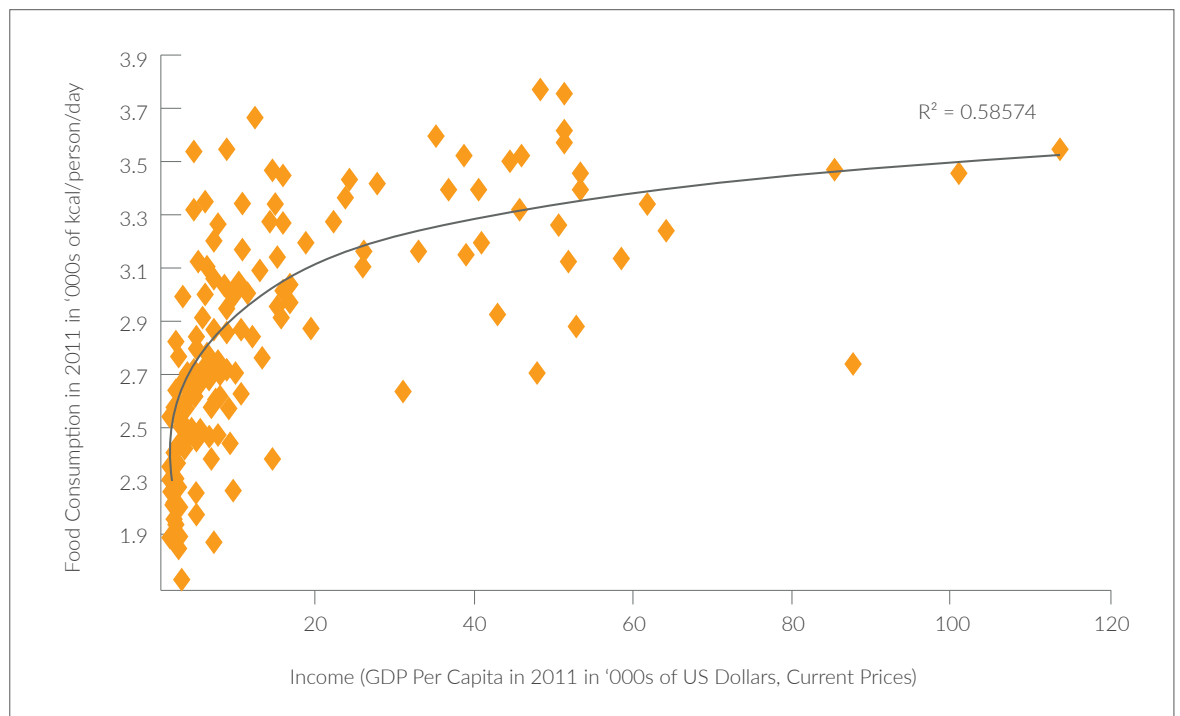


Figure 7: Relationship between national income and food consumption for countries worldwide

Note: Each point on this graph represents an individual country in the year 2011 with a given *GDP/person/year* and *kcal/person/day*. A logarithmic function has been used to create a line of best fit through the data.

Source: Food and Agriculture Organization [61] and World Bank [62]

What will a wealthier world be eating? Come 2050, the mix of foods being eaten will have changed—most dramatically in developing countries, where the diet will include slightly more cereals and pulses, an increase in roots/tubers and sugar, and considerably more vegetable oils, meat and dairy. Overall energy intake is predicted to increase from 2619 kcal to 3000 kcal per person per day [5]. The contribution of other foods (vegetables, fruits and nuts) indicates food diversity will also grow. In developed countries, consumption of roots and tubers (for example, carrots and potatoes) will decline; cereal, sugar, pulses and vegetable oils will be consumed at similar levels; and meat and dairy will increase, but not as much as in developing countries.

Income growth and diet diversity. Coming decades will see over one billion people in Asia transition out of poverty and into the middle-income bracket, earning between US\$6000 and US\$30,000 per year [63]. Disposable income in China has been growing steadily, increasing 14 per cent from 2011 to 2012 [64]. This has major implications for global food markets because increases in household income are associated with diet diversification. Research also shows that a more diversified diet is healthier, especially for children [65]. As a consequence, diet diversity is a commonly used measure of household or national food security. A few of the many population-wide studies demonstrating the link between income and diet diversity include:

1. a study of 4632 households in Germany found that the variety of foods consumed significantly increased with household income [66]. This study also finds that age has a significant impact, with older people being likely to have a more diverse diet than younger people.
2. a study of 11,658 adults aged 19–74 in the United States examined consumption of dairy, meat, grain, fruit, and vegetable food categories. The researchers found a significant positive relationship between both income and education with diet diversity amongst these categories [67].
3. a survey of 188,835 households in Bangladesh during 2003–2005 measured dietary diversity as the number of days per week each household consumed every item from seven different food groups (yellow/orange fruits and vegetables, green leafy vegetables, meat, chicken, fish, eggs, pulses). This was found to be positively associated with monthly per capita food expenditure. Higher incomes were associated with more diverse and nutritional diets [68].

Wealth growth for lower-income groups (as opposed to already-wealthy people) has more impact on food markets. That's because when an already wealthy person becomes even wealthier, their already-diverse diet doesn't change that much. Individuals in this category are more likely to shift their discretionary expenditure into non-food goods (cars, houses, fashion and so forth). However, when a low-income person in a developing economy moves into the middle-income bracket there is likely to be a substantial change in diet: they move beyond eating staple foods such as rice or grains and start eating a more diverse range of foods including fruit, vegetables, dairy, fish and meats.

This transition is already happening, and about to happen, for over one billion citizens living in the developing Asia region as they cross the middle-income threshold. However, it's more than income growth. The world is also becoming more educated and more aged, both of which are linked with diet diversity. The coming decades will see an opportunity for Australia's rural industries to supply a much more diverse range of food products into the developing countries and contribute to improved food security.

The Westernisation of Asian diets. Income growth in emerging Asian economies is seeing diets switch away from staple foods towards livestock, seafood, dairy, and fruit and vegetable products. This is often referred to as the westernisation of Asian diets, as eating patterns come to resemble those of Europe, North America and Australia. This trend is being reinforced by globalisation, the rise of the new urban middle-income class and the rapid spread of supermarket chains and fast food restaurants.

As a consequence, Asian agriculture is on an irreversible path leading away from its traditional pre-occupation with cereal crop production, especially rice, towards a production system that is becoming increasingly commercialized and diversified.

- Prabhu Pingali, Food and Agriculture Organization (FAO), United Nations [69].

Agricultural products Asia is likely to make or sell. The rise of meat, milk and vegetable oils in Asian diets augers well for Australian production. Australia can compete on both price and product quality. With a burgeoning population of middle-income consumers in close geographical proximity there is scope to promote products based on their safe, clean and quality status. However, much of the food needed in Asia will be produced locally [70]. Asian countries will rely more heavily on imports for red meat, dairy, coarse grains and on oilseed to support local livestock production. Vegetable oils and wheat will continue to be important for countries such as Indonesia where there is little local production. Asia is likely to be close to self-sufficiency for sugar, vegetables and fruit, with little demand for wine in many countries due to cultural preferences [70]. This does not preclude opportunities for high-value horticulture, but rather highlights the need to focus on market windows and quality in addition to price attributes. Most Asian countries have significant tariffs on food imports [70] and the increased trend towards bilateral free trade agreements in the Asian region is aiding market access.

Growth in protein consumption. Right across the world's emerging economies, demand is rising rapidly for most types of high-protein food, including dairy, tree nuts, legumes, eggs, beef, pig meats, poultry, sheep meats and seafood products. Growth in Asia is faster than for most other regions (Figure 8). This is associated with rapid income growth and with the westernisation of Asian diets. For example, it is estimated by the Australian Government Department of Agriculture that beef consumption in the Association of South East Asian Nations (ASEAN) member states will increase 120 per cent and dairy consumption will double by the year 2050 [71]. Data from the United Nations Food and Agriculture Organization reveal the extent of growth in protein consumed from all sources since the 1960s within Asia and worldwide. As Asian diets westernise, they are likely to close the gap and in 20 years' time may have similar levels of protein consumption as Australia. Many of the following trends compare and contrast Australian consumption patterns with Asian consumption patterns. This is because there is an expectation that the Asian diet will more closely resemble the Australian diet within coming decades.

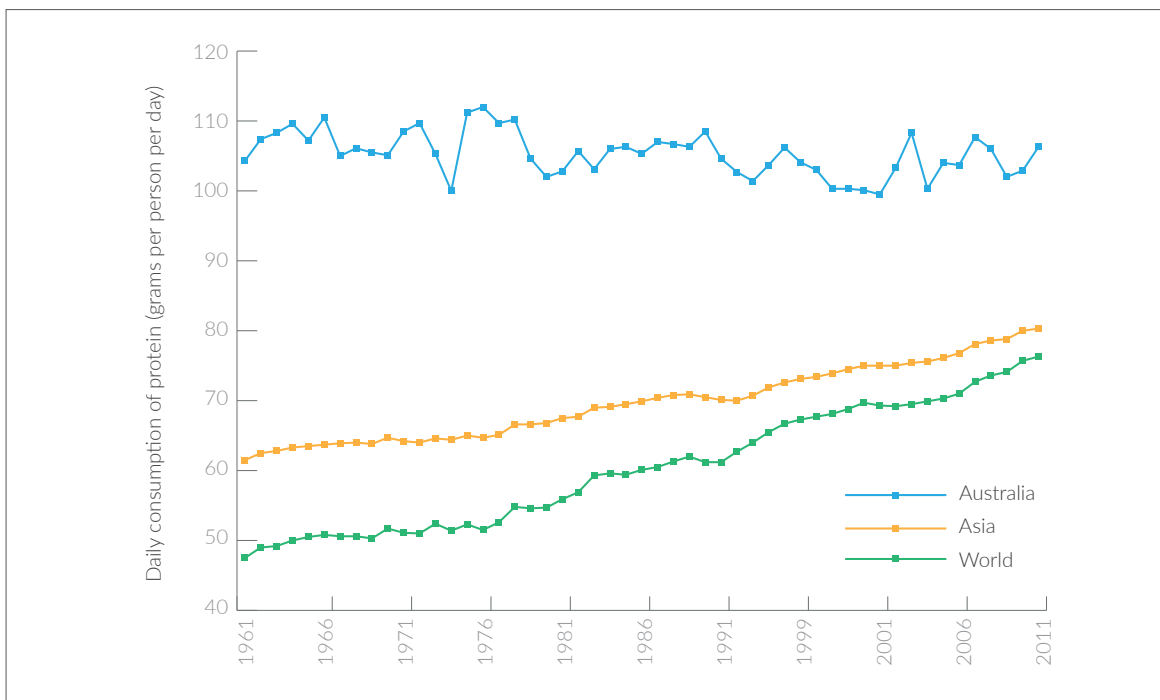


Figure 8: Protein consumption in Australia, Asia and the world.

Source: United Nations Food and Agriculture Organization FAOSTAT [61]

Beef consumption trends. Beef consumption has been steadily declining in Australia since the 1970s. According to the United Nations Food and Agriculture Organization dataset, Australians consume around 112 grams of bovine (cattle) meat per day. The Meat and Livestock Association (MLA) industry body provides the slightly lower estimate of 89 grams per person per day [72]. This compares to only 12 grams per day across Asia. Unlike Australia, beef consumption is growing rapidly within Asia, roughly trebling since the 1970s. It is set to continue to grow in coming decades. If Asian diets become westernised and approximate an Australian diet, Asians may be eating 10 times the amount of beef by midway through this century. The major opportunity for Australian beef producers is overwhelmingly in overseas markets.

Growth in seafood consumption but Australian exports are flatlining. Seafood is distinct within the story of rising protein consumption because it shows strong growth with similar year-on-year increases and consumption rates in both western and emerging markets. Most other forms of protein consumption are relatively stable in western countries whilst they are growing rapidly in emerging economies. However, seafood consumption shows strong growth in all markets—Australian, Asian and worldwide. In all these markets, people on average consume roughly twice as much fish today as they did in the 1970s. Daily consumption in Australia is 70 grams per person, slightly above Asia at 60 grams per person [61]. Based on these trends, continued growth in the years ahead is likely. Despite growing consumption, the Australian Government Department of Agriculture data shows Australian seafood exports have fallen from 64,700 tonnes of product in 2000–01 to 40,500 tonnes in 2011–12 [73]. This partly results from competitive pressures associated with Asia’s expanding aquaculture industry. For example, prawn exports to Japan, Hong Kong and the United States more than halved over this period as local suppliers increased market share. The share of seafood produced via aquaculture versus wild-catch continues to increase. The United Nations Food and Agriculture Organization datasets suggest the wild-catch volume worldwide levelled off in the late 1980s. Continued growth in total fish production comes from growth in aquaculture [73]. This points towards possible future opportunities for Australian aquaculture exports to meet growing world demand.

Rising egg consumption. Egg consumption patterns differ from other forms of protein because Australian daily consumption rates are considerably lower than those in Asia. During the 1960s, 1970s and 1980s, egg consumption declined rapidly in Australia (roughly halving) and grew sharply in Asia. Today, Asians consume more eggs than Australians on a per capita basis, according to data held by the United Nations Food and Agriculture Organization. However, in recent years, egg consumption has grown in Australia from an estimated 14 grams per person per day in 2005 to around 20 grams per person per day in 2011. The Victorian Government Department of Primary Industries reports a similar pattern, citing a 46 per cent reduction in Australian egg consumption during the 1940s to 1990s with a rebound in the late 1990s [74]. According to the Australian Egg Corporation (AECL) industry body, Australian consumption increased from 170 eggs per person in the year 2003 to 210 eggs per person in the year 2013 [75]. The egg industry in Australia sells the bulk of its product to domestic (as opposed to overseas) consumers. The industry figures show a gross value of farm gate egg production of A\$583.4 million in 2011–12 compared to exports of A\$2.13 million. The industry identifies exports as a potential new market for Australian egg producers [76]. However, eggs (unlike many other high protein foods) may see stronger demand in Australia compared to international markets. The data from the United Nations Food and Agriculture Organization show that Australians consume fewer eggs (on average) than people living in Asia. The data also point towards the possibility of a recent upswing—also observed by industry [76]—in Australian egg consumption. Data collated by the industry body AECL show that Australian people have (on average) increased egg consumption from 3.8 eggs per week in 2009 to 4.1 eggs per week in 2013—a 10 per cent increase over a five-year period [77].

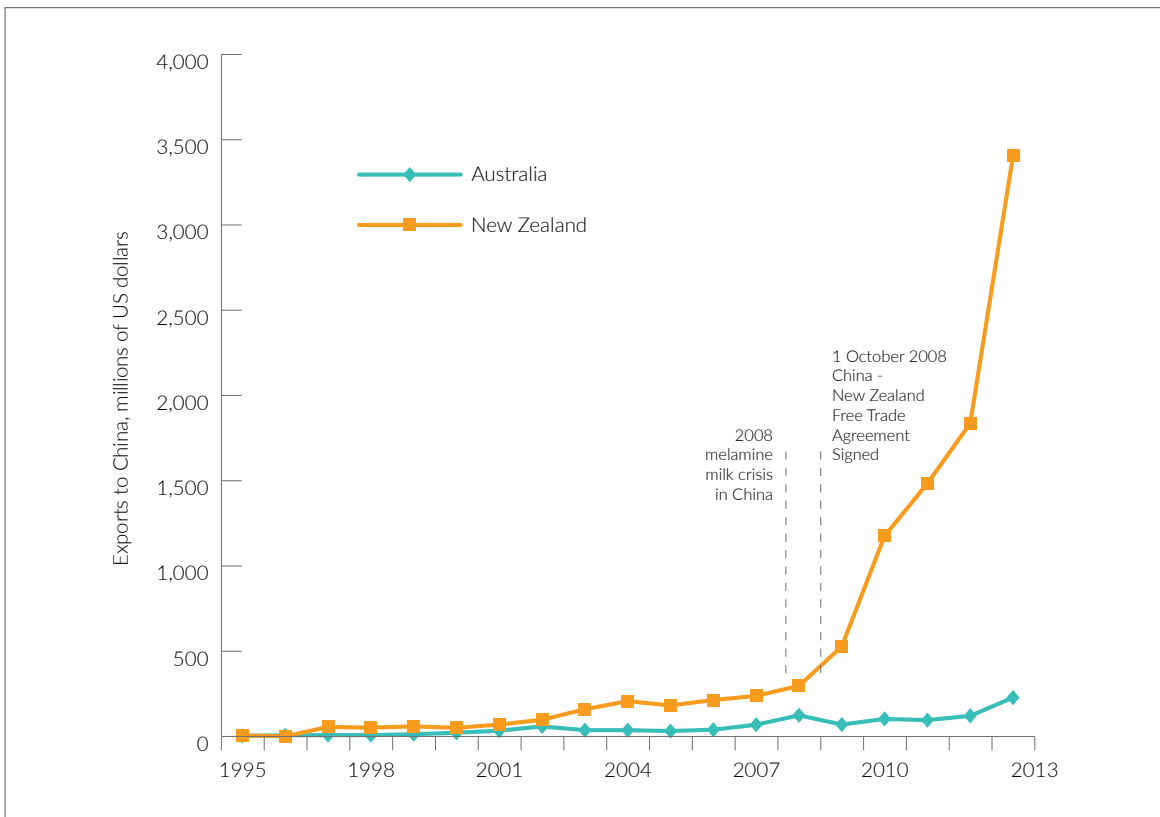


Figure 9: Dairy exports to China from Australia and New Zealand

Source: United Nations Conference on Trade and Development (UNCTAD) [78]

Free Trade Deal with China

During the November 2014 G20 meetings Australia and China announced a free trade deal. A report on ABC News published on 17 November 2014 says:

The [Australian] Government said 14 commercial agreements were signed, covering projects potentially worth more than \$20 billion in total. Among the big winners will be the mining sector, dairy farmers and wine exporters ... The Australian dairy sector is expected to get an equal, if not better, deal than New Zealand, with tariffs to be phased out by 2025.

The trade deal will also reduce barriers for beef, sheep, horticulture, seafood, barley and sorghum exports from Australia to China. A deal was not achieved for sugar and rice but this may be revisited in three years.

Rural Reporter Lucy Barbour, 17 November 2014 ABC News Online.

Dairy exports—comparing Australia and New Zealand. In the 1960s around 88 per cent of New Zealand's dairy products were sent to the United Kingdom [79]. The formation of the European Union saw a change in trade relationships and, since the early 1990s, New Zealand dairy exports to the United Kingdom have dropped to a negligible amount. However, New Zealand's dairy exports have continued to achieve overall growth (Figure 9). This is largely due to steep demand growth from China. Today China is the largest export market for the New Zealand dairy industry. The New Zealand dairy product was seen by the Chinese consumer as a healthy and high-quality option, especially in the wake of the melamine powdered milk tragedy of 2008 which saw many domestic consumers reluctant to buy locally made dairy products. Even though both Australia and New Zealand industries are large and produce a high quality product, exports of milk from Australia to China have not achieved the same level of growth. New Zealand's 4.6 million dairy cows produce around A\$20.5 billion in exports. However, there are opportunities for the future: according to recent news reports, the Australian dairy co-operative Norco, operating out of northern NSW, has successfully negotiated quarantine protocols with China [80]. These protocols will allow fresh milk to reach Chinese consumers from Australia within 7 days (down from the previous 14-21 days). According to the news reports, the manufacturer (Norco) says it now has the potential to export 20 million litres of milk per year to China. Furthermore, what happened in dairy export markets may occur in other markets (for example, tropical fruits, nuts, legumes) as new wealthy Asian consumers seek products with certain quality attributes.

China's agricultural (crop & livestock) imports and exports.

According to data from the United Nations Food and Agriculture Organization, China is establishing itself as a net importer of crop and livestock products (Figure 10). During the 10-year period from 2002 to 2011, China increased imports of crop and livestock products from US\$25 billion to US\$128 billion. During the same period, exports also rose but only from US\$17 billion to US\$52 billion. This led to a large trade deficit of -US\$76 billion. However, the opportunity is not uniform across all food/commodity types. For grains, beef, dairy and tropical fruits, China is a net importer. However, for specialised horticultural products such as garlic, China is a net exporter. In 2011 China exported some 1.7 million tonnes of garlic—an amount 350 times greater than imports, which were only 5 thousand tonnes [61].

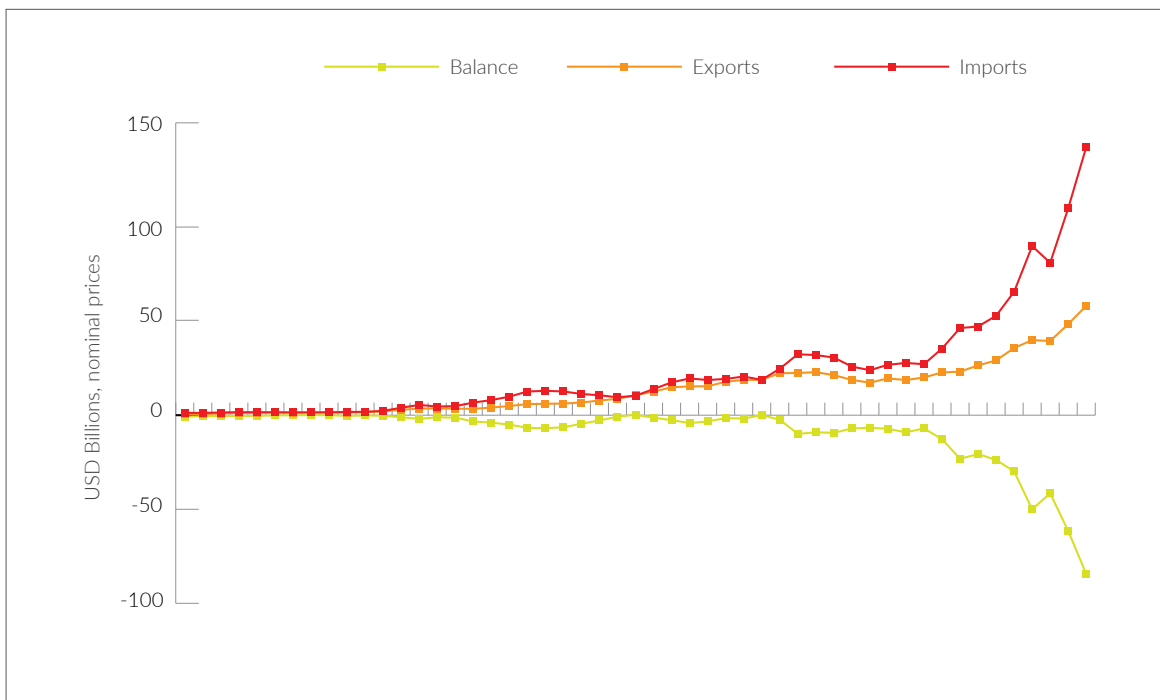


Figure 10: Imports and exports of crop and livestock products for China.

Source: United Nations Food and Agriculture Organization FAOSTAT [61]

Note: These data are from the United Nations Food and Agriculture Organization FAOSTAT trade dataset for crops and livestock products. The selection filters the country to 'China'; elements to 'import value' and 'export value'; items (aggregated) to 'agricultural products total + (total)' and for all years. The balance is obtained by subtracting imports from exports.

Demand for delicacies (such as wine, tropical fruit, tree nuts). Agricultural produce import data for China compiled by the United Nations Food and Agriculture Organization tell a story of rising demand for wine, tropical fruit, nuts and other boutique foods. This is associated with income growth and diet diversification. For example, the quantity of bananas—a tropical fruit widely considered a delicacy in emerging economies—being imported into China has risen from 75 thousand tonnes in 1993 to almost 1 million tonnes in 2011 [61]. Pineapples show a similar growth story. The Organisation for Economic Cooperation and Development also notes that China increased champagne imports from 0.1 per cent of the world share in the 1990s to 0.3 per cent of the world share in the 2000s [81].

Emerging economy demand for ethical food. The rise in wealth and educational levels across Asia may be associated with growing consumer demand for food and fibre products which have been produced in an environmentally sustainable, socially responsible and/or ethical manner. The potential for organic food markets in China—which may encompass organic food, green food, non-harmful products and good agricultural practices—has been studied by researchers at Jiangnan University and published in the *Journal of the Science of Food and Agriculture* [82]. This research argues that, whilst organic food consumption in large cities such as Beijing, Shanghai and Guangzhou is small (accounting for 0.08 per cent of total food consumption), there is the possibility of future growth. According to industry statistics, organic produce represents 4 per cent of all food and beverage sales in wealthy countries such as the United States [83]. The China Organic Food Certification Centre (COFCC) estimates that sales volume in organic certified food produce in China has risen from 135 million tonnes in 2003 to 1.96 billion tonnes in 2006. Over this same period the number of products bearing organic certification labels has grown from 231 to 3010. The researchers surveyed some 432 consumers in China to identify factors influencing the choice for organic produce. They found that consumer choice was strongly influenced by income, degree of trust in the organic label, acceptance of price and concerns about health impacts. Also of importance were the consumer's age, education level and concerns about the environment. Overall, the westernisation of Asian diets may also have implications for organic and ethical produce, as Australia's rural industries may achieve market differentiation by supplying a more ethical product.

Implications for Rural Industry Innovation

1. An opportunity to diversify exports and grow new markets.

The evidence presented here suggests a new wealthy Asian and emerging-economy customer will have a much more diverse and westernised diet. This represents an opportunity for Australian rural industries to identify the new food types and connect to new markets. A diversified rural export base is likely to be more resilient in response to within-market supply and demand shocks.

2. Enhancing the reputation of Australian products.

A critical competitive advantage for Australia is to maintain and extend its reputation as a supplier of high-quality products with high environmental, health and safety standards. If Australian farm produce is perceived by increasingly wealthy Asian consumers as fresher, healthier and responsibly produced it will out-compete produce from many other countries.

3. Selling food and fibre to China.

The recent free trade deal with China has helped open up market access for some Australian rural industries to this very large population of increasingly wealth consumers. These industries now have an opportunity to establish and grow these markets as the agreement progressively takes greater effect.

4. Opportunity for boutique products.

Income growth within target countries is likely to be associated with a surge in demand for conventional as well as boutique or luxury foods such as cheeses, beer, wine, tropical fruits and nuts. These products typically have very high specifications and quality requirements but also attract a significant price premium.

5. Opportunity for aquaculture.

Australian seafood exports have been stable while global demand has been growing strongly. Asian aquaculture is more competitive in this market than wild-caught fish from Australia. Australia could potentially develop increased on-farm aquaculture production for particular markets, allowing farm businesses to diversify income streams.

Emerging questions

- Will advances in science and technology within the agricultural sectors of Asian countries make them relatively more competitive than our own food and agricultural sector?
- Is Australia better off focusing on the commodities which have provided most of the export earnings or should Australia be working hard to respond to the demand for a more diverse range of boutique, luxury and niche food & fibre goods (that is, to become the delicatessen of Asia)?
- Do we have the supply chain infrastructure and the persistence to get a broader range of desirable agricultural products to Asian markets competitively?



05

CHOOSY CUSTOMERS

'I wish for your help to create a strong, sustainable movement to educate every child about food, inspire families to cook again and empower people everywhere to fight obesity.'

- JAMIE OLIVER, CELEBRITY CHEF, TED TALK 2010

The consumer of the future will be increasingly choosy about the food and fibre products they consume. They will also be empowered with information technology and a greater variety of choices. Today's consumer has different tastes, preferences and concerns to the consumer of 20 years ago. Organic certification, free range eggs, health labels and fair trade logos were much harder to find in the supermarket of 1985; farmers' markets were rare events. However, in 2015 these labels are commonplace in supermarkets and farmers' markets occur at multiple locations on a weekly basis in most large cities. The trend is likely to continue into the decades ahead. Consumers will be empowered by advances in modern information technology which will allow them to be increasingly discerning on perceptions of quality, healthiness, provenance, ethics and other factors.

Health is likely to become a particularly prominent driver of food choice and consumption patterns. It has impacts both within and beyond the farm gate. Many people's lives are being cut short by poor diets and at current trajectories government budgets could become crippled by unsustainable growth in healthcare expenditure. Much of the impact is highly avoidable and comes down to what people choose to eat. Rural industries will achieve product differentiation and market presence by identifying and communicating the health benefits of crop and livestock products. Industry is likely to encounter greater community and government scrutiny relating to the healthiness of food products.

However the issues of environment, provenance and ethics will also play a vital role. The consumer of the future will have greater expectations for these qualities in the food and fibre products they choose to buy. Information technology will increasingly enable the consumer to selectively access, share and validate information about products along the whole farm-to-fork supply chain. This shift will apply to both wealthy and emerging economies alike, albeit at different stages of market development. Consumers will be information-empowered and rural industries stand to gain or lose market share on a broader range of consumer perceptions.

The health imperative—from individuals to society. One of the biggest challenges before Australia and the world is the rising prevalence of obesity and associated lifestyle illness. Obesity is linked to both diet and exercise. This rise in obesity will be a major factor influencing government policy in coming decades. In Australia, one in two people are overweight and the proportion of people who are overweight is projected to rise a further 15 per cent over the next 10 years [84]. Data from Access Economics shows that in 2008 some 3.7 million Australians were obese. This is forecast to rise to between 4.7 to 7.5 million persons by 2028 in the baseline low-to-high scenarios [85]. Obesity is associated with Type 2 diabetes. Diabetes is the fifth leading cause of death in most developed countries [86] and has a strong prevalence in Australia. In 2011, 5.7 per cent of Australian adults aged 20–79 were estimated to suffer from diabetes. The OECD standard is 6.5 percent. Australian children aged 0–14 were above the 16.9 per cent OECD standard, with an estimated 22.4 per cent suffering diabetes [86]. Reducing the prevalence of obesity and lifestyle related illness is likely to become an increasingly important priority for governments and society.

Not just a rich country phenomenon. Whilst obesity rates tend to be higher in wealthy countries, the issue has worldwide impact. It is estimated that some 904 million people in developing countries are overweight or obese, compared to 557 million in high-income countries. The regions of North Africa, the Middle East and Latin America have overweight/obese rates almost level with Europe at 58 percent. Income growth is closely related to rising prevalence of these conditions. Since the 1980s rates have almost doubled in China, Mexico and South Africa, where incomes have also grown rapidly [87, 88].

Economic savings from improved diets. A study by KPMG, commissioned by Medibank, estimates the total cost of obesity to the Australian economy at A\$37.7 billion per year, comprised of direct costs (for example, treatment), indirect costs (for example, being absent from work) and 'burden of disease' costs (broader social impacts). This study notes that lifestyle intervention activities—including dietary improvements—are successful for around 11 per cent of the target population [89]. Similar findings are emerging from countries worldwide. Research published in the *American Journal of Health Promotion* shows that improved diets can reduce overweight and obesity issues and substantially reduce healthcare expenditure [90]. This study of the entire US adult population (224 million people) examined the prevalence of overweight/obesity, uncontrolled hypertension, elevated cholesterol, and related chronic conditions under various hypothetical dietary changes. It found that 'modest to aggressive' changes in diet could reduce national medical expenditures by US\$60 billion to US\$120 billion per year. The research also found that permanent reductions of (a) 100 kcal in daily consumption would prevent 7.2 million cases of overweight/obesity; (b) 400 mg per day of sodium would eliminate 1.5 million cases of hypertension; and (c) 5 grams per day of saturated fat intake would prevent 3.9 million cases of elevated cholesterol levels. In the United Kingdom, researchers estimate that diseases associated with poor diet cost £UK5.8 billion per year. This means choice of diet is the largest single behavioural issue in terms of financial cost for the entire UK healthcare system [91].

The diet/healthy-eating industry—evidence of consumer demand. Evidence of how much consumers increasingly care about the impacts of diet on lifestyle comes from the phenomenal rise in the ‘diet industry’ (or what may be better termed the ‘healthy eating industry’) over the past decades. Future growth is likely to continue apace. According to IBISWorld (as reported by SmartCompany), Australians will spend A\$6.6 billion on health and weight-loss products in 2013–14, with booming growth in personal trainers, gym memberships and weight loss counselling services [92]. A large number of food providers, including in the fast food sector, advertise a healthy-products range for customers. Worldwide companies such as WeightWatchers, SlimFast, Jenny Craig (recently purchased by Swiss Multinational Nestle) have experienced strong growth. Many food manufacturers provide ‘light’, ‘low fat’ or ‘low sugar’ variations on existing products. Whilst the effectiveness of this activity is debated, it does provide evidence of strong and growing consumer preference for foods perceived as healthy. The future is likely to see a more information-hungry and more information-empowered consumer, which may drive deeper changes in the food industry and in the agricultural sector which creates the raw products.

Expectations for healthy food. The health impacts of food are an increasingly important consideration for the consumer. In recent history, health perceptions have had an impact on market demand for crop and livestock products. For example, beef [93], eggs [94], pork [95], seafood [96], olive oil [97] and many other foods and commodities have both lost and gained market share from changes in consumer sentiment about health impacts. These shifts in consumer sentiment are accompanied by thousands of scientific studies producing a range of findings. Whilst often in agreement, the research findings are sometimes contradictory and change through time as new discoveries occur. Regardless of the debates for/against different food types, science is increasingly identifying the links between what people eat and their health and wellbeing. The coming decades will most likely see a more informed consumer attempting to choose foods which, they believe, will improve their health. This is likely to see a response in an agribusiness sector aiming to identify and communicate the health benefits of particular products. Industry associations and companies will be quick to respond when they perceive that consumers are being misinformed about the health impacts of their products.

Growing weight of evidence—the relationship between diet and wellbeing.

The weight of evidence about how diet can have positive and negative impacts on human health has been growing in recent decades and is likely to increase in the years ahead. Whilst there is much debate about which foods, in what quantities, increase the length and quality of life, there is widespread acceptance that diet has a significant impact [98]. There are proponents of Mediterranean diets, low-calorie diets and a wide range of anti-ageing diets. Some diets are backed by solid scientific studies and empirical data [99]. Extending the length and quality of life will be a powerful motivator for food consumers in the coming decades as science continues to dispel myths and identify effective eating patterns. Changes to diets have also been shown to improve mental health [100], mitigate behavioural problems [101], reduce cancer risk [102], improve immunity against infectious disease and mitigate a wide range of chronic illness [103]. One estimate suggests that diet and nutrition explain 30–50 per cent of the worldwide incidence of colorectal cancer [102]. As the evidence base continues to expand, consumers and regulators are likely to increasingly filter foods on the basis of diet and nutrition impacts.

How a small change in diet could make a big difference—the example of dietary fibre.

With an ageing population and higher rates of lifestyle/chronic illness dietary fibre intake is of greater society-wide and economy-wide importance. The average intake of fibre for United States children and adults is half of the recommended level [2]. Australians adults on average consume 20–25 grams of fibre daily below the Heart Foundation recommendation of 25–30 grams daily for adults [104]. The types of food with high dietary fibre content include barley, wheat or oat products and wholegrain/multigrain bread and cereal products. Fruit and vegetables are also an important source of fibre. The health benefits of fibre are well established and new research is continually emerging to reinforce this finding. As the health benefits of a high fibre diet become more widely known, consumption rates may rise and the demand for agricultural products which have high fibre content may also rise. There are many other nutritional deficiencies in people's diets which, if corrected, would yield substantial benefits.

The benefits of improving diet: the case for fibre

A recent review paper [2] on the benefits of fibre by authors from several United States medical research institutes and published in the journal *Nutrition Reviews* states :

Individuals with high intakes of dietary fiber appear to be at significantly lower risk for developing coronary heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal diseases. Increasing fiber intake lowers blood pressure and serum cholesterol levels. Increased intake of soluble fiber improves glycemia and insulin sensitivity in non-diabetic and diabetic individuals. Fiber supplementation in obese individuals significantly enhances weight loss. Increased fiber intake benefits a number of gastrointestinal disorders including the following: gastroesophageal reflux disease, duodenal ulcer, diverticulitis, constipation, and hemorrhoids. Prebiotic fibers appear to enhance immune function. Dietary fiber intake provides similar benefits for children as for adults.

Anderson et al. (2009) Health benefits of dietary fiber. *Nutrition Reviews* [p. 188].

Lessons from tobacco—how science and health imperatives can change consumption patterns.

The story of smoking shows how a once widely accepted and widely used product was found to be harmful through scientific studies and was eventually regulated, leading to a substantial change in consumer behaviour. During the period 1975 to 2005, tobacco consumption in Australia decreased by 60 per cent from 3205 grams per person per year to 1315 grams per person per year. In recent times the prevalence of smoking has continued to decline: today around 17.5 per cent of the Australian adult population smoke, compared to around half the population (75 per cent of males and 26 per cent of females) in the year 1945. The declining rates in recent decades have resulted from government programs and regulations informed by scientific studies which established the linkages between smoking, lung cancer and many other illnesses [105].

Why and how governments may take actions to improve diets. The Organisation for Economic Cooperation and Development (OECD) and the World Health Organization (WHO) jointly developed the chronic disease prevention model which, amongst other functions, identifies the benefits of government actions to improve diets. The model is run for seven countries with different income scales including Brazil, China, England, India, Mexico, Russia and South Africa. The results are described in a journal paper published in *The Lancet* [106]. This reveals that the biggest and quickest health benefit—as measured using disability-adjusted life years which provides an estimate of quality of life following intervention—results from physician counselling, fiscal measures (for example, taxes on unhealthy foods) and food labelling. The biggest cost savings result from fiscal measures followed by worksite interventions, food labelling and physician counselling. The authors of this research argue that a multiple intervention strategy involving all these activities is by far the most cost effective and delivers much larger health gains. The OECD and WHO chronic disease prevention model has implications for the agricultural sector in addition to the health sector. The large health benefits and cost effectiveness of interventions may cause governments to regulate and/or tax foods which are high in fat, sugar or other ingredients which, if over-consumed, are harmful to health.

Health literacy. As educational levels improve over time, Australians are becoming increasingly health literate. However, there is much room to increase literacy rates. Health literacy is the ability to access, interpret and act upon information relating to the health impacts of products. The Australian governments at federal, state/territory and local levels, and many other governments worldwide, have policies and programs (including 229 different initiatives) to improve health literacy [107]. According to the Australian Bureau of Statistics, 41 per cent of adults aged 15–74 have ‘adequate or better’ health literacy skills [108]. This means they can perform tasks such as combining text and graphs to correctly assess the safety of a product. However, the remainder of the adult population lack the skills required to make every day decisions about health impacts. The substantial policy effort by government at all levels is likely to see health literacy rates increase over the coming years. This will result in a more informed, more aware and more empowered food consumer. As health literacy rates improve, food marketing [109]—which may give products the appearance of being healthy regardless or not of whether they are—will be less effective. The demand will most likely shift towards foods which deliver genuine health benefits.

Functional foods. A more health-literate consumer is likely to search for foods with more specific qualities. The future may see diets move beyond foods which are naturally healthy and towards foods which have been designed and modified to achieve higher levels of target health benefits suited to the needs of individuals. 'Functional foods' are designed to provide a specific health benefit above and beyond basic nutrition. A recent review paper published in the journal *Food Science and Biotechnology* [110] suggests that functional foods may be classified as bioactive compounds, dietary supplements, medical foods, natural health products or nutraceuticals. Functional foods are usually based on existing food types such as dairy, egg, meat, fish, cereal, fruit and vegetable products.

Consumers across the world are increasingly interested in functional foods, with the global market estimated at US\$90.5 billion in 2013. The largest regional markets are Europe and Japan, which account for 90 per cent of total sales. However, the United States market is growing rapidly. One estimate suggests 21 per cent year-on-year sales growth, out to 2015, with large demand for probiotic yoghurts. The Australian Government agency Austrade identifies Japan as one of the most important growth markets for Australian functional food producers. A recent analysis by Austrade [111] identifies functional food sales in Japan in 2012 as follows:

- Intestinal regulation (JPY284 billion or A\$3.2 billion)
- Lifestyle disease prevention (JPY228 billion or A\$2.5 billion)
- Nutritional fortification (JPY219 billion or A\$2.4 billion).

The drivers of demand are considered to be Japan's ageing population; rising lifestyle-related illness; consumer demand for health and beauty products; and disease prevention. Examples of products under most demand are caffeinated soft drinks, which help burn body fat, and yoghurts, which improve immunity against infectious disease. Overall, the functional food industry is set to grow. The exciting prospect is that functional food is an emerging area of science far from maturity. Many discoveries about food designs which improve health and wellbeing—sometimes with incredible results—are yet to occur. Innovation in the agricultural sector is seeing scientific discoveries translate into viable products within relatively short time frames.

An example of a functional food—BARLEYmax. BARLEYmax is a well-known Australian functional food product. The research, design and manufacture all occurred within Australia. BARLEYmax is a natural wholegrain. It provides health benefits including decreased risk of heart disease and stroke; weight control; reduction in Type 2 diabetes; bowel health and regularity; cholesterol and blood pressure improvements; and reduced cancer risk. The risk of heart disease may be reduced 40 per cent by having four serves of wholegrains daily. BARLEYmax contains twice the dietary fibre of regular grains and four times the resistant starch and has a low glycaemic index (GI). Currently, there are breakfast cereal, porridge, cereal bar, flat-bread wrap, loaf bread and rice blend products available containing BARLEYmax grain. This brief summary was extracted from the CSIRO website and the BARLEYmax nutrition report [3].

The demand for ethical food in Europe and North America. Food consumers are increasingly concerned about the environmental, social and animal welfare impacts of what they eat. This is associated with a rise in the prevalence of certification systems and product labels. A recent study found that ethical foods account for 5–10 per cent of the food markets in wealthy economies of Western Europe, North America, Australia and parts of Asia. This covered foods labelled as ‘fair trade’, ‘free range’, animal-welfare friendly and environmentally responsible. The researchers suggest the rise in ethical products holds significant opportunities, and challenges, for Australian rural industries [112]. Whilst only a small part of the total food market, ethical food is showing signs of strong growth. There are also signals, especially from Europe, that consumers are willing to switch to ethical products to a greater extent when labelling becomes more commonplace, better understood and more trusted. A recent study [113] in Belgium finds that 9 in every 10 consumers favour a free-range product and consumers are, on average, willing to pay a price premium of 43–93 per cent for a free-range product. The study also finds that 87 per cent of Belgian consumers would welcome the introduction of a European Union (EU) animal welfare logo. British supermarkets recently reported a 164 per cent year-on-year increase in product sales under the UK Freedom Food scheme [114]. In a cross-country survey by the European Union, 41 per cent of respondents said ‘yes probably’ or ‘yes definitely’ when asked whether they wanted to be better informed about the way animals were treated on food product labels [114].

The demand for ethical food in Australia. Research is still uncovering the extent of current and future demand for ethical food in Australia. However, early signals would suggest Australian demand for ethical produce has similar prospects to Europe. A report on *ABC Rural* identifies research underway at the University of Adelaide which aims to understand how consumer values will influence the livestock industry and retailers. The issues of animal welfare and environmentally responsible production are already featuring high on the agenda. The news story by the ABC reports Cattle Council Chief Executive Jed Matz as saying ‘many consumers are now looking for a product with a story, and that often includes cattle that are grass fed, organic or free range’. Consumer demand in Australia and in export markets means the coming decades are likely to see increased use of labels and certification systems for ethical produce.

Provenance matters. ‘Provenance’ refers to the origins of food. This includes the geographic region, the plant and animal species and the methods of production. Large companies in the fashion, furniture and agri-food industries are increasingly using claims of provenance—which include claims about socially responsible production—to increase their market share. When customers’ expectations of provenance are not met there can be a significant market backlash. The fallout from the 2013 horsemeat scandal in the United Kingdom highlighted the importance of provenance. According to reports by the BBC [115], the scandal emerged in January 2013 when food inspectors claimed to have found traces of horsemeat in some frozen burger products labelled as ‘beef’ and stocked by leading UK supermarkets. This led to product recalls and plummeting sales in certain frozen meat products. However, media reports suggest that local butchers with personal knowledge of the supply chains (and provenance) benefited [115]. Butchers were able to provide transparency about supply chains and build trusted relationships with customers. In Australia there have

been controversies about the geographic labelling of food products. Australian farming regions like the Barossa, McLaren Vale, the Tamar Valley, Margaret River, King Island and Bundaberg have associated food products with geographic locality. Many successful businesses have emerged in recent decades, based on brand-association with these regions.

Proving provenance—an emerging challenge. The Australian Competition and Consumer Commission (ACCC) has recently been involved in cases to establish whether claims of provenance to popular regions are genuine [116]. Companies often make claims of provenance but analysis of supply chains may reveal products are sourced from numerous geographic regions. The ensuing public debate, covered in the media and online on social media, reveals the importance of provenance to a significant market segment. Provenance for seafood is a contested area, as many Australians will pay a price premium for local products. This is partly due to health and environmental concerns often associated with aquaculture in developing countries which may be made under different standards/processes. The United Nations Food and Agriculture Organization provides a zonal system which allows consumers to quickly check the geographic location from which fish products are sourced. It is now commonplace to see the FAO Catchment Zone on frozen fish products in the supermarket, which the customer can easily check and view on a smartphone. It is possible that the coming decades will see similar systems develop for a wider range of food products in response to consumer demand for provenance.

The growing popularity of farmers markets. The first farmers' market in Australia began trading in the year 1999 [117]. According to a study by the Australian Government [118] there were 70 farmers' markets across Australia in the year 2004. This grew to 152 by the year 2011. The number of markets continues to grow and the Australian Farmers' Market Association estimates there are now over 160 markets in operation [117]. Of these markets, 43 per cent are held on a weekly basis and 44 per cent are held monthly [119]. Farmers' markets are estimated to account for 7 per cent of total market share for fresh food compared to supermarkets at 50 per cent [118]. The perception of the future within the industry is positive. Surveys reveal that 97 per cent of market managers believed their market was viable in the long-term [118]. The markets are largely staffed by volunteers and the customers are interested in organic production and in the provenance of food. Often the farmers' market is chosen because it allows the customer to interact directly with the farmer and understand where and how food is produced. A study by the Rural Industries Research and Development Corporation [120] finds that farmers use markets because they are a profitable and direct link to consumers; a reliable distribution channel; and a positive environment to learn. The coming decades are likely to see farmers' markets expand and diversify further. They will be an increasingly important avenue for people to buy fresh produce. However, supermarket chains may seek to develop systems of supply-chain transparency and quality assurance which provide customers with a similar experience.

Online communication and social media. Social media will accelerate and magnify the role of provenance, ethics and health in agricultural markets and food markets. The rise of internet communication and social media use is changing the way people access information and make choices. According to the *Yellow Social Media Report* [121], 69 per cent of Australians use social media and 27 per cent use social media every day. This includes Facebook (95 per cent), LinkedIn (24 per cent), Instagram (21 per cent), Twitter (19 per cent), Google (19 per cent), Snapchat (16 per cent), Pinterest (12 per cent) and Tumblr (6 per cent). The most popular means of accessing social media—noting that people may access social media by multiple tools—is via a smartphone (71 per cent) followed by laptop computers (55 per cent). There are 11.2 million smartphone users in Australia and 7.5 million Australians who access the internet from a smartphone [122]. The growth of social media and of smartphones will empower the consumer to a greater extent: they will be able to access selective information about products at point of sale; see rating scales for product health/quality based on customer reviews; and provide feedback. For example, supermarket chain Tesco PLC has introduced a smartphone application in Thailand which allows users to scan the QR code (a unique product identifier) of fresh food (for example, meat, fruit, vegetables) to instantly see where the produce originated and to view nutritional information [123].

Social media and digital technology make supply chains transparent. Digital technology allows events along the entire food supply chain to be easily captured on film and rapidly disseminated to a wide audience. The fast-food industry in China was recently impacted after television footage showed factory workers repackaging expired meat and repackaging meat scraped up from the factory floor. As reported in the *Sydney Morning Herald* [124], this led to the seizure of 160 tonnes of raw material and 1100 tonnes of finished products by the Chinese Government regulators. It also caused considerable and lasting reputational damage for several well-known global fast food companies that had been using these meats in their products. The future is likely to see more instances where supply chain issues are recorded/reported and disseminated widely over social media with impacts on food retailers, agribusinesses and rural industries.

Implications for Rural Industry Innovation

1. Utilise technologies to build transparent farm-to-fork supply chains.

Increasingly, consumers will care much more about where and how their food is grown, made, transported and packaged and they will be much more empowered to access this information at point of sale. There is an opportunity for rural industries to demonstrate 'credence' characteristics, traceability and quality control using technologies including sensory and communication technologies for customer needs, to help build trust and respond to preferences in order to grow these markets and increase value.

2. Understand and communicate the health benefits of products.

As the health imperative intensifies, rural industries will be challenged to understand and communicate the health impacts of their products to empowered and informed consumers who want to know more. Historical swings in consumer perceptions of healthiness have caused food products to lose or gain substantial market positions. This is likely to intensify into the future.

3. Opportunities to make foods functional.

There is a significant market opportunity for food components that have specific benefits beyond nutrition. Many foods contain these components and they can be extracted, purified and sold as new and high-value products. It is possible that many rural businesses may be able to diversify into functional foods to meet health-induced demand growth.

4. Improve industry-wide standards and develop labelling and accreditation.

A failure of one farm business to meet industry-wide standards can harm the whole industry through reputational impact. As provenance, ethics, environmental performance and biosecurity become more important from the customer's perspective, the development of standards and accreditation systems industry-wide will become more critical.

5. Look for opportunities to advance supply chains in different ways.

The internet is providing an opportunity for product suppliers to bypass normal marketing channels such as retailers by creating new avenues for producers to connect directly to customer. A number of food producers successfully market directly to customers and maintain contact by using social media tools (for example, Twitter. This is one effective way to demonstrate provenance, as the customer can communicate directly with the farmer about how, where and when their food was made and with other customers about their degree of satisfaction.

Emerging questions

- Will credence characteristics become a defining feature of the larger market segments or will it remain confined to smaller niche-market segments? Will industries ignore it at their peril?
 - In the face of soaring diet-related health costs, will governments become more interventionist in controlling the components of food and diets? What impacts could this have for the food and agriculture sector?
 - Does Australian agriculture primarily produce commodities that others countries add value to and, if so, why—and what can be done to increase Australia's role in value-adding?
 - Could the future see large consumer markets in Asia and elsewhere require certification of foods based on standards of provenance, traceability, environmental credentials ethical and health considerations?
 - Will the trend to ready-made portion-controlled meals (for example, frozen ready-made dinners) continue to take over and reduce the customer's link to traditional non-processed food?
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06

TRANSFORMATIVE TECHNOLOGIES

*'It's hard to find things
that won't sell online'.*

- JEFF BEZOS, FOUNDER, AMAZON

Agriculture is an Australian industry with an impressive track record of speedy and successful technology adoption. Today's farming systems routinely use global-positioning systems, digital mapping technology, sensory devices and intelligent chemicals and fertilisers. The coming decades will most likely see exponential growth rates in technology advancement continue apace, with the world beyond 2020 operating very differently than it does today.

The way we 'do agriculture' will change due to advances in genetics, sensory systems, the 'Internet of Things' (IoT), device-connectivity and remote sensing; automation and customers' ability to trace food from farm-to-fork will change supply chains. However, technology will also disrupt markets, with demand-side impacts in addition to supply-side impacts. Technology will make new synthetic food and fibre products which compete with conventional products.

Exactly which technologies, and how they will shape Australian farming over the next 30 years, is hard to envisage—but we do know they will be transformative. Thinking about technology advances over the previous 30 years takes us back to 1984, one year on from winning the America's Cup, when was no desktop computing, limited mobile communications, dawning recognition that modern pesticides were fallible, significant industry protection (including the wool reserve-price scheme, single-desk wheat market, drought subsidies) and lots of ploughing. Technological advances have transformed agriculture.

The 'Transformative technologies' megatrend explores the way growth in a selection of key technologies—including digital technology, genetic science and materials science—will change the way food and fibre products are made.

The rising use of genetics for crop production. Since the mid-1990s the global area of genetically modified crop has grown to 150 million hectares (Figure 11), mainly in the Americas but also in Asia, incorporating genes for pest, herbicide and disease resistance into a range of crops (including cotton, maize, canola, potatoes) [125]. This trend is set to grow as new technologies are applied in plant breeding.

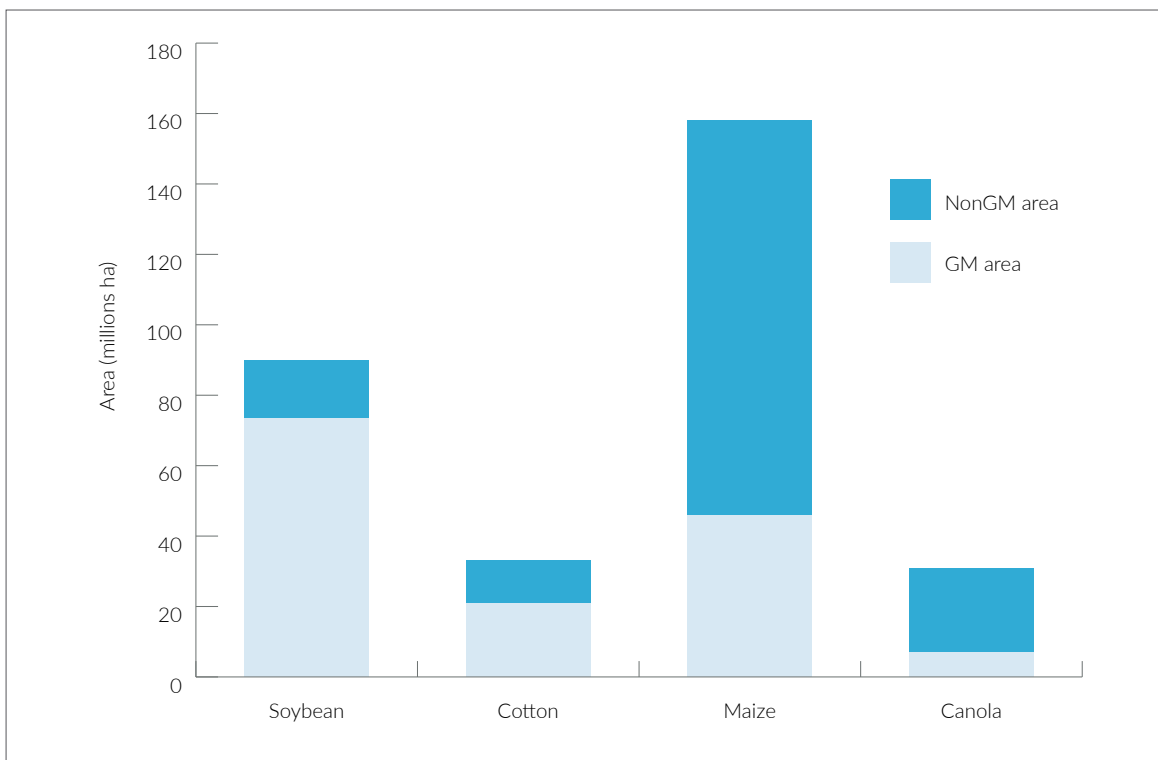


Figure 11: Global production area for genetically modified (GM) crops.

Source: United Nations Food and Agriculture Organization [125]

Towards pest-proof, weed-proof and smart crops—the RNA interface (RNAi) breakthrough.

A biological process called RNAi can be used to inhibit gene expression in a whole range of living organisms—from mushrooms to monkeys, bees to birds and peas to poppies (in fact all organisms that contain cells with a nucleus). This Nobel award winning discovery opens up a plethora of opportunities in human health and agriculture, to control pests and diseases and to enhance and regulate physiological functions. Through this technology, gene expression can be regulated in plants themselves or in the pests attacking them.

Faster and better seed cloning—the apomixis breakthrough.

Many plants are reproduced by cloning stems and leaves which is very efficient system but does not offer any on-going improvement, while others are produced by very expensive breeding programs that cross highly improved strains to give hybrid seeds for planting. Apomixis is clonal reproduction through seeds—a technological breakthrough that gives the best of both worlds, enabling efficient production of seed that produces high quality and consistently yielding crops. Cereal hybridisation has delivered large yield increases over the last 30 years. However, seed from these crops does not breed true to type, as the next generation reverts back to the characteristics of the parent strains. Apomixis allows seed from the improved variety to breed true to type, revolutionising industries that rely on hybrid varieties and giving sectors that rely on ‘seed saving’ from one crop to the next the chance to benefit from high-performance strains.

The Predictive Ocean Atmosphere Model for Australia (POAMA)

Along with the fertiliser history for the property, digital records will assume a value and become part of the asset value of a farm. The IoT will link business operations into the existing big data functionality of systems such as POAMA seasonal forecasting and earth observation systems. POAMA is a state-of-the-art seasonal to inter-annual seasonal forecast system based on a coupled ocean-atmosphere model and ocean-atmosphere-land observation assimilation systems. This is the tool that drives seasonal weather predictions for the El Niño Southern Oscillation Index.

Source: Bureau of Meteorology

Online at <http://poama.bom.gov.au>

Genetic improvement is more than genetically modified organisms (GMOs).

Not all new genetic technologies will achieve impact by producing a genetically modified organism. New technologies such as 'gene editing' will be used to produce favourable mutations, a traditional way of achieving genetic diversity and selection for improved crop cultivars; metagenomic advances will be used to discover new bioactives; and whole genome sequencing will be used to identify and design superior breeding stock, both plant and animal.

The *Internet of Things* (IoT) down on the farm. The era of harvesting information from embedded devices and putting it to use to improve systems is only just commencing. Billions of devices, plugged into billions of other devices over an internet connection, creates meta-level system functionality. Coined the 'Internet of Things (IoT)', this technology will transform our lives over the next three decades, and IoT will apply to farming just as it does to the energy sector (for example, 'smart meters'), mining (for example, Rio's driverless trains) and tracking devices (for example, the Find My iPhone app). This will play out in many and varied ways on farms [126], only limited by the imagination and business ingenuity of our innovators. Some examples are:

- knowledge of where each animal is located, if it is moving (or dead), and if it is healthy. Mustering becomes much easier when the farmer knows where each animal is located.
- field operations on automatic—spraying, planting, harvesting, enabled by GIS positioning, sensors on fuel use, tyre pressure, engine performance, seed flow rates.
- automated irrigation systems that turn the water on when your plants are thirsty—based on soil moisture probes, pumps, flow meters.
- smartphone photo snaps to analyse insect loads on crops and the amount of pasture on offer.

As smart devices are linked to sophisticated software for data analysis and decision making, farmers will spend less time driving around the farm and more time interpreting the high-density real-time data streaming from their paddocks and animals. Not only is it farmers who have a vested interest in the IoT, but so have major suppliers such as machinery manufactures and agri-businesses such as Monsanto—as evidenced by their recent acquisition of The Climate Corp, a business that specialises in smart farming tools.

Seeing the whole supply chain. With IoT enabling technologies, supply-chain management will reach back onto the farm in ways not seen before, with real-time tracking of quantity and quality of product whilst under production. This will see farmers recording their management practices in systems that can be audited and identifying their produce in a standardised manner that can be picked up by supply chain partners to pass on important information on characteristics such as GM-free, sustainable harvest, organic, free-range, carbon footprint and fair-trade. Smartphones in the hands of consumers will also form part of the IoT, with shoppers interrogating food labels to see the provenance of their purchases.

Scanning the supermarket aisles. Radio Frequency Identification (RFID) is an established means of embedding live information into products so consumers, retailers, logistics companies and farmers can enter or extract data. While the technology is not new (cattle tags in Australia have used this technology for some time), its implementation as a tracking device across fresh food supply chains is in its infancy in Australia. Most shops still use a barcode and paper-based system for trace-back, not fast enough for fresh food, and cumbersome to apply. The trend overseas has been for companies to implement a fully integrated tracking system that allows them—not only to do trace-back in the advent of a food safety concern—but, more importantly, to track and manage the flow of product through their distribution systems [127]. And the Australian seafood industry is onto this [128] with pilot projects to use RFID and smart software to trace our prawns and lobsters as they make their way onto our plates.

Automated farmhands. Increasingly we will see the application of robotics to agriculture, as advanced analysis of farm operations identifies those aspects that are open to automation. While it may not be feasible to automate a whole process (such as harvesting of speciality crops), mobile robots will be used to assist field workers, reducing injury and improving labour efficiency. We are seeing an increasing trend towards the application of robotics, from single task robots to move pots in nurseries through to automatic milking systems [129], that not only use advanced robotics but integrate data collection into the system.

Advances in remote sensing imagery. Over the next three decades our knowledge of the landscape is set to burgeon as new earth observation tools come to hand, ranging from drones to satellites. At the macro-level we have the GEOGLAM (Global Agricultural Monitoring) initiative using satellite and ground-based observations to predict regional and national crop yields, feeding data into AMIS (a system designed to help manage global food shortages). The quality and resolution of images is accelerating to the point where technologies such as stereo digital aerial photography can be used to map vegetation at the scale of individual bushes, an approach that is being used to monitor the impact of Chevron Australia's liquefied natural gas plant on Barrow Island.

Unmanned aerial vehicles (UAVs). Agriculture is predicted to become one of the largest commercial applications of unmanned aerial vehicles [131]. Low-flying drones, equipped with sensors and digital imaging, such as infrared, X-ray and hyperspectral imaging, can detect water stress, nutrient deficiencies and disease. Orchards can be monitored for flowering, weed invasion can be detected and livestock located. Not only will new observational data be used for analysing our landscapes, but with super-computing breakthroughs, the back catalogue of satellite data will be harnessed to look at land-use change over time, an approach already being taken to run audits on land clearing history for certification of sustainable oilseed production.

Bots and bees at the bottom of the farm. Increasingly we will see the application of robotics to agriculture as advanced analysis of farm operations identifies those aspects that are open to automation. While it may be some time before it is feasible to automate a whole process (such as harvesting of speciality crops or pruning grape vines), mobile robots are being used to assist field workers—reducing injury and improving labour efficiency. Groups from France, New Zealand and California have viticulture robots under development, tasked with learning how to prune, diagnose vine health and eventually harvest grapes without any human intervention. At the more creative end of the spectrum is the Australian ‘Robotic Rover’, designed to replace the trusty cattle dog by using 3D sensors and GIS to move cattle at a pace consistent with their walking habits [132]. We are seeing an increasing trend towards the commercial application of robotics, from single-task robots to move pots in nurseries through to automatic milking systems [129] that not only use advanced robotics but integrate data collection into the production system.

Automated farming systems need not always involve mechanical robotic solutions. The same principles are being applied via completely natural means. For instance, researchers at the University of Adelaide are ‘training’ honey bees to act as biological control agents. In this system the bees deliver a daily dose of fungicide to cherry blossoms as each flower opens. This combats the problem of ‘brown rot’ which is a major problem for Australia’s A\$150 million/year cherry industry [130].

Nanomaterials in agriculture—size matters! While there are few nanomaterials in use yet for agriculture, there is a clear trend for increasing research, as evidenced by patent applications for products such as nanopesticides [133], which over time will translate into commercial products. In the animal health area, the benefits offered by this technology are more targeted release of compounds and better efficacy from poorly water-soluble materials. The nanoscale dimension is similar to that of naturally occurring bio-molecules, which are effective in getting into the cells where they will work—but which also increases the risk for both the target animals and the environment. While the technology holds promise across a range of domains and applications, there are considerable technological and regulatory hurdles before we will see widespread implementation.

Advanced materials—what we wear. In the developed world there is a move to consider the design aesthetics and functional aspects of clothing and how different fibres contribute to the ease and consistency of manufacture. The trend to more integration between sporting, casual and work attire sees innovation that gives added function to fabrics (for example, the presence of elastane in fabrics to give greater stretch and ease of wear, and the introduction of high performance thermal sportswear [134]). Some innovations complement the performance of natural fibres while others displace natural fibres. The future application of 3-D printing to garment manufacture, totally revolutionising the way a garment can be constructed, will open up the range of compounds that can be used for fabrication.

Growth in synthetic textiles in emerging economies. The growth in textiles will be far greater in markets in developing countries over the next three decades, as this is where population growth will be concentrated. There is a strong trend towards synthetic textiles in these countries (Figure 12), hence synthetic fibres will contribute the most to growth in world apparel consumption [135]. A shifting pattern of wealth may temper this, but the large expansion in textiles is going to be for synthetic rather than cellulosic fibre.

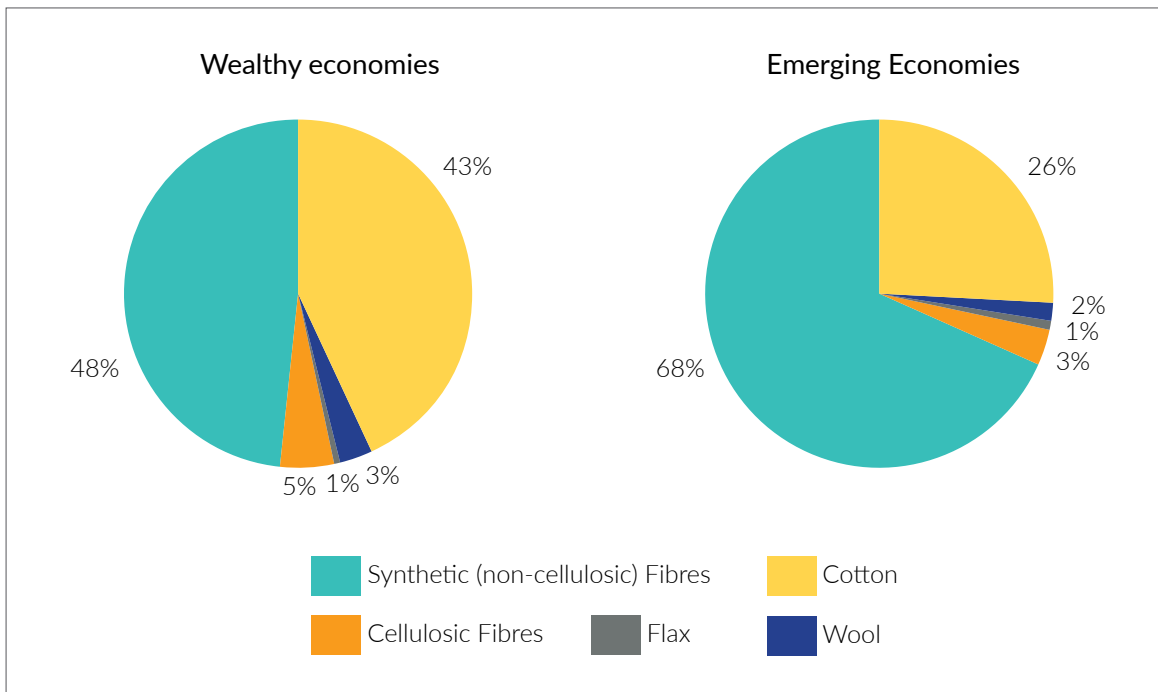


Figure 12: Comparison of apparel fibre consumption in developed and developing countries in 2010

Source: International Cotton Advisory Committee [135]

Synthetic food—recent advances. Just as synthetic products have eaten into the market share of natural fibres, there’s a possibility that synthetic foods, at some point, will take some portion of the market share occupied by natural foods. How far this trend goes may depend more on consumer sentiment than on technology breakthroughs: already scientists have succeeded in producing a beef burger by growing a cow’s muscle tissue in a laboratory. A reporter from the BBC World News service [136] attended the taste testing of the lab-grown beef burger in London in August 2013 and reported the conclusions of the food critics: ‘One food expert said it was close to meat, but not that juicy and another said it tasted like a real burger’. Researchers from the University of Oxford recently published a study in the *Journal of Environmental Science and Technology* comparing cultured (lab-grown) meat with conventional meat (Figure 13). When midpoint values are estimated for their high–low ranges, the results show cultured (lab grown) meat uses 26 per cent less energy, 89 per cent less water, 99 per cent less land and 87 per cent less greenhouse gas (GHG) emissions compared to conventional meat [137].

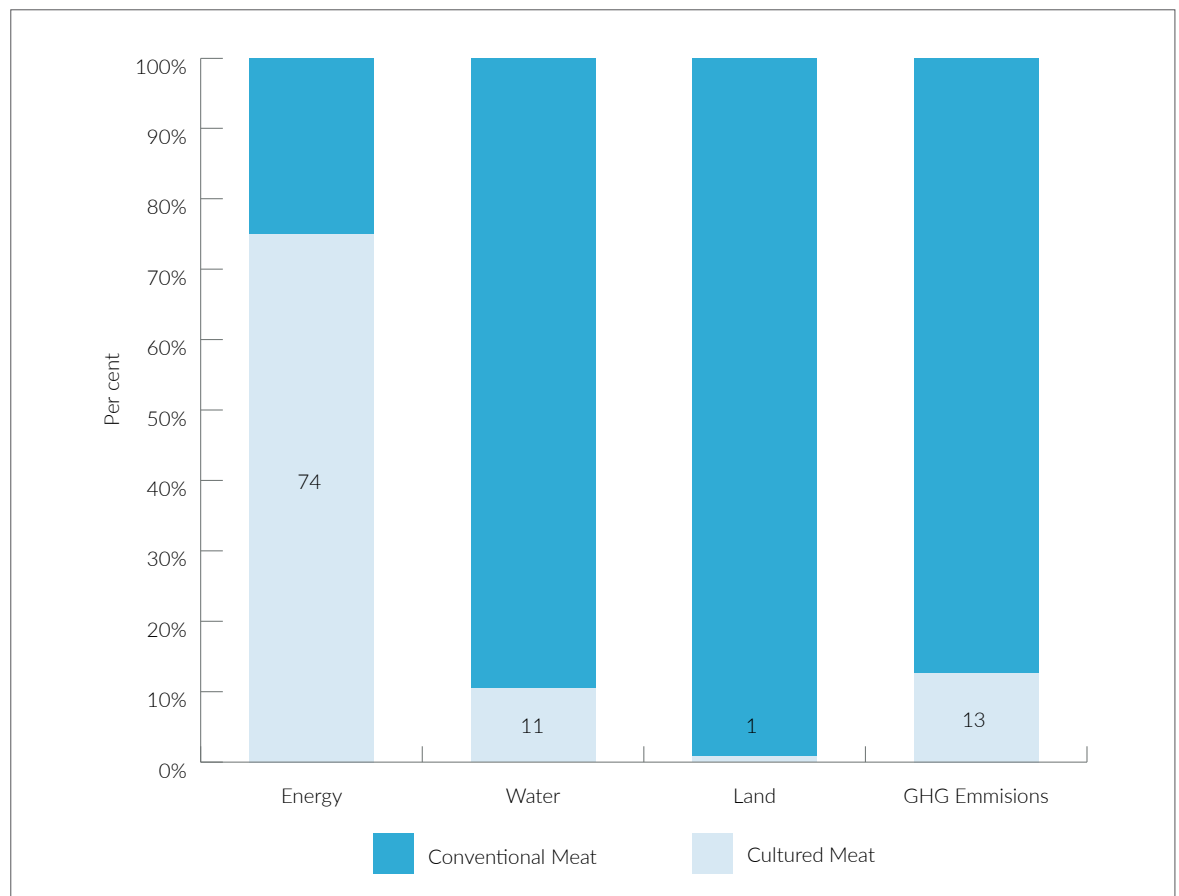


Figure 13: Percentage of resources consumed by cultured (lab grown) meat compared to conventional meat.

Source: *Journal of Environmental Science and Technology* [137]. Note: the original publication provided percentage ranges of high-to-low (based on different types of meat); midpoint values are used here.

Not all synthetic food needs advanced genetics. Does the recent taste testing of a beef burger grown in a laboratory mark a significant step on the path to commercially cultured meat? In this instance, the burger was grown from a culture of cells sourced from a cow, multiplied up in a nutrient solution and then structured into thin strands of protein. While technically feasible, this technology is not likely to appear in a supermarket near you any time soon, mainly because it is still more economical to produce the real thing at the current time. However, the costs of genetic technology have fallen rapidly in other fields. The cost of mapping the human genome, for example, fell from billions of dollars to hundreds of dollars. However, even putting genetic science aside, there are some intermediate food products that represent the first steps to more industrialised production from raw ingredients. For many decades now, industrial processing of maize and soybean have produced ingredients that are used as the basic building blocks for much of our diet—corn syrup, food starch, thickeners and emulsifiers. Some products are sort of identifiable (like cheese-flavoured chips), while other are more cutting-edge combinations designed to give convenience and nutrition at a low price (like muesli bars). The next step would be to produce these compounds from their basic building blocks, rather than getting plants to grow them, and there are research labs working on just this [138]. Foods of the future may be entirely new creations built from scratch.

Consumer resistance to modified animal food products. If corn and soybeans were considered in the same light as milk, we would never have had cornflakes on our breakfast tables. Consumers react differently to modified animal food products. Australia recently saw a hostile reaction by consumers to the presence of ‘permeate’ in fresh milk—a safe and regular practice of standardising milk components [139] that met with such fierce consumer resistance that all major supermarkets now claim their fresh milk is ‘permeate free’. Another modified animal product hit by strong resistance is ‘lean finely textured beef’ (LFTB). This is produced when fat is removed from low-grade beef trimmings and the product is treated with food-grade ammonium hydroxide to kill microbes [140]. This food-safety-approved modified beef product is competitively priced in the market and can be used as a food additive (10–20 per cent by volume) in manufacturing beef in the United States. However, the accompanying furore over ‘pink slime’ in 2011, resulting from a greater awareness of the food components in ground beef, led to McDonald’s withdrawing LFTB from their burgers [141]; the USDA to re-evaluate of use of LFTB in school lunches; and the withdrawal of ground beef containing LFTB from many large supermarket chains. Consumers seem much more willing to tolerate reconstructed plant foods as opposed to reconstructed animal foods.

Decarbonising energy systems. The growth of liquid biofuels has been rapid—from 68.3 million tonnes in 2006 to 130 million tonnes in 2011, now utilising over 45 million hectares of land for production of feedstock [142]. This will continue to expand, with two major markets having in place legislated targets for biofuels [143]. Further expansion will be largely driven by global and national climate change policy and the need to decarbonise transport fuels. For the period up to 2020 the market will be dominated by first-generation biofuels, based on food products (maize, canola, soybeans, sugar, wheat), as technologies for second-generation fuels (based on cellulose, hemicellulose or lignin) are yet to reach industrial scale.

Second generation biofuels. Although there is pressure for current feedstock to be superseded by second-generation feedstock, so as to relieve the pressure on food supplies globally [43], even second-generation biofuels will rely on land-based systems to produce biomass, resulting in increasing competition for a broader class of land. The demand for biofuels may be moderated somewhat by technologies for electric ground transport powered by low-carbon energy sources, but there are few low-carbon alternates to biofuel for air and sea transport. More than 75 per cent of global biodiesel production is expected to come from vegetable oil in 2020, which is of particular relevance to the Australian canola industry, which exports over 50 per cent of national production for biodiesel.

Implications for Rural Industry Innovation

1. Farmers will have sophisticated tools to assist with decision making

Advanced data analytics, statistical forecasting, sensory systems and other digital technologies will bring better risk management approaches to Australian agriculture. Weather and crop/pasture yields, for example, will be much more predictable. An improved capacity for risk management will lead to increased productivity of the Australian agricultural sector.

2. Many new business models will develop in the agri-business sector.

The need for inter-operability of smart devices, and the systems built around them, will open up first-mover advantage to innovative agri-businesses.

3. The concept of farming will be expanded to non-food land use.

New markets and opportunities for land-based products will emerge in response to climate change and the need for renewable energy.

4. Farming will be a much more transparent activity

Agriculture will need to respond to the greater scrutiny—from the community, governments and consumers—that internet technologies, robots and earth-observation systems enable.

5. Farming will be less manual and more digital (and less about muscle power and more about brain power).

The rollout of fast broadband, robotics and sensors will improve labour productivity and farming precision. Improving the level of technology skills of farm managers and staff will be a key to enhancing uptake and application of these smart technologies.

6. Maintaining competitive advantage will call for informed decisions.

Attitudes to technologies (for example, genetic modification) will need to be reconsidered rationally to improve competitiveness, where appropriate, as our international competitors increasingly adopt and benefit from these technologies in product lines central to our export markets.

Emerging questions

- Will market perceptions hold back Australian agriculture by restricting access to advanced technologies being used by our major competitors?
 - How will farmers manage a higher level of scrutiny of their operations?
 - What changes are needed to ensure the education and skill base needed to apply new technologies are in place in the different industry sectors?
 - Will synthetic food and fibre products become viable competition to more natural products?
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07

A BUMPIER RIDE

*“The future ain’t what
it used to be.”*

- LAWRENCE PETER 'YOGI' BERRA, EX NEW YORK YANKEES BASEBALL PLAYER

Risk is an ever-present characteristic of Australian agriculture. However, the coming decades will see changes in the global climate, environmental systems and world economy which will create new and potentially deeper risks for farmers. This is largely due to the interconnectedness of worldwide environmental and socio-economic systems. The risk profile is set to change.

Climate change is elevating the frequency and severity of extreme weather (for example, droughts, floods, bushfires). The globalisation of supply chains which provide inputs critical for agriculture (for example, fertilisers, fuel, chemicals) increases the number of links in the production system, and therefore, the risk of supply-chain breakdowns. Changes to environmental systems are impacting food production systems. Weed and pest resistance to herbicides and pesticides is reducing their effectiveness and increasing farm vulnerability to these problems.

This last megatrend describes new and emerging challenges that are likely to express themselves to a greater extent in coming decades. However, Australian agriculture has demonstrated an amazing capacity to adapt and respond to risks in the past. With today's innovative technologies and deeper knowledge base Australian agriculture is well positioned to respond to risks in the future.

Climate change and extreme weather. The global mean temperature of the earth has increased by 0.85 degrees Celsius since 1880 [144]. The fifth assessment by the International Panel on Climate Change says:

Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise.

This includes a forecast increase in average temperature, during the period 2016–2035, of between 0.3 to 0.7 degrees. By the year 2100 global temperatures may have increased by 2 degrees Celsius compared to historic averages. The Bureau of Meteorology makes the following observations about Australia's climate [144]:

- Warming of the climate by 0.9 degrees Celsius since the year 1910
- Slight increase in average rainfall across the continent since 1900, with the largest increases in the north west regions occurring since the 1970s
- Decreased average rainfall in the south west regions of Australia since 1990
- Temperatures expected to rise in coming decades with more extremely hot days and fewer extremely cool days

- Australian mean temperatures forecast to increase by 0.6 to 1.5 degrees Celsius by the year 2030 and from 1.0 to 2.5 degrees Celsius by the year 2070
- Extreme fire weather days forecast to increase by 10–50 per cent for low global emissions scenarios and 100 to 300 per cent for high emissions scenarios by the year 2070
- Average rainfall expected to decline in coming decades with droughts becoming more severe and frequent in southern Australia
- Heavy rainfall events (for example, associated with flooding) also forecast to become more frequent
- Continued decreases in average rainfall are anticipated for Southern Australia with a 0–20 per cent decrease by the year 2070
- Rainfall in northern Australia forecast to change within the range of -20 to +10 per cent (that is, it may either increase or decrease) by the year 2070
- Changes in the frequency and severity of tropical cyclones, based on historic data available since the 1970s, are inconclusive
- Sea levels forecast to rise by 0.3 to 0.6 metres, associated with increased frequency and severity of coastal inundation.

All these changes in climate conditions have the potential to impact Australian agriculture. The extent of climate change during this century depends on the level of global greenhouse gas emissions. However, many of the nearer-term impacts are unavoidable regardless of emissions reductions, due to historic greenhouse gas emissions. The consequence will be that Australian food and fibre production systems will experience increased climate shocks and will need to operate within greater climate variability. There is likely to be considerable innovation and effort in designing and implementing systems which mitigate climate shocks.

Climate change and food production. The effects of climate change on food production will vary geographically. Overall there are more negative impacts than positive impacts [145]. There is evidence that climate change impacts (in particular the adverse impacts of heat and water stress) have contributed to food shortages and price spikes observed over the last 6 years. However, extreme weather events are likely to be only a part of the complexity of high and volatile food prices [146], with other likely causes being biofuel demand and commodity trading [147]. The projected trend required for yield improvement (1.1 per cent per annum) is a key contributor to food provision [25] and the risk associated with achieving these rates is raised considerably by climate change for key crops such as maize and wheat [148]. As the certainty grows around how climate change will play out in terms of regional rainfall and temperatures, there will be a concerted effort to better quantify the impacts on local food production and supplies into international markets.

Biosecurity and global movements. There has been a strong upward trend in the number of people arriving in Australia over the last 50 years [149]. In 1976, arrivals were about 137,000 per month; in 2014, arrivals averaged almost 1.4 million per month. These figures include all people clearing Customs into Australia, including tourists from other countries, Australians returning home and permanent immigrants. Alongside the massive increase in people-movement has been a corresponding increase in arrivals of ships at Australian ports, with the average number of vessel calls at Australian ports growing from 19,500/year in the early 1990s to 29,500/year since 2010 [150]. This trend in movement of people and cargo comes with an increased risk of exotic disease incursion into Australia that can have devastating effects on agricultural industries. An example of this has been the introduction of cucumber green mottle virus into the Northern Territory. While there is currently no clear trend for an increase in incursions of exotic disease and pests, largely due to Australia's strict and effective quarantine measures, global trends such as travel and trade increase biosecurity risk for our agricultural industries [151].

Globalisation of supply chains and emerging risks. Just about all Australian industries are becoming more dependent on global supply chains to create the products they sell to end consumers. A 'supply chain' can be thought of as a network containing a series of linked nodes which take a product from the original raw materials to the final customer. As more links and nodes are added to a supply chain the risk of the network breaking down increases. The idea is that a chain is only as strong as its weakest link. A global supply chain usually has more links than a domestic supply chain and therefore a global supply chain usually holds greater risk. Writing in the *International Journal of Physical Distribution & Logistics Management*, researchers from the University of Texas observed (p. 192):

Global supply chains are more risky than domestic supply chains due to numerous links interconnecting a wide network of firms. These links are prone to disruptions, bankruptcies, breakdowns, macroeconomic and political changes, and disasters leading to higher risks and making risk management difficult. [152].

Australian rural industries increasingly depend on global supply chains for production inputs and market access. As supply chains become yet more globalised in the coming decades, these risks will increase.

Reliance on offshore fertiliser production. Fertilisers are essential production inputs on many Australian farms. They are used to boost plant growth and achieve higher yields. However, Australia is increasingly reliant on offshore fertiliser companies to secure essential crop and pasture nutrients. According to federal government data [14], Australian farmers used 1099 kt of nitrogen in the year 2012. Of this amount 949.4 kt (86 percent) was imported. Phosphorus and potassium are two other elements used in fertilisers and are essential for plant growth. In the same year, 54 per cent of phosphorus and 90 per cent of potassium were imported. Australian agriculture is increasingly dependent on global supply chains to source essential fertilisers.

Concentration of global fertiliser production. A recent study from the International Food Policy Research Institute (IFPRI) finds that 50 per cent of the world's nitrogen, phosphate and potash fertilisers come from only five countries: China, India, Russia, the United States and Indonesia [153]. The Middle East is becoming an increasingly important region supplying fertiliser to Australia. According to the company website [154], Incitec Pivot is Australia's sole producer of urea fertiliser, making around 250,000 tonnes per year. However, annual consumption of urea in Australia is 1.5 million tonnes, with the balance of 1.25 million tonnes coming from the Middle East. Given this region has a history of instability, there is a risk that trade-related shocks will impact Australian rural industries by restricting fertiliser availability.

Increasing reliance on offshore chemicals industries. Farms depend on a wide range of chemical products for day-to-day operations. These would include lubricants, herbicides, pesticides, soil ameliorants (for example, lime) and many other chemicals. Without access to a wide range of chemical products many current farming systems would be unviable. However, these chemicals are increasingly being sourced from offshore. Since the year 2005, Australia's trade deficit in plastics and chemical products has been increasing by ≈ 5 per cent per year. This is mainly due to cost-competitive supply of imported products, mostly from Asian regions. As Asia continues to build advanced and modern infrastructure and continues to increase production and exports, this trend is likely to continue [155]. Since 2007–08, the total number of businesses in the chemicals and plastics industry has been decreasing [156]. The largest drop was experienced in 2007–08, likely due to economic conditions, given that the industry is considered cyclical and sensitive to economic conditions [157]. However, the total number of businesses operating has continued to decline. Employment in the industry has declined from 64,000 persons in 2005 to 54,000 persons in 2011 and jumped 12 per cent, from A\$10.6 billion in 2006–07 to A\$11.8 billion in 2007–08. However, growth stalled in the following three years. From 2007–08 to 2009–10 the industry value-add contracted from A\$11.8 billion to A\$11.4 billion with negative growth of 4 per cent [158]. Australia is increasingly reliant on offshore suppliers to design and provide chemicals essential for farming.

Oil prices and food prices. Oil prices have an impact on the prices of most primary commodities through the use of energy-intensive inputs [159]. Fertilisers and food are sensitive to oil-price changes [159]. The cross-price elasticity of demand from crude oil to fertilisers is approximately 0.33. This means that a 10 per cent increase in price of crude oil would lead to a 3.3 per cent increase in the price of fertilisers [159]. This would then flow through into other commodities for which fertiliser is an input. Food has a cross-price elasticity with oil of 0.18. Therefore, a 10 per cent increase in the price of crude oil would lead to a 1.8 per cent increase in food prices [159]. Over the past 10 years, the world crude oil price has experienced periods of extreme volatility. This has been associated with large and rapid changes in farm production costs and volatility in global food commodity markets. As at November 2014, world crude oil prices are unusually low. The price of Brent crude oil has fallen to US\$74/barrel, which is 30 per cent below the June 2014 price. However, volatility measures provided by the US Energy Information Administration and Bloomberg [160]—which provide a proxy for uncertainty about future oil price movements—have been at their highest levels for over one year. Longer-term forecasts in either oil prices or volatility are unreliable. However, the decades ahead could see the oil price shocks of the late 1970s and late 2000s repeated as the world changes the mix of energy sources. This will have an impact on the costs of agricultural production and food prices.

Long-term energy forecasts and climate policy. Projections for energy prices suggest that coal and oil prices will continue to rise to 2050, at a steeper rate for oil as known reserves are depleted [161]. Gas prices are predicted to stabilise by 2040, reflecting the large expansion of unconventional reserves (tight sands, shale gas and coal bed methane). These price projections reflect the Copenhagen/Cancun pledges for greenhouse gas mitigation, and should deeper cuts in emissions be agreed, the trends could substantially shift [162]. Price increases will continue to drive incremental improvements in efficiency for the manufacture of fertiliser and chemicals. Agriculture is more exposed to the trend for liquid fuel prices; hence oil shocks pose the largest long-term risk in terms of input costs. Exchange rates can also have a major impact on input costs, where purchase of raw materials and/or production occurs off-shore but these are somewhat balanced out for agricultural production that is exported.

Dependence on offshore oil production. Oil prices are watched closely by the agricultural sector because they have a big impact on overall production costs. Every farm depends upon crude oil for diesel and petroleum to power vehicles and other machinery and to transport goods to market. According to the BP Statistical Review of World Energy, in the year 2013 Australia's daily production rate of oil was 416,000 barrels—the lowest level of production since 1972. Over the same period oil consumption hasn't changed much. According to an article by a researcher from Griffith University on the academic news website *The Conversation* [163], the gap is being filled by increases in oil imports. Forecasts suggest that Australia's self-sufficiency in oil will drop from 48 per cent in 2011 to 20 per cent by 2020. Much of Australia's refined petroleum products come from Singapore, which is dependent on the Middle East for 80 per cent of its crude oil supplies. This means geopolitical destabilisation in the conflict-prone Middle East creates a supply-chain risk for Australia. According to the International Energy Agency (IEA), Australia's stockpiles of oil would last the country only 53 days in the event of complete supply shutdown.

This compares to 103 days for New Zealand, 186 days for the United Kingdom and 245 days for the United States. These statistics point to supply-chain risks for Australia's rural industries [164].

Pesticide resistance. Within a population, some individual insects have greater resistance than others against a particular pesticide. Therefore, when pesticides are applied to a whole population, individuals with higher resistance are more likely to survive via processes of natural selection. Over time the insect population will contain a higher percentage of resistant individuals, which decreases the effectiveness of the pesticide for the farmer in future applications. Today more than 450 arthropod species worldwide have been reported to have resistance to one or more pesticides [165]. One such pest species in Australia is the diamondback moth which damages brassicaceous crops such as broccoli, brussels sprouts and cabbage [166]. Today the diamondback moth has resistance to all modern insecticides which have been in use since the 1990s. The coming decades are likely to see the problem of pesticide resistance increase with impacts on all rural industries. This will call for new and innovative mechanisms of pest control.

Herbicide resistance. Herbicides are chemicals used to manage weeds which harm crop and pasture production systems. Weeds can out-compete productive plants for space, soil nutrients and water. Weeds are estimated to cost Australian agriculture around A\$4 billion per year [167]. As with pesticides, the use of herbicides eventually results in more resistant target weed populations as a result of natural selection. The most recent international survey [168] finds 437 unique types of herbicide resistant weeds in existence. The survey also finds that one or more weed species are resistant to 155 different herbicides and that resistant weeds have been found in 84 crops in 65 countries. In Australia, 104 unique weed types are identified from New South Wales, Victoria, Queensland, Western Australia and South Australia. The CSIRO, the Australian Herbicide Resistance Initiative (AHRI) and many other research organisations are working to identify solutions to the rising issue of herbicide resistance in weeds. The future is likely to see more weeds develop resistance, calling for increased innovation in methods of weed management.

The Baby-Boomer handover. The proportion of younger farmers (<35 years of age) has decreased by 75% over the last 50 years, due in part to farm aggregation (where remaining farmers with the means to purchase property are older); structural aging of the overall Australian workforce; delayed entry into the workforce as more people undertake higher level education; and a low rate of exit of farmers over the age of 65 [169]. However, there is a natural limit to how old farmers can get, and transition to different ownership will accelerate as the Baby-Boomer generation leaves active farming. However, this is not predicted to create any threat to food security or export volumes, and it will manifest in a higher rate of aggregation of farms which may bring associated improvement in productivity. In the small farm portfolio there is likely to be more ownership by people from a non-farming background.

Implications for Rural Industry Innovation

1. Develop climate-resilient agriculture.

Agriculture is arguably the industry most heavily impacted by changes in the global climate. Extreme weather events such as droughts, heatwaves, floods and bushfires have the potential to impact crop and livestock production systems. Longer periods of drier, wetter and hotter weather will also have an impact on the regions that are suitable for particular enterprises. Production systems that can be designed to anticipate, prepare for and respond to these changes are essential for a growing sector.

2. Identify and develop systems for carbon sequestration.

The reduction of greenhouse gas emissions remains an important policy priority for Australian and overseas governments. A range of policy tools are likely to affect the operations of the sector, as well as potentially providing opportunities: agriculture is an industry that may be well positioned to create the greenhouse gas savings sought by these policies while simultaneously improving productivity.

3. Document and understand supply chain risks and build mitigatory mechanisms.

Overseas supply chains may be a cost-effective way to source inputs required by rural industries. However, if the supply chains are narrow they do create risks to supply. Scenario planning can help rural industries run 'what if' style analyses to identify the impact of supply shocks (and price shocks) for critical inputs such as fertiliser and fuel. Understanding the risks will help mitigate them and build more secure supply chains.

4. Develop alternative mechanisms for managing pests and weeds.

Pest and weed resistance to insecticides and herbicides is likely to continue worsening. Furthermore, some important chemicals are also being deregistered for health and environmental reasons. Food production in many rural industries depends on the ability to combat pests and weeds, and chemicals have historically been an efficient and effective means of doing this. The armoury of tools is thin for some industries and it is costly and time-consuming to produce new products. Ongoing innovation—in chemicals, in alternative approaches such as genetic technologies (for example, BT cotton) and in the identification of new management strategies (for example, integrated pest management)—is a vital risk management strategy.

5. Identify viable options for ‘indoor farming’.

These may involve techniques such as hydroponics, hot houses and synthetic foods that are insulated from the climate. Whilst these options may not initially be competitive with traditional agriculture they may become an important part of food and fibre production in the future if severe climate and environmental risks materialise.

Emerging questions

- Is there a possibility of much deeper and more damaging climate change impacts than commonly envisaged and could these damage agriculture to the point that food security is compromised in Australia?
 - Are we being complacent and underinvesting in risk management in the food and agriculture sector?
 - Will the increasing level of risk in the sector constrain future growth or will Australian farmers learn to manage more risky physical and economic operating environments?
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CONCLUSION

Overall there is a bright future for Australian agriculture, laden with deep and diverse opportunity. Strong drivers are in place, building momentum for global growth in demand for food and fibre products. Income growth in Asia will see diets diversify, protein consumption rise and niche markets for boutique foods become mainstream markets. New technologies will create opportunities to reduce costs, improve product quality, manage risk and make entire supply chains operate more efficiently. A knowledgeable and information-hungry customer, more demanding of products demonstrating provenance, ethics, sustainability and health benefits, will be a challenge for some producers and some industries but an opportunity for others.

The risk profile for Australian agriculture will reshape over coming decades. Whilst helpful in some ways, disruptive technology also has the potential to crowd-out existing markets. Cotton, for example, is a natural fibre product increasingly under pressure from modern synthetics such as polyester. Over time, other synthetic products may increasingly compete alongside traditional crop and livestock products. Technology will also make supply chains more transparent. Breaches in ethical, environmental or provenance standards are likely to be quickly detected via recording devices and widely disseminated over social media with substantial reputational damage for industries. Whilst the breach may have occurred in a single business within the entire supply chain, the entire industry can incur the reputational impact.

Climate change, globalisation and environment change also pose new and emerging risks for agriculture. Australian farms are increasingly reliant on complex offshore supply chains for essential inputs. The warming of the world climate is a well-recognised phenomenon and some of the impacts are already visible. However, the deeper and more severe impacts lie in the decades ahead. Australian farms will need to operate under increased weather uncertainty, with long range forecasts for more droughts, floods, heatwaves and bushfires. Southern parts of Australia are forecast to have less rain overall and some parts of northern Australia may see more rainfall. The rise of pest and weed resistance to insecticides and herbicides is a lesser-known but significant threat to current production practices.

The effectiveness by which Australian agriculture captures the opportunities and avoids the risks largely comes down to innovation. Through centuries past, repeated innovation is what allowed Australian farmers to expand into new land areas, develop water resources and increase crop and pasture yields. As we look to the decades ahead, innovation has become more important. In a world of exponential growth in both technology and global trade, it's about working smarter not just working harder.

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