STOCKTAKE OF
Megatrends shaping Australian agriculture (2021 update)

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More from less: The permanent race for advantage
Relentless innovation drives improved productivity, and more efficient use of materials, energy, water, land and labour. Maintaining profitable and competitive food and fibre enterprises will require ongoing innovation and change.
But the benefits of change will not be shared evenly, often exacerbating existing pressures on rural industries and regional communities. Improved productivity may benefit consumers (through lower prices) more than producers. Regional population will continue to drift from farms and smaller towns to larger regional centres and capital cities.

Fractal politics: Beware the dance of giants
Deep shifts in economic, military and cultural power will continue to reshape the world, as the rise of multiple global powers erodes previous certainties, notwithstanding increasing global integration.
International trade and relations – along with food and fibre markets, supply chains and relationships – will all become more complex as nations assert their sovereignty, often in pursuit of populist appeal rather than mutual economic gains.

Disruptive technologies: Opportunities for the brave
Exponential advances in digital technology, automation, genetics, and synthetics will disrupt and change how food and fibre products are made, marketed, and delivered. Production systems, supply chains, and customer engagement will become more agile and interconnected, requiring new skills and partnerships, and creating risks and opportunities for agricultural producers and regional communities.

Cascading planetary risks: Coming, ready or not
Accelerating changes in earth systems at all scales – from global to microbial – are creating multiple risks and challenges, and some opportunities.
Agriculture is already impacted, and adapting. Climate and commodity prices will become more volatile, while emerging markets for carbon and ecosystem services could transform landscapes and business models.

Growth juggernaut: Three billion empowered consumers
Rapid growth in emerging economies, particularly in Asia, will lift incomes, expectations, and economic capacity. An expanded and empowered middle class will demand higher volumes and quality of food and fibre, including more diverse diets and more protein – with rising expectations for health, provenance, sustainability, and ethics.

Positioning for the future: Will the lucky country surf or sink?
Australia is indeed lucky: a ‘lifestyle superpower’ with competitive industries, vibrant communities, and unique landscapes and environmental assets. But unearned advantage risks complacency, and each generation needs to create the luck – and advantages – it will pass on to the next generation. Will Australia choose to surf or sink?
Australia’s food and fibre industries will be shaped by multiple interacting changes over the coming decades.

These changes will occur at global, national, and local scales. They will create opportunities and challenges for all food and fibre industries and farm businesses. They will also impact on Australian lifestyles, landscapes, communities, and wider society and economy.

In order to better understand these evolving changes, this article updates previous CSIRO analysis (Hajkowicz 2015, Hajkowicz and Eady 2015), setting out five global megatrends that will shape Australian life and choices, and exploring their implications for Australian food and fibre industries to 2040 and beyond.

A megatrend is defined as a trajectory of change that will have profound implications across many areas of industry and society. Each megatrend occurs at the intersection of multiple more specific trends and patterns of change – including geopolitical, economic, environmental, social or technological trends.

For each megatrend we provide a short summary, identify key implications for Australian agriculture, food and fibre industries, and suggest some further readings (with reference details provided on page 33).

The aim of this Insights article is to help individuals, enterprises, sectors, and governments to explore and better prepare for an uncertain future, including through making choices and developing strategies that are tailored to their specific context and objectives, to harness emerging trends and opportunities while managing key uncertainties and risks.
Growth juggernaut: Three billion empowered consumers

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Positioning for the future: Will the lucky country surf or sink?

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Growth juggernaut: Three billion empowered consumers

Rapid growth in emerging economies, particularly in Asia, will lift incomes, expectations, and economic capacity. An expanded and empowered middle class will demand higher volumes and quality of food and fibre, including more diverse diets and more protein – with rising expectations for health, provenance, sustainability, and ethics.

Rising incomes in emerging Asian economies, including China, Indonesia, and India, are the primary drivers of this long-term global growth.
1.1 Empowered consumers will shape markets

Notwithstanding the current global pandemic, global average incomes are projected to rise substantially in coming decades, with the number of people in high-income countries projected to triple by 2050, adding more than 3 billion new consumers to this group (see Figure 1). Rising per capita incomes are the primary driver of this change, with increases in population playing a smaller role. Emerging Asia accounts for the majority of the projected global increase in economic activity and purchasing power, with average incomes across this group increasing by around 150% (to 2.5 times 2015 levels) by 2050, while population increases by a third (see notes to Figure 1). While the precise timing of reaching specific milestones will be sensitive to current and potential future shocks, and policy responses, the momentum of increasing per capita incomes is almost unstoppable.

Increasing trade volumes are both an important driver, and consequence, of global economic growth. Unfortunately, shifts towards increased protectionism appear likely in agriculture markets (see Sections 2.1 and 3.3 below). This risks slowing the rate of global growth and reducing the extent of new trade opportunities for Australian exporters from this megatrend.
1.2 Demand for high quality food will continue grow strongly

Rising incomes in developing countries will see shifts in food demand, from grains, rice and other starchy staples towards protein-rich animal products, plant-based sources of oils and protein, and fruits and vegetables.

ABARES analysis of food consumption and export opportunities in major Asian countries (Andrews and Gunning-Trant 2013) finds that imports are likely to increase as a share of total consumption across all developing Asian markets. Consumption and total import demand are projected to grow most strongly for fruit and vegetables, red meat, and dairy – with consumption of these commodities projected to double in many markets – along with strong growth in vegetable oils in some markets (see Figure 3). By contrast, only modest growth is projected for coarse grains and rice.

**FIGURE 2** Growth in Asian imports strongest for fruit and vegetables, dairy, and meat

![Graph showing consumption and import growth by commodity](image-url)

Notes: Projected growth in the value of consumption and imports by commodity from 2015 to 2050, US$ billion (2015 real values).

Data Source: Andrews and Gunning-Trant 2013

Meat and dairy products currently account for two-thirds of the protein in Australian exports (44% and 20% respectively), with a further 5% from nuts, oilseeds, vegetable oils and legumes, and 4% from fish and seafood (data for 2014 from FAO 2020). Cereal exports provide significant protein (35%) but are generally thought of as a source of calories rather than protein.

Long-term price trends for different commodities and food items will depend on the balance between changes in demand (due to population, income growth and shifts in preferences), changes in productivity per hectare for crops and livestock (including as result of climate and water availability), and the area of land available for agriculture and food production. While real commodity prices (adjusted for inflation) trended down over most of the last century, some experts project trend increases in prices, with strong income growth in emerging economies and increasing competition for arable land outweighing increased yields (see Section 1.5 below).

1.3 Consumer attitudes and expectations will continue to evolve

Rising incomes, urbanisation, and other changes will shift consumer expectations for food and agricultural products, with increased demand for products that are viewed – and can be verified – as convenient, healthy, ethical and environmentally sustainable (see Sections 5.1 and 5.2 below).

Health, nutrition and food safety will become increasingly important drivers of food choice and consumption patterns. Many people's life expectancy, and quality of life, are being undermined by poor diets – resulting in malnutrition in some low-income countries and obesity in many high-income countries. Many of these negative impacts are avoidable through well informed food choices, reinforcing the opportunity for food producers and suppliers to identify and communicate the health benefits of crop and livestock products (see Section 5.2 below). The experience of COVID-19 is likely to reinforce these trends, giving increased weight to food safety, traceability and assurance systems.
Global demand for high-protein foods (including meat, diary, and nuts), fruits and vegetables will grow more strongly than demand for staple crops (such as wheat and rice). But consumer expectations and requirements around animal welfare, Genetically Modified Organisms (GMO), and environmental impacts vary across different contexts and cultures, and so the implications of rising incomes are more difficult to predict.

The same drivers will create new opportunities for diversifying farm income and developing new or expanded non-agricultural rural businesses, particularly around food, tourism, hospitality, and appreciation of nature and rural landscapes.

These shifts will present opportunities for consumer-focused Australian producers, but are also likely to require changes in industry practices and attitudes over time. Challenges can occur, particularly if Australian expectations – and regulations – are out of sync with those in our key export markets, which could threaten our competitiveness and brand positioning.

**FIGURE 3** Demand for healthy and environmentally sustainable products is already strong

*Dominant concerns today*

![World map showing survey results on dominant public concerns in 2015, mapped in terms of those groups of countries' shares of projected global GDP in 2035. Data Source: Dominant concerns from Edelman Trust Barometer 2015. Projected GDP in 2035 from unpublished data for Existing Trends scenario, IRP (2019).]

Notes: World map on the left shows survey results on dominant public concerns in 2015, shown on right in terms of those groups of countries' shares of projected global GDP in 2035. Data Source: Dominant concerns from Edelman Trust Barometer 2015. Projected GDP in 2035 from unpublished data for Existing Trends scenario, IRP (2019).
1.4 Key implications for agriculture

- Rising incomes in Asia will have greater impacts on export demand than increases in global population. Global demand for protein will continue to grow, including for plant-based protein. The outlook for livestock exports face some challenges, however, including potential environmental concerns around greenhouse emissions – which have motivated the red meat and livestock industry’s target to be carbon neutral by 2030 (see MLA 2020).

- Australia appears well positioned – by geography, natural endowments, and institutions – to supply international markets and take advantage of these changes, if producers and supply chains adapt and respond to consumer expectations and concerns. Understanding trends in consumer attitudes across key markets and customer segments will be crucial.

- Consumer demand and market access for Australian produce will be influenced by Australia’s reputation, particularly in relation to food safety, quality, governance, and environmental performance. Australia’s reputation is a ‘shared resource’, and so the reputation of the many is vulnerable to actual or perceived poor practices by a minority of producers. Trust and reputation are generally difficult to repair if they are damaged.

- Long-term increases in the volume and diversity of global trade to 2040, along with high numbers of international visitors and students, is expected to result in a substantial increase in biosecurity risks for Australia. Additional effort, investment, and innovation will be required to manage these increased risks (see Craik et al 2017, CSIRO Futures 2020).

1.5 Resources and further reading

ABARES analysis of *What Asia wants* (Andrews and Gunning-Trant 2013, see Fell 2020) presents long-term projections for agricultural consumption and import demand by major Asian countries and regions, as summarised above.

The long-term outlook for agricultural prices is uncertain. Hertel et al. (2017) reviews results from 13 global agriculture models. Projected prices for 2050 range from a 30% fall from current levels in real terms to a 50% increase, with falling prices considered slightly more likely than increases. CSIRO’s *Australian National Outlook* (2015) found commodity prices were likely to trend up, using the GTEM global model (Hatfield-Dodds, Adams et al. 2015, Grundy et al. 2015). Hajkowicz and Eady (2015) outline how the world might meet rising food demand in a hungrier world. Fukase and Martin (2017) assess the importance of rising incomes in emerging and developing economies, and associated shifts in food demand.

Greenville et al. (2020) explores the case for reducing the emissions intensity of Australian livestock production, to guard against emerging policy and consumer risks. While some high-profile studies argue that dramatic reductions in red meat production could both reduce emissions and improve human health (Willet et al. 2019), the impact of these views on consumer demand is not clear. More stringent climate policies will, however, draw attention to the emissions intensity of different agricultural commodities (see Mayberry et al. 2019, CCC 2019), and the Australian red meat industry has announced it will work towards becoming carbon neutral by 2030 (MLA 2020), with some producers already moving to offer red meat products that are certified as carbon neutral. This highlights the importance of innovation in reducing environmental impacts and improving the sustainability of the food system (Herrero et al. 2020).
2 Fractal politics: Beware the dance of giants

Deep shifts in economic, military and cultural power will continue to reshape the world, as the rise of multiple global powers erodes previous certainties, notwithstanding increasing global integration.

International trade and relations – along with food and fibre markets, supply chains and relationships – will all become more complex as nations assert their sovereignty, often in pursuit of populist appeal rather than mutual economic gains.
2.1 Seven giants will pursue their individual interests

Geopolitics over coming decades will increasingly reflect the ‘dance of giants’, with seven nations or regions together accounting for between half and two-thirds of global population, economic activity, energy, food production, and resource extractions (see Figure 4). Each of these nations or regions is a great power in its own right, and each will tend to look first to their own internal imperatives and narrative – and give less attention to the norms and institutions of the rules-based international order, which are particularly important to international trade.

The shift from a bi-polar world (split between East and West) to a more fluid multi-polar world risks more complex and unstable geopolitics and economics, making international cooperation both more difficult and more important.

FIGURE 4 Seven giants already account for half to two thirds of global activity

Notes: Figure shows share of global population, economic activity (GDP) at market exchange rates, final energy supply, and food production in calories in 2015 (inner circle) and projected for 2035 (outer circle). Percentages labels are shown for total share for the seven giants in 2035. The seven giants account for 68-70% of global resource extractions (not shown) over the period from 2015 to 2035. Data for EU excludes the UK and includes Iceland, Liechtenstein, Norway and Switzerland.

Data Source: Population, GDP, energy and resource extractions from unpublished data for the Existing Trends scenario, IRP (2019), calories for an equivalent scenario from extended data from Beach et al. (2019), see Robinson et al. (2015).
2.2 Volatility, uncertainty, complexity and ambiguity require improved cooperation, but make it more difficult

Volatility, uncertainty, complexity and ambiguity are all likely to become more pronounced in future, relative to recent decades (see Figure 5 for definitions and potential responses). These trends reflect multiple drivers, including shifts in economic activity and power (Section 2.1), lower income growth and increasing inequality in many regions, increasing environmental pressures (Section 4.1 and 4.2), and disruptive technologies (Section 5.1). And the impacts and implications of this trend will occur across multiple domains – including international relations, domestic politics and policy making, business planning, and operational management of farms and businesses.

One implication is that cooperation across different groups is likely to become more difficult, both globally and nationally. But the same challenges will increase the benefits of cooperation, and help motivate actors to find ways to work together and learn from each other across enterprises, sectors and countries.

The Australian bushfire season in late 2019 and early 2020 demonstrates the cascading challenges that can occur when systems face new stresses and circumstances, while the rapid emergence and spread of COVID-19 illustrates both the multiple challenges created by national and global events, and the potential to evolve new approaches and solutions in the face of deep uncertainty, complexity and ambiguity.

![FIGURE 5 Defining and responding to volatility, uncertainty, complexity, and ambiguity (VUCA)](image)

## Uncertainty
**Characteristics:** Underlying cause and effect are known, but some important information on the current situation is not available. Change is possible but not a given.

**Example:** A competitor’s expected product launch muddies the future of your market.

**Approach:** Invest in information – collect, interpret and share it. This works best with structural changes, such as creating or improving analysis networks, to reduce ongoing uncertainty.

## Volatility
**Characteristics:** The situation involves unexpected or unstable challenges, perhaps of unknown duration, but it is not necessarily hard to understand and information is available.

**Example:** Prices fluctuate after a natural disaster disrupts supply.

**Approach:** Build in slack and devote resources to preparedness – such as stockpiling inventory or overbuy talent. These steps are typically inexpensive; your investment should be calibrated to the risk.

## Ambiguity
**Characteristics:** Causal relationships are unclear or completely unknown. No precedents exist; you face ‘known unknowns’.

**Example:** You are moving into immature or emerging markets, or launching products outside core competencies.

**Approach:** Experiment. Generate and test hypotheses to understand cause and effect. Design strategy to inform key decisions, and allow lessons to be applied broadly.

## Complexity
**Characteristics:** The situation has many interconnected elements and variables. Some information is available or can be predicted, but system relationships, interactions and thresholds are difficult to identify and understand.

**Example:** Doing business in many countries, each with distinctive regulations, cultures, values and practices – which all interact.

**Approach:** Restructure; develop or secure specialists; and build up resources required to address complexity.

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How well can you predict the results of your actions?

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Volatility</th>
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How much do you know about the current situation?

Source: Adapted from Bennett and Lemoine (2014)
2.3 Declining trust in evidence and institutions could amplify threats and weaken cooperation

Declining respect for – and trust in – science, evidence, and institutions is likely to exacerbate the impacts of this more fluid national and international context. This decline in public trust in institutions (including government, business, and the media) is associated with a shift towards people relying on sources of information that are aligned with their pre-existing views.

Special interests (including state actors in some cases) will also increase their efforts to undermine informed debate by manufacturing doubt and spreading falsehoods, leveraging technology and human nature for political and economic advantage.

These trends increase the risk that public debate will become more polarised, combative and vulnerable to misinformation. Without open-minded discussion, this will make it more difficult to build consensus and support for how nations and communities might best to respond to social and economic challenges.

The diversity of global experiences with COVID-19 illustrates the both the opportunity to foster bipartisan support for evidence based approaches by government and business, and the risk that political and cultural divides can undermine consensus and effective action – with potentially disastrous consequences (see Kahan and other authors, Section 2.5 below).

FIGURE 6 Distrust of institutions and trust gaps are at record levels in many countries

Notes: Figures shows reported levels of trust for 28 markets. The survey was conducted in October and November 2019, and found eight countries with substantial trust gaps (shown in dark red), the highest number on record, and substantially higher than one to three countries in each year from 2012 to 2018. The height of the columns in the chart show the difference between the general public trust score for that country and the 28 country average. The colour of the column is based on the trust gap, as measured the difference in results for ‘informed public’ versus ‘general population’ for that country. A large trust gap indicates a record high for that country, and in all cases other than Russia, also indicates larger gap than the 2020 cross-country average. Survey involves more than 34,000 respondents.

Data source: Edelman Trust Barometer 2020, Global Report, page 8
2.4 Key implications for agriculture

- Realising the potential benefits of increasing global trade volumes for Australian agricultural exporters will require effective market access and effort to discourage protectionist policies (which generally disadvantage consumers in those countries). While external shocks may become more frequent, and global volatility is likely to increase, export orientated sectors will experience lower overall volatility than sectors who are primarily focused on serving domestic markets (given the variability of Australian conditions).

- Australian exporters will face increased risks around market access and consumer attitudes in importing nations, including cross-sector effects where concerns in other areas impact on food and fibre markets. This will increase the ‘option value’ of having access to and relationships with multiple destination markets, reducing the adverse impacts of disruptions to demand from specific countries or market segments.

- Australia’s reputation for supplying healthy, high-quality, ethical and sustainable products is likely to become more important, but cannot be taken for granted (see Section 4.3 below). The most effective responses will establish trusted information platforms, engage authentically with consumer concerns, acknowledge and address poor practices, and provide evidence of improvements over time.

2.5 Resources and further reading

Coral Bell’s (2015) *Living with Giants* introduces the global dance of giants, primarily from a security perspective, and the associated geopolitical shift from ‘balance of power’ to a more dynamic ‘concert of powers’, before exploring five potential disruptive global scenarios.


Dan Kahan (2010) provides a quick introduction to ‘cultural cognition’ – that on complicated and contested topics, people tend to agree with and remember facts and findings that are aligned with the values of their tribe, and which do not have uncomfortable implications for people and groups they care about. This human trait is often leveraged by interest groups to shape debates and influence political outcomes, as illustrated by Oreskes and Conway (2010) and Farrell (2016). Kahan and Braman (2006) set out key causes and dynamics of cultural cognition in more detail. Amanda Ripley (2018) provides guidance on promoting open minded conversations on contested issues by complicating – rather than simplifying – the narrative.
Relentless innovation drives improved productivity, and more efficient use of materials, energy, water, land and labour. Maintaining profitable and competitive food and fibre enterprises will require ongoing innovation and change.

But the benefits of change will not be shared evenly, often exacerbating existing pressures on rural industries and regional communities. Improved productivity may benefit consumers (through lower prices) more than producers. Regional population will continue to drift from farms and smaller towns to larger regional centres and capital cities.
3.1 Outputs up, inputs down

Australian agriculture is strongly export oriented, exporting around 70% of production, with relatively low levels of government support (Jackson et al. 2020). Ongoing productivity improvements have been – and will continue to be – crucial to maintaining profitable and competitive farm enterprises, and to the goal of lifting the value of agricultural output to $100 billion by 2030 (NFF 2019).

Net farm income has increased more rapidly than output value, reflecting productivity growth and more efficient use of inputs, including labour. On-farm employment, including work by farm owners, has fallen by one quarter (25%) over the past three decades, while the gross value of agricultural production has risen one quarter (26%) and value-added by three quarters (74%) respectively, see Figure 7. Much of this productivity growth has been driven by increases in farm scale (discussed below), improved genetics and varieties, and continuous innovation in management practices.

These broad trends are expected to continue, along with their implications for rural industries and regional communities.

FIGURE 7 Australian productivity growth has kept pace with other advanced economies, but productivity of producers in emerging countries is growing faster

Increases in farm size account for at least half of broadacre agricultural productivity growth over the last three decades (Sheng et al. 2015, ABARES calculations 2020). Increased farm size supports improved productivity through several channels: supporting access to better technology; diffusing better farm management practices; and enabling improved knowledge and labour management (Jackson et al. 2020). These changes have been supported by deregulation of agricultural markets and economy-wide microeconomic reforms.

The shift towards fewer, larger farms has also been crucial for maintaining farm household incomes. While smaller farms are less profitable on average than larger farms, farm households on smaller farms still compare favourably to the Australian population as a whole, with comparable income, lower debt, and higher net wealth than the average Australian household. Although new business models are emerging, the family farm remains the most common ownership structure in Australian agriculture. Other opportunities for agricultural productivity growth include improving commercialisation and uptake of our R&D investments; ensuring regulation is as efficient as possible; strengthening supply chains; and enhancing labour availability and skills (see Section 3.5 below and Grey et al. 2014).
3.2 Improved yields will increase output volumes, but consumers may benefit more than producers

Global food supplies and consumer access has improved dramatically over the last 70 years, driven by increased physical productivity and crop yields – particularly as a result of the Green Revolution (Pingali 2012).

These trends are set to continue as the application of new technologies and management practices improve potential yields, including through deployment of genetically modified (GMO) crops incorporating genes for pest, herbicide, and disease resistance (Atici 2014). There are also many non-GMO technologies for achieving improved yields and profitability, including through reducing farm inputs and management costs (Hajkowicz and Eady 2015). New varieties and practices can also reduce environmental pressures, including chemical use and water demand, highlighting the role of innovation in promoting sustainability (Herrero et al. 2020).

Closing existing yield gaps – the difference between potential and actual output – could lift global output of wheat and rice by around 50% and rice and soybeans by 30% or more (Hajkowicz and Eady 2015). This would boost ‘catch-up’ productivity growth in emerging and developing agricultural producers (see Figure 7 above), where yield and productivity gaps are larger than in advanced countries.

Improved yields, expansion of agricultural land, increased trade, and more efficient transport and supply chains have together resulted in long run falls in real commodity prices (see Figure 10), and substantial benefits for consumers. Whether this trend continues will depend on whether increases in supply can continue to outpace increases in demand associated with population growth and rising average incomes (see Section 1.5 above).

**FIGURE 8** Real prices of major agricultural commodities have fallen dramatically since 1950

![Graph showing real prices of major agricultural commodities](image)

Notes: Real prices, adjusted to remove the effects of inflation. Index 1900 prices = 100. Source: ABARES 2020
3.3 Social concerns will shape competitiveness

Global increases in incomes and resource use will expand the range of issues consumers and governments care about, reflecting the satisfaction of more basic needs and the increased sense of agency and control often associated with higher incomes (see 1.3 above). Along with rising environmental concerns, this will continue to shape trade and market access, consumer preferences for different products, and expectations around natural resource management.

Several markets and countries already limit specific technologies or practices, such as prohibiting GMO food crops or banning certain livestock management practices. Regulations of this kind appear more likely to increase than decrease over coming decades, reflecting rising incomes and more fractal politics – risking additional constraints on productivity growth, but also offering new producer opportunities or improved environmental outcomes in some cases.

Competitiveness and access is also affected by the level and nature of producer support in destination markets. While many high-income nations have shifted to less distortionary forms of domestic support and agricultural protection over recent decades, many emerging economies have increased their levels of support – including some of the most important markets for Australian agricultural exports (see Figure 9). This risks a tug-of-war between increasing demand for food in emerging economies – requiring increased imports over time (see Section 1.2 above) – and their increasing willingness to support domestic producers.

FIGURE 9 Producers support and protection is trending up in key emerging markets

Geopolitical tensions and a potential slide towards domestic populism in some countries (see Section 2.1 above) will increase the risk of trade wars – where agricultural trade is likely to be caught in the cross fire.

Delivering the intent of the Sustainable Development Goals (SDGs) will require increases in the quality and quantity of food, to improve nutrition and food security, while reducing or reversing land clearing for agriculture and irrigation-related stress on freshwater systems (UNEP 2015, IRP 2019). This could help protect the quality and productivity of natural assets and systems that underpin agricultural production, but may also limit the quantity of land and water available for agriculture in some countries.
3.4 Key implications for agriculture

- Farm management practices, technology, regional infrastructure, and wider economic policy settings are all important for maintaining and improving agricultural productivity. Allowing resource reallocation between farms and sectors is crucial, as is ensuring innovation and R&D investments are well targeted.

- The trend to fewer, larger farms will continue, supporting higher productivity and helping to maintain farm incomes. Continued productivity gains (including labour productivity) will be required to maintain export competitiveness. On-farm work will account for a declining share of regional employment, and off-farm income will remain important for households on smaller farms (see Section 1.3 above).

- Maintaining and improving access to high value markets and consumers will require government and industry to ensure management practices keep pace with customer expectations, and that this can be demonstrated from paddock to plate at relevant scales (see Sections 5.1 and 5.2 below).

- Productivity growth and the race for advantage will benefit consumers (through lower prices and improved quality) as well as producers, but there are opportunities to improve producer margins by establishing a clear customer value proposition (Craik, W, Palmer, D & Sheldrake, R 2017; CSIRO Futures 2020).

3.5 Resources and further reading

ABARES Snapshot of Australian agriculture (Jackson et al. 2020) provides a useful summary of Australian agriculture, and its context and contributions. The Snapshot also summarises key issues in agricultural productivity and competitiveness (including the role of farm scale), and how farmers manage significant price and climate variability.

Previous ABARES research (Grey et al. 2014) finds several decades of policy reform have lifted agricultural productivity growth and improved on-farm risk management, through removing policies that insulated farmers from market disciplines and discouraged resource reallocation to the most efficient farmers, along with more general economy-wide reforms. However, as Australia now has relatively low levels of producer support, there is limited scope to further improve agricultural productivity growth in this way. Instead, the main opportunities for productivity growth involve continuing innovation by producers and all participants in agrifood supply chains, and allowing farm consolidation and the reallocation of resources between different producers and industries. Government has important ongoing roles in supporting the rural research, development and extension system (EY 2019, DAWE 2020; DAWE website 2020); reducing unnecessary regulatory burdens; and improving labour availability and skills.

Pingali (2012) reviews the achievements and impacts of the Green Revolution, in which substantial investments in crop genetics and agricultural systems delivered a three-fold increase in crop output from 1966, with only a 30% increase in the area of crop land. Investment levels, and benefits achieved, have declined since 1990, prompting calls for renewed efforts to improve food access and security through agricultural research and institutional reforms (see Herrero et al. 2020).

Greenville (2020) reports that previous trend reductions in trade distorting support has stalled in recent years, while support and protection has been increasing in many emerging countries (see Figure 9 above). This constrains global agricultural production and trade, costing Australian agriculture an estimated $8-10 billion a year in forgone exports, and reducing global food security.
4 Cascading planetary risks: Coming, ready or not

Accelerating changes in earth systems at all scales – from global to microbial – are creating multiple risks and challenges, and some opportunities.

Agriculture is already impacted, and adapting. Climate and commodity prices will become more volatile, while emerging markets for carbon and ecosystem services could transform landscapes and business models.
4.1 Science suggests major challenges ahead

Multiple lines of evidence suggest current patterns of resource use are resulting in multiple environmental pressures, that will have increasingly negative impacts human wellbeing if not addressed. These impacts are not inevitable, however, and action by government, business, and communities could decouple economic growth from environmental pressure, to reduce and repair environmental damage while boosting incomes and human wellbeing (IRP 2019).

Global greenhouse gas emissions continue to rise, despite large-scale shifts to renewable energy. In the absence of more ambitious global efforts and policies to reduce emissions, the world is on track for temperature increases this century of around 3°C above pre-industrial levels. Climate science suggests Australia will become hotter, and that southern areas are already experiencing a shift towards drier conditions with lower streamflow. Droughts, storms, fires and heatwaves will become more intense – and perhaps more frequent – creating significant challenges for agricultural producers and regional communities (CSIRO and BOM 2018).

ABARES research finds hotter and drier conditions since 2000 have reduced the profitability of broadacre farming by 22%, relative to estimated output under pre-2000 climate and seasonal conditions. Cropping farms are particularly effected, with profit down 35%, while livestock farms have been less effected. Adaptation efforts have reduced, but not eliminated, the impact of the observed shift in climate over the last two decades. Looking forward, ABARES modelling explores potential scenarios for irrigated agriculture in the Murray Darling Basin (Gupta et al. 2020) and is developing capability to assess potential future climate scenarios on different types of broadacre farms across Australia.

FIGURE 10 Australian annual temperature anomalies for two global emissions pathways, relative to 1961–1990 average

Notes: Australian mean annual surface temperature in the past and for future emissions pathways, relative to the 1961-1990 average. Observations are the Bureau of Meteorology ACORN-SAT version 2 dataset. Shading is the 10–90% percentile range of annual temperature anomalies from up to 37 CMIP5 models. Thick lines are the CMIP5 multi-model ensemble mean. Bars at the right of the plot show 10–90% range for temperature outcomes for the high and low emission scenarios for 2090. The CMIP5 projections do not account for the reinforcing feedbacks discussed in Section 4.2 below.

Source: Redrawn from CSIRO and BOM 2016, page 5, with historical data updated to 2019.
4.2 Interactions and feedbacks often amplify risks

Interactions across and within social, economic, and biophysical systems can amplify the impacts of individual trends. Rising pressures on natural ecosystems increases the risk of coronavirus and other zoonotic diseases infecting humans, while the rapid growth of international travel and connectivity accelerate and amplify the impacts of pandemics, such as COVID-19. Increased population and development in coastal areas puts more people at risk from severe storms and inundation. Growing resistance to herbicides, pesticides and antibiotics makes managing increasing biosecurity risks even more challenging. Trend increases in temperature increase the likelihood of longer and more intense bushfire seasons.

Current trends in global greenhouse gas emissions are bringing the world closer to climate thresholds which, if passed, would see reinforcing feedbacks accelerate the extent of climate change – including rising temperatures and sea level – regardless of reductions in emissions from industry, agriculture and land use change (Steffen et al. 2018). These feedbacks could add at least 0.24°C of warming by the end of the century, with a best estimate of an additional 0.47°C on top of projected warming as a direct result of emissions from human activities (shown in Figure 10 above). Accounting for reinforcing feedbacks strengthens arguments to make rapid reductions in global emissions, to accelerate efforts to create and enhance biological carbon sinks, and to aim for the more stringent end of the Paris temperature range – each of which would reduce the likelihood and extent of these additional increases in temperatures.

![Figure 11: Reinforcing feedbacks could increase global temperatures an additional 0.5°C by 2100](image)

Notes: Estimates of extent of reinforcing feedbacks by 2100, assuming average global warming of 2°C. Feedbacks are in addition to direct warming as result of human emissions, as shown in Figure 10 above.

Source: Steffen et al. 2018 Table 1
4.3 Reducing net emissions and protecting natural assets could benefit landholders

Consumers and regional communities will increasingly expect producers to value and protect natural assets – including maintaining healthy ecosystems, water quality, and avoiding loss of species and habitat – and will require action by business and consumers, as well as new government policies in some instances (see Sections 1.3 and 3.3 above). Many environmental services, like pollination or replenishment of fish stocks, can no longer be taken for granted – and are often becoming more commercially valuable due to both declining natural supply and increasing demand.

Improved environmental stewardship could offer substantial opportunities for land owners and regional communities, with some studies finding new markets for carbon and conservation payments could double landholder incomes over coming decades (see further reading below). The mix of outcomes achieved – including regional jobs and incomes, other economic benefits, biodiversity and ecosystem resilience, tonnes of carbon sequestered, and impacts on food production – will depend on the details of markets design and operations (see Figure 12), reinforcing the importance of engaging regional communities as early as possible.

These policies could also deliver national economic benefits, particularly in scenarios where other nations are willing to pay for the high quality carbon credits Australia is able to supply. (Hatfield-Dodds, Adams et al. 2015).

**FIGURE 12 Different policy choices will drive different patterns of benefits and impacts**

<table>
<thead>
<tr>
<th>Policy Scenario</th>
<th>Benefits and impacts of markets for carbon and ecosystem services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon focused scenario</td>
<td><img src="image1.png" alt="Native habitat" /> <img src="image2.png" alt="Carbon sequestration" /> <img src="image3.png" alt="Landholder income" /> <img src="image4.png" alt="Protein output" /> <img src="image5.png" alt="Impact of water interceptions" /></td>
</tr>
<tr>
<td>Balanced scenario</td>
<td><img src="image1.png" alt="Native habitat" /> <img src="image2.png" alt="Carbon sequestration" /> <img src="image3.png" alt="Landholder income" /> <img src="image4.png" alt="Protein output" /> <img src="image5.png" alt="Impact of water interceptions" /></td>
</tr>
<tr>
<td>Water sensitive, balanced</td>
<td><img src="image1.png" alt="Native habitat" /> <img src="image2.png" alt="Carbon sequestration" /> <img src="image3.png" alt="Landholder income" /> <img src="image4.png" alt="Protein output" /> <img src="image5.png" alt="Impact of water interceptions" /></td>
</tr>
<tr>
<td>Habitat focused scenario</td>
<td><img src="image1.png" alt="Native habitat" /> <img src="image2.png" alt="Carbon sequestration" /> <img src="image3.png" alt="Landholder income" /> <img src="image4.png" alt="Protein output" /> <img src="image5.png" alt="Impact of water interceptions" /></td>
</tr>
</tbody>
</table>

Notes. The figure contrasts the implications of different assumed policy approaches to the design of markets for carbon sequestration and ecosystem services, reporting five economic and environmental outcomes in 2050 relative to the same scenario without these new markets. All scenarios assume the same carbon price and abatement incentive, which increases over time, with some scenarios harnessing carbon revenues to support biodiversity outcomes. Carbon payments reach $50/tCO2 in 2028 for the carbon focused scenario, 2032 for the balanced scenarios, and in 2037 for the habitat focused scenario. The water sensitive scenario assumes higher water use efficiency and that carbon plantings must offset their water interceptions, and so results in zero net interceptions in 2050. Water interceptions from new plantings are shown for water limited catchments, relative to agricultural water use in those catchments without plantings. Carbon sequestration is shown relative to national emissions without carbon and biodiversity plantings.

Data source: Redrawn from Hatfield-Dodds, Adams et al. (2015) Figure 15, using data from Hatfield-Dodds, Schandl et al. (2015) data pack.
4.4 Key implications for agriculture

- Maintaining access to premium consumers and markets will increasingly require approaches that combine profitable farming with protecting or improving environmental assets. Customers and other stakeholders will be increasingly unlikely to accept practices that risk environmental damage or poor animal welfare.

- Droughts, fires and floods are likely to become more disruptive and severe, and agricultural commodity prices and market access may become more volatile.

- Trends towards hotter and drier conditions will impact the profitability of agriculture, and will drive changes in farming practices and the location of some types of farming. Well-functioning water markets and governance arrangements will remain crucial for irrigated agriculture, regional communities, and other stakeholders.

- Climate and emissions reductions policies around the world are likely to become more stringent over time, increasing demand for land sector carbon credits from new plantings as well as for reducing greenhouse emissions from livestock and other agricultural activities (see Section 1.5 above). Popular ideas of ‘agriculture’ and ‘farming’ will increasingly include forestry and markets for environmental services.

4.5 Resources and further reading

The World Bank (2012) explores how a 4°C world would involve “unprecedented heat waves, severe drought, and major floods in many regions” (executive summary). This world can be avoided, however, with rapid global action that could likely hold warming below 2°C. Chapter Six summarises impacts on agriculture and food production, particularly staple crops, including from higher temperatures, changes in rainfall, and increased CO₂ fertilization. Combined impacts are on crop yields and food security are negative overall in most areas of the world where temperature increases are above 2-3°C, with more pronounced negative impacts in hotter regions, such as Australia and India. Campbell et al. (2007) explore implications of three climate scenarios for geopolitics and national security, providing some challenging food for thought (although aspects of the climate projections are now a little dated).

Two recent ABARES reports explore implications of climate variability for Australian agriculture. Hughes et al. (2019) assesses the impacts of observed hotter and drier conditions on broad acre farming over the last two decades, while Gupta et al. (2020) explores future scenarios for irrigated agriculture in the southern Murray-Darling Basin, including a potential drier future scenario.

CSIRO’s Australian National Outlook 2019 report (Deverell et al. 2019) finds payments to landholders for carbon and conservation services could more than double returns to landholders and see the share of land-based industries increase from 2.1% of the economy (without carbon and conservation markets) to 5.2% by 2060. Securing the benefits of such a shift would require policies that allow sale of carbon credits, development of support industries (such as plant nurseries, and carbon finance providers), and careful planning engagement to ensure arrangements deliver benefits to regional communities and natural systems as well as participating landholders.
Disruptive technologies: Opportunities for the brave

Exponential advances in digital technology, automation, genetics, and synthetics will disrupt and change how food and fibre products are made, marketed, and delivered. Production systems, supply chains, and customer engagement will become more agile and interconnected, requiring new skills and partnerships, and creating risks and opportunities for agricultural producers and regional communities.
5.1 Information-rich production systems will provide new levels of control, and accountability

New technologies will apply new information in new ways: automating farming systems; accelerating genetic gains; refining input and cost control; and improving sector and system-level performance in relation to market access and biosecurity (see Figure 13 below). In essence, each of these pathways uses information (in on-farm and supply chain data systems, or the DNA of plants and livestock) to increase the productivity of materials and energy employed in delivering food and fibre to customers and consumers. This megatrend is thus closely linked to, and builds on, the more-from-less megatrend (see page 9 above) – including our predictions that improved genetics will increase yields, and that evolving attitudes and social concerns will create new market opportunities and constraints.

The era of harvesting information from embedded devices and putting it to use to improve systems is only just commencing. Connectivity across billions of devices, often described as the ‘Internet of Things (IoT)’, will transform production systems and supply chains over coming decades. Examples include real-time knowledge of the location and health status of each farm animal informing mustering and other management actions; data driven planting, spraying, and harvesting machinery – gathering precise spatial data on yields and adjusting seeding and fertiliser application to maximise profitability; and automated irrigation systems that account for soil moisture, water prices, weather forecasts, and plant needs.

New types of robotics will unlock new data streams, creating a transformational cycle of data collection and automation. Low-flying drones, equipped with sensors and digital imaging will monitor crops and orchards for flowering, water stress, nutrient deficiencies, disease, and weeds – informing automated responses such as robot or drone-based weed control.

**FIGURE 13** Digital agriculture could unlock significant benefits, particularly if industries work together

<table>
<thead>
<tr>
<th>Estimated benefits from industries working together</th>
<th>Estimated total benefits by industry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within industry gains</strong></td>
<td><strong>$20.3b</strong></td>
</tr>
<tr>
<td>Market access and biosecurity (e.g. pest and disease control)</td>
<td><strong>$6.7b</strong></td>
</tr>
<tr>
<td>Tailoring inputs to need (e.g. fertiliser, seed and water)</td>
<td><strong>$1.0b</strong></td>
</tr>
<tr>
<td>Genetic gains through objective data (e.g. animal and variety selection)</td>
<td><strong>$2.3b</strong></td>
</tr>
<tr>
<td>Automation and labour savings (e.g. machinery, animal handling and product processing)</td>
<td><strong>$2.9b</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$13.6b</strong></td>
</tr>
</tbody>
</table>

Notes: Estimated potential increase in the gross value of agricultural production by industry assuming high uptake of digital technologies, and increase associated with industries working together by source of benefit.

5.2 Revolutionary connectivity will enable new types and levels of customer engagement

Integrated data will see supply-chain management reach back onto the farm in ways not seen before, with real-time tracking of quantity, quality and characteristics of food and fibre products. This will build on current best practice, involving fully integrated tracking systems that allow companies to track and manage the flow of product through their distribution systems – from farm to fork – and trace-back items in the advent of a food safety concern.

In the very near future access to capital and to premium markets will increasingly be linked to farmers recording their management practices in systems that can be audited, with standardised information flowing along supply chains to certify characteristics such as nutritional values, provenance, organic or GM-free certification, animal welfare, and social and environmental performance (including fair-trade, sustainability, and carbon footprint). Producers and suppliers who can access ‘return flows’ of information on wholesale, retail, and consumer price points and link these to purchasing decisions will gain additional advantages from better informed offerings to, and engagement with, downstream customers.

Competitive advantage will increasingly rest on the use of data to understand and engage with customers and stakeholders, in ways that are tailored to context and purpose (see Figure 14). Different commodities, types of farm, regions, and customer issues will present different needs and opportunities. The best results will be achieved when the insights gained are integrated into production systems, driving continuous innovation in products, practices and value propositions.

FIGURE 14 The right type of engagement depends on context and purpose

Source: Adapted from Arnstien’s (1969) ‘ladder of engagement’, see IAP2 (2015) page 11
5.3 Unlocking these opportunities will require new data sharing and governance

Harnessing and realising the benefits of these disruptive technologies will require new approaches to managing data and information, including the development and implementation of shared data ecosystem (see Figure 15) that enables a collect once use many times approach. Key success factors will include:

- **Clear data sharing arrangements** – that are easily discoverable and understandable for data users and make data available at its most detailed, with appropriate privacy protections.
- **Common data standards** – that support collection of multiple types of public and private data and ensure stakeholder data needs are met, while limiting respondent burden and production costs.
- **Common linking keys and data management standards** – that ensure data is comparable and can be integrated to support analysis and decision making by diverse users up and down agriculture and food value chains.
- **Cooperative approach to stewardship arrangements and resourcing** – that ensures the data ecosystem meets industry and government needs, including public good elements.

Trust and collaboration will be central to success. Leaders in agricultural innovation, such as the Netherlands and United States, are well positioned to take advantage of the opportunities big data will bring. In the Netherlands, the innovation sector is driven by multi-agency research projects that have established a culture of collaboration and trust between government, industry, farmers and other supply chain participants. In the United States, a sophisticated for-profit R&D industry and a large farm sector provide strong incentives for innovation and data sharing. Underpinning both these innovation systems are well-resourced statistics agencies that provide high quality data for R&D providers to target and assess the value of project outputs.

**FIGURE 15** Australia’s agricultural data ecosystem will need to be reinvented to realise the full benefits of new opportunities

<table>
<thead>
<tr>
<th>Non-government data sources</th>
<th>Collecting and generating</th>
<th>Storing, securing and processing</th>
<th>Sharing, curating and publishing</th>
<th>Using and re-using for diverse purposes</th>
<th>Value to users across industry, government and non-profit sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government and administrative data sources</td>
<td>Published data; administrative data; sensor data (e.g. satellite); requested data (e.g. surveys)</td>
<td>Storage; quality management; catalogue; cleansing; privacy management</td>
<td>Data sharing platforms; open data services and websites; manage requests and agreements</td>
<td>Statistical analysis and machine learning; visualisation; decision support; performance insights</td>
<td>Across industry, government and non-profit sectors</td>
</tr>
</tbody>
</table>

ABARES 2020, unpublished
In contrast, Australian agriculture's digital readiness lags behind, see Leonard et al. (2017). To realise the benefits of digitisation and remain competitive in global markets, Australian agriculture needs to establish a new operating model centred on collaboration and information sharing that aims to meet the current and future needs of the agriculture and food industries as a whole. This is a significant departure from the siloed structure of Australia's agricultural innovation system, which has been good at addressing sector specific issues but lacks a history of collaboration and cross-sector integration. The move to more collaborative and integrated approach would build scale and scope. This will strengthen incentives for private sector engagement and innovation tailored to domestic needs, enhancing industry productivity and profitability.

The benefits and necessity of this transformation is widely recognised by key stakeholders in Australia's current data and statistics systems. They also recognise that past efforts have lacked the resources, coordination, breadth, and impetus to address these whole of system issues. Success will require renewed effort and commitment, and a consensus-building approach that brings together stakeholders from multiple sectors, who on their own could not realise the productivity, profitability and traceability improvements offered by collaboration.

### 5.4 Key implications for agriculture

- Well-informed decision making and risk management will remain central to Australian farming. Increasingly, however, the most important farm 'knowledge assets' will shift from inside the heads of farmers towards sophisticated computer and data-based decision support systems.

- Integrated and inter-connected systems will provide new options for managing volatility and uncertainty (see Figure 5 above), including just-in-time production and supply chain management; improved transport and logistics; and new forms of insurance, finance and risk sharing.

- Effective data use will shape access to capital, including through unlocking new forms of investment and risk sharing, including equity investments in family farms. New business models and partnerships will emerge for farming, and food and fibre supply chains. In some cases, this will provide opportunities to capture the value of intangible attributes of farming systems – requiring new skills in marketing, engagement, and relationship management.

- Realising the full benefits of these disruptive technologies will require new approaches to managing data and information, including new roles and responsibilities for government and the private sector, to create a new shared data ecosystem (see Figure 15) that embodies a collect once from diverse sources and use many times approach. Success cannot be taken for granted and will require renewed commitment across the board.
5.5 Resources and further reading

A major collaborative research project assesses the current state, future options, and likely benefits of enabling digital agriculture in Australia. The ‘precision to decision’ project (Leonard et al. 2017) found that current capacity is immature, and that substantial cross-sector and cross-industry collaboration and investment are required. If Australia rises to the challenge, they estimate digital agriculture could lift the gross value of agriculture, forestry and fisheries by 25% – or more than $20 billion (as detailed in Figure 13 above). Growing a digital future for Australian agriculture sets out the next steps being taken by the industry (Trindal et al. 2019).

Wolfert et al. (2017) reviews the implications and outlook for the use of big data in farming systems. They find smart sensors and devices will provide unprecedented automation and decision capabilities, and that big data will cause major shifts in roles, power relationships and business models (see Figure 14 above). This will require the development of new governance arrangements for data ownership, access, privacy and security. Boston Consulting Group (2020) argues that successful digital transformation rests on four pillars: digitizing customer relationships, building digital talent and organisation, harnessing data and advanced technology, and automating and digitizing operations and processes.

A guide to the right engagement (DIIS 2019) provides policy-oriented overview for how to diagnose the nature of a problem and identify the most suitable general engagement approach, along with a catalogue of specific engagement and communication tools and methods that can be used. The Open dialogue roadmap (OGP 2019 volumes I and II) provides more detailed resources.
Positioning for the future:
Will the lucky country surf or sink?

Australia is indeed lucky: a ‘lifestyle superpower’ with competitive industries, vibrant communities, and unique landscapes and environmental assets. But unearned advantage risks complacency, and each generation needs to create the luck – and advantages – it will pass on to the next generation. Will Australia choose to surf or sink?
Position and momentum are crucial to surfing waves of change

Australia responded to the warning signs and poor economic performance of the 1960s and ’70s by implementing a range of market-based reforms, updating previous policies to deal with new realities. These changes, while challenging for many, have contributed to more resilient and profitable agricultural enterprises and industries (Grey et al. 2014, Greenville 2020). Maintaining and improving competitiveness involves tough choices, but the alternative is worse.

Australian agriculture and regional communities are well positioned to build on their strengths.

Our agricultural producers are export oriented and internationally competitive, managing high levels of price and climate variability with very low levels of government assistance. Policy settings provide valuable support for households and communities in need, when required, while avoiding assistance to businesses, which can undermine efficiency and adaptation.

Business, government, and communities all have crucial roles

While business is the primary engine of improved productivity, policy has an important enabling role in supporting innovation and change – rather than protecting the past.

Policy settings can never be ‘set and forget’, and require constant attention to ensure they provide the best possible support for agricultural industries and rural communities. It is crucial to ensure industry is getting the best possible outcomes from investments in research and development, including through reducing fragmentation and enabling investment in prospective cross-cutting technologies. Australian citizens have high expectations of government, and a healthy regard for responsible budget management. Federal and state governments have excellent credit ratings and are well positioned to finance infrastructure investments where they are in the national interest. Australia can afford better public services, or lower taxes, but achieving both at the same time may be difficult.

Determining the best way forward takes effort. It is important to encourage open minded discussion and constructive debate of options and opportunities for reform, drawing on relevant evidence and expertise.

Prediction is difficult, especially the future

The future is uncertain. But we know we cannot take prosperity for granted.

Australian industry, government, and communities need to work together to understand the risks and opportunities they face, and together create the future they want. We hope this summary of megatrends shaping Australian agriculture and regional communities supports this process.
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Stocktake of megatrends shaping Australian agriculture (2021 update)

ABARES insights

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