Australia's National
Science Agency

Ag2050 Scenarios Report

2024

Authorship

This report was lead authored (in alphabetical order) by Philippa Clegg, James Deverell, Micheala Kuen, Kate McMahon, Yasmin Morgan, Rohini Poonyth and Katherine Wynn with input from over 100 participants across different organisations from government, industry and research leaders.

CSIRO Futures

At CSIRO Futures, we bring together science, technology and economics to help you develop transformative strategies that tackle your biggest challenges. As the strategic and economic advisory arm of Australia's national science agency, we are uniquely positioned to transform complexity into clarity, uncertainty into opportunity and insights into action.

CSIRO Agriculture and Food

CSIRO's work in agriculture and food is solving the greatest challenges through innovative science and technology to build a profitable, productive, trusted and sustainable agrifood and fibre sector for the future. Working with CSIRO provides access to world-class multidisciplinary science, technology and facilities, relevant intellectual property and global networks across the value chain (from gene to the plate). Our people and partnerships span Australia and 25 countries, fostering a shared vision to create measurable economic, environmental and social impact, and delivering new pathways and new technologies for the future.

Accessibility

CSIRO is committed to providing web-accessible content wherever possible. If you are having difficulties with accessing this document, please contact csiro.au/contact

Acknowledgement

CSIRO acknowledges the Traditional Owners of the land, sea and waters, of the areas that we live and work on across Australia. We acknowledge their continuing connection to culture and we pay our respects to their Elders, past and present.

The project team is grateful to the many stakeholders who generously gave their time to provide input to this project through consultations, workshops, reviews and feedback. In particular, we would like to acknowledge Aaron Quigley, Anton Wasson, Brad Pfeffer, Brent Henderson, Cara Stitzlein, Carmel Pollino, Cathryn O'Sullivan, Claire Naughtin, Dave Henry, David Beatty, Frank Sperling, Jen Taylor, Katrina Szetey, Maja Arsic, Margaret Jewell, Navinda Kottege, Nina Welti, Rick Llewellyn, Rose Roche, Steve Swain, Stuart Whitten and Zaynel Sushil for providing significant reviews.

We thank the members of the project's Steering Committee, including representatives from the Department of Agriculture, Fisheries and Forestry, the Australian Farming Institute and CSIRO

Project partnership

The Ag2050 Scenarios Report project was led by CSIRO with financial and in-kind support from the Australian Government Department of Agriculture, Fisheries and Forestry. CSIRO would like to acknowledge the contributions of DAFF as advocates of co-design and connecting with industry to ensure their involvement and for bringing policy insights to the co-design process.

Copyright

Foreword

Agriculture is a key industry for Australia, shaping our society, and providing the food we eat. While many Australians may never step foot on a farm, our farming systems touch every family and individual. This report, spanning land-based farming, forestry, aquaculture and fisheries explores the complexity and interconnection of these systems.

Despite Australia's significant role in agriculture and innovation, the sector faces threats to productivity, resilience and sustainability. Cross-sectoral, evidence-based exploration is essential to build our understanding and shape a shared vision for what farming systems should, could and need to look like by 2050.

This report seeks to motivate discussions among industry, researchers and government entities regarding the plausible futures for Australian farming systems. The primary aim is to expand the scope and urgency of collaborative and strategic planning, ultimately shaping a comprehensive plan for effective transformative change across the entire agricultural system.

This report marks the first phase in a four-year CSIRO program, Ag2050, to identify the necessary interventions, innovations and support crucial for a productive, resilient and sustainable future for Australian agriculture. CSIRO, as Australia's national science agency, draws on deep expertise across farming systems, integrating insights from a range of stakeholders including government, industry and research groups. Together with our project partner, the Department of Agriculture, Fisheries and Forestry, we thank all the stakeholders who contributed to this critical report.

Australia's response to emerging trends and challenges will determine the future of its farming systems. The increasing risk posed by climate change, increasing geopolitical uncertainty, labour constraints, changing consumer demands and the rapid pace of innovation underscores the complexities faced by Australian farms. However, within these challenges lie opportunities that Australia is well-positioned to leverage with its natural assets and global position.

The core message conveyed in this report is that attaining a productive, resilient and sustainable future for Australian agriculture is within reach. However, it will require significant expertise, experience, energy and a collaborative commitment across both public and private sector organisations.

This report presents a suite of plausible, contrasting future scenarios, some more desirable than others, but each scenario presents trade-offs and implications. These are intended to stimulate discussion and raise questions for further research that will contribute to the transformation and adaptation of our farming systems, ensuring they are fit for the future.

We would like to acknowledge the absence of Aboriginal and Torres Strait Islander voices in the future scenarios in this report. This gap reflects the significant current underrepresentation of Aboriginal and Torres Strait Islander knowledge in agriculture systems. We want to do our part in influencing the national agriculture systems to be more inclusive. This report will be followed by the *Indigenous Futures Caring for Country and Agriculture 2050* initiative, a collaboration with CSIRO and the Department of Agriculture, Fisheries and Forestry. Taking a relationship-first approach, this 2-year initiative aims to increase R&D partnerships with Indigenous organisations and communities, increase Indigenous-led science and engagement, and increase diversity, inclusion and belonging in the agriculture system.

I am motivated by the collaborative, evidence-based and long-term possibilities presented in this report, and I hope you will be too.

Michael Robertson
Director Agriculture and Food, CSIRO

Participating organisations

CSIRO would like to thank all consulted organisations and individuals for contributing to this project through consultations, workshops and reviews. Listed below are those organisations that consented to be named.

Agricultural Innovation Australia

Agriculture Victoria

AgriFutures Australia

AGZero 2030

Australian Bureau of Agricultural and Resource Economics and Sciences

Australian Centre for International Agricultural Research

Australian Eggs

Australian Farm Institute

Australian Food and Grocery Council

Australian Forest Productions Association

Australian National University (ANU)

Australian Wool Innovation

Bayer Crop Science Australia

Biosecurity Advisory Service

Bureau of Meteorology

CaneGrowers

Carbon Farmers of Australia

Coles

Costa Group

Cotton Seed Distributors

CropLife

Dairy Australia

Department of Agriculture, Fisheries and Forestry

Department of Climate Change, Energy, the Environment and Water

Department of Industry, Science and Resources

Department of Primary Industries and Regions

Department of Prime Minister and Cabinet

Department of Regional NSW

Fisheries Research and Development Corporation (FRDC)

Fonterra Australia

Forest and Wood Products Australia

Future Farmers Network

GrainCorp

Grains Research and Development Corporation (GRDC)

InterGrain

LiveCorp

Loam Bio

Main Sequence Ventures

Meat and Livestock Australia

National Farmers Federation

Nestle Australia

Nous Group

NRM Regions Australia

NSW Department of Primary Industries

Protected Cropping Australia

Rabo Bank

SA Department of Primary Industries and Regions (PIRSA)

Simplot Australia

Syngenta

TAS Department of Natural Resources and Environment

The Queensland Alliance for Agriculture and Food Innovation

University of Adelaide

Wildlife Health Australia

Contents

Executive summary

The Ag2050 Scenarios Report explores a range of significant trends, risks and opportunities to identify key shifts and actions needed to support Australian farming systems into the future. This report aims to motivate discussions and actions around plausible futures and seeks to answer the question: what does a productive, resilient and sustainable future look like for Australian farming systems by 2050?

Why agriculture?

As of early 2024, agriculture in Australia has seen several years of high yield and profitability through continuous adaptation and leading innovation. However, there are several key threats to farm productivity, resilience, and sustainability that are already impacting farming systems, fisheries and forestry. These growing threats include climate change, emissions reduction targets, supply chain disruptions, workforce access, changing consumer preferences, market access, and innovation timelines.

Why now?

The last two decades have shown long-term reductions in farm profit, with projections estimating that these growing threats could cause profitability decline in some areas by up to 50% by 2050.[1] Australian agriculture has an active innovation system focussed mainly on short to medium-term deliverables (5–10 years) and commodity groups within existing farming systems. Australia will need to accelerate the transformation of its current farming systems to respond to these complex and whole-of-sector challenges and deliver against the sustainability, productivity and profitability needs of 2050. As such, there is a need for whole-of-system planning that provides the agricultural innovation system with achievable stepping stones towards long-term transformative system change.

Why future scenarios?

The goal of this report is to motivate discussions between industry, researchers and policy makers on the strategy and coordination needed for the Australian agriculture innovation system to productively address cross-sectoral challenges and opportunities. By exploring four plausible, alternative futures for Australian farming, this report aims to expand the scope and urgency of collaborative and whole-of-sector strategic thinking for decision makers at all levels across the agriculture sector.

This work combines research by CSIRO and input from leaders and organisations across the Australian agriculture industry, research and government sectors to develop a set of four plausible and evidence-based scenarios for 2050. It was developed through a highly collaborative approach over 6 months that combined input from **over 100 participants across 54 organisations** in a co-design workshop series.

1 Hughes N, Gooday P (2021) Climate change impacts and adaptation on Australian farms. ABARES, DAFF. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1032401/0> (accessed 31 January 2024).

How to read this summary

Immerse yourself in the four contrasting future scenarios below. These scenarios are evidence-based and plausible explorations of what Australian farming systems could look like by 2050. While some may have more desirable elements than others, it is important to note that there is no one preferred future scenario and every scenario presents trade-offs.

What is possible for Australian farming if the agriculture innovation system achieves its full potential?

- Scenario 1 – Regional Ag capitals
- Scenario 2 – Landscape stewardship

What can be achieved with incremental innovation and proactive climate adaptation?

- Scenario 3 – Climate survival

What if agriculture fails to effectively respond to the challenges and needs of 2050?

- Scenario 4 – System decline

Each scenario contains a set of key signposts. Signposts are the unique trends, events or signals that could indicate the sector is on a pathway to the future described in the scenarios.

Next, explore the five fundamental shifts Australia needs to make to identify and pursue the future it wants for its farming systems.

Five shifts: climate adaptation, land and water, industry, regions and whole-of-system change were developed drawing on insights from the co-design workshops and CSIRO's research. A set of action areas were defined for each fundamental shift. These action areas are not exhaustive, but help to articulate the initial changes, assumptions testing, and initiatives required. Ultimately, achieving the most optimistic future is plausible for Australian agriculture. However, it will require significant effort, collaboration and action across the public and private sectors.

Methodology

Through a rigorous literature review and extensive consultation with stakeholders, 14 drivers of change were identified. These drivers will shape the direction and speed of change across Australian farming systems to 2050. For each driver, two contrasting and alternative outcomes were developed. In a series of co-design workshops, these driver outcomes were logically grouped to form the foundation of the four future scenarios in this report.

Over the next few years, the CSIRO Ag2050 program will continue to iterate these initial future scenarios through modelling and consultation to inform the policy and R&D actions required by industry and government to facilitate a preferable future.

It is important to note that the four future scenarios included in this report cover a wide range of plausible outcomes, however they are not mutually exclusive, nor exhaustive of the future possibilities. Additionally, while these scenarios will have implications across broader agrifood value chains, the scope of this report is pre-farm gate.

Regional Ag capitals

Large multinational corporations have consolidated and seamlessly integrated much of Australia's agriculture value chains. By leveraging transformative technologies, increased levels of productivity have been unlocked. New workforce opportunities have emerged, concentrated in a select few regional cities where multiple sectors are experiencing growth.

How do we know we are heading here?

- ↑ **industry investment in novel climate adaptation strategies**
- ↑ **industry-led collaboration and R&D investments**
- ↑ **rates of industry and supply chain consolidation**
- ↑ **investment in novel food and fibre production**
- ↑ **concentration of investment in select regional centres.**

What does the agriculture sector look like in 2050?

- **Increasing yields and productivity gains**
- **Food and fibre focus through new and intensified production systems**
- **Decreasing emission intensity and plateaued absolute emissions**
- **Improvements to the health of ecosystem services**
- **Skilled and diverse workforce in select growing regional cities**
- **Step-change investment and uptake of disruptive agritech**
- **Evidence-based and Australian-led trade frameworks**

Landscape stewardship

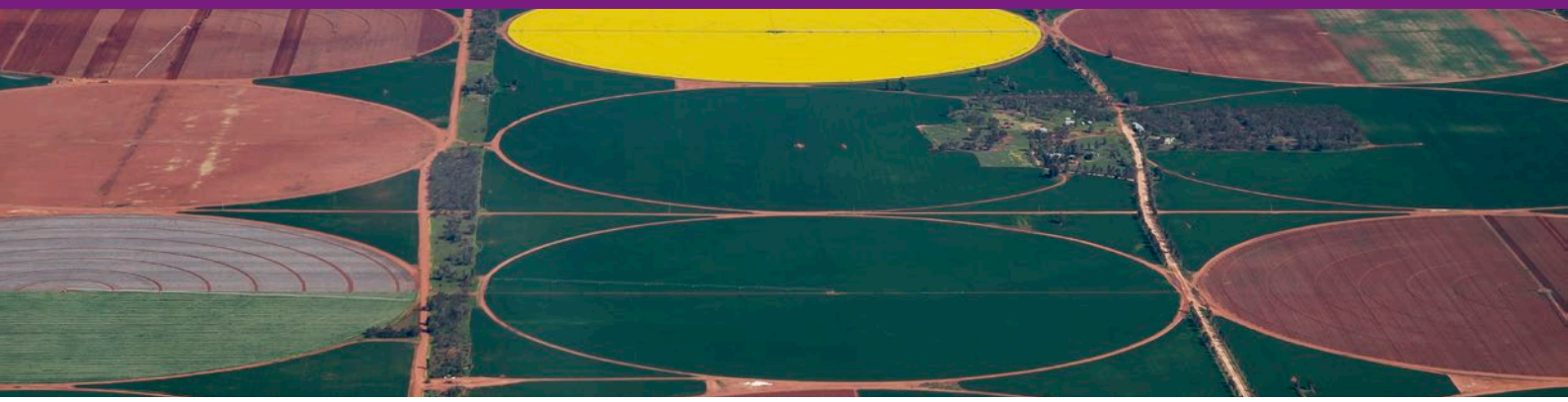
Using the land to support the energy transition through carbon capture and the restoration of the environment is a national priority. Farming systems are resilient and productive because producers have taken advantage of a range of diverse income streams, blurring the lines between farming, biodiversity, carbon sequestration, and energy and fuel production.

How do we know we are heading here?

- ↑ **investment in novel climate adaptation strategies**
- ↑ **R&D investments across industries and sectors**
- ↑ **strength of governance and guidance across land uses**
- ↑ **application of novel cross-sector and diversified business models**
- → **growth in food and fibre production.**

What does the agriculture sector look like in 2050?

- **Increasing productivity gains and resilience**
- **Diversified into innovative new market opportunities**
- **Decreasing absolute emissions and increasing carbon sequestration**
- **Active improvement to biodiversity and ecosystem services**
- **Skilled and diverse workforce attracted to the sector**
- **Step-change investment and uptake of disruptive agritech**
- **Strong Australian brand for high-value goods**



Climate survival

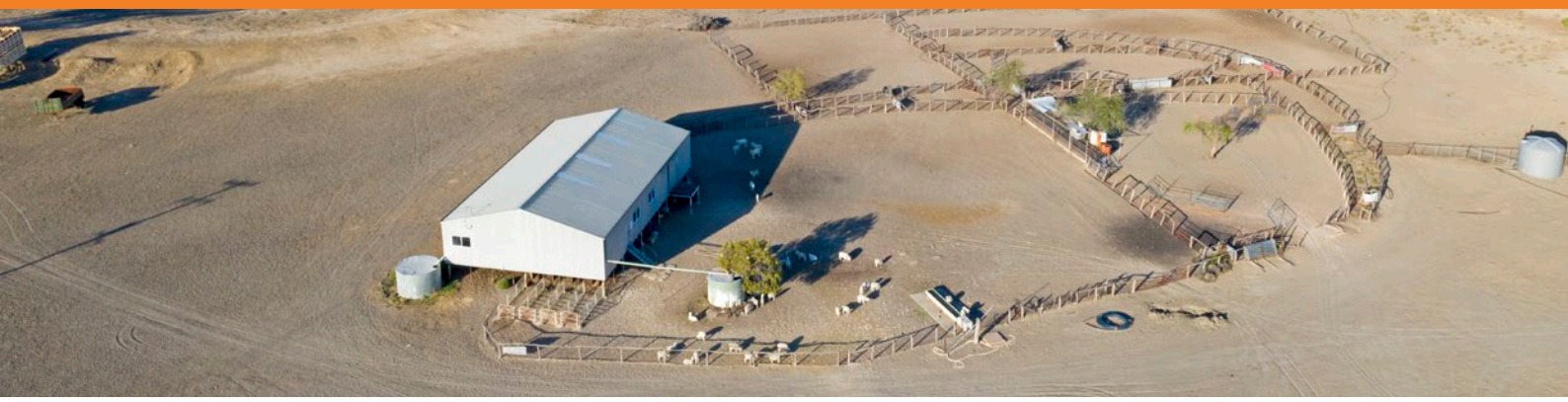
Without transformative change, the agriculture sector is forced to focus on surviving rather than thriving. Producers relocate and incrementally adapt and diversify their farming systems to offset the impacts of climate change. However, they remain uncertain about the long-term viability of their businesses.

How do we know we are heading here?

- ↑ **adoption of compounding of incremental climate change adaptation strategies**
- → **agriculture R&D investments**
- ↑ **application of diverse land management practices**
- ↓ **collaboration between industry and government**
- ↓ **trust in Australian agriculture brand.**

What does the agriculture sector look like in 2050?

- **Plateauing productivity and efficiency gains**
- **Diversified land management practices and products**
- **Some reduction in emissions intensities while lagging national net zero targets**
- **Slow deterioration of biological biodiversity and ecosystem services**
- **Some talent attraction and retention**
- **Incremental investment and uptake of low-risk technologies**
- **Diverse relationships to maintain an export market**



System decline

The Australian agriculture sector has reached a tipping point. Delayed and fragmented decision-making has left producers facing the economic and environmental consequences of extreme weather events and biosecurity outbreaks. With only incremental advances in agritech, many farm businesses are struggling to maintain profit.

How do we know we are heading here?

- ↓ **collaboration on climate change adaptation strategies**
- ↑ **short-term and reactionary focus of R&D system**
- ↑ **on-farm production intensity**
- ↑ **rates of biodiversity loss**
- ↑ **regional marginalisation.**

What does the agriculture sector look like in 2050?

- **Declining yields and productivity gains**
- **Food and fibre focus with traditional intensified production systems**
- **Lagging reduction in emission intensities and failing emissions reduction targets**
- **Declining biodiversity and ecosystem services health**
- **Shrinking workforce and increasing number of farmers exiting the sector**
- **Incremental investment and uptake of low-risk technologies**
- **Export focus to low price markets**

Considerations for policy and R&D actions

How Australia responds to trends and challenges will determine, in large part, its future outcomes. The four future scenarios describe plausible alternative futures for Australian agriculture each with benefits and challenges. This section outlines five initial shifts that Australian agriculture will need to make to identify the future it wants for its farming systems.

The shifts listed below do not offer all the solutions. Instead they present the types of changes, assumptions tests, and initiatives required. They draw on the insights developed during the co-design workshops and CSIRO's research and reflect existing aspirations for Australian agriculture. Significant effort and actions are required from Australia's agriculture innovation system to turn these aspirations into strong long-term sector plans for achieving the more desirable future outcomes and avoiding the less desirable ones for Australian farming systems by 2050.

Climate adaptation

A climate adaptation shift will support Australian food and fibre production to pursue growth in profitability and productivity within the context of a changing climate.

Increase research into climate change impacts – understand and forecast the impacts of climate change and offset strategies on ecosystem services and agriculture production at a regional level.

Increase research on adaptation approaches – identify adaptation approaches through continued research and strengthening international cross-collaboration.

Test for likely success of adaptation activities – test and demonstrate that adaptation strategies are adequate measures under a variety of global conditions, what social and policy measures are needed in regions, and how to monitor adaption action in the sector.

Land and seas

A land and sea shift will create a profitable and sustainable mix of food, fibre, and energy production and provide opportunities in carbon markets.

Improve understanding of on-farm emissions reduction including technology adoption challenges and incentives – model trade-offs between emission reduction and productivity under different global settings, incentivise the adoption of emission reduction through solving for process and technology challenges.

Model further land and sea use options and impacts – models to optimise alternative land and sea uses in regions, maps and tracking of land and sea use changes, monitoring impact on nearby ecosystems, and identifying repurposing of non-arable land.

Deepen understanding of carbon sequestration and ecosystem services opportunities – identity incentives for long-term sustainable practises, carbon sequestration opportunities, and in new technologies such as biotech and synthetic ecosystem services.

Foster sustainable agricultural practices through Indigenous-led research and Indigenous-led co-design – use co-design and two-way learning approaches to respectfully develop new knowledge bases for agricultural R&D that integrate Indigenous and scientific knowledge systems.

Industry

An industry shift will enable a productive and resilient agricultural sector and economy and provide new opportunities for exports and income streams.

Build support for skills and human capital – identify and communicate the skills and jobs required in the future, barriers and incentives to education and career pathways in regions, potential trade-offs and co-benefits of automation, and establish strategic partnerships to build education and talent pipelines for regional locations.

Broaden Australia's agriculture export focus – model the impacts of consolidation and diversification on exports, design policies that balance IP protection with knowledge sharing and collaboration, promote Australian sustainability and biosecurity credentials that can be evidenced by producers with minimal cost and effort.

Establish support from finance and diversified income streams – understand the settings needed from finance and insurance industries to support farm viability and resilience under various climate change and geopolitical scenarios.

Recommended areas for policy and R&D

Ultimately, achieving the most optimistic future is plausible if significant action is taken by Australian agriculture. This will require long-term strategic planning across the fundamental shifts: climate adaptation, land and seas, industry, and regions.

The expertise, experience and energy needed to achieve the more positive outcomes described in this report extend beyond any single organisation. Effective and urgent collaborative effort is needed from both public and private sector organisations.

Over the next few years, the Ag2050 program will continue to iterate these initial future scenarios through modelling and consultation to inform the policy and research and development (R&D) actions required by industry and government to facilitate a preferable future.

Regions

A regional shift will enable well-connected and vibrant regional communities that offer quality jobs, lifestyle amenities, education, and other services.

Target investment in infrastructure – map and assess regional centres to identify potential for growth and investment from agriculture and other sectors, to support other centres that are at risk of marginalisation and find new ways to connect and engage city-based communities better with agriculture.

Leverage mixed land use opportunities – harness land use mixes that leverage the energy transition and allow for more diverse income streams and quality jobs in regional areas, adopting relevant best practice from overseas around good planning and investment decisions.

Whole-of-system

A whole-of-system shift will mean the agricultural system has the planning and investment to achieve step changes towards long-term transformation.

Renew strategy guidelines – build on available strategic planning and forsighting tools, such as the future scenarios contained in this report, to enable industry, research organisations and government to develop effective strategy and standard evaluation frameworks in response to transformational and cross-commodity priorities.

Restructuring the agricultural R&D system – identify, evaluate and implement the strategy, structures, interactions, funding models, roles and responsibilities across Australian agriculture innovation needed for effective responses to cross-sector challenges and opportunities.

Strengthen relationships and dialogue with Aboriginal and Torres Strait Islander partners – incorporate Indigenous led co-design and research into the development of opportunities and re-engage with traditional methods to advance sustainable farming practices.

Productive, resilient and sustainable farming systems in 2050

Glossary

Absolute emissions	Refers to the total amount of greenhouse gases emitted into the atmosphere from a specific sector or activity over a specific period (tonnes CO_2eq).
Ag	Short reference to agriculture.
Agriculture	The practice of cultivating soil, raising livestock for food, fibre and other products. Includes fishery and forestry industries.
Agritech	Modern tools, technologies, business models and farming practices in agriculture to enhance and optimise agricultural activities.
AI	Artificial intelligence. A general-purpose technology that uses data-driven algorithms to autonomously solve problems and perform tasks without explicit human guidance. Includes machine learning, computer vision, natural language processing, robotics and deep learning.
Alien species	Non-native organisms introduced by humans (intentionally or accidentally) to an ecosystem, region or country outside of their usual habitats.
Aquaculture	The rearing of aquatic animals or the cultivation of aquatic plants for food.
Arable land	Land capable of producing agricultural crops.
ASEAN	Association of Southeast Asian Nations
Biotechnology	Describes the process of using living things to create or change products.
Bio-economy	Leveraging biological resources for the development of goods and services.
Carbon sequestration	A natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form (i.e. captured by soils or seas).
Circular economy	A regenerative production–consumption system in which inputs and outputs are minimised.
Climate adaptation	Process of modifying agricultural and natural systems to mitigate the negative impacts of climate change.
Climate mitigation	Actions taken to reduce or prevent greenhouse gas emissions and impacts from agriculture on climate systems, with the goal of preventing further climate change.
Complementary proteins	Non-animal, plant-based and novel proteins created from advanced biomanufacturing processes using yeast, fungi, algae and insects.
CRCs	The Cooperative Research Centres program. An Australian Government initiative started in the 1990's to fund industry-led collaborations with researchers and end-users.
Ecosystem services	The benefits gained from nature, such as food, water, air and soil, that directly and indirectly contribute to human well-being, survival and quality of life.
Emissions intensity	The amount of greenhouse gas emissions produced per unit of production activities, measuring how efficiently processes or industries generate emissions relative to output.
Farming system	A complex and interrelated set of agricultural activities, practices and resources used to produce agricultural products. For this report, includes forestry and fisheries systems.
Farmer	A person engaged in agriculture or forestry, often owning or managing a farm enterprise ranging from small family farms to large commercial operations.
Fisher	A person engaged in commercial fishing or aquaculture.

Friend-shoring	A trade practice where supply chain networks are focused on countries regarded as political and economic allies, to strengthen and build on-shore resilience.
Marginal land	Land that has little to no agricultural or industrial value.
Mixed farming	The combination of different types of agricultural activity, often crops and livestock, within a single farm instead of specialising in one type of crop or livestock at any one time.
Net emissions	The amount of greenhouse gas emissions considering the removal of such gases during a defined period.
Non-arable land	Land not suitable for crop production, including meadows, pastures and woody vegetation.
NTMs	Non-tariff measures. Policy measures, other than customs duties, used to regulate and control imports and exports, including regulations, standards, licensing requirements and quotas.
OECD	The Organisation for Economic Co-operation and Development
Producer	An individual or entity that produces agricultural products from farming, forestry, aquaculture etc. Unlike farmer, 'producer' refers to both land and sea-based activities.
RDCs	Rural research and development corporations
R&D	Research and development
Seas	Saltwater sources covering the earth (i.e. oceans and seas).
SPS	Sanitary and phytosanitary measures
Sustainable intensification	The process or system of increasing agricultural yields without adverse environmental impacts and without conversion of additional land.
Total factor productivity	A measure of how efficiently outputs are produced using inputs.
Waters	Inland waters including rivers, creeks, underground sources and lakes.

1 Introduction

The Ag2050 Scenarios Report explores significant trends, risks and opportunities to identify the key shifts and actions needed to support Australian farming systems into the future. It seeks to answer the question: what could Australian farming systems look like to be productive, resilient and sustainable in 2050? This report combines research by CSIRO with input from leaders and organisations across the Australian agriculture industry, research and government sectors to develop a set of evidence-based, plausible scenarios for what Australian farming systems could look like in 2050. This report and its scenarios aim to motivate further discussion on securing Australian agriculture's long-term prosperity.

The imperative for Australian agriculture

Agriculture in Australia has seen several years of relatively high yield and profitability benefitting from an emphasis on adaptation and leading innovation. However, there are some key long-term threats to farm productivity, resilience and sustainability that are already impacting the farming, fisheries and forestry systems.

- Climate change is growing as a significant threat as weather conditions and natural disasters become more frequent or disastrous, exacerbating biodiversity loss and environmental degradation. The agriculture and land sectors may provide effective solutions to support other industries in achieving long-term net-zero targets.
- Uncertainty in the long-term geopolitical outlook is growing as a threat to Australia's export-orientated agricultural industries. Recent geopolitical shocks from the Ukraine–Russia war and COVID-19 are examples of the risks posed to the supply of key inputs such as fertilisers and pesticides and to key trade relationships.
- Even before COVID-19, the sector faced constrained labour availability.[2] As the median age of the Australia agricultural workforce continues to rise, barriers to entry of diverse and skilled workers will exacerbate the existing labour gap and impact innovation and adoption of new technologies, as well as the long-term productivity of the sector.
- Rising incomes in Asia will shift demand and expectations for Australia's food and fibre exports. The sector is well positioned to benefit, especially from growing demand for proteins. Challenges may arise, however, in maintaining trust and reputation for Australian produce and responding to changes in consumer demand in time to maintain favourable market access.[3]
- Innovation timelines for agriculture are long and the net production gain of 2–4% per annum over the past 20 years will not be enough to maintain a competitive position in key export markets nor achieve shorter term industry growth targets.[4] A step change in the pace of innovation is needed.

2 CSIRO (2021) Labour impacts on agriculture. <https://www.csiro.au/en/research/environmental-impacts/sustainability/labour-impacts-on-agriculture> (accessed March 2024).

3 Australian Bureau of Agricultural and Resource Economics (ABARES) (2021) Growth juggernaut: three billion empowered consumers. <https://www.agriculture.gov.au/abares/products/insights/megatrends-2021/growth-juggernaut> (accessed March 2024).

4 Australian Farm Institute (AFI) (2019) Submission: perspectives on growing agriculture to a $100 billion industry by 2030. <https://www.farminstitute.org.au/wp-content/uploads/2021/03/AFI-Submission_100-billion-by-2030-ag-GVP_FINAL.pdf> (accessed March 2024).

Australia will need to transform its current farming systems to respond to these complex and long-term challenges and deliver against the sustainability, productivity and profitability needs of 2050.

Australian farming systems are complex and interconnected. They cover soil, water, crops, livestock, machinery, energy, labour, capital and other inputs and are influenced by a range of other systems such as political, economic, institutional and social systems. This report considers land-based farming systems as well as aquaculture, forestry and fisheries. These systems are critical components of wider and equally complex domestic and global agrifood systems that connect production to consumption. Over the past decades, farming systems in Australia have become highly efficient and globally competitive. Australia's research and innovation capabilities have been a significant contributor to this growth and prosperity. $2.3 billion was invested in agriculture research and development (R&D) in 2022–23. This included $1.3 billion in public funding and $1 billion in private funding,[5] with $500 million in levy payments made by agriculture industries.[6] This money goes towards Australian and state government entities, including CSIRO, universities, Rural Research and Development Corporations (RDCs) and Cooperative Research Centres (CRCs) and the private sector.

The Rural RDC Vision 2050 report and the EY Agricultural Innovation report suggest that an important feature of Australia's agricultural R&D system is that it was not established as a coherent system but developed through a collection of interconnected and independently managed components, each following a variety of strategic priorities to fund, facilitate and deliver R&D.[7] This has led to siloed and disjointed innovation and funding focused on commodity groups and short- or medium-term targets. Strengthened capacity is needed across the agricultural industries to adapt and transform in response to growing uncertainty and risk in a globally changing world. To prepare for multiple future scenarios, it will be important to rebalance and align the current Australian agriculture innovation system around cross-sectoral, long-term challenges and opportunities.

To define and lead this industry transformation, a whole-of-system coordinated approach across the breadth of research and innovation that applies to farming systems is needed.

This report does not predict what Australian farming systems will look like in 2050 nor does it propose a single future vision for the Australian agriculture innovation system. Instead, it aims to motivate conversations between industry, researchers and government on what actions are needed to secure a desirable future for Australian farming systems. The overall goal is to expand the scope and urgency of collaborative and strategic thinking on a whole-of-system plan for effective transformative change of the Australian agriculture innovation system.

Report methodology

This report was developed using a highly collaborative approach that combined input from participants of a co-design workshop series with a literature review and scenario analysis (Figure 1). Although these scenarios will have implications across Australia's agrifood value chains, including food processing and manufacturing, the scope of this report is pre-farm gate.

As the initial phase of the Ag2050 program, the future scenarios in this report are presented qualitatively. It is acknowledged that quantitative assessment, modelling and testing are essential steps to further validate and refine these scenarios. By sharing qualitative insights first, this report aims to showcase the diverse views and creative thinking of stakeholders involved in the project. This approach not only fosters transparency but also invites collaboration and feedback from a wider range of organisations and experts. Sharing this report prior to conducting quantitative analysis allows conversations to begin, laying the groundwork for collaborative efforts as the Ag2050 program moves forward with the quantitative phase of scenario testing and downscaling.

5 ABARES (2023) Agricultural research and development investment in Australia: 2022–2023 update. <https://www.agriculture.gov.au/abares/research-topics/productivity/agricultural-research-and-development-investment-in-australia> (accessed 20 February 2024).

6 Department of Agriculture, Fisheries and Forestry (DAFF). About levies and the levy system. <https://www.agriculture.gov.au/agriculture-land/farm-food-drought/levies/about-levies> (accessed 20 February 2024).

7 Ernst & Young (EY) (2019) Agricultural innovation: a national approach to grow Australia's future. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF> (accessed 8 February 2024); Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

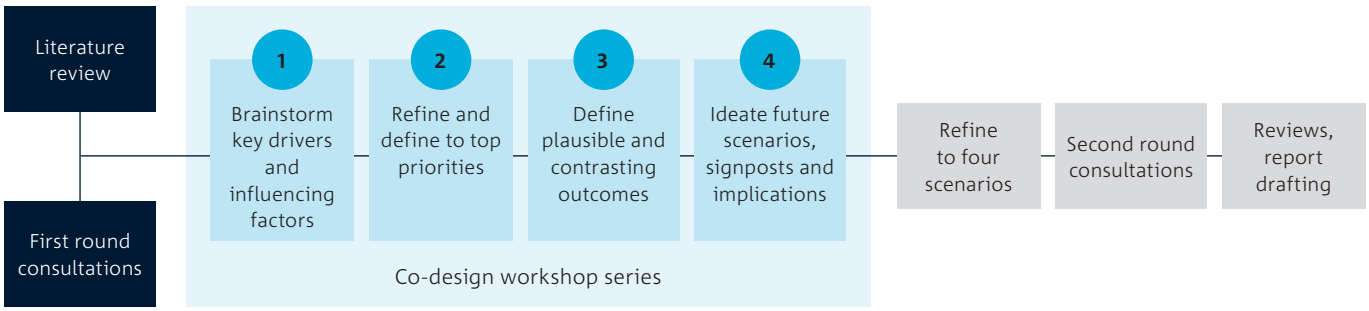


Figure 1: Co-design methodology

A broad horizon scan, including literature review and consultations with a range of experts and stakeholders, was used to identify global and national forces – megatrends, factors and influences – that would impact the future of agriculture. In early workshops, participants further developed these forces, initially brainstorming over 100 ideas and ultimately developing them into a set of 14 drivers. These were categorised under five broad areas: global context, environment and climate, land and water, innovation and productivity, and trade and market access. Many of the drivers are internal forces that Australian agriculture can influence. But there are also external forces, particularly the drivers included under global context, that are outside the control of the sector. There is some overlap and interconnectedness of drivers and they are not mutually exclusive. These drivers will shape the direction and speed of change across Australian farming systems to 2050 and are the foundational pillars of the future scenarios in this report.

There are various outcomes the drivers may lead to by 2050. Two or more contrasting and alternative outcomes were developed for each driver to align with relevant trends. These outcomes were tested and iterated based on recent literature, participant guidance and the assistance of internal researchers from CSIRO. The driver outcomes were combined into logical groupings to construct an initial set of over 30 scenarios that described a range of plausible futures for Australian farming systems.

Through further co-design workshops and consultations, the scenarios were iterated and refined to a final set of four scenarios that participants considered best explored valuable contrasts and trade-offs. The outcomes and implications of the future scenarios were developed with participant guidance and CSIRO research using published literature, recent trends and consultations. It should be noted that although the final four future scenarios included in this report cover a wide range of plausible outcomes, they are not mutually exclusive nor exhaustive of the possibilities – there are likely many other plausible futures.

This report involved CSIRO research, including the Australian National Outlook, State of the Climate report and the Our Future World report, input from the Department of Agriculture, Fisheries and Forestry, policymakers and participants to identify how the research community and industry could fully use these scenarios and achieve the more desirable and avoid the less desirable outcomes presented in the scenarios. This led to a set of initial action areas, including building upon existing initiatives, which would be required to identify and pursue the future Australia wants for its farming systems. These action areas form the basis of the five shifts described in this report.

Engaging Aboriginal and Torres Strait Islander peoples

During the preliminary phase of Ag2050, we identified gaps in our engagement efforts. We specifically acknowledge the absence of Aboriginal and Torres Strait Islander voices in our initial discussions. It is clear that a one-size-fits-all approach to stakeholder engagement is insufficient. Engaging meaningfully with Aboriginal and Torres Strait Islander peoples requires dedicated time and culturally centred methodologies.

We acknowledge with respect the vital contributions of Aboriginal and Torres Strait Islander peoples, whose Indigenous ways of knowing, being and doing have nurtured Country for thousands of years. The Ag2050 Initiative is keenly aware of the importance of these traditions in shaping a sustainable future for agriculture and food systems in Australia. In line with this, we are committed to the principles of Caring for Country, bolstering economic strength and enhancing food security and nutrition within Aboriginal and Torres Strait Islander communities.

This intention recognises that we are on a journey with Aboriginal and Torres Strait Islander partners and that the scenarios outlined in our report are starting points for deeper dialogue to explore their pivotal role in fostering sustainable agricultural practices. We understand that incorporating Indigenous-led co-design is essential for a just and effective development of these opportunities. There's an established and growing field of Indigenous-led research advocating for a re-engagement with these traditional methods to advance sustainable farming across Australia. Indigenous agricultural techniques, honed over tens of thousands of years connecting land, sea, sky, waterways and cultural laws, can offer invaluable insights into planning for the future with our Ag2050 program.

Where possible, further detail on integrating Aboriginal and Torres Strait Islander opportunities will be drawn out in future work as part of the Ag2050 program. The program aims to ensure that the opportunity for collaboration to incorporate Indigenous knowledge and land management practices into future farming systems is adequately explored and aligns with the goals and objectives of local Indigenous community groups. As such, the program is addressing this through an in-depth network analysis and collaborative process to establish an Indigenous-led Steering Committee. Delivered under the leadership of an Indigenous Research Scientist, this initiative will take a 'relationship-first' approach, where building trust and understanding with Indigenous partners is the runway for all subsequent activities. Further engagement activities with Aboriginal and Torres Strait Islander leaders and organisations, including grassroots organisations from across Country, will be designed to encourage two-way learning between CSIRO and Indigenous partners. A data-sharing framework will be co-developed with the Indigenous-led Steering Committee and with support from existing CSIRO research in this space. To contribute to this process, email Ag2050@csiro.au.

As we move forward, we pledge to commit our efforts to bridge these gaps. We will strive for an approach that not only reaches out but also resonates with Aboriginal and Torres Strait Islander peoples, fostering meaningful collaboration for the benefit of current and future generations. This commitment is fundamental to the integrity and success of the Ag2050 Initiative.

How to read this report

This report starts by presenting the key national and global forces impacting the future of Australian farming systems. The plausible outcomes of these key drivers of change form the foundational pillars of the four future scenarios presented later in the report.

1. **Start by diving into the national and global forces that will impact the future of Australian farming systems in *Chapter 2 Priorities for Australian agriculture*.**

These forces cover five overarching areas: the global context, environment and climate, land and water, productivity and innovation, and trade and market access. The direction, pace and plausible future outcomes of these trends and forces will shape Australia's farming systems out to 2050.

2. **Next, immerse yourself in the four contrasting future scenarios in *Chapter 3 Future scenarios*.**

These scenarios are evidence-based and plausible explorations of what Australian farming systems could look like by 2050. Although some may have more desirable elements than others, it is important to note that there is no one preferred future scenario and every scenario presents trade-offs.

What is possible for Australian farming if the agriculture innovation system achieves its full potential?

Scenario 1 – Regional Ag capitals

Scenario 2 – Landscape stewardship

What can be achieved with incremental innovation and proactive climate adaptation?

Scenario 3 – Climate survival

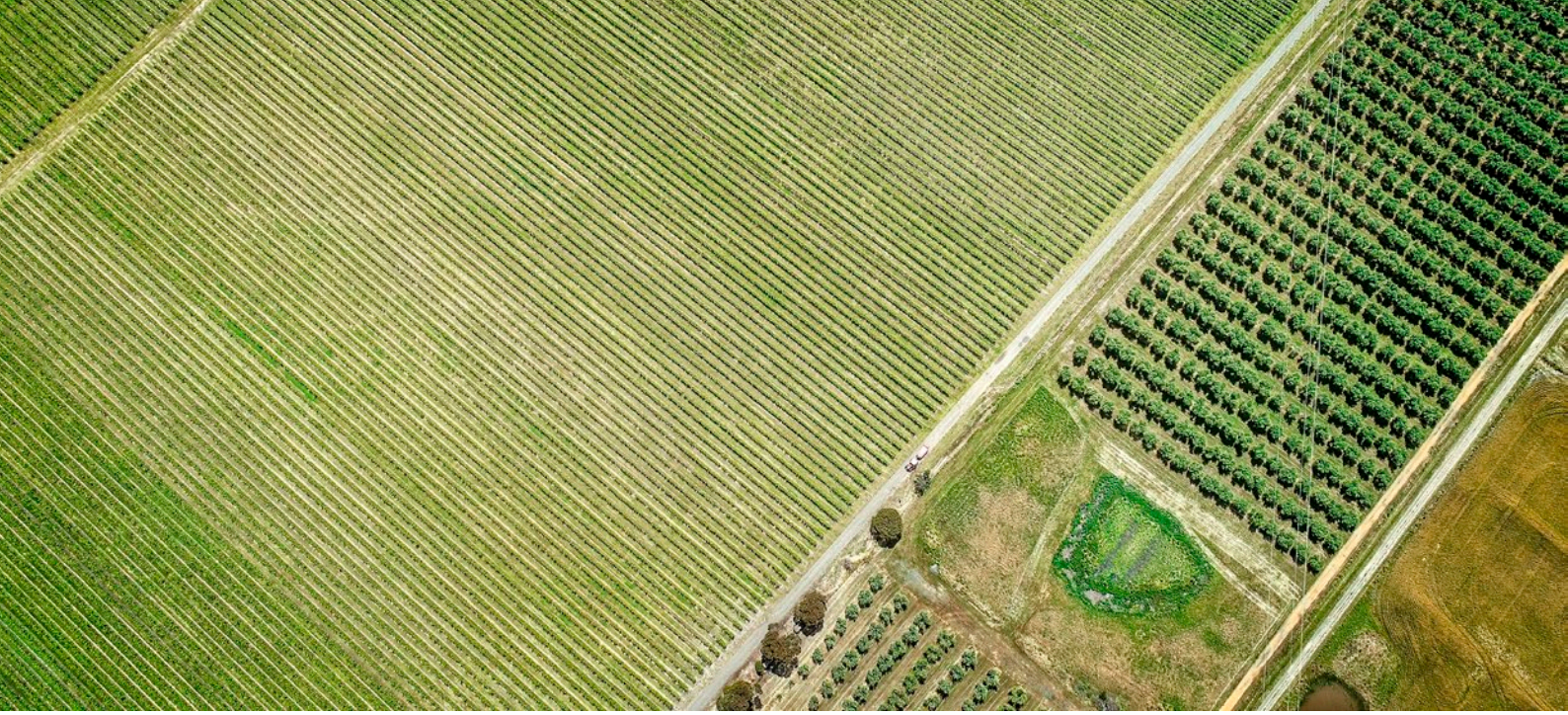
What if agriculture fails to effectively respond to the challenges and needs of 2050?

Scenario 4 – System decline

Each scenario contains key signposts and implications. Signposts are the unique trends, events or signals that could indicate the sector is on a pathway to the future described in the scenarios. Implications highlight the key trade-offs and consequences of each scenario.

3. **Finally, explore the five fundamental shifts Australia needs to make to identify and pursue the future it wants for its farming systems in *Chapter 4 Considerations*.**

Five shifts were developed, drawing on insights from the co-design workshops and CSIRO's research: climate adaptation, land and water, industry, regions and whole-of-system change. A set of action areas was defined for each fundamental shift. These action areas are not exhaustive, but help to articulate the initial changes, assumptions testing and initiatives required. Ultimately, achieving the most optimistic future is plausible for Australian agriculture. However, it will require significant effort, collaboration and action across the public and private sectors.



Three points to consider throughout this report

This report presents four scenarios: *Regional Ag capitals* and *Landscape stewardship* in which farming systems transform in different ways to reach new heights of potential; *Climate survival* in which systems successfully adapt and produce in the face of climate change; and *System decline* in which systems fail to build resilience to external factors.

There are three main points to consider across these future scenarios.

The value in these scenarios is not in determining an optimal future, but in understanding the implications of setting different priorities and the associated trade-offs: Each of the scenarios presents a mix of desirable and less desirable components. Considered together, the scenarios can help identify various potential key roles for the Australian agriculture sector into the future, develop proactive actions needed to pursue more positive future outcomes and identify the no-regret actions needed to avoid the impacts of a less desirable future. The future of agriculture may be a combination of the four scenarios, depending on the regional, industry and global context, and the extent of actions taken by the sector. But it is the trade-offs within these scenarios that can facilitate richer decision-making on which future the agriculture sector wants to pursue.

The sector can achieve positive future outcomes despite global uncertainties: The future of Australian agriculture will be affected by external global forces outside its control. The sector, however, can control how it responds to the global context to improve the outcomes for farming systems. Stakeholders that participated in the development of this report expect global uncertainty and volatility to continue to rise between now and 2050. To make the scenarios more manageable, testable and comparable, all scenarios are set in the same global context. Although other global contexts are plausible, the future scenarios presented in this report are a starting point for considering how farming systems are impacted by a variety of global factors.

***The productivity, resilience, and sustainability of Australian agriculture can and must be strengthened, which requires immediate action and long-term planning*:** Achieving the more positive outcomes described in this report is beyond the scope of any single organisation. It will require significant expertise, experience, energy and a collaborative effort across both public and private sector organisations. This report does not address every trend, challenge or plausible future, nor offer all the solutions. Instead, it aims to motivate discussion and identify questions for further research and discussion.

2 Priorities for Australian agriculture

The past successes of Australian agriculture and several recent years of high yields and profitability conceal the disruption Australian farming systems face now and in the future. Multiple global and national forces impact Australian farming and fisheries systems. These forces are complex and interconnected. Together they are escalating risk to the long-term productivity, resilience and sustainability of the agriculture sector. Yet they also create opportunities for Australian agriculture to innovate farming systems, develop new sources of growth, protect and restore Australia's natural resources and ensure the long-term viability of the sector.

Through a literature review and an extensive consultation period, experts and stakeholders viewed five overarching areas as critical priorities for Australian agriculture:

- global context
- environment and climate
- land and water
- productivity and innovation
- trade and market access.

Across these five areas, 14 drivers of change were developed, covering the breadth of factors and trends influencing Australian farming systems (Figure 2). The pace and direction of these drivers will impact the future outcomes for Australian farming and fisheries systems to 2050. This chapter provides an overview of these drivers and the challenges and sectoral opportunities they may bring.

Although the agriculture, forestry and fisheries industries face similar threats, the impacts of these threats can vary, particularly for fisheries and aquaculture. For specific insights into how these drivers impact fisheries and aquaculture, see Box 1.

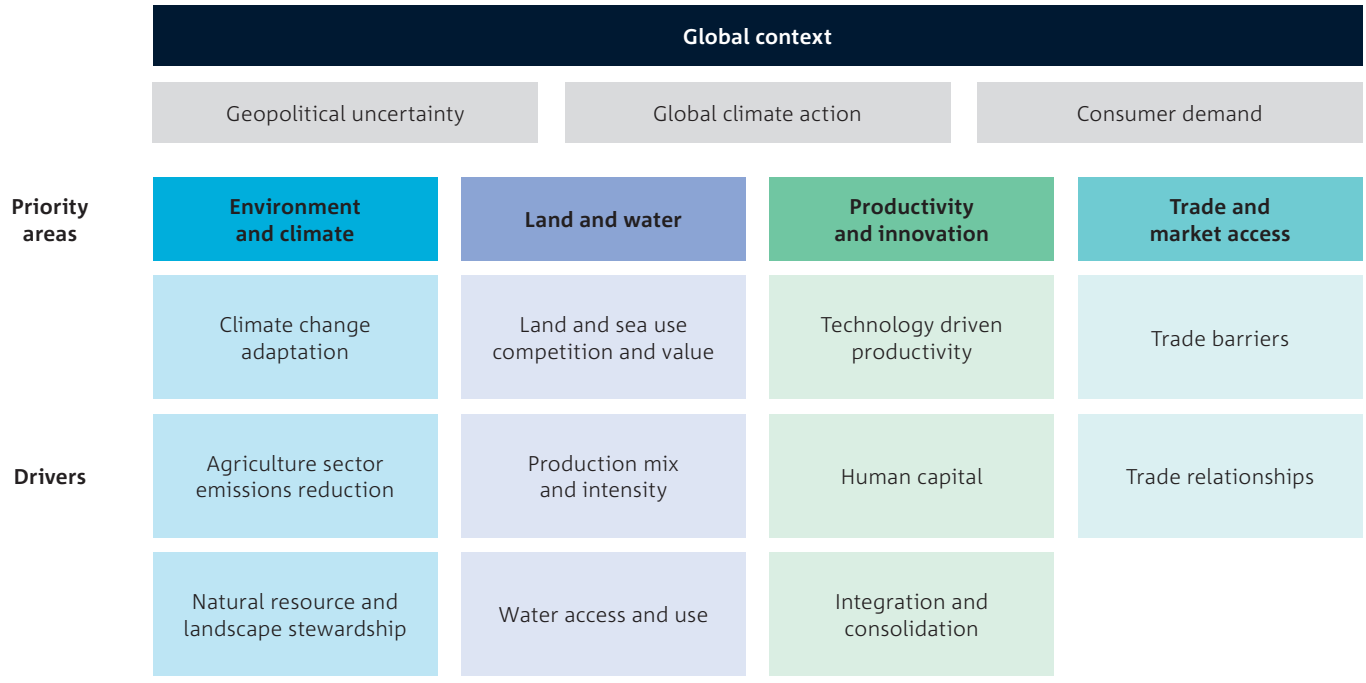


Figure 2: The five priority areas and the associated drivers of change

Global context

Australia's ability to secure critical agricultural inputs and to export produce is susceptible to external global forces, including global climate action, consumer demands and geopolitical uncertainty. Australia is recognised globally as a producer of high-quality, safe food and fibre, and a significant contributor to global food security. Agriculture in Australia is heavily export-orientated and the shifts and demands of the export market greatly influence Australian producers. Exports account for 72% of the total value of agriculture, including forestry and fisheries, representing 11.6% of total goods and services exported.[8] Recent impacts from the COVID-19 pandemic and the Ukraine–Russia war have highlighted the susceptibility of the Australian agriculture sector to global fluctuations and disruptions.[9] How the agricultural industries, and Australia more broadly, respond to global forces is critical for the long-term profitability, sustainability and resilience of Australian farming systems.

Human-induced global warming has caused Australia's climate to warm by an average of 1.4°C since national records began in 1910,[10] with surrounding ocean temperatures also increasing. The latest United Nations Environment Programme report shows that despite numerous worldwide initiatives,[11] it is likely that global warming will exceed 1.5°C. As stated in the 2022 Intergovernmental Panel on Climate Change report, global pathways that limit global warming to 1.5°C or even 2°C involve almost immediate reductions in greenhouse gas emissions across all sectors.[12] Mitigating further warming of Australia's climate depends greatly on effective and equitable global collaboration that delivers rapid and sustained transformation across all sectors.

An increasing global population and a growing middle class are shifting the demand profile of agriculture export markets and the preferences that exporters must meet to remain competitive. The total global food demand is expected to increase by 35–56% between 2010 and 2050.[13] At the same time, a rise in average global incomes is expected to add over 3 billion new middle-class consumers by 2050,[14] primarily in Asia.[15] As consumers become wealthier in developing nations, their diets are diversifying[16] and they are demanding premium, sustainable and healthy foods at a competitive price.

Geopolitical uncertainty increases as global economic and political relationships become more complex and volatile. The current, dynamic multipolar world is dominated by seven global powers: the United States, China, India, the European Union, Brazil, Indonesia and Russia. Together they account for over two-thirds of global economic activity.[17] As they pursue their interests, they are disrupting the previous certainties of the rules-based international order. To build resilience to these shifting geopolitical settings, Australian producers are looking to increase diversification of agricultural export partners (see Trade and market access). Australia is already seeing an increasing value of exports to the Middle East, Africa and the ASEAN region compared to recent years (Figure 3). The risk for countries, including Australia, in navigating their relationships with these growing powers is becoming increasingly complex.[18]

8 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023).

9 Naughtin C, Hajkowicz S, Schleiger E, Bratanova A, Cameron A, Zamin T, Dutta A (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO Publishing, Brisbane, Australia.

10 CSIRO and Bureau of Meteorology (BOM) (2022) State of the Climate. Australia: ©Government of Australia. <https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate> (accessed 13 March 2024).

11 United Nations Environment Programme (2023) Emissions Gap Report 2023: Broken record – Temperatures hit new highs, yet world fails to cut emissions (again), Nairobi. <https://www.unep.org/emissions-gap-report-2023> (accessed 12 December 2023).

12 IPCC (Intergovernmental Panel on Climate Change) (2023) AR6 Synthesis Report Climate Change 2023. <https://www.ipcc.ch/report/ar6/syr/resources/spm-headline-statements> (accessed 12 December 2023).

13 Van Dijk M, Morley T, Rau ML (2021) A meta-analysis of projected global food demand and population at risk of hunger for the period 2010-2050. Nature food 2, 494-501. <https://doi.org/10.1038/s43016-021-00322-9> (accessed 23 January 2024).

14 Hatfield-Dodds S, Hajkowicz S, Eady S (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

15 Hafi A, Parker J, Fell J, Duver A, Addai D (2023) What Asia wants: long-term agrifood demand in Asia (2023 revision). ABARES Research Report 23.10, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1034701/0> (accessed 12 December 2023).

16 Herforth A, Ahmed S (2015) The food environment, its effects on dietary consumption, and potential for measurement within agriculture: nutrition interventions. Food Section (7), 505–520. <https://doi.org/10.1007/s12571-015-0455-8> (accessed 12 December 2023).

17 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

18 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

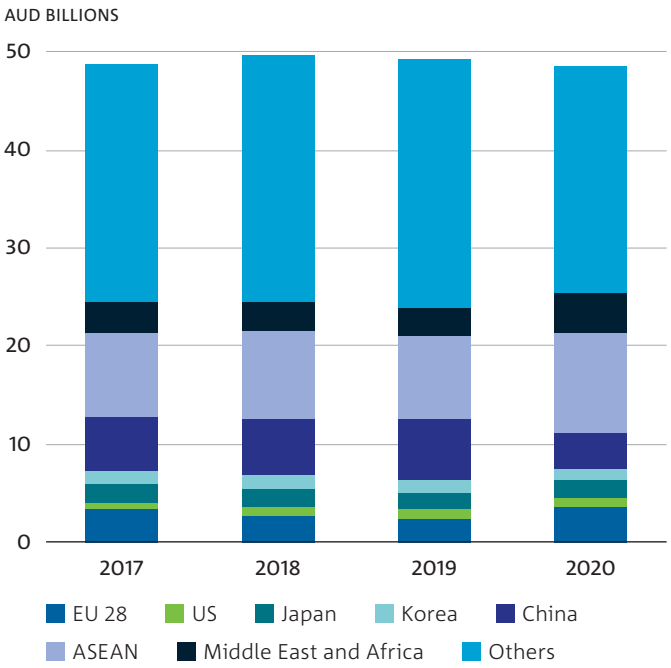


Figure 3: Australian exports have increased to the Middle East, Africa and the ASEAN region

Notes: Figure shows the export value of Australian agriculture, fisheries and forestry by destination between 2018 and 2021. The category 'ASEAN' comprises the 10 member states and East Timor.[19]

Challenges

A lack of global action and collaboration to curb global warming will lead to numerous impacts on Australia's climate and environment, including the expansion of pests and diseases, increasing biosecurity risks, marine heatwaves and an increase in extreme fire weather.[20]

Without a significant reduction in global greenhouse gas emissions, Australian farms could face global warming scenarios of over 2°C by 2050.[21] Although farmers in some regions may derive short-term gains from increasing temperatures, in the long term, Australian farms, the ecosystem services they depend on and regional communities will be under increasing stress to navigate and adapt to more frequent or extreme weather events.[22] Intensified competition for resources such as arable land and water access rights may drive up the price of land and water and this, in turn, can damage the viability and profitability of farms.[23] These impacts threaten farming and fisheries systems and will likely increase costs associated with climate adaptation and planning (see Environment and climate).[24]

Consumer trends and stringent trade requirements will dictate farming systems' actions around sustainability and welfare, biosecurity and traceability to remain competitive.[25] The sector will need to build and strengthen a global 'green and clean' brand to meet the preferences of the increasingly wealthy middle-class populations in Asia.[26] Australia has a strong environmental sustainability record, including efficient use of pesticides and fertilisers, low-tillage practices and below-average emission intensities for several commodity groups compared to major developed country producers.[27] Maintaining a competitive sustainable and healthy brand will require proactively responding to the changing climate by collaborating and investing in mitigation and adaptation efforts, as well as investing in national biosecurity monitoring and prevention measures.[28]

19 ABARES (2022) Agricultural commodities and trade data. <https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data> (accessed 20 January 2024).

20 CSIRO, BOM (2022) State of the Climate. Australia: ©Government of Australia. <https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate> (accessed 13 March 2024).

21 Lee JY, Marotzke J, Bala G, Cao L, Corti S, Dunne JP, Engelbrecht F, Fischer E, Fyfe JC, Jones C, Maycock A, Mutemi J, Ndiaye O, Panickal S, Zhou T (2021) Future global climate: scenario-based projections and near-term information. <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-4/> (accessed 24 Jan 2024); United Nations Environment Programme (2023) Emissions Gap Report 2023: Broken record – Temperatures hit new highs, yet world fails to cut emissions (again). Nairobi. <https://www.unep.org/emissions-gap-report-2023> (accessed 12 December 2023); Matches IPCC scenarios for SSP3-7.0.

22 Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

23 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023); Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

24 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

25 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023); National Farmers Federation (NFF) (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

26 NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

27 Read A, Rollan J, Creed C, Fell J (2023) Sustainability and Agri-environmental Indicators: International Comparisons. ABARES Insights, Issue 2, Canberra, Australia. <https://doi.org/10.25814/zzdq-4t23>. (accessed 13 March 2024).

28 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

At a national level, government and industry representatives will be challenged with negotiating and cooperating with various global partners to stabilise supply chains and maintain access to key export markets.[29] Escalating protectionist policies and a volatile geopolitical context weaken economic cooperation and trade liberalisation.[30] Ongoing disruptions and unpredictability, driven by geopolitical conflicts, can impact major trade and supply chain routes,[31] which in turn can limit Australian farmers' access to crucial agricultural inputs such as fertilisers and chemicals, leading to lower crop yields and export potential.[32] It can also hinder the ability of Australian agricultural exporters to deliver their goods using timely and efficient freight, subsequently impacting profit margins and product integrity.[33]

Opportunities

Australia cannot directly influence the pace or success of global action on climate change. It can, however, strive towards reducing its own contribution to global warming through net zero strategies. Across the Australian economy, science, innovation and strategy are already driving changes.[34] The agriculture sector has opportunities available to indirectly influence the direction of global climate action, including supporting the growth of low-carbon export industries such as sustainable aviation fuels, participating in low-waste, circular food systems, and decarbonising heavy freight transport further down the supply chain.[35] Reducing and sequestering emissions, and restoring environments, provide additional opportunities to target products to environmentally conscious consumers (see Trade and market access).[36]

By understanding the shifting preferences of the growing middle-class populations in Asia and responding in time, the sector can secure its position as a supplier of high-quality food and fibre goods to these high-value export markets. For example, to meet the growing demand for proteins, Australian producers have an opportunity to supply complementary proteins to middle-class consumers.[37] The rapidly growing complementary protein market is expected to grow by $3.1 billion in 2030.[38] Complementary proteins can provide producers an opportunity to grow into value-added industries, with higher and less volatile prices than commodity markets. However, the extent to which the sector can capitalise on demand from the growing middle class will depend, in part, on the sector's ability to navigate new geopolitical uncertainties and to maintain and build positive trade relationships with multiple established and growing economies.

29 Australian Government Department of Foreign Affairs and Trade (2023) World Trade Organisation. <https://www.dfat.gov.au/trade/organisations/wto/Pages/agricultural-trade> (accessed 12 December 2023); CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023); Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

30 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

31 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

32 Greenville J, Cameron A (2022) Where to Next for Australian Agriculture? ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/vb1b-xr37> (accessed 12 December 2023).

33 Greenville J, Cameron A (2022) Where to Next for Australian Agriculture? ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/vb1b-xr37> (accessed 12 December 2023); Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

34 DAFF (2024) Agriculture and land sectoral plan. <https://www.agriculture.gov.au/agriculture-land/farm-food-drought/climatechange/ag-and-land-sectoral-plan> (accessed 5 March 2024).

35 CSIRO (2023) Sustainable aviation fuel opportunities for Australia. <https://www.csiro.au/en/research/technology-space/energy/sustainable-aviation-fuel> (accessed March 2024); CSIRO (2023) Reshaping Australian food systems. < https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/agriculture-and-food/reshaping-australian-food-systems> (accessed March 2024).

36 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023); Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

37 Lawrence S (2021) Australian agriculture & alternative proteins: a view for the future. Food Frontier, Australia. <https://www.foodfrontier.org/australian-agriculture-alternative-proteins/> (accessed 12 December 2023).

38 Admassu S, Fox T, Heath R, McRobert K (2020) The changing landscape of protein production: opportunities and challenges for Australian agriculture. AgriFutures, Australia Publication No. 20-001. <https://agrifutures.com.au/product/alternative-proteins/> (accessed 12 March 2024).

Environment and climate

Australia's natural environment and climate are vital in sustaining the agricultural industries now and into the future. Today, agriculture faces significant challenges due to climate change, deteriorating natural resources and pressures to decarbonise. Shifts in rainfall and temperature patterns have been shown to affect farmer incomes, with recent short-term favourable conditions reflected in record profits.[39] However, over the past two decades, average annual farm profits have reduced by an estimated 23%, with persistent climate variability predicted to double the risk of meagre farm returns compared to the past 50 years.[40] Droughts, floods, fires and sea levels are all increasing and tropical cyclones are becoming less frequent but potentially more intense.[41] To remain productive and resilient into the future, Australian agriculture faces the challenge of balancing more diversified production methods and income sources, contributing to meeting Australia's national emissions reduction targets and implementing effective management practices for soil health, water access, biodiversity and land restoration.

Between 1910 and 2022, the average Australian temperature increased by 1.4°C and since 1970 there has been a 20% and 10% reduction in winter rainfall in south-western Australia and south-eastern Australia, respectively.[42] Air pollution is expected to worsen as climate change causes greater natural emissions from dust, biogenic sources and bushfires.[43] Essential ecosystem services continue to decline, including terrestrial, vegetation and freshwater ecosystems, due to intense competition.[44] Land degradation and intensive land use have led to erosion, acidification, compaction and nutrient decline of land, along with the loss of biodiversity.[45] Australia has the highest rate of species decline among the Organisation for Economic Co-operation and Development (OECD) countries, with these losses expected to continue to 2050.[46]

In 2023, agriculture contributed 18% to Australia's net greenhouse gas emissions,[47] mostly arising from methane and nitrous oxide from livestock feed consumption and the decay or combustion of living and dead biomass (Figure 4). Over the past 27 years, the sector has reduced greenhouse gas emissions intensity (emission as a proportion of value added by the sector) by 63% (Figure 5), largely attributed to a decline in livestock numbers associated with multiple droughts across Australia.[48] Projection estimates suggest a 3% decline in total agricultural emissions by 2035.[49] Continuing efforts to further reduce emissions from agricultural activities involve investments in carbon sequestration, complementary protein use, integrated management systems, low-emission technologies, land use changes and a federal commitment to achieving net zero by 2050.[50]

39 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023).

40 Hughes N (2021) Analysis of Climate Change Impacts and Adaptation on Australian Farms. Department of Agriculture, Water and the Environment (DAWE), Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1032401/0> (accessed 12 December 2023).

41 CSIRO, BOM (2022) State of the Climate. Australia: ©Government of Australia. <https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate> (accessed 13 March 2024).

42 Hughes N (2021) Analysis of Climate Change Impacts and Adaptation on Australian Farms. DAWE, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1032401/0> (accessed 12 December 2023).

43 Department of Climate Change, Energy, the Environment and Water (DCCEEW) (2021) Australia State of the Environment 2021: air quality. <https://soe.dcceew.gov.au/air-quality/outlook-and-impacts> (accessed 30 January 2024).

44 Cresswell ID, Janke T, Johnston EL (2021) Australia state of the environment 2021: overview. Independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra. <https://soe.dcceew.gov.au/sites/default/files/2022-07/soe2021-overview.pdf> (accessed 12 December 2023).

45 Cresswell ID, Janke T, Johnston EL (2021) Australia state of the environment 2021: Overview. Independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra. <https://soe.dcceew.gov.au/sites/default/files/2022-07/soe2021-overview.pdf> (accessed 12 December 2023).

46 DCCEEW (2021) Australia State of the Environment 2021: Biodiversity. <https://soe.dcceew.gov.au/biodiversity/outlook-and-impacts> (accessed 30 January 2024).

47 DCCEEW (2023) Australia's Emissions Projections 2023. DCCEEW, Canberra. <https://www.dcceew.gov.au/sites/default/files/documents/australias-emissions-projections-2023.pdf> (accessed 13 March 2024).

48 DCCEEW (2023) National Inventory Report: 2021. <https://www.dcceew.gov.au/climate-change/publications/national-inventory-reports> (accessed 31 January 2024); NFF (2018) 2030 Roadmap: Australian Agriculture's Plan for a $100 Billion Industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

49 DCCEEW (2023) Australia's Emissions Projections 2023. DCCEEW, Canberra. <https://www.dcceew.gov.au/sites/default/files/documents/australias-emissions-projections-2023.pdf> (accessed 13 March 2024).

50 Commonwealth of Australia (2023) National Statement on Climate Change and Agriculture. DAFF, Canberra. <agriculture.gov.au/national-statement-climate-change-agriculture> (accessed 12 December 2023).

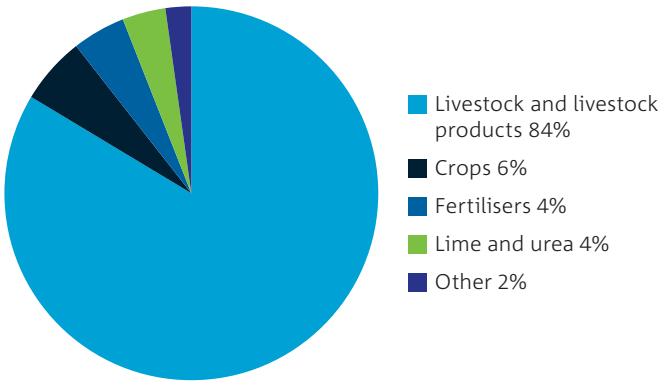


Figure 4: Absolute emissions in agriculture are dominated by the livestock sector

Notes: Figure shows absolute or actual emissions in the agriculture sector by sources for the year 2023.[51]

Challenges

Extreme climate events challenge the profitability of the agricultural sector and limit the productive capacity of Australia's growing regions. Hotter conditions have reduced the profitability of broadacre farming by 22% between 2000 and 2019, relative to pre-2000 data.[52] Increasing variability in rainfall patterns is challenging water availability and elevating water scarcity concerns in the Murray-Darling Basin, a key agricultural area supplying 40% of produce in Australia.[53]

Without a strong focus on landscape stewardship and maintaining the ecosystem services relied upon by farming systems, the ongoing viability of agricultural industries is at risk. Acidification, salinity, erosion and loss of organic carbon matter are causing soil health to decline, limiting crop choices and yields.[54] Rising atmospheric CO_2 concentrations increase ocean acidity and damage phytoplankton, challenging Australia's fish supply (see Box 1 for more information on the fisheries sector).[55] The compounding effect of multiple environmental changes increases the pressure on farming systems.

Emissions in the agriculture sector are hard to abate. Some emissions from on-farm activities may be mitigated by electrifying small farm vehicles and some farm machinery and switching to renewable fuels, but solutions to reduce emissions from ruminant livestock and fertilisers that suit the Australian farming context are yet to be scaled and adopted. Producers will require support to navigate the costs and knowledge burden of implementing new processes, systems and equipment to mitigate on-farm greenhouse emissions and to comply with global reduction policies and consumer expectations. If the sector does not reduce its emissions, export opportunities will be impacted by the growing number of import tariffs on emissions-intensive goods such as red meat.[56]

Opportunities

Through climate change adaptation and natural resource and landscape stewardship, there is an opportunity to improve ecosystem health, protect farm productivity and capitalise on new climate- and service-related industries. For example, there is an opportunity to advance agricultural innovation, improve crop resilience in extreme climates and safeguard communities dependent on agricultural produce by proactively investing in the development of the Australian synthetic biology industry.[57] With greater soil management techniques (conservation tillage, organic soil enrichment, carbon sequestration), there is an opportunity to restore landscape health, increase soil resilience to climate change, improve water storage and filtration and improve crop production.[58]

51 DCCEEW (2023) Australia's emissions projections 2023. DCCEEW, Canberra. <https://www.dcceew.gov.au/sites/default/files/documents/australias-emissions-projections-2023.pdf> (accessed 20 January 2024).

52 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

53 Australian Government (2023) The Basin. Murray-Darling Basin Authority. <https://www.mdba.gov.au/basin> (accessed 12 December 2023); Mallawaarachchi T, Auricht C, Loch A, Adamson D, Quiggin J (2020) Water allocation in Australia's Murray-Darling Basin: managing change under heightened uncertainty. Economic Analysis and Policy (66), 345–369.

54 Food and Agriculture Organization of the United Nations (FAO) (2015) Intergovernmental Technical Panel on Soils (ITPS) Status of the World's Soil Resources (SWSR) – Main Report: FAO and ITPS; DCCEEW (2021) Australia State of the Environment 2021: land. <https://soe.dcceew.gov.au/land/environment/soil> (accessed 13 March 2024); CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

55 Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

56 Wood T, Reeve A, Ha J (2021) Towards Net Zero: Practical Policies to Reduce Agricultural Emissions. Grattan Institute, Melbourne, Australia.

57 CSIRO Futures (2021) A National Synthetic Biology Roadmap: Identifying Commercial and Economic Opportunities for Australia. CSIRO, Canberra, Australia.

58 DAWE (2021) National Soil Strategy. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/national-soil-strategy.pdf> (accessed 7 March 2024).

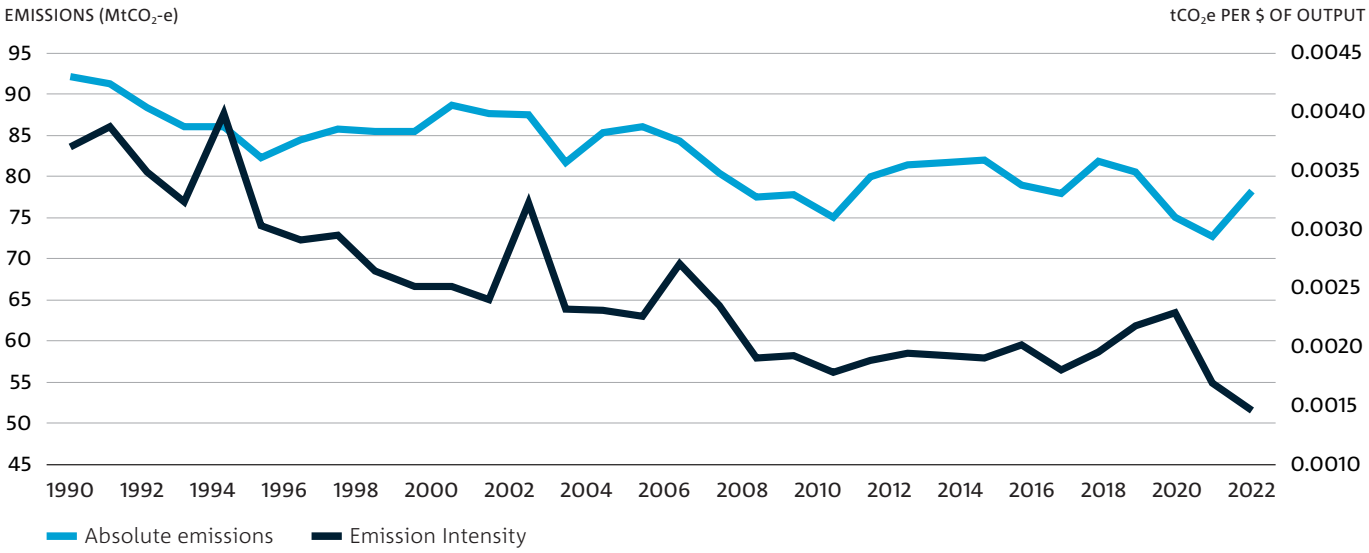


Figure 5: Absolute emissions and emission intensity in the agriculture sector have been falling

Notes: Figure shows estimated absolute emissions or actual emissions in $MtCO_2e$ and emission intensity in the agriculture sector in tCO_2e per $ of output between 1994 and 2021. Emission intensity was calculated as actual emissions divided by gross value added by the agriculture sector (chain volume measure). Definition of agriculture excludes forestry and fisheries due to what emissions in the agriculture sector consist of. Years shown on axis are fiscal years, i.e., 1994 is July 1994 to June 2021.[59]

Opportunities for partnership with Aboriginal and Torres Strait Islander peoples

Aboriginal and Torres Strait Islander peoples have a long-standing experience of observing and managing Country through several climatic events. Partnering with Aboriginal and Torres Strait Islander peoples could strengthen the land and agriculture sector's understanding and response to ongoing environmental changes through their practices and culture of cooperation. For example, with several Indigenous seasonal calendars based on ecological, meteorological and hydrological changes,[60] their unique understanding of the local environments and the relationships within them can be integrated into modern systems to prevent the spread of harmful organisms and improve natural resource management.

Different regions are likely to experience a range of challenges and opportunities due to the different impacts of climate change across Australia's vast expanse of agricultural land.[61] With many farms already migrating cropping activity to higher-rainfall zones to adapt, those already in favourable areas could pivot to new land uses, establish themselves and boost profitability.[62]

Carbon farming opportunities can reduce or offset emissions, increase food and fibre production and increase the biodiversity of ecosystems. Carbon forest sequestration could produce profitably on over 30 million hectares of land, of which there is double of the more marginal agricultural land in Australia's intensive use zone.[63] Integrating trees within agricultural landscapes reduces wind speed, soil surface evaporation, surface water flow speed, soil erosion and localised salinity in addition to the benefits of improving crop and stock productivity.[64]

59 ABARES (2022) Agricultural commodity statistics. DAFF, Canberra. <https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data> (accessed 20 January 2024); DCCEEW (2023) Actual emissions for the agriculture sector. DCCEEW, Canberra. <https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-gas-inventory-quarterly-update-june-2023> (accessed 20 January 2024).

60 CSIRO (2022) About the Indigenous seasonal calendars. <https://www.csiro.au/en/research/indigenous-science/Indigenous-knowledge/Calendars/About> (accessed 6 March 2024).

61 Hughes N, Lu M, Soh WY, Lawson K (2022) Modelling the effects of climate change on the profitability of Australian farms. Climatic Change 172, 12. <https://doi.org/10.1007/s10584-022-03356-5>

62 Hughes N, Gooday P (2021) Climate Change Impacts and Adaptation on Australian Farms. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/589v-7662> (accessed 31 January 2024).

63 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

64 Fitch P, Battaglia M, Lenton A, Feron P, Gao L, Mei Y, Hortle A, Macdonald L, Pearce M, Occhipinti S, Roxburgh S, Steven A (2022) Australia's Sequestration Potential. CSIRO. <https://www.csiro.au/en/research/environmental-impacts/emissions/carbon-sequestration-potential> (accessed 13 March 2024).

Land and water

With growing pressure on availability of land and water resources for Australian agriculture, the sector must look to new land and water management practices to ensure long-term improvements to productivity. Currently, agriculture is the biggest land user, occupying over half of Australian land (Figure 6).[65] In addition, agriculture accounts for over 70% of nationally distributed water use (Figure 7). However, pressures from population growth, urban sprawl, competing land uses and climate variability are impacting arable land availability and causing shifts in the cost of land and water. Proactive response to changes in the availability and location of arable land, exploring opportunities in new alternative industries and looking for ways to diversify and intensify production with potentially limited water supplies will need to be considered to maintain and boost productivity, resilience and sustainability.

Land used for farming in Australia has declined from 65% of the country's landmass in 1973 to 55% in 2020, with a general trend towards increased intensification.[66] Property prices have seen unprecedented growth rates of 20% in 2022, largely due to consistent favourable weather conditions boosting commodity productivity and limited agriculture land on the real estate market.[67] With the total number of farms gradually decreasing over the decades, the share of output among the larger farms makes up around half of Australia's total agricultural output.[68] In 2021–22, there were 54,400 broadacre and dairy farm businesses, with 62% classified as livestock farms, 30% as cropping farms and 9% as dairy farms.[69] As the climate shifts, these farming systems are moving further south and competing with expanding urban centres.[70] Major cities have continued to see the loss of farmland to expanding urban development and other competing land uses; for example, Victoria is expected to lose another 11,000 hectares to housing developments.[71]

There has been a compositional shift in agricultural outputs over the past 50 years.[72] Horticultural commodities, meat, oilseed and pulses now surpass the milk and wool production share, and the demand for complementary proteins is rapidly growing.[73] Mixed farming has grown in some regions as farmers alternate between crops and pastures to safeguard against climate threats, divert marginal land for carbon sequestration and improve the quality of ecosystem services. Australia has previously lagged behind the rest of the world in the uptake of protected cropping, largely due to its diverse geography and natural resources for outdoor production, minimising strong drivers for change.[74] With the economic impacts from climate variability affecting producers more strongly, the horticulture industry is shifting, with protected cropping becoming a rapidly growing sector showing average growth rates of 60% per year.[75]

65 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023).

66 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023); Naughtin et al. (2022) Our Future World: Global Megatrends Impacting the Way We Live Over Coming Decades. CSIRO, Brisbane, Australia.

67 Jasper C (2023) High demand and tight supply drive Australian farmland values to new highs. ABC News. <https://www.abc.net.au/news/2023-05-16/australian-farmland-values-surge-rural-bank/102350560> (accessed 5 February 2024); Rural Bank (2023) Australian farmland values. <https://www.ruralbank.com.au/siteassets/_documents/publications/flv/afv-2023.pdf> (accessed 5 February 2024).

68 DAFF (2023) ABARES reports show Australian farmers adapting and adjusting to help offset climate effects. <https://www.agriculture.gov.au/about/news/abares-report-australian-farmers-offset-climate-change> (accessed 12 December 2023).

69 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

70 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

71 Hynninen (2021) Thousands of hectares of farmland being lost to residential developments in regional Victoria. ABC News. <https://www.abc.net.au/news/rural/2021-03-20/thousands-of-hectares-farmland-lost-to-residential-developments/13262012> (accessed 5 February 2024); Parliament of Australia (2023) Australian food story: feeding the nation and beyond. Inquiry into food security in Australia. <https://www.aph.gov.au/Parliamentary_Business/Committees/House/Agriculture/FoodsecurityinAustrali/Report> (accessed 5 February 2024).

72 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023).

73 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023); Witte B, Obloj P, Koktenturk S, Morach B, Brigl M, Rogg J, Schulze U, Walker A, Von Koeller E, Dehnert N, Grosse-Holz F (2021) Food for thought: the protein transformation, Boston Consulting Group and Blue Horizon. <https://web-assets.bcg.com/a0/28/4295860343c6a2a5b9f4e3436114/bcg-food-for-thought-the-protein-transformation-mar-2021.pdf> (accessed 12 December 2023).

74 Hort Innovation (2021) Australian Protected Cropping Strategy 2021–2030. <https://protectedcropping.net.au/wp-content/uploads/Australian-Protected-Cropping-Strategy-2021-2030.pdf> (accessed 1 February 2024).

75 Protected Cropping Australia (2020) Growing protected cropping in Australia to 2030. <https://protectedcropping.net.au/wp-content/uploads/Protected-Cropping-2030-140120.pdf> (accessed 1 February 2024).

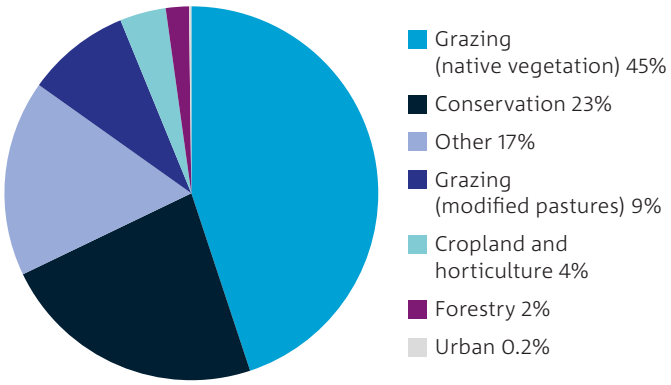


Figure 6: Australia's land use is dominated by grazing

Notes: Figure shows the proportion of land in the different categories in Australia. The category 'Other' includes defence land, stock routes, residual native cover, mining and waste areas, waste bodies and land under rehabilitation.[76]

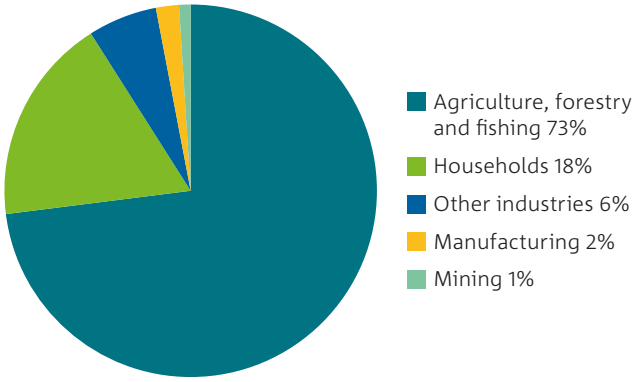


Figure 7: Australia's water use is dominated by agriculture

Notes: Figure shows the proportion of distributed water used by selected industries and households for the fiscal year 2021–22. Distributed water refers to water flows from one user (or supplier) to another user after extraction and excludes reuse of water, self-extracted water uses and wastewater collected. Distributed water is therefore not equal to total water use.[77]

Irrigated agriculture uses less than 1% of agricultural land[78] and produces approximately 25% of Australia's total agricultural value. However, it accounts for more than 60% of all extracted water.[79] There is broad acceptance that long-term trends of extended drought periods and lower winter rainfall have affected water availability and use in the past and will continue to challenge the whole sector's water security.[80] It will be important to consider the water policy management practices needed to respond to ongoing trends of climate variation as well as extreme weather conditions such as flooding that can positively impact water availability.

Challenges

The energy transition and continued urban growth will intensify land use competition in Australia.[81] Infrastructure will likely need to be built on productive agricultural land to meet national renewable energy targets by 2050.[82] Emission reduction efforts through carbon sequestration and agroforestry are expected to trigger significant land use shifts. Traditional approaches to land and water use will be challenged in the future to maximise arable land for valuable agricultural goods and reduce the impact on over-allocated water catchment systems while maintaining farm sustainability, productivity and profitability.[83]

Reduced water availability for irrigated agriculture and continued over-extraction could decrease yields in regions unable to switch to rain-fed production.[84] As access to water becomes more unreliable with more varied drought and flood conditions across the country, and as the demand from different sectors grows, agriculture will be challenged with maintaining a positive water balance and achieving significant efficiency gains.[85]

76 Climateworks centre (2019) Land use futures. <https://www.climateworkscentre.org/project/land-use-futures/> (accessed 20 January 2024).

77 ABS (2021) Water Account: Australia 2021–22. <https://www.abs.gov.au/statistics/environment/environmental-management/water-account-australia/latest-release#:~:text=Australian%20households%20used%201%2C773%20GL,of%20all%20household%20water%20use> (accessed 20 January 2024).

78 ABS (2018) Gross value of irrigated agricultural production: 2016–17. <https://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.008> (accessed 12 December 2023).

79 ABS (2018) Gross value of irrigated agricultural production: 2016–17. <https://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.008> (accessed 12 December 2023).

80 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

81 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023); Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

82 NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

83 Fitch et al. (2022) Australia's Sequestration Potential. CSIRO. <https://www.csiro.au/en/research/environmental-impacts/emissions/carbon-sequestration-potential> (accessed 13 March 2024).

84 ABS (2018) Gross value of irrigated agricultural production: 2016–17. <https://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.008> (accessed 12 December 2023).

85 DCCEEW (2021) Australia State of the Environment 2021: inland water. https://soe.dcceew.gov.au/inland-water/outlook-and-impacts (accessed 30 January 2024).

Opportunities

There is an opportunity for Australian farmers to create new revenue streams from marginal farmland. Carbon sequestration is viable on over 30 million hectares of marginal land and planting on this scale with high carbon prices could double landowner returns to as much as $114 billion per annum.[86] There is also a growing base of literature on green, circular and bio-economies and the role that technological or nature-based solutions can play in tapping into those areas.[87] Circular and bio-economies may represent another opportunity for farmers to diversify their revenue streams and tap into new industries such as waste utilisation and bioenergy.[88]

Expanding and progressing diverse mixed farming systems and protected cropping offer an opportunity for climate resilience and food security in the Australian agriculture sector.[89] Mixed crop–livestock systems reduce global warming potentials, lower nitrogen losses, increase soil organic carbon, increase water use efficiency and lower total production costs at the farm scale.[90]

Although mixed crop–livestock systems are in place in Australia (e.g. 47 million hectares in southern areas and Western Australia),[91] new and further diversified production systems may offer solutions to further build resilience and increase benefits to biodiversity. These mixed systems open up many circular economy opportunities, including using livestock waste and other biological byproducts as cropping inputs or as biomass feedstocks, or turning food waste into protein for livestock feed.[92] In contrast, integrated aquaponics, hydroponics or protected cropping systems with alternative feed options, biodegradable products and out-of-season produce can improve long-term climate buffering and reduce land use degradation.[93] Investing in disruptive production methods decoupled from land use could address challenges in traditional agriculture.[94] The sustainable intensification of land could improve land use efficiency while minimising environmental impacts.

86 CSIRO (2019) Australian National Outlook. CSIRO, Canberra. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/innovation-business-growth/australian-national-outlook> (accessed 12 December 2023).

87 D'Amato D, Droste N, Allen B, Kettunen M, Lähtinen K, Korhonen J, Leskinen P, Matthies BD, Toppinen A (2017) Green, circular, bio economy: a comparative analysis of sustainability avenues. Journal of Cleaner Production 168, 716–734. <https://doi.org/10.1016/j.jclepro.2017.09.053> (accessed 13 March 2024); D'Amato D, Korhonen J (2021) Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. Ecological Economics, 188, 107143. <https://doi.org/10.1016/j.ecolecon.2021.107143> (accessed 13 March 2024).

88 Gomez San Juan M, Harnett S, Albinelli I (2022) Sustainable and Circular Bioeconomy in the Climate Agenda: Opportunities to Transform Agrifood Systems. FAO, Rome, Italy.<https://doi.org/10.4060/cc2668en> (accessed 13 March 2024).

89 Protected Cropping Australia (2020) Growing protected cropping in Australia to 2030. <https://protectedcropping.net.au/wp-content/uploads/Protected-Cropping-2030-140120.pdf> (accessed 1 February 2024).

90 Baker E, Kerr R, Deryng D, Farrell A, Gurney-Smith H, Thornton P (2023) Mixed farming systems: potentials and barriers for climate change adaptation in food systems. Current Opinion in Environmental Sustainability 62, 101270; NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

91 Charles Sturt University (2019) Developing a mixed farming systems RD&A program. Meat and Livestock Australia. <https://www.mla.com.au/research-and-development/reports/2019/developing-a-mixed-farming-systems-rda-program/> (accessed 20 February 2024).

92 Craine R, Wells V (2021) Agriculture and the Circular Economy. CEAT, Australian National University. <https://ceat.org.au/agriculture-and-the-circular-economy/> (accessed 6 February 2024).

93 Baker et al. (2023) Mixed farming systems: potentials and barriers for climate change adaptation in food systems. Current Opinion in Environmental Sustainability 62, 101270.

94 Petrovics D, Giezen M (2021) Planning for sustainable urban food systems: an analysis of the up-scaling potential of vertical farming. Journal of Environmental Planning and Management 65(5), 785-808.

Opportunities for partnership with Aboriginal and Torres Strait Islander peoples

Aboriginal and Torres Strait Islander peoples connection to land, sea, sky, waterways, plants, animals and cultural laws over tens of thousands of years provides the opportunity for knowledge sharing and partnership to integrate Indigenous agricultural techniques and crops into new farming systems. Greater collaboration and integration of Indigenous land and sea management practices can promote healthy soil, improve water access and quality, increase biodiversity, build resilience, expand land restoration outcomes and develop two-way learning with Indigenous partners.[95]

As a key resource to the sector, implementing new plant breeding techniques as well as smart water governance and infrastructure advancements that enable more productive water capture and use can achieve better water use efficiency and management. For example, data analytics and in-field sensing capabilities could determine the best timing for irrigation based on crop and soil type, climate conditions, water availability and risk.[96] Expanding on current initiatives, such as the National Farmers Federation's target to increase water use efficiency by 20% by 2030,[97] can be considered to promote water recovery projects that enhance environmental outcomes and communities.[98]

95 Scale Climate Action (2023) Indigenous crop knowledge: sustainable adaptation for local environments. <https://scaleclimateaction.org/agriculture/indigenous-crop-knowledge-sustainable-adaptation-for-local-environments/> (accessed 24 January 2024).

96 Petrusa J, Decker E, Tilley A, O'Connor A (2021) Prospective Analysis of WaterWise: Final Case Study Report. CSIRO, Pullenvale, Australia.

97 NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023).

98 DCCEEW (2023) Off-farm Efficiency Program. <https://www.dcceew.gov.au/water/policy/programs/open/off-farm-efficiency-program> (accessed 7 March 2024).

Productivity and innovation

The innovation, development and adoption of new technologies, including tools, business models and farming practices, have been key drivers for the productivity and profitability of Australian farms amid the many challenges facing the sector. Australia has globally recognised agriculture R&D capabilities and a strong R&D pipeline.[99] Innovation in the agriculture sector has led to significant productivity gains over the past decades. However, the current agriculture innovation system faces several challenges in delivering the technology-driven productivity gains needed to ensure long-term profitability and competitiveness for Australian farming systems, as recognised in several reviews of the current system.[100] Despite the strong pipeline of research and innovation, Australian agriculture is yet to achieve whole-sector digital maturity.[101] Australian agriculture is a relatively small market and faces a growing disadvantage in commercialising and securing investment for the development and scaling of new technologies domestically. The sector faces a growing labour shortage and increasing competition for the critical skills needed to unlock technology-driven productivity.[102] Consolidation and integration of farm businesses bring benefits to those businesses,[103] such as buying power, step-change technologies and direct paths to major retailers via vertically integrated supply chains. Smaller and niche farms face challenges with continuing consolidation, including higher prices for agricultural land and barriers to adoption of new technologies.[104]

Over the past three decades, Australian agriculture has benefited from strong productivity gains driven by increases in farm scale, new and efficient practices and improved varieties and genetics.[105] Emerging economies are now benefiting from these same drivers and their growth has overtaken Australia's, along with agriculture sectors in other advanced economies.[106] There are also signs that the pace and success of collaboration and innovation in the entirety of Australia is slowing. Although Australia ranked 7th of OECD countries on its relative number of innovation-active businesses in 2023, it ranked 24th in the Global Innovation Index, which is backwards from its 17th ranking in 2015.[107] Australia's broadacre productivity growth, incorporating factors such as farm innovations, research investment and investment in human capital, has declined from annual growth of 2.2% between 1978 and 2000 to an average yearly growth of 0.4% between 2000 and 2022.[108] Adjusted for climate change, broadacre productivity growth has increased by 28% since 1989.[109] This increase has offset the negative impacts of climate change over this period and enabled at least stable productivity gains for the sector. As the impacts of continuing climate change grow, improvements to the commercialisation and adoption of R&D will be critical to maintain the profitability and global competitiveness for Australian farming systems.

99 DAWE (2022) Digital Foundations for Agriculture Strategy: Driving the Development and Uptake of Digital Technologies in the Australian Agriculture, Fisheries and Forestry Industry. DAWE, Canberra, Australia.

100 EY (2019) Agricultural innovation: a national approach to grow Australia's future. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF> (accessed 8 February 2024); Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

101 DAWE (2022) Digital Foundations for Agriculture Strategy: Driving the Development and Uptake of Digital Technologies in the Australian Agriculture, Fisheries and Forestry Industry. DAWE, Canberra, Australia.

102 EY (2019) Agricultural innovation: a national approach to grow Australia's future. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF> (accessed 8 February 2024).

103 Jackson T, Zammit K, Hatfield-Dodds S (2018) Snapshot of Australian Agriculture. ABARES Insights, Canberra, Australia. agriculture.gov.au/abares/publications/insights> (accessed 24 Jan 2024).

104 ANZ (2017) Agtech – Advance Australia Agriculture. Australia and New Zealand Banking Group Limited. <https://bluenotes.anz.com/content/dam/bluenotes/images/articles/2017/June/ANZ_agtech_advance_australia_report.pdf> (accessed 12 December 2023).

105 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

106 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

107 Cornell University, INSEAD, WIPO (2015) The Global Innovation Index 2015: Effective Innovation Policies for Development. Fontainebleau, Ithaca, and Geneva; DISR (2023) Business innovation data. <https://www.industry.gov.au/publications/science-research-and-innovation-sri-budget-tables-2023-24/business-innovation-data> (accessed 6 March 2024).

108 ABARES (2023) Australian agricultural productivity: broadacre and dairy estimates. <https://www.agriculture.gov.au/abares/research-topics/productivity/agricultural-productivity-estimates#references> (accessed 12 December 2023).

109 Hughes N (2021) Analysis of Climate Change Impacts and Adaptation on Australian Farms. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/589v-7662> (accessed 13 March 2024).

The trend towards consolidating and corporatising agriculture businesses has led to greater scale, buying power and productivity growth. The number of Australian farms has halved from over 180,000 in the early 1970s to approximately 90,000 today (Figure 8).[110] The declining number of farmers from 1993 to 2023 (Figure 9) is also indicative of farm aggregation over the years. Larger farms tend to have stronger assets and access to capital to uptake new and riskier technologies and practices compared to small businesses, leading to better productivity outcomes.[111] The increase in business size is estimated to have contributed to 62% of the increase in agricultural output over the past three decades.[112] Currently, the largest 10% of broadacre farms produce 50% of total output, while the smallest 50% of farms produce 10% of total output.[113]

Although Australian farms have enjoyed productivity gains over the past decades, they now face the challenge of a significant human capital gap in regional areas, driven by an ageing workforce and barriers to entry for new talent. As stated in the 2023 ABARES snapshot of Australia's agriculture workforce,[114] Australian agriculture employed 239,093 people, which is a 4.7% increase from 2016, and made up 2% of the Australian workforce. On-farm employment has fallen by 25% over the past three decades, but the workforce has steadily been growing since the early 2000s. Between the 2016 and 2021 census, the proportions of women, young people aged under 35, workers aged 65 and over, and workers from cultural and linguistic backgrounds all increased. Simultaneously, a large portion of the workforce has gradually aged (Figure 9).

The low proportion of young people is largely due to several barriers to entry and retention of these workers. These include the consolidation of farms, which reduces the opportunities for entry, difficulty gaining capital and credit for young people, urbanisation leading to less investment in regional infrastructure and services, and a lack of quality modern agriculture-related education that is accessible from remote locations.[115]

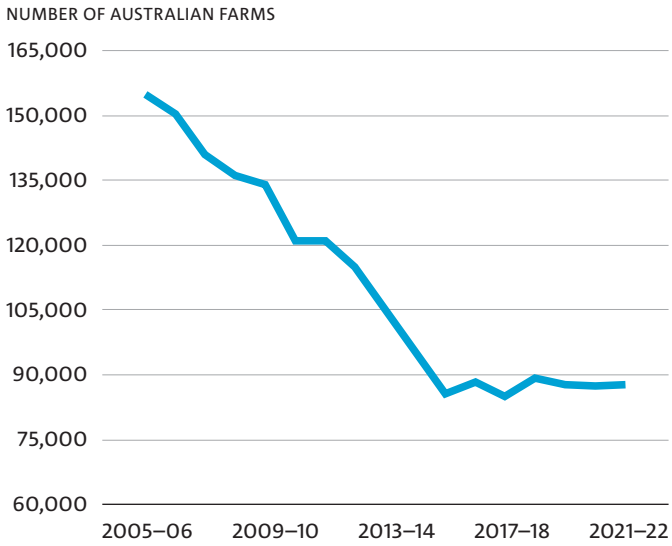


Figure 8: The number of Australian farms is decreasing

Notes: Figure shows the number of farms or agricultural businesses in Australia between the period 2005-06 to 2021-22. Missing data for the year 2005-05 and 2016-17 was calculated using the reported increase or decrease (in percentage) in the following year. Data was imputed for missing years of 2013-14 to 2014-15 by using the difference between the 2012-13 and 2015-16 data points.[116]

110 ABS (2021-22) Agricultural Commodities, Australia. ABS Website, Canberra, Australia. <https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release> (accessed 13 March 2024).

111 ANZ (2017) Agtech – Advance Australia Agriculture. Australia and New Zealand Banking Group Limited. <https://bluenotes.anz.com/content/dam/bluenotes/images/articles/2017/June/ANZ_agtech_advance_australia_report.pdf> (accessed 12 December 2023).

112 ANZ (2017) Agtech – Advance Australia Agriculture. Australia and New Zealand Banking Group Limited. <https://bluenotes.anz.com/content/dam/bluenotes/images/articles/2017/June/ANZ_agtech_advance_australia_report.pdf> (accessed 12 December 2023).

113 DAFF (2023) ABARES reports show Australian farmers adapting and adjusting to help offset climate effects. <https://www.agriculture.gov.au/about/news/abares-report-australian-farmers-offset-climate-change> (accessed 12 December 2023).

114 ABARES (2023) Snapshot of Australia's Agricultural Workforce. ABARES Insights, issue 3, Canberra, Australia. <https://doi.org/10.25814/x21d-td14> (accessed 12 December 2023).

115 Wu W, Dawson D, Fleming-Muñoz D, Schleiger E, Horton J (2019) The Future of Australia's Agricultural Workforce. CSIRO Data61, Canberra, Australia.

116 ABS (2021-22) Agricultural Commodities, Australia. ABS Website, Canberra, Australia. <https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release> (accessed 13 March 2024).

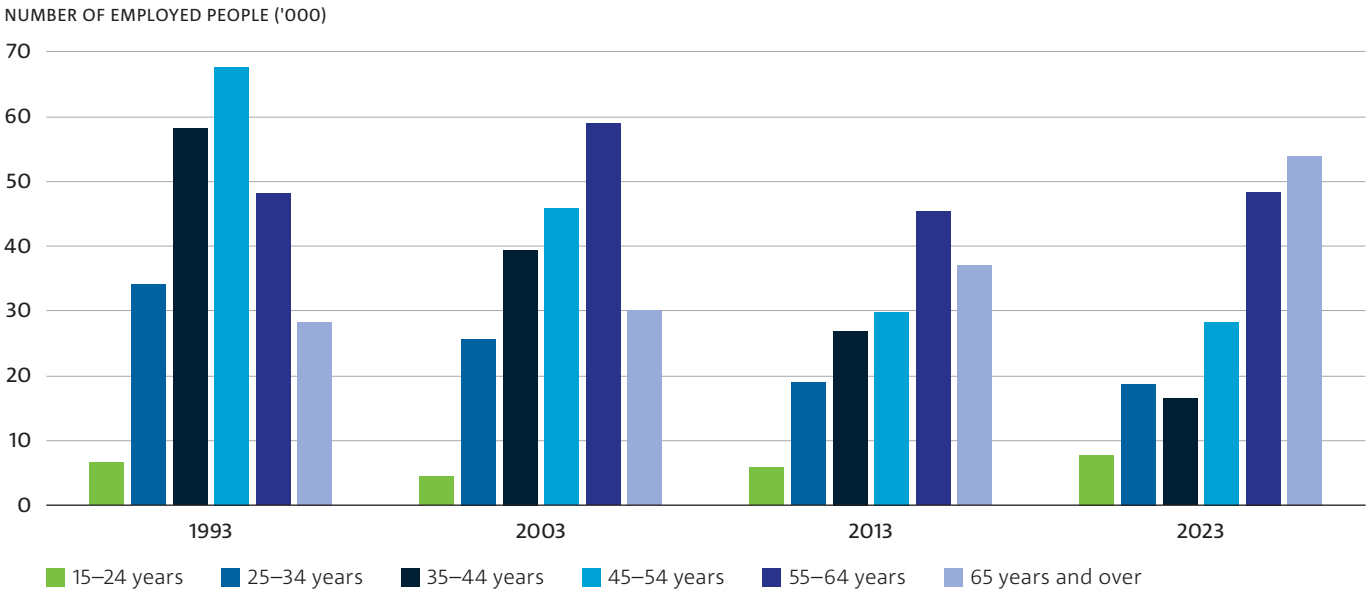


Figure 9: The average Australian farmer is getting older

Notes: Figure shows the number of farmers and farm managers by age group in the agriculture sector every decade between 1993 and 2023. Data from the years shown on the axis are the month of November (i.e. 1993 is November 1993 and 2023 is November 2023). To calculate total employment, figures for part-time and full-time employment were aggregated and figures for males and females were subsequently aggregated.[117]

Challenges

Innovation has helped develop efficient and globally competitive agriculture, forestry and fisheries industries, but changes are needed to the current approaches to agricultural R&D in Australia to deliver solutions to the complex challenges outlined in this chapter.[118] Perceived or real concerns regarding the cost–benefit analysis and suitability of a given technology, regulatory complexity and a reluctance of first movers to share data collectively hinder the widespread adoption of innovative agritech.[119] Further, the current focus of R&D strategy and funding is on commodity groups, short- or medium-term targets and incremental improvements.[120] More efficient innovation is needed to tackle cross-sector challenges and enable Australian farming systems to remain globally competitive and achieve the productivity gains needed to offset the impacts of continuing climate change under various global warming scenarios.[121] There have been steps taken to address these challenges over the past few years, such as the establishment of Australian Innovation Agriculture, which targets cross-sector opportunities and challenges.[122] However, significant investment in step-change technologies and cross-sector strategic collaboration and action is still needed to secure long-term sustainability and productivity, and in the shorter term, to achieve the 3% annual productivity growth required in pursuit of the current industry goal of a $100 billion industry by 2030.[123]

117 ABS (2023) Labour Force: Australia. <https://www.abs.gov.au/statistics/labour/employment-and-unemployment/labour-force-australia/jun-2023#:~:text=Key%20statistics&text=employment%20increased%20to%2014%2C045%2C800.,worked%20increased%20to%201%2C956%20million?> (accessed 20 January 2024).

118 Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

119 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

120 Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

121 Hughes N (2021) Analysis of Climate Change Impacts and Adaptation on Australian Farms. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/589v-7662>.

122 Agricultural Innovation Australia (2023) Re: Submission to climate-related financial disclosure consultation paper. <https://treasury.gov.au/sites/default/files/2023-04/c2022-314397-aia.pdf> (accessed 20 February 2024).

123 AgriFutures Australia (2019) Agriculture: A $100b sector by 2030? ACIL Allen Consulting, Australia. <https://agrifutures.com.au/wp-content/uploads/2019/08/19-025.pdf> (accessed 12 December 2023).

A growing skills gap could further compound barriers to adoption. There is a need for more workers with sectoral knowledge and technical skillsets, as well as skilled agricultural advisors and consultants to assist farm decision-making. Despite adopting autonomous systems to reduce manual activities, there is a fivefold workforce demand for tertiary agriculture graduates compared to the available supply.[124] Approximately one-third of farmers report that a lack of digital literacy and skills is a major barrier to their uptake of new digital solutions.[125] Regional and rural areas are falling behind in digital access (accessing digital networks) and digital ability (digital skills and literacy).[126] Moreover, agriculture has the second lowest share of labour income in Australia. As regional populations grow closer to large city centres, employers must compete with many other sectors of the Australian economy.[127] A lack of incentive programs, agricultural education and career pathways, and low efforts to attract young, diverse and skilled talent have been cited as constraints to the adoption of technologies and filling the labour shortage.[128]

Opportunities

Maximising productivity growth offers the opportunity to increase food production, lower consumer prices, reduce production costs over time, improve international competition and enable producers to remain profitable amid changing environmental and market conditions.[129] This potential depends on the widespread adoption of new technologies and technology-focused infrastructure. For example, AI-powered automation, robotics and advanced data analytics can boost productivity, fill labour shortages, reduce risks to workers and transform the efficiency of production systems and supply chains.[130] Improved data sharing and more efficient digitally enabled processes can bolster collaboration across the supply chain, improve customer engagement and allow producers to make more timely and agile decisions.[131] To unlock these productivity gains, continued public and private investment in innovation and the establishment of a cohesive and collaborative innovation system is needed to reach the goal of a $100 billion value of agricultural outputs by 2030.[132]

124 NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023); CSIRO (2015) Australian National Outlook 2015: Living standards, resource use, environmental performance and economic activity, 1970-2050. CSIRO, Canberra. <https://www.researchgate.net/publication/283495802_Australian_National_Outlook_2015_Economic_activity_resource_use_environmental_performance_and_living_standards_1970-2050> (accessed 12 December 2023).

125 Robotics Australia Group (2022) A robotics roadmap for Australia. <https://www.roboausnet.com.au/robotics-roadmap> (accessed 12 December 2023); Dufty N, Jackson T (2019) Information and Communication Technology Use in Australian Agriculture. ABARES Research Report 18.15, Canberra, Australia (accessed 12 December 2023).

126 Thomas J, McCosker A, Parkinson S, Hegarty K, Featherstone D, Kennedy J, Holcombe-James I, Ormond-Parker L, Ganley L (2023) Measuring Australia's Digital Divide: Australian Digital Inclusion Index: 2023. ARC Centre of Excellence for Automated Decision-Making and Society, RMIT University, Swinburne University of Technology, and Telstra.

127 Greenville J, Cameron A (2022) Where to Next for Australian Agriculture? ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/vb1b-xr37> (accessed 12 December 2023).

128 Ives B (2023) Listen Up: young people's perspective on the future of Australian agriculture and rural industries. AgriFutures. <https://agrifutures.com.au/wp-content/uploads/2023/06/23-079.pdf> (accessed 12 December 2023); NFF (2018) 2030 Roadmap: Australian agriculture's plan for a $100 billion industry. Australia. <https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf> (accessed 12 December 2023); CSIRO (2015) Australian National Outlook 2015: Living standards, resource use, environmental performance and economic activity, 1970-2050. CSIRO, Canberra. <https://www.researchgate.net/publication/283495802_Australian_National_Outlook_2015_Economic_activity_resource_use_environmental_performance_and_living_standards_1970-2050> (accessed 12 December 2023).

129 ABARES (2020) Productivity introduction. <https://www.agriculture.gov.au/abares/research-topics/productivity/productivity-introduction#key-articles> (accessed 12 December 2023).

130 AgriFutures (2021) Future Forces: a ten-year horizon for Australian agriculture. <https://agrifutures.com.au/wp-content/uploads/2021/04/21-049.pdf> (accessed 12 December 2023); Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

131 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

132 DAWE (2022) Delivering Ag2030. DAWE, Canberra, Australia. <awe.gov.au/publications> (accessed 12 December 2023).

An opportunity exists to pursue growth industries that draw on Australia's current human capital strengths and attract a different type of worker to the agriculture sector. As agriculture becomes increasingly digitised, there is an opportunity to establish jobs that support the demand for skilled labour in new alternate industries such as technology services. Building on existing efforts to emphasise the diversity of career opportunities in agriculture and drive effective retention measures can create opportunities for greater technology adoption and innovation in the sector.[133] Expanding the existing development of regional infrastructure, services and education can support making the sector more attractive.[134]

As farm consolidation continues, opportunities for agricultural productivity and profitability could be enhanced when appropriately managed. Increased farm size is a platform for the improved commercialisation and uptake of R&D investments and new digital technologies.[135] With greater integration and interconnected agricultural systems, there is a significant opportunity for streamlined supply chain management and improved risk aversion.[136]

Opportunities for partnership with Aboriginal and Torres Strait Islander peoples

The sector can address labour gaps alongside integrating Aboriginal and Torres Strait Islander knowledge by increasing the effort to attract Indigenous peoples into employment and ownership. In 2021, Indigenous peoples made up 1.8% of the agricultural workforce and in 2020 made up 0.6% of business owners in the sector. The median age of the Indigenous workforce was 37 years in 2021, compared to 49 years for the sector overall.[137] In 2021, the unemployment rate for Aboriginal and Torres Strait Islander peoples was 12%.[138] In addition, there is a growing field of Indigenous-led research, advocating and developing innovative and sustainable agricultural methods that can help support the transformation of farming across Australia. For example, Indigenous communities make unique contributions such as the growing 'bush foods' industry, valued at $21.2 million.[139] Considering this, there is an opportunity to attract and activate greater inclusion, representation and employment of Aboriginal and Torres Strait Islander peoples in the agricultural workforce.

133 DAWE (2021) Building the Agricultural Workforce of the Future. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/aus-govt-response-building-ag-workforce-dec-2021.pdf> (accessed 12 December 2023).

134 NSW Government Budget (2023) Our Plan for Regional NSW. <https://www.budget.nsw.gov.au/2023-24/budget-papers/regional-nsw#:~:text=New%20South%20Wales%20is%20home%20to%20more%20than,additional%20%24298.5%20million%20toward%20biosecurity%20and%20agricultural%20programs> (accessed 31 January 2024).

135 ANZ (2017) Agtech – Advance Australia Agriculture. Australia and New Zealand Banking Group Limited. <https://bluenotes.anz.com/content/dam/bluenotes/images/articles/2017/June/ANZ_agtech_advance_australia_report.pdf> (accessed 12 December 2023).

136 Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

137 DAFF (2024) Fast Facts - Minister for Agriculture, Fisheries and Forestry. <https://www.agriculture.gov.au/fast-facts-aff#first-nations> (accessed 5 March 2024).

138 ABS (2021) 2021 Census Aboriginal and/or Torres Strait Islander people. QuickStats. <https://www.abs.gov.au/census/find-census-data/quickstats/2021/IQSAUS> (accessed 5 March 2024).

139 ABARES (2023) Snapshot of Australia's Agricultural Workforce. ABARES Insights, issue 3, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1035161/0> (accessed 12 December 2023).

Trade and market access

Keeping Australian agricultural exports competitive depends on overcoming trade barriers and strengthening the diversity and quality of trade relationships. Australia's agricultural production is export-orientated, representing a $76 billion market in 2021–22.[140] ABARES 2022 analysis of Australia's future agricultural trade advantagestates that as Australia's competitors, such as the EU and South American countries, continue to negotiate equivalent or more favourable trade agreements with key markets, there is a growing threat to Australia's agriculture market access and competitive advantage.[141] Reducing non-tariff measures (NTMs), opening biosecurity export pathways, strengthening multilateral trading, addressing trade distortion and agricultural subsidies and responding to changing consumer concerns could be considered to ensure Australia maintains competitiveness in global markets.[142] Achieving these objectives requires greater emphasis on innovation, effective negotiation for trade frameworks and further strengthening of Australia's strong diplomacy and relationship-building capabilities for public and private actors.

Australia's vast natural resources and climate enable it to be a significant net exporter of agricultural commodities. Three-quarters of Australia's trade in 2020–21 was destined for Australia's Free Trade Agreement partners.[143] Globally, agricultural tariffs have declined and NTMs have increased, alongside global trade distortions and global subsidies.[144]

The main NTMs applied to Australian agricultural exports are sanitary and phytosanitary measures (SPS), which apply to biosecurity compliance, health and food safety, traceability and sustainability, reflecting a post-pandemic and climate-affected world.[145] Among the different types of NTMs, it is SPS measures and technical trade barriers that have consistently increased since 1980 (Figure 10). As of 2019, Australian agricultural exports are subject to 18,000 NTMs across all commodity types, most of which are applied to horticulture, followed by dairy, grains, oilseeds and pulses, and meat and livestock.[146]

Australia's trade relationships and major export markets continue to create value. As of 2019–20**,** China accounted for approximately 30% of the value of all Australian agricultural and fisheries exports.[147] Other key markets include Japan, the United States, the Republic of Korea and Indonesia.[148] As a result of the pandemic and subsequent global restrictions on the movement of goods, agricultural exports have diversified. For example, the share of exports to the top five markets has fallen from an average of 60% in 2019–20 to 51% in 2021–22.[149] As geopolitical tensions increase, there is a growing trend towards friend-shoring (i.e. securing access to international markets and supply chains of countries considered political and economic allies).[150]

140 ABARES (2023) Snapshot of Australian Agriculture 2023. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/rk1z-qm36> (accessed 12 December 2023).

141 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023).

142 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023); Hatfield-Dodds et al. (2020) Stocktake of Megatrends Shaping Australian Agriculture: 2021 Update. ABARES, Canberra, Australia. <https://doi.org/10.25814/w3be-an37> (accessed 12 December 2023).

143 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023).

144 Fell J (2022) Analysis of Australia's Future Agricultural Trade Advantage. ABARES Insights, Canberra, Australia. <https://doi.org/10.25814/2e44-ah64> (accessed 12 December 2023).

145 Levantis G, Fell J (2021) Non-tariff Measures Affecting Australian Agriculture. DAFF, Canberra, Australia. <https://www.agriculture.gov.au/abares/research-topics/trade/non-tariff-measures> (accessed 12 December 2023).

146 Levantis G, Fell J (2021) Non-tariff Measures Affecting Australian Agriculture. DAFF, Canberra, Australia. <https://www.agriculture.gov.au/abares/research-topics/trade/non-tariff-measures> (accessed 12 December 2023).

147 ABARES (2022) Agricultural Export Markets Continue to Diversify. DAFF, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/august-2022-agricultural-export-markets-continue-diversify.pdf> (accessed 12 December 2023).

148 Varrall M, Ferguson D, Ginger D, Poole R (2020) Australian agriculture in a geopolitical maelstrom. KPMG. <https://assets.kpmg.com/content/dam/kpmg/au/pdf/2020/australian-agriculture-in-a-geopolitical-maelstrom.pdf> (accessed 12 December 2023).

149 ABARES (2022) Agricultural Export Markets Continue to Diversify. DAFF, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/august-2022-agricultural-export-markets-continue-diversify.pdf> (accessed 12 December 2023).

150 United Nations Conference on Trade and Development (UNCTAD) (2023) Global trade update. <https://unctad.org/system/files/official-document/ditcinf2023d3.pdf> (accessed 30 January 2024).

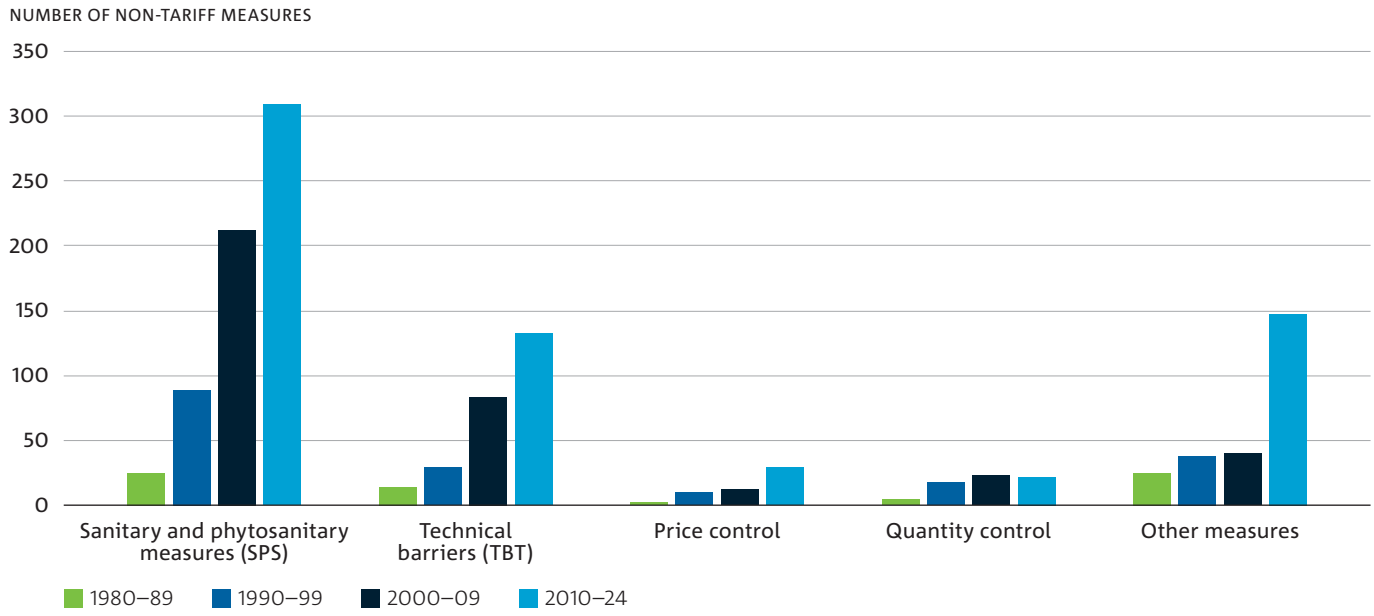


Figure 10: Non-tariff measures have increased over the past 40 years

Notes: Figure shows the various categories of NTMs imposed on Australian agricultural products between 1980–99 and 2010–24. Quality control measures refer to measures aimed at restraining the quantity of goods that can be imported and include non-automatic licensing, quotas, prohibitions, export restraint arrangements and quantity control measures other than for SPS and technical barriers to trade. Price control measures concern measures, other than tariffs measures, that increase the cost of imports in a manner like tariffs. Data for each period represents the cumulative total of specific NTMs introduced during that timeframe.[151]

Challenges

Although NTMs increase compliance costs for agriculture exporters, they are generally viewed as an acceptable cost of conducting international commerce and play a significant role in assuring consumers of food safety standards and environmental and biosecurity protection. However, some NTMs may create unjustified, unsubstantiated and expensive barriers to trade and threaten Australia's global competitiveness and the benefits gained through FTAs.[152] Use of SPS allows importing countries to safeguard against any risks or perceived risks, but they should be based on sufficient scientific evidence to avoid arbitrary discrimination between countries. Changes to trade requirements are a regulatory burden, requiring considerable time and proactive diplomacy skills to negotiate, which can have significant and long-term impacts on the agriculture sector. They also bring a cost and knowledge burden to producers as they face pressure to comply with various export standards and compete with other producers globally that may not face the same compliance burdens. Current distortions in global trade contribute to price volatility and estimates suggest that global subsidies and trade barriers (of which NTMs are a subset) cost Australian agriculture between $8 billion and $10 billion in exports annually.[153] Effective advocacy and collaboration between trading partners are needed to ensure future NTMs, including new frameworks around sustainability, low-carbon requirements and biosecurity measures, applied to the farming context across Australia, do not conflict with Australia's interests or unnecessarily increase compliance costs for exporters.

151 UNCTAD (2024) Non-tariff measures. <https://trainsonline.unctad.org> (accessed 20 January 2024).

152 Levantis G, Fell J (2021) Non-tariff Measures Affecting Australian Agriculture. DAFF, Canberra, Australia. <https://www.agriculture.gov.au/abares/research-topics/trade/non-tariff-measures> (accessed 12 December 2023).

153 Greenville J (2020) Analysis of Government Support for Australian Agricultural Producers. ABARES Research Report, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1030322/0> (accessed 12 December 2023).

Australia's heavy reliance on a few trade partners for its vital agricultural inputs and exports exposes the sector to supply chain vulnerabilities arising from ongoing geopolitical shocks. This vulnerability will impact agricultural inputs' availability and affordability and the reliability of export routes. There is a challenge for national negotiators and policymakers to identify diverse export opportunities for emerging markets and for industry to consistently utilise these pathways to ensure a resilient balance between strong trading partners and risk aversion.

Opportunities

Australia already has one of the strongest biosecurity systems internationally.[154] Continued advancement of this system can contribute to efforts to safeguard the country against climate-induced pest and disease risks, improve market access, open new premium markets, uphold the integrity of the Australian brand and enhance the competitiveness of Australian producers on the international stage. It is important to ensure that existing Australian-led sustainability frameworks are continuously evolving through ongoing collaboration with scientists to refine and adapt methodologies based on new data. Additionally, efforts to ensure that Australian sustainability frameworks are understood and accepted by trading partners can position Australia as a world leader in agricultural sustainability.[155] Moreover, enhanced and digitised provenance and tracking systems have the potential to assist agricultural exporters in complying with new regulatory requirements. Together, a targeted and informed approach to biosecurity and sustainability trade barriers could reduce the risk of unjustified NTMs, reduce the cost of compliance and ensure justified NTMs improve export returns.

The successful management of trade relationships and the gradual shift towards greater diversification of trading partners promise to expand Australian agriculture's horizons. The strategic identification of emerging economies and negotiating favourable FTAs can strengthen international relationships and 'friend-shoring'. Doing so can protect the sector from increased volatility and uncertainty from anticipated external shocks. Scaled-up support available to producers, including greater access to market intelligence, support services and additional technical experts, can open and expand market access.[156] As a result, Australian agricultural exports can be better positioned to respond to consumer trends and understand the risks and opportunities when navigating through these new markets, improving their international competitiveness.

Opportunities for partnership with Aboriginal and Torres Strait Islander peoples

Aboriginal and Torres Strait Islander peoples are well placed to utilise traditional knowledge and innovative techniques to meet consumer demands for sustainability. Incorporating Indigenous credentials into traceability systems, such as recognising authenticity as an Indigenous product, can promote Australia's support of local communities. In addition, it can create the opportunity for Indigenous peoples to gain access to premium markets alongside the economic and social implications that could provide.[157]

154 CSIRO (2020) Australia's Biosecurity Future: Unlocking the Next Decade of Resilience (2020–2030). <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/CSIRO-futures/Agriculture-and-Food/Biosecurity-Futures> (accessed 13 March 2024).

155 McRobert K, Fox T, Heath R (2023) Bringing the AASF to Life: Groundwork for Implementing the Australian Agricultural Sustainability Framework. Australian Farm Institute. <https://www.farminstitute.org.au/wp-content/uploads/2023/09/Bringing-the-AASF-to-life_-AFI-Final-Report_July-2023_COMPLETE.pdf> (accessed 13 March 2024).

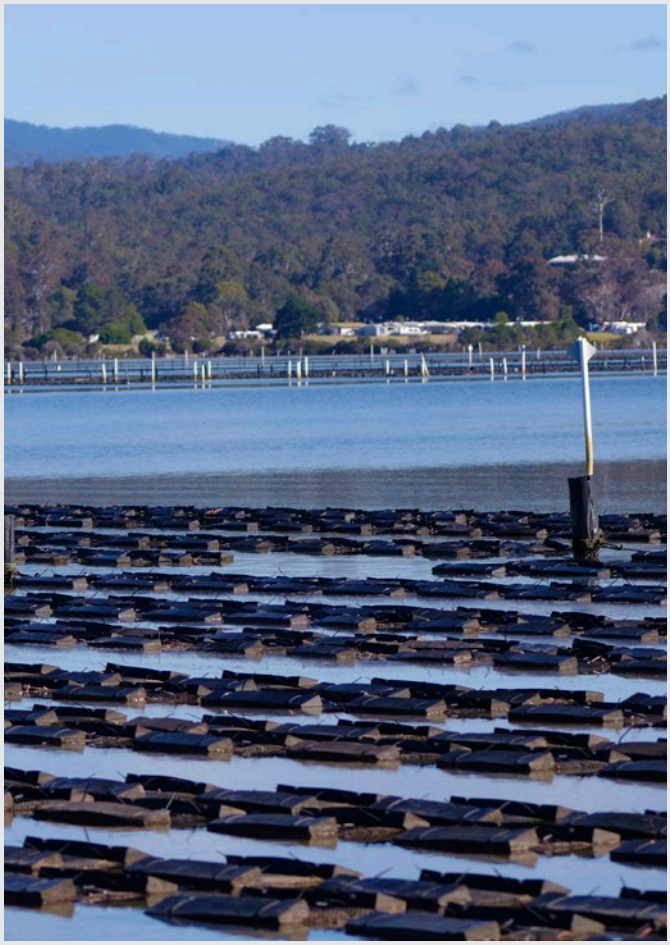
156 Australian Government Department of Foreign Affairs and Trade (2021) Business Envoy July 2021: agribusiness expansion initiative. <https://www.dfat.gov.au/about-us/publications/trade-investment/business-envoy/july-2021/agribusiness-expansion-initiative> (accessed 12 December 2023).

157 DAFF. Agricultural traceability projects: Indigenous agricultural product framework. <https://www.agriculture.gov.au/biosecurity-trade/market-access-trade/national-traceability/agricultural-traceability-projects#indigenous-agricultural-product-framework> (accessed 5 March 2024).

Box 1: Fisheries and aquaculture

The Australian fisheries and aquaculture industry faces similar threats to those for agriculture and forestry, including trade tensions,[158] climate change and the increase in consumer demand for sustainably produced seafood.[159] However, the fisheries and aquaculture industry faces different impacts compared to other sectors, including ocean acidification, the challenges with ocean and sea ownership and access, marine-specific skills and less of an export-driven market. As global fish consumption is projected to grow 14.8% by 2030,[160] the future socioeconomic value of Australian fisheries and aquaculture hinges on its ability to respond to this growth.

The Australian Fishing Zone, which covers Commonwealth waters, spans 8 million km^2.[161] In 2021–22, wild catch contributed 58% and aquaculture 42% to total production volume.[162] Wild catch is not expected to grow, given regulations and policies to promote sustained ecosystem health and economic returns in both State and Commonwealth fisheries and the low biological productivity of fish species in Australian waters.[163] In contrast, aquaculture is considered a growth industry, with the recent doubling of the industry's value to $2.3 billion in 2022–23 compared to 2012–13.[164] This growth is projected to continue but be slow to meet national and global demand.[165]



158 Curtotti R, Tuynman H, Dylewski M (2022) Australian Fisheries and Aquaculture: Outlook to 2026–27. ABARES Research Report, Canberra, Australia. <https://doi.org/10.25814/k54g-9m23> (accessed 20 February 2024).

159 OECD/FAO (2023) OECD-FAO Agricultural Outlook 2023–2032. OECD Publishing, Paris. <https://doi.org/10.1787/08801ab7-en> (accessed 20 February 2024)

160 OECD/FAO (2023) OECD-FAO Agricultural Outlook 2023–2032. OECD Publishing, Paris. <https://doi.org/10.1787/08801ab7-en> (accessed 20 February 2024)

161 Mobsby D, Curtotti R (2018) Snapshot of Australia's Commercial Fisheries and Aquaculture. ABARES, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/abares/documents/AustraliaCommercialFisheriesAquaculture20181218_v1.0.0.pdf> (accessed 20 February 2024).

162 ABARES (2023) Australian Fisheries and Aquaculture Statistics 2022. ABARES, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1035343/0> (accessed 20 February 2024).

163 Department of Agriculture and Water Resources (DAWR) (2018) Commonwealth Fisheries Harvest Strategy Policy. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/domestic/hsp.pdf> (accessed 20 February 2024); Mobsby D, Curtotti R (2018) Snapshot of Australia's Commercial Fisheries and Aquaculture. ABARES, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/abares/documents/AustraliaCommercialFisheriesAquaculture20181218_v1.0.0.pdf> (accessed 20 February 2024); OECD (2021) Fisheries and aquaculture in Australia. <https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/documents/report_cn_fish_aus.pdf> (accessed 20 February 2024).

164 Curtotti R, Dylewski M, Cao A, Tuynman H (2023) Australian Fisheries and Aquaculture Outlook to 2027–28. ABARES Research Report, Canberra, Australia. <https://doi.org/10.25814/vzbj-nw33> (accessed 5 March 2024).

165 DAWR (2017) National Aquaculture Strategy. Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/aquaculture/national-aquaculture-strategy.pdf> (accessed 20 February 2024).

Environment and climate

Despite leading in sustainable fisheries management, Australian fish production faces uncertainty in adapting to climate-induced impacts such as rising sea levels and temperatures and ocean acidification.[166] This requires embracing innovative technologies,[167] actively reducing sector emissions[168] and engaging in international policy negotiations.[169]

Land and water

As with agriculture, sustained pressures from population, industry and climate are reducing available resources and intensifying competition.[170] In contrast to land ownership, Australia's marine management framework maintains that no single user has exclusive ownership rights of oceans.[171] As the 'coastal squeeze' tightens,[172] hard to regulate inter-industry competition between oil and gas exploration,[173] renewable energy projects such as offshore wind farms[174] and commercial fisheries are also likely to introduce fresh challenges.[175]

Productivity and innovation

To enhance the sector's productivity and value, ongoing innovation in aquaculture is required. With 1103 aquaculture businesses in Australia as of 2024, growing at an average annual rate of 0.5% over the past five years, there is evident growth.[176] Similar to advancements in agriculture, aquaculture requires new skills and infrastructure. The future expansion of this sector hinges on its ability to attract and retain a diverse workforce of water-quality specialists, engineers, oceanographic and marine experts and environmental scientists.[177]

166 Australian Government (2022) National Fisheries Plan. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/national-fisheries-plan.pdf> (accessed 20 February 2024); OECD/FAO (2023) OECD-FAO Agricultural Outlook 2023–2032. OECD Publishing, Paris. <https://doi.org/10.1787/08801ab7-en> (accessed 20 February 2024).

167 Australian Government (2022) National Fisheries Plan. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/national-fisheries-plan.pdf> (accessed 20 February 2024); CSIRO (2021) Aquaculture research. <https://research.csiro.au/aquaculture/wp-content/uploads/sites/217/2021/07/20-00364_AF_BROCHURE_Aquaculture4ppUpdates_WEB_210316.pdf> (accessed 20 February 2024).

168 DCCEEW (2021) Australia State of the Environment 2021: coasts. <https://soe.dcceew.gov.au/coasts/pressures/industry#aquaculture> (accessed 20 February 2024).

169 DAFF (2023) Analysis: opportunities for Australian seafood exports under the A-UKFTA. <https://www.agriculture.gov.au/about/news/analysis-opportunities-for-Australian-seafood-exports> (accessed 20 February 2024).

170 DCCEEW (2021) Australia State of the Environment 2021: coasts. <https://soe.dcceew.gov.au/coasts/outlook-and-impacts> (accessed 20 February 2024).

171 Australian Government (2022) Supporting Cooperative Coexistence of Seismic Surveys and Commercial Fisheries in Australia's Commonwealth Marine Area. Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/guidance-framework-supporting-cooperative-coexistence-seismic-surveys-commercial-fisheries.docx> (accessed 20 February 2024); DAFF. Managing Australian fisheries. <https://www.agriculture.gov.au/agriculture-land/fisheries/domestic/managing-australian-fisheries> (accessed 20 February 2024).

172 DCCEEW (2021) Australia State of the Environment 2021: coasts. <https://soe.dcceew.gov.au/coasts/outlook-and-impacts> (accessed 20 February 2024).

173 AIMS (Australian Institute of Marine Science) (2021). AIMS Index of Marine Industry. AIMS, Townsville, Australia.

174 Hemer M (2021) SoE 2021 Marine Expert Assessment: Pressure – Offshore Renewable Energy Generation. Australian Ocean Data Network, Hobart, Australia.

175 DCCEEW (2021) Australia State of the Environment 2021: overview. <https://soe.dcceew.gov.au/overview/pressures/industry#energy-production> (accessed 20 February 2024).

176 Blue Economy CRC. Bass Strait Blue Economy Zone. <https://blueeconomycrc.com.au/blue-economy-zone/> (accessed 5 March 2024); IBIS World (2023) Aquaculture in Australia: number of businesses 2008–2030. <https://www.ibisworld.com/au/number-of-businesses/aquaculture/4225/> (accessed 20 February 2024).

177 DAWR (2017) National Aquaculture Strategy. Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/aquaculture/national-aquaculture-strategy.pdf> (accessed 20 February 2024).

Trade and market access

Australia is known for supplying safe, high-quality seafood with a focus on high-value exports to Asian markets.[178] Unlike agricultural production, which is export-orientated, Australia is considered a minor producer globally and imports 62% of edible seafood to meet domestic demand at lower costs.[179] As fisheries are considered stewards of public oceans, there are growing demands both domestically and internationally for them to prove their sustainability through product traceability and data sharing.[180] As a trade-exposed industry, Australian fisheries and aquaculture will remain highly susceptible to global market prices, expectations and trends unless there is diversification of products and trading partners.[181]

Future opportunities

Looking ahead, the Australian fisheries and aquaculture industry has several opportunities:

- Australia's coastal blue carbon ecosystems hold 5–11% of global blue carbon stock, can store more carbon than terrestrial forests and are an important nature-based solution to climate change.[182]
- Embracing new technologies such as AI, applied breeding techniques, multi-omics and smart monitoring systems could enhance sector efficiency and sustainability.[183]
- Strengthening and diversifying trade ties, as seen in agreements such as the Australian-UK FTA, could promote market growth.[184]
- A focus on traceability and data sharing could enhance Australia's international reputation and build greater trust among domestic consumers.[185]

178 Mobsby D, Curtotti R (2018) Snapshot of Australia's Commercial Fisheries and Aquaculture. ABARES, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/abares/documents/AustraliaCommercialFisheriesAquaculture20181218_v1.0.0.pdf> (accessed 20 February 2024); Seafood Industry Australia (2023) Market opportunities and impediments for Australian seafood to Europe. <https://seafoodindustryaustralia.com.au/wp-content/uploads/2023/01/European-Union_Market-opportunities-and-impediments-for-Australian-seafood.pdf> (accessed 20 February 2024).

179 DAFF. Australia's seafood trade. <https://www.agriculture.gov.au/agriculture-land/fisheries/aus-seafood-trade> (accessed 20 February 2024); DAFF (2023) Analysis: opportunities for Australian seafood exports under the A-UKFTA. <https://www.agriculture.gov.au/about/news/analysis-opportunities-for-Australian-seafood-exports> (accessed 20 February 2024); Department of Agriculture (2015) Australia's seafood trade. Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/aus-seafood-trade.pdf> (accessed 20 February 2024).

180 DAWR (2017) National Aquaculture Strategy. Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/aquaculture/national-aquaculture-strategy.pdf> (accessed 20 February 2024).

181 Curtotti et al. (2022) Australian Fisheries and Aquaculture: Outlook to 2026–27. ABARES Research Report. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1033321/0> (accessed 20 February 2024); DAFF (2023) Analysis: opportunities for Australian seafood exports under the A-UKFTA. <https://www.agriculture.gov.au/about/news/analysis-opportunities-for-Australian-seafood-exports> (accessed 20 February 2024).

182 The Blue Carbon Initiative. <https://www.thebluecarboninitiative.org/> (accessed 20 February 2024).

183 Australian Government (2022) National Fisheries Plan. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/national-fisheries-plan.pdf> (accessed 20 February 2024); CSIRO (2021) Aquaculture research. <https://research.csiro.au/aquaculture/wp-content/uploads/sites/217/2021/07/20-00364_AF_BROCHURE_Aquaculture4ppUpdates_WEB_210316.pdf> (accessed 20 February 2024).

184 DAFF (2023) Analysis: opportunities for Australian seafood exports under the A-UKFTA. <https://www.agriculture.gov.au/about/news/analysis-opportunities-for-Australian-seafood-exports> (accessed 20 February 2024).

185 Australian Government (2022) National Fisheries Plan. DAWE, Canberra, Australia. <https://www.agriculture.gov.au/sites/default/files/documents/national-fisheries-plan.pdf> (accessed 20 February 2024).


OPTOMETRIST

3 Future scenarios

This project has explored the significant global and national drivers that are expected to shape the direction and pace of change for Australian farming systems by 2050. Four plausible future scenarios are presented based on extrapolations of the trends and drivers and input from co-design participants. By exploring various plausible scenarios, policymakers, researchers and industry leaders can determine how they respond to these drivers to have agency over the future outcomes for farming and production systems in Australia.

How to read this chapter

First, view the four scenarios at a high level in Figure 11 and dive into the details in Table 1 to understand how the trends and drivers have been used to create the scenarios.

Two contrasting and alternative outcomes for 2050 were developed for each of the 14 drivers of change. The outcomes extrapolate the existing trends outlined in *Chapter 2 Priorities for Australian agriculture* and were guided by the input and expertise of co-design participants. The driver outcomes for 2050 were then combined in different ways to create the foundation for the four alternative, plausible future scenarios presented in this chapter. For more detailed descriptions of these drivers' definitions and alternative driver outcomes, see the Appendix.

Next, familiarise yourself with the global context for all four future scenarios in Box 2.

To provide a set of easily comparable and testable future scenarios, the same assumptions about the global context in 2050 have been applied to all future scenarios. However, this report does not intend to predict what the global context will be in the coming decades. Rather, increasing uncertainty and volatility in the global context are expected and further sensitivity analysis of the future scenarios is a recommended next step. The intention of this report is to present a set of scenarios that are a starting point for exploring the range of global uncertainties that farming systems must prepare for. See Box 2 for a more detailed discussion.

Then, immerse yourself in the four plausible futures for 2050.

The narrative for each scenario describes in detail how the driver outcomes interact in 2050. An initial set of signposts accompany each scenario to help identify pathways towards this future. These signposts are trends, events or signals that indicate the decisions and choices that Australia has made before 2050 to be on the trajectory leading to the future described in the scenario. There are likely many more signposts for each scenario and the ones presented are just a starting point. Finally, key trade-offs for each scenario are explored in a set of implications and prompting questions.

The narratives showcase the diverse views and creative thinking of stakeholders involved in the project, as well as a qualitative exploration of assumptions and the broader context for the future scenarios. Quantitative assessment, modelling, and testing are essential steps to further validate and refine these scenarios. The qualitative work presented here is intended to spark conversation and lay the groundwork for collaborative efforts as the Ag2050 program moves toward the quantitative phase of scenario testing and downscaling.

What is possible for Australian farming if the agriculture innovation system achieves its full potential?

Scenario 1 – Regional Ag capitals

Scenario 2 – Landscape stewardship

What can be achieved with incremental innovation and proactive climate adaptation?

Scenario 3 – Climate survival

What if agriculture fails to effectively respond to the challenges and needs of 2050?

Scenario 4 – System decline

Scenario 1 – Regional Ag capitals
A consolidated and tech-savvy sector is thriving, prioritising food and fibre security.

Scenario 2 – Landscape stewardship
The sector embraces new opportunities and novel technologies, allowing the environment to flourish.

Scenario 1 – Regional Ag capitals	Scenario 2 – Landscape stewardship
Increasing yields and productivity gains	Increasing productivity gains and resilience
Food and fibre focus through new and intensified production systems	Diversified into innovative new market opportunities
Decreasing emission intensity and plateaued absolute emissions	Decreasing absolute emissions and increasing carbon sequestration
Improvements to the health of ecosystem services	Active improvement to biodiversity and ecosystem services
Skilled and diverse workforce in select growing regional cities	Skilled and diverse workforce attracted to the sector
Step-change investment and uptake of disruptive agritech	Step-change investment and uptake of disruptive agritech
Evidence-based and Australian-led trade frameworks	Strong Australian brand for high-value goods

Figure 11: Scenario summary

Scenario 3 – Climate survival
A focus on climate adaptation and incremental changes allows the sector to survive.

Plateauing productivity and efficiency gains

Diversified land management practices and products

Some reduction in emissions intensities while lagging national net zero targets

Slow deterioration of biological biodiversity and ecosystem services

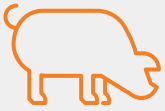
Some talent attraction and retention

Incremental investment and uptake of low-risk technologies

Diverse relationships to maintain an export market

Scenario 4 – System decline
The system fails to address growing challenges and is at a tipping point.

Declining yields and productivity gains



Food and fibre focus with traditional intensified production systems

Lagging reduction in emission intensities and failing emissions reduction targets

Declining biodiversity and ecosystem services health

Shrinking workforce and increasing number of farmers exiting the sector

Incremental investment and uptake of low-risk technologies

Export focus to low price markets

Table 1: Overview of four future scenarios for Australian farming systems in 2050 and the driver outcomes that have been applied to them

Drivers		Regional Ag capitals	Landscape stewardship	Climate survival	System decline
Environment and climate	Climate change adaptation	Proactive, coordinated and equitable adaptation and mitigation		Proactive, coordinated and equitable adaptation	Reactive and costly adaptation, threatening productivity
	Agricultural emissions reduction	Emissions intensity decrease and absolute emissions plateau	Emissions decrease and net zero track	Slight absolute emissions increase and intensity decrease	Increase absolute emissions and plateauing emission intensity
	Natural resource and landscape stewardship	Ecosystem, biodiversity and soil health maintained	Active efforts for landscape restoration and improved ecosystem services	Ecosystem, biodiversity, and soil health decline	
Land and water	Land and sea use and competition and value	Food and fibre output focus	Attractive, non-traditional uses of agricultural land		Food and fibre output focus
	Production mix and intensity	Disruptive forms of highly intense production decoupled from land	Intensification of suitable land, diverse farming on other land		Intensification of land, diverse farming systems emerge in some areas
	Water access and use	Improvements in water management and increased efficiency in water capture, storage and use		Limited efficiency, access and competing uses for water	
Productivity and innovation	Technology driven productivity	Transformative benefits from technologies realised		Stagnating productivity gains realised from new technologies	
	Human capital	Diverse and skilled workforce in a few select regions	Diverse and skilled workforce	Some diverse and skilled labour attractionand retention remains	Low labour attraction and retention
	Integration and consolidation	Significant consolidation of farms	Integration and consolidation follow historic trends		
Trade and market access	Trade barriers	Proactive action to anticipate and influence trade barriers	Trade barriers do not align with national interests		
	Trade relationships	Diversified trade portfolio and supply chains			Heavy reliance on a select few trade partners
Global context		High geopolitical uncertainty; global temperature rise of 2°C and above;[186] global population 9 billion and above[187] and steadily growing middle-class			

186 Lee et al. (2021) Future global climate: scenario-based projections and near-term information. IPCC. <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-4/> (accessed 24 January 2024); Matches IPCC scenarios for SSP3-7.0.

187 United Nations (2022) Population: comparison of United Nations projections, World. Our World Data. <https://ourworldindata.org/grapher/comparison-of-world-population-projections> (accessed 24 January 2024).

Box 2: Considering the global context

For the most part, the outcomes of the four future scenarios are determined by choices made by the Australian agriculture sector. The more positive consequences of the *Regional Ag capitals* and *Landscape stewardship* scenarios depend on proactive decision-making with a long-term perspective. However, the future of Australian farming will also be affected by global or external drivers outside its control.

The global drivers of cooperation on climate change, consumer preferences and geopolitical settings may lead to a range of plausible future global settings that will impact future Australian farming systems. The future scenarios presented have intentionally all been set within one of these plausible future global contexts. This was done to make the scenarios simpler, more manageable, more testable and provide future scenario narratives, trade-offs and implications that are easily comparable.

In deciding which global context to apply, it was the overwhelming preference of stakeholders in the co-design process to explore a challenging global context of increasing geopolitical volatility and rising global temperatures. Stakeholders viewed these more challenging settings as the more likely future context and the more useful to explore compared to more desirable and favourable global conditions. Research and reporting on current trends around geopolitical settings, consumer preferences and global action on climate change (see Chapter 2) indicate this global context is plausible and likely.

However, other global contexts are plausible. The future scenarios are a starting point for considering how a variety of global contexts will impact the likelihood, signposts and implications of each scenario. Several initial considerations for different global contexts are provided below.

In the more fractious global context, positive environmental outcomes in *Regional Ag capitals* and *Landscape stewardship* will be more challenging to achieve without significantly impacting farm productivity and profitability. The demand for bulk agriculture goods from a large global population, lack of strong carbon markets and extreme geopolitical uncertainty may increase the opportunity cost of alternative land uses, disincentivising the transformation of agriculture land use in *Landscape stewardship*, while the capital and stable investment needed to achieve the productivity boost in *Regional Ag capitals* may be severely limited. With an average global temperature rise of 4°C, the breakeven outcomes of *Climate survival* will become harder to secure and *System decline* will become more plausible and bring more negative consequences to Australian farming.

In a more cooperative global context, Australian agriculture could achieve significantly better environmental, economic and social outcomes in *Regional Ag capitals* and *Landscape stewardship* through firm actions and long-term decisions. Without this proactive and long-term planning, *Climate survival* may become more likely. *System decline* may become more likely with challenging external pressures, particularly from higher global temperatures.

Avoiding a more fractious global context will yield significant benefits for Australian agriculture. Although Australia cannot directly control these external drivers, it is worth considering the ways it can influence and respond to the global context and minimise the impact on Australia.

More fractious global context

Protectionist rhetoric and geopolitical conflict unravel trade liberalisation and economic and political diplomacy, global population rapidly increases to 10 billion before 2050 and there is no firm action on climate change, resulting in an average global temperature rise of 4°C by 2100.

More cooperative global context

Strengthened collaboration and more positive trade reduces geopolitical tensions and trade barriers, populations grow along a low–moderate trajectory with middle-classes growing steadily; strong cooperation and collaboration results in actions that limit global temperature rises to 1.56°C by 2050.

Scenario 1: Regional Ag capitals

Large multinational corporations have consolidated and seamlessly integrated much of Australia's agricultural value chains. By leveraging transformative technologies, increased levels of productivity have been unlocked. New workforce opportunities have emerged, concentrated in a select few regional cities where multiple sectors are experiencing growth.

What does the agriculture sector look like in 2050?

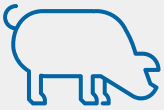
Farms across Australia have focused on optimising remaining viable land for new, intensified and transformative ways of producing food and fibre. The fisheries, conservation and energy sectors have equitable access to Australian seas and waters. The national emphasis on boosting food and fibre productivity is driven by translating disruptive and integrated agritech.

Step-change advances in agritech, biotechnologies and investments in digital infrastructure and services have concentrated and established a few growing regional centres for multiple industries in Australia. Adopting disruptive, large-scale technology systems has enabled seamless value chain integration, unlocked trusted data sharing and created new types of on-farm roles, synergising AI-powered automation with human intelligence. The demand for local testing, implementation and maintenance of new fit-for-purpose systems has led to the growth of regional-based agritech service industries. The agriculture, food processing, technology services and other growing industries, such as the energy sector, have collaborated to strategically co-locate in the same regional cities while maintaining traditional boundaries between sectors. This has been driven by mutual industry commercial interests. Extensive and intensive production systems are connected through transport and communications to these regional centres. The various attractive career pathways and lifestyles draw a diverse and skilled workforce to live and work in these areas.

As some regional cities are booming, other towns without growing agritech or other industries will decline. Without a strong national governance to incentivise the various sectors to invest in more regions, smaller towns will struggle to transition into economic regional centres. The sector is commercially driven to improve natural assets, biodiversity and ecosystem services to ensure optimal water and soil health quality and optimise productivity for farming systems.

Increasing yields and productivity gains

Food and fibre focus through new and intensified production systems



Decreasing emission intensity and plateaued absolute emissions

Improvements to the health of ecosystem services

Skilled and diverse workforce in select growing regional cities

Step-change investment and uptake of disruptive agritech

Evidence-based and Australian-led trade frameworks

Improved efficiency and precision of using inputs such as water and fertiliser, and a strong circular economy, limit the environmental side effects and pollution of farming processes in these regions. Although a few farming and fishery businesses have used cost-effective systems to develop niche, local products, many low-rainfall regions from where agricultural activity has shifted away are neglected. Even though more land has been made available due to intensified practices, without commercial activity these lands have degraded with no active effort or incentives to improve ecosystems and biodiversity through conservation, restoration or biodiversity plantings.

Significant consolidation of farming businesses has reshaped the agricultural industry landscape. Smaller farming and forestry businesses struggle to establish economies of scale to offset the capital investments required for new technologies. As such, many small farms in the growing regions have sold to larger businesses. The multinational agriculture conglomerates have leveraged step-change agritech, economies of scale and vertical integration in the supply chain from paddock to end-consumer, to own and control much of the food and fibre value chains. Through investment in the necessary infrastructure and training, big businesses have achieved trusted data sharing and a synergy between technology and human intelligence. They have used their influence on the Australian agricultural innovation system to drive investment and innovation that supports their competitive advantage. The combination of consolidation and co-location of new industries in select regional towns has led to ongoing public and private investment in the development of social services, infrastructure and connectivity to boost these regional economies, while other regional areas have become increasingly marginalised.

Agritech and biotech have enabled new production systems for climate-resilient, productive and intensive farming of food and fibre. Farmers have implemented highly efficient new systems for fertilisation, pesticide application and irrigation and established new breeding techniques. In some centralised production facilities, farmers can control climate and weather variables.

New production systems using biotechnologies, protected cropping, land-based aquaculture and lab-grown food and fibre have grown, introducing approaches to intensifying production decoupled from land. Plantations and native forests around the regional cities are in optimal locations to maintain ecosystem service health and biodiversity for broader agricultural productivity. Livestock are cycled between extensive systems and feedlots to intensify production while enabling the distribution of methane-reducing feed and vaccines. This rotating hybrid system is improving sustainability through world-leading animal welfare management, efficient use of inputs and sourcing of feed and enabling some carbon abatements. Significantly improved efficiencies have reduced the emission intensities of intensive production. Despite a greater number of livestock and cropping operations to meet global demand, technology gains have successfully offset any increase in absolute emissions. Carbon offsets are available from the land sector, but with a global priority for food security, agriculture has minimal incentives from markets and domestic policy to use them to meet net zero.

Australia has positioned itself as a secure and reliable source of high-quality food and fibre in the global market. Despite the high cost of skilled labour, production outputs remain highly competitive and accessible in global markets due to the efficiencies and augmentation of labour unlocked from technology gains. The reduction of emission intensities is seen as a preferred global climate mitigant over net and absolute emissions, given their role in global food security. Although intensified systems increase the threat of biosecurity breaches, the regions are integrated into national state-of-the-art predictive and surveillance biosecurity systems and can prove to international markets that outbreaks are well-contained and managed. Although global demand for Australian products has enabled proactive negotiations and lobbying for favourable evidence-based trade frameworks, producers face challenges in meeting the sustainability expectations of more discerning consumer groups.

How do we know we are heading here?

- ↑ **industry investment in novel climate adaptation strategies**
- ↑ **industry-led collaboration and R&D investments**
- ↑ **rates of industry and supply chain consolidation**
- ↑ **investment in novel food and fibre production**
- ↑ **concentration of investment in select regional centres.**

Implications

An oligopoly for the agriculture sector: With the emergence of an oligopoly for agricultural production, a few large firms exist and influence the priorities for R&D investment, governance, industry practices and trade negotiations.

What type of governance and policies can to be implemented to ensure consolidation of businesses promotes a competitive sector, while also safeguarding the interests of consumers and small farms?

Greenhouse gas emissions: The sector's role is to prioritise food production over mitigating further emissions from agricultural activities. A focus on maximising productivity and ensuring global food security minimises the market incentives for any greater active efforts to reduce further emissions or access offsets.

To what extent should the agriculture sector continue to contribute to national absolute emissions and what measures need to be in place to offset these emissions?

Intensification makes more land available: Through sustainable intensification, Australia's farming systems have become highly efficient and more concentrated, resulting in more land becoming available for other uses such as environmental restoration.

How can the newly available land be utilised to ensure long-term sustainability and who should bear the cost of conservation and land restoration?

Scenario 2: Landscape stewardship

Using the land to support the energy transition through carbon capture and the restoration of the environment is a national priority. Farming systems are resilient and productive because producers have taken advantage of a range of diverse income streams, blurring the lines between farming, biodiversity, carbon sequestration and energy and fuel production.

What does the agriculture sector look like in 2050?

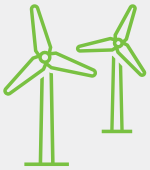
Farming systems have adapted non-arable and marginal land for growing biofuel feedstocks, renewable energy production, carbon sequestration, agritourism and ecosystem services. Strong governance and a national holistic and strategic approach to sustainability have driven this diversification to support the entire land sector. In a similar direction, there has been a nationally coordinated approach to equitably allocating marine waters for alternative uses. The fisheries industry has diversified its activities to benefit from circular economy opportunities, such as carbon sequestration and repurposing waste products. These opportunities minimise biosecurity risks and are more economically attractive than food and fibre production. The resulting plateau in food and fibre output has ultimately redefined what constitutes farming systems in Australia.

The land benefits from Aboriginal and Torres Strait Islander peoples knowledge, maximising productivity, and the broader ecosystem benefits from natural landscape restoration. Farming systems have undergone fundamental transformations by harmonising with broader environmental systems, including forestry, and are evolving from traditional food and fibre production to enhancing crop species richness and assuming pivotal roles in restoring and maintaining natural landscapes and waterways. Ongoing collaboration with Aboriginal and Torres Strait Islander peoples and with industry has seen the integration of Indigenous knowledge into standard farming practices and land management.

Integrating innovative practices and step-change technologies are central to addressing climate challenges and enhancing productivity in Australia's agriculture sector in various markets. Disruptive cutting-edge technologies and enabling systems bolster economic resilience, provide protection against biosecurity threats and improve efficiency with less environmental impact. Water management is optimised for regional conditions through highly efficient use unlocked by agritech.

Increasing productivity gains and resilience

Diversified into innovative new market opportunities



Decreasing absolute emissions and increasing carbon sequestration

Active improvement to biodiversity and ecosystem services

Skilled and diverse workforce attracted to the sector

Step-change investment and uptake of disruptive agritech

Strong Australian brand for high-value goods

A balanced approach to plantations and sustainable native forest logging has unlocked new levels of biodiversity health and management. A reduction in emissions has been achieved through a combination of technologies, including reduced emission intensities from agritech such as methane vaccines, alternative feed sources and improved fertiliser efficiency, and reduced absolute emissions from entry into complementary and plant-based protein markets to meet the growing demand for protein outside of increased livestock numbers. The scale of land use change and adoption of new practices and technologies have enabled farmers and fishers to achieve net zero for on-farm and fisheries activities, while also providing carbon offsets to other parts of the economy. Through the blue economy, soil sequestration and carbon forests, producers and fisheries are able to inset their activities, while also gaining income and benefits from selling carbon credits and biodiversity credits.

Producers embracing sustainable practices and technologies before 2050 now enjoy a significant first-mover advantage in the market, with resilient, diversified income sources and more attractive propositions for investors. Some small businesses needing more capital, time or knowledge to transition and diversify simultaneously have lost out to more prominent corporations. The sector's international recognition for its high-value products continues to attract further investment in innovation.

Redefined agricultural activities have generated various high-quality job opportunities that attract a diverse and skilled workforce to some areas, with many maintaining a base in urban centres, leading to the development of a fly-in fly-out workforce. A divide between the communities of more productive and less productive areas has emerged. Similarly, the competition for diverse labour and the coexistence of large, consolidated farms alongside smaller, niche farms continue to create tension. Some small farms have established niche products while others are coordinating with their neighbours to establish regional diversification as a shared opportunity to compete with the economies of scale of bigger businesses.

Farmers leverage strong environmental credentials to access key markets. However, where consumer sustainability demands do not align with best land management practices, producers are challenged with balancing export trade access and keeping prices low. Trade negotiations have supported diversified exports into new markets and secured sources for the importing of critical agricultural inputs. Australia maintains its reputation as a bio-secure country and boosts its brand as a producer of sustainable, high-value goods by ensuring strong compliance with frameworks introduced by their trading partners. Governance and policy settings support and cultivate viable farming systems and ensure domestic food security. Doing so has bolstered trust within the agricultural industry during uncertain times.

How do we know we are heading here?

- ↑ **investment in novel climate adaptation strategies**
- ↑ **R&D investments across industries and sectors**
- ↑ **strength of governance and guidance across land uses**
- ↑ **application of novel cross-sector and diversified business models**
- → **growth in food and fibre production.**

Implications

Diverse income streams: Greater diversification leads to enhanced economic resilience by enabling farmers and fishers to unlock significant productivity and profitability gains stemming from operating in multiple industries.

How can farmers innovate their business models to seize this opportunity while minimising maintenance and capital costs?

Market signals and land use optimisation: Producers must navigate market signals and policy directives in making decisions on how to best use the land they have available. These signals and directives may not always align. For example, farmers might be required by policy to use portions of their land for carbon or biodiversity plantings, impacting their flexibility in adapting land to respond to shifting market demands for other farm outputs.

How can policy and governance around land use be framed to pursue positive sustainability and environmental outcomes while ensuring producers can effectively respond to consumer demand and optimise their revenue?

Resource-intensive transformation: A significant change to farming systems requires producers within each specific region to continually evaluate and optimise their land and seas for diverse uses. Continuous consideration of factors such as climate conditions, social dynamics and market demands requires significant time, resources and investment.

How can support be provided to producers to make this transition without making them responsible for all the costs required?

Scenario 3: Climate survival

Without transformative change, the agriculture sector is forced to focus on surviving rather than thriving. Producers relocate and incrementally adapt and diversify their farming systems to offset the impacts of climate change. However, they remain uncertain about the long-term viability of their businesses.

What does the agriculture sector look like in 2050?

Farmers and fishers have continued to make incremental adjustments to technologies and practices to adapt to changing climates. Continuous and compounding changes that build on decades of experience adapting to climate change have enabled producers to maintain productivity levels. These have included relocating to less disaster-prone regions and diversifying their production and business activities. Producers have adopted alternative crop–livestock systems, bioenergy production, carbon sequestration and agritourism initiatives to optimise the balance between risk mitigation costs and profitability. However, without strong governance and collaboration with producers, many struggle to obtain finance, insurance and guidance on the transformative best practices for their farming system. Producers have focused their resources on responding to the increasingly more severe and frequent droughts, floods and biosecurity risks to ensure their resilience. With little transformative innovation, the impacts of these events are more keenly felt. Short-term decision-making over land use, sea access and fragmented sharing of best practices across regions and industries have disadvantaged producers attempting to enter new markets. The only climate mitigation has been a result of adaptation efforts rather than direct efforts to mitigate contribution.

As climate events exacerbate the impacts on many regions across Australia, the health of Australian waterways and landscapes and the levels of biodiversity have slowly deteriorated. Producers and taxpayers shoulder the rising costs of managing the health of the natural environment, declining arable land and increasing biosecurity threats. The risk of failure of crucial ecosystem services has increased and businesses and communities grapple with more frequent and extreme weather events – droughts, floods and bushfires – and the increasing economic burden of climate disaster recovery. Farming in some regions is only still viable due to continued climate adaptation and investment to recover from the impacts of climate change on landscapes, waterways and farming communities.

Plateauing productivity and efficiency gains

Diversified land management practices and products

Some reduction in emissions intensities while lagging national net zero targets

Slow deterioration of biological biodiversity and ecosystem services

Some talent attraction and retention

Incremental investment and uptake of low-risk technologies

Diverse relationships to maintain an export market

Water health is slowly declining as many regions struggle to have reliable access to and efficiently use the resource. Despite producers recognising the importance of healthy soils, waterways and ecosystems, the complexity of accessing resources and support and the lack of incentives have discouraged many from pursuing restoration or regeneration initiatives.

Land management solutions, such as diversification, and compounding incremental technology gains have managed to offset the impacts of climate change on yield and maintained positive year-on-year productivity gains. Many producers have implemented new systems, such as advanced data analytic platforms and selective breeding, to support decision-making and efficiency after they have become cost-effective and proven in other industries. A lack of coordinated and scalable technology investments in Australian R&D alongside scientifically outdated regulatory frameworks for technology uptake has continued to create a disconnect between industry and researchers. Without transformative change, producers have missed the potential for Australian farms to urgently break out of historical productivity trends and thrive in the new climate, geopolitical and market environments. Productivity rates for Australian farms have fallen well below the global frontier. Watching the global competition adopt large-scale, radical, technology-driven production systems, many producers view the long-term viability of their enterprises with uncertainty.

AI-powered sensing and robotics systems are ubiquitous across Australian industries and have been used to automate some remote and manual on-farm activities. Despite this automation, producers face a significant human capital gap and have been unable to compete with advanced technology, manufacturing industries and the energy sector to attract and retain skilled, entrepreneurial and diverse talent. Barriers to entry, including access to financial support, prevent many from entering the sector.

The agriculture sector has done little to change its emissions from historical trends. The compounding impact of incremental technologies and climate adaptation practices, such as efficient fertiliser use, selective breeding and electrification, have provided a slight decrease in emission intensities. However, the number of livestock has continued to increase over the decades to meet global protein demand, causing absolute emissions to gradually escalate. As other sectors decarbonise, the proportion of agricultural emissions relative to total emissions in Australia increases. Most producers have prioritised selling their high-quality carbon credits to stabilise their income, with only the few remaining low-quality credits being used to offset their own.

More discerning consumer and advocacy groups have begun to weaken the ‘green’ brand image of Australian agriculture and undermine the sustainability credentials of Australian producers. Exporters have struggled to match competitors on price. Non-tariff measures that have been implemented by other countries do not fit the context of Australian farming systems and have weakened the market position for Australian agricultural goods. Strong preferences for sustainability and biosecurity integrity have disadvantaged many in accessing wealthy markets. Forestry and fishery industries have seen their social licences deteriorate as discerning international consumer groups criticise the slow movement away from production activities viewed as outdated and environmentally damaging. Effective relationship-building by industry and government representatives has offset these approaches to market acceptance by opening trade with diverse markets, including emerging economic powerhouses with growing middle-class consumer groups. Diversifying across multiple products and markets has helped Australian producers position themselves for less discerning, cost-driven consumers.

How do we know we are heading here?

↑ **adoption and compounding of incremental climate change adaptation strategies**

→ **agriculture R&D investments**

↑ **application of diverse land management practices**

↓ **collaboration between industry and government**

↓ **trust in Australian agriculture brand.**

Implications

Short-term productivity gains: Low-risk climate change adaptation measures and incremental technologies have ensured farming systems are maintaining their productivity in the short term, but risk not being substantial enough to support the sector in the long term.

For how long can farming systems maintain productivity with these solutions before climate change challenges escalate and impact farm viability?

Incremental innovation: With a lagging innovation system, farmers are less able to address challenges such as the increasing competition for natural resources or to capitalise on opportunities in 2050 such as meeting the rising demand for high-quality food and fibre products.

How can the current agricultural innovation system and extension services evolve to facilitate step-change innovation for long-term productivity, sustainability and economic resilience?

Inequality between regions: Climate change will have a varying impact across different regions of Australia, with some areas experiencing more significant impacts than others. Farmers in those regions without continual investment or who do not possess the resources to relocate could potentially see farming become unviable and suffer from significant economic losses.

How can climate change adaptation strategies be devised and implemented to enable equitable climate resilience across all regions in Australia?

Scenario 4: System decline

The Australian agriculture sector has reached a tipping point. Delayed and fragmented decision-making has left producers facing the economic and environmental consequences of extreme weather events and biosecurity outbreaks. With only incremental advances in agritech, many farm businesses are struggling to maintain profit.

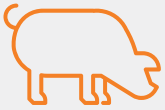
What does the agriculture sector look like in 2050?

Without strong action, long-term decision-making to address climate change impacts and significant improvements to productivity, many farming systems have experienced significant effects on yields, nutritional quality and productivity rates. Declining soil and water health and ecosystem service management have forced some farmers to shift their farms to the remaining arable land available, while others focus on getting what they can out of their land. Ongoing outbreaks of pests and diseases contribute to the decline in biodiversity. Producers have minimal resources to manage biosecurity risks and restore degraded ecosystems. Most farms have focused on intensive farming of food and fibre to remain viable.

Producers are incentivised to get as much return out of their land as possible to support domestic and global food and fibre demand, regardless of their emissions. The number of livestock has drastically increased, causing an increase in absolute emissions. With more land being degraded, producers are forced to bring greater numbers of livestock into feedlots and intensify broadacre cropping. Despite incremental gains in practices and electrification, any decrease in emission intensities has been offset by the increase in intensive production. Reaching net zero targets seems unachievable.

Other industries have seized opportunities to move into new markets, such as carbon sequestration and energy production, leaving most producers without alternative revenue sources to offset the impacts of climate change and external volatility. Young and skilled workers are drawn to these reliable and highly profitable industries, leaving the agricultural labour gap to grow. Fisheries are given low-priority access to marine landscapes due to stronger competition from the conservation and energy sectors and are at a tipping point. In some areas of Australia, unsustainable native forestry practices have been adopted in order for the forestry industry to remain viable.

Declining yields and productivity gains



Food and fibre focus with traditional intensified production systems

Lagging reduction in emission intensities and failing emissions reduction targets

Declining biodiversity and ecosystem services health

Shrinking workforce and increasing number of farmers exiting the sector

Incremental investment and uptake of low-risk technologies

Export focus to low price markets

Industries compete for critical and increasingly costly resources, water and skilled labour. Farm businesses that mobilised earlier can leverage the first-movers' advantage, enabling greater accessibility to capital for expansion through the acquisition of smaller farms and their land.

Decreasing R&D investment, capacity building and a breakdown of industry strategic approaches to delivering the digital revolution have led to only incremental developments in on-farm agritech. Fragmented approaches to adopting best land practices and step-change innovations in agritech have resulted in minimal collaboration and scaling across Australia. Inefficient use of water and agricultural inputs has impacted soil health, water pollution and ecosystem services. Despite innovative new agritech being available and demonstrated in overseas markets, Australian producers have little capacity and support to navigate the process of investing and trialling them.

The increasingly volatile global conditions and fragmented approaches to supporting and improving farming systems have made farming one of the most challenging professions in Australia. More frequent, extreme climate-related disasters, including droughts, floods, bushfires and disease outbreaks, are eroding the resilience of farms and causing significant economic losses. Regional communities and producers and are experiencing continual stress about income security and struggling alone to navigate ongoing challenges. As such, many producers are choosing to leave the industry, with more land becoming abandoned and degraded. The labour gap continues to grow as younger workers turn to alternative and more attractive careers in urban centres.

Regions with substantial land and water assets have farming systems that are benefitting from changed climate conditions and are successfully increasing productivity and yields. Producers have the capital to invest in luxury services such as natural resource management to prioritise healthy ecosystems or alternative products such as plant-based proteins. Carbon offsets in these regions serve as valuable income due to the high demand from other sectors. These regions exhibit optimism for improved food security, reduced waste and emissions, and better food system connections. However, social fragmentation is exacerbated by the many communities and ecosystems that are suffering and facing an uncertain future.

Traditional export markets apply ideologically led sustainability trade frameworks that deteriorate the market positioning of Australian agriculture. With falling product quality and constraints on yield and productivity, Australian agricultural industries are struggling to position themselves competitively in markets, whether as providers of high-value products or low-price bulk commodities. Unsustainable native forestry practices, unchanged overall sector emissions and poor biodiversity and biosecurity restrict the sector's ability to meet sustainability credentials for trade. Exporters are forced to shift to less discerning markets, prioritising low prices over stringent quality and sustainability credentials.

How do we know we are heading here?

- ↓ **collaboration on climate change adaptation strategies**
- ↑ **short-term and reactionary focus of R&D system**
- ↑ **on-farm production intensity**
- ↑ **rates of biodiversity loss**
- ↑ **regional marginalisation.**

Implications

Worsening climate: Fragmented efforts in mitigating and adapting to climate change have resulted in deterioration of ecosystem services' quality, alongside the degradation of natural resources and biological biodiversity.

How might outcomes worsen under higher global warming scenarios?

Loss of market access: The decline in both the quality and quantity of Australian agricultural exports impacts Australia's market position and access, consequently leading to falling demand for Australian produce. This might necessitate a shift in Australia's export strategy towards less discerning markets, prioritising low prices over stringent quality and sustainability credentials.

Could Australian producers maintain profitability despite exporting at lower prices to less discerning markets?

4 Considerations

How Australia responds to trends and challenges will determine, in large part, its future outcomes. Chapter 3 presented a set of scenarios that describe plausible alternative futures for Australian agriculture. Each scenario has benefits and challenges, and achieving some of the more desirable outcomes and avoiding the less desirable ones will require significant effort and action. This chapter draws on the insights developed during the co-design workshops and CSIRO's research to outline five fundamental shifts Australia needs to make to identify and pursue the future it wants for its farming systems: climate adaptation, land and water, industry, regions and whole-of-system change (Figure 12).

The five shifts include multiple action areas. These are not exhaustive but help to articulate the initial changes, assumption testing and initiatives required, nor are they exclusive, with many interconnections among the five shifts. Progress towards achieving these shifts is not a linear journey. Success will require a continuous and iterative approach that blends incremental adjustments with transformative steps.

Note that the stakeholders referred to are the participants in the co-design workshop series and consultations. They represent organisations from across State and Commonwealth governments, research organisations, industry peak bodies, environmental conservation groups, agriculture and finance businesses.

Climate adaptation

A climate adaptation shift will support Australian food and fibre production to pursue growth in profitability and productivity within the context of a changing climate.

Increase research into climate change impacts – understand and forecast the impacts of climate change and offset strategies on ecosystem services and agriculture production at a regional level.

Increase research on adaptation approaches – identify adaptation approaches through continued research and strengthening international cross-collaboration.

Test for likely success of adaptation activities – test and demonstrate that adaptation strategies are adequate measures under a variety of global conditions, what social and policy measures are needed in regions, and how to monitor adaption action in the sector.

Land and seas

A land and sea shift will create a profitable and sustainable mix of food, fibre, and energy production and provide opportunities in carbon markets.

Improve understanding of on-farm emissions reduction including technology adoption challenges and incentives – model trade-offs between emission reduction and productivity under different global settings, incentivise the adoption of emission reduction through solving for process and technology challenges.

Model further land and sea use options and impacts – models to optimise alternative land and sea uses in regions, maps and tracking of land and sea use changes, monitoring impact on nearby ecosystems, and identifying repurposing of non-arable land.

Deepen understanding of carbon sequestration and ecosystem services opportunities – identity incentives for long-term sustainable practises, carbon sequestration opportunities, and in new technologies such as biotech and synthetic ecosystem services.

Foster sustainable agricultural practices through Indigenous-led research and Indigenous-led co-design – use co-design and two-way learning approaches to respectfully develop new knowledge bases for agricultural R&D that integrate Indigenous and scientific knowledge systems.

Industry

An industry shift will enable a productive and resilient agricultural sector and economy and provide new opportunities for exports and income streams.

Build support for skills and human capital – identify and communicate the skills and jobs required in the future, barriers and incentives to education and career pathways in regions, potential trade-offs and co-benefits of automation, and establish strategic partnerships to build education and talent pipelines for regional locations.

Broaden Australia's agriculture export focus – model the impacts of consolidation and diversification on exports, design policies that balance IP protection with knowledge sharing and collaboration, promote Australian sustainability and biosecurity credentials that can be evidenced by producers with minimal cost and effort.

Establish support from finance and diversified income streams – understand the settings needed from finance and insurance industries to support farm viability and resilience under various climate change and geopolitical scenarios.

Figure 12: Recommended areas for policy and R&D

Regions

A regional shift will enable well-connected and vibrant regional communities that offer quality jobs, lifestyle amenities, education, and other services.

Target investment in infrastructure – map and assess regional centres to identify potential for growth and investment from agriculture and other sectors, to support other centres that are at risk of marginalisation and find new ways to connect and engage city-based communities better with agriculture.

Leverage mixed land use opportunities – harness land use mixes that leverage the energy transition and allow for more diverse income streams and quality jobs in regional areas, adopting relevant best practice from overseas around good planning and investment decisions.

Whole-of-system

A whole-of-system shift will mean the agricultural system has the planning and investment to achieve step changes towards long-term transformation.

Renew strategy guidelines – build on available strategic planning and forsighting tools, such as the future scenarios contained in this report, to enable industry, research organisations and government to develop effective strategy and standard evaluation frameworks in response to transformational and cross-commodity priorities.

Restructuring the agricultural R&D system – identify, evaluate and implement the strategy, structures, interactions, funding models, roles and responsibilities across Australian agriculture innovation needed for effective responses to cross-sector challenges and opportunities.

Strengthen relationships and dialogue with Aboriginal and Torres Strait Islander partners – incorporate Indigenous led co-design and research into the development of opportunities and re-engage with traditional methods to advance sustainable farming practices.

Productive, resilient and sustainable farming systems in 2050

Climate adaptation

A climate adaptation shift will support Australian food and fibre production to pursue growth in profitability and productivity within the context of a changing climate.

Action areas that support climate adaptation in Australia include:

- *Increasing research into climate change impacts:* Stakeholders identified a need to better understand the repercussions of climate change on water availability and key ecosystem services at a regional level across Australia to improve resource management. Other identified needs included developing maps, future scenarios and forecasts of climate change impacts on agricultural production at a regional level, as well as modelling and testing what offsetting climate change impacts would mean at the regional level for various farming systems.
- *Increasing research on adaptation approaches:* Stakeholders recognised a need for continuing research on various climate adaptation approaches to identify potential solutions to test, including crop protection, agroecology solutions and new cultivar studies among others. Strengthening international collaboration on climate adaptation research and innovation practices was another identified need to promote global action and strategy.
- *Testing for likely success of adaptation activities:* Stakeholders also identified a need for testing whether climate adaptation activities will be adequate to maintain farm productivity levels under various global warming and global geopolitical settings to determine what climate adaptation means from a social point of view, what policy mechanisms are required to support adaptation in regional communities and what investment models may enable effective climate adaptation. Defining the capabilities needed to deliver industry-wide climate adaptation, developing relevant tools for producers to inform their decision-making and understanding how institutional arrangements (such as organisations, policies, systems and regulations) may manage and monitor adaptation action in the agriculture sector were also identified.

Land and seas

A land and sea shift will create a profitable and sustainable mix of food, fibre and energy production and provide opportunities in carbon markets.

Action areas that support land and seas in Australia include:

- *Understanding on-farm emissions reduction, including technology adoption challenges and incentives:* Stakeholders acknowledged the challenges of the land sector offsetting other parts of the economy while agricultural emissions remain hard to reduce. In addition to the land and agriculture sector plans already underway,[188] they noted the need to understand and model the potential trade-offs and co-benefits of emissions reduction, productivity and profitability; to understand how to incentivise producers to reduce emissions; and to understand and solve technology adoption challenges (i.e. when emission-reducing technologies are not adopted because of various on-farm challenges). Stakeholders also noted the importance of identifying and understanding through global consequential models any negative impacts to overseas markets from various emissions reduction pathways for Australia.
- *Understanding of land and sea use options and impacts:* Stakeholders cited the need for additional research and modelling to compare and optimise alternative uses of land and seas at the producers' level and for particular regions, including climate, social and market access considerations as well as trade-off and potential co-benefits between sustainability, productivity and risk; the need for regional-specific digital maps of land and sea use to track usage changes and monitor the impact on nearby natural assets and ecosystems; the need to calculate the costs of land use transitions; providing landowners and producers, including fisheries, with accessible resources to inform their decision making; and incentivising the identification and repurposing of non-arable land for alternative use as well as for wetlands and waterways that could provide alternative opportunities to fisheries.

188 DAFF (2024) Agriculture and land sectoral plan. <https://www.agriculture.gov.au/agriculture-land/farm-food-drought/climatechange/ag-and-land-sectoral-plan> (accessed 5 March 2024).

- *Increased understanding of carbon sequestration and ecosystem services opportunities*: Stakeholders identified a need for financial incentives to support investment in long-term sustainable production practices; better understanding and modelling of the contribution of on-farm, fisheries and aquaculture activities to supply chain greenhouse gas emissions and of carbon sequestration opportunities for various farming systems including soil and sea sequestration. Stakeholders recognised that achieving decarbonisation and productivity in agriculture, including fisheries and forestry, will be challenging without sustaining ecosystem health and that sequestering carbon and improving ecosystem services will be harder under most global warming scenarios due to hotter temperatures and lower rainfall. This highlighted the need for investment in solutions such as biotechnologies and synthetic ecosystem services that can enhance the sequestration potential of Australia's land and waterways and improve biodiversity health under these conditions.
- *Fostering sustainable agricultural practices through Indigenous-led research and Indigenous-led co-design:* Stakeholders recognised there is an established and growing field of Indigenous-led research advocating for a re-engagement with Indigenous ways of nurturing Country to advance sustainable farming across Australia. Indigenous agricultural techniques, honed over tens of thousands of years connecting land, sea, sky, waterways, plants, animals and cultural laws, can offer invaluable insights into planning for the future of Australian farming. Stakeholders identified that a broader knowledge base integrating Indigenous, scientific and other knowledge systems across Australia will further develop and improve the future scenarios and implications presented in this report, as well as other forecasting and scenario development work across Australia's R&D system.[189] This knowledge base can be developed by co-creating innovative tools with Indigenous partners that include Indigenous knowledge in decision-making, build non-Indigenous peoples' understanding and respect for Indigenous knowledge and encourage two-way learning between Indigenous and non-Indigenous partners. The development of these partnerships and respectful knowledge sharing will take dedicated time and culturally centred ways of collaboratively planning a way forward (see below for the whole-of-system recommendation on strengthening Indigenous partnerships).

Industry

An industry shift will enable a productive and resilient agriculture sector and economy and provide new opportunities for exports and income streams.

Action areas that support the industry include:

- *Support for skills and pathways into agriculture:* Stakeholders recognised that the skills and capabilities available in the workforce are important drivers of productivity, but improving the education and career pathways into agriculture and developing the skills needed in the future is a complex task. They recommended more research to understand the skills and jobs needed for Australia's agricultural future and the barriers and incentives for undertaking the required study and attracting talent to jobs and opportunities to become farm operators in the regions. They also noted the need for understanding and communicating the trade-offs and co-benefits between automation and labour; for more strategic partnerships and a collaborative approach to developing, incentivising and maintaining education and talent acquisition pipelines; the need to identify and compare strategies to access talent from regional locations; and to facilitate networking and upskilling, including events, scholarships and training for producers and diverse and young skilled workers.
- *Expansion of Australian agriculture's export focus*: Stakeholders acknowledged agriculture's long-term success in supporting Australia's economic growth and believed this could continue with proactive efforts. They noted the need for policies to balance protection of intellectual property with attractive commercialisation opportunities for multinational innovation, collaboration and knowledge sharing; to standardise and promote the consistent application of Australian sustainability, Indigenous and biosecurity credentials for continued trade and market access; to develop efficient systems for evidencing these credentials with minimal additional effort and cost to producers; and to support new technology-enabled growth opportunities and forms of competitive advantage. They also noted the need to understand and model the impacts of diversification and consolidation on enterprise types, exports and land uses.

189 Woodward E, Hill R, Harkness P, Archer R (2020) Our Knowledge Our Way in Caring for Country: Indigenous-led Approaches to Strengthening and Sharing Our Knowledge for Land and Sea Management. Best Practice Guidelines from Australian Experiences. NAILSMA and CSIRO, Cairns, Australia.

- *Support for finance and diversified income streams*: Stakeholders identified a need for more collaboration between agriculture and the finance and insurance industries to understand the settings needed to support farm viability and resilience under various climate change and geopolitical scenarios; better support for small–medium producers to access capital for land and technologies through diversified financial products such as revenue-contingent loans, loans that recognise carbon and biosecurity outcomes as lower risk and alternative sources of finance; better support for small–medium producers to manage the changes to their farming systems through new land ownership models or business models; ways to enable producers and local service providers (e.g. mechanics) to establish income streams as founders, investors and participants in growing agritech industries; and explore other potential income streams such as in niche and luxury natural resource management, agritourism and land restoration services.

Regions

A regional shift will enable well-connected and vibrant regional communities that offer quality jobs, lifestyle amenities, education and other services.

Action areas that support regions include:

- *Investment in infrastructure:* Stakeholders called for further research that builds on existing work[190] to identify regional cities with the potential for significant growth in agriculture, agritech and related industries, including assessing and mapping planned investment in connectivity and infrastructure from other industries such as the renewables sector and considering future climate conditions. Stakeholders also noted the need to identify and develop the support services for regional centres that will not necessarily benefit from similar economic growth; for research into the changing attitudes and perceptions of mainstream society about the agriculture sector as a thriving, regional-based ecosystem; and for engagement and communication planning to better connect mainstream, city-based society to agriculture.
- *Promotion of mixed land use opportunities:* Stakeholders recognised the importance of planning and promoting land use mixes that leverage the energy transition and allow for more diverse income streams and quality jobs in regional areas. In addition to the actions described under 'land use', they recommended a better understanding of the experiences learned from overseas around good planning and investment choices.

Whole-of-system

A whole-of-system shift will mean the agricultural innovation system has the planning and investment to achieve step-changes towards long-term transformation.

Action areas that support whole-of-system change include:

- *Strengthened strategy guidelines and strategy testing frameworks:* Stakeholders acknowledged the value of plausible future scenarios to help them understand potential future pathways and outcomes but identified the need for better tools to use and refine in supporting industry, research organisation and government alignment and collaboration and the development of organisational strategy planning.
- *Restructuring the agricultural R&D system:* Research and development in Australian agriculture has enabled growth and prosperity for many decades. However, reports have suggested that agricultural R&D in Australia was not established as a coherent system, but has developed through a collection of interconnected and independently managed components, each following a variety of strategic priorities to fund, facilitate and deliver R&D.[191] These include the Commonwealth, State and Territory governments, universities, RDCs, CRCs and the private sector.[192] R&D in Australia has historically been organised by commodity, with a focus on improving profitability. Although this system has delivered focused, industry-specific solutions and benefits, stakeholders noted that agricultural innovation in Australia is currently disjointed and siloed with strategy and funding focused on commodity groups and short- to medium-term targets.[193] Therefore, this report intends to emphasise the importance and urgency of these action areas.

190 NFF (2022) Regional development precincts. <https://nff.org.au/wp-content/uploads/2022/03/220301-FINAL-NFF_A4_Regional-Development-Precincts_2022_FA-lr-1.pdf> (accessed 20 February 2024); NSW Government. Special Activation Precincts: Regional NSW. <https://www.nsw.gov.au/regional-nsw/regional-business-and-economy-nsw/special-activation-precincts> (accessed 20 February 2024).

191 EY (2019) Agricultural innovation: a national approach to grow Australia's future. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF> (accessed 8 February 2024) (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

192 Chancellor W (2023) Agricultural Research and Development Investment in Australia. ABARES, Canberra, Australia. <https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1034621/0> (accessed 20 February 2024).

193 Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024).

- *Strengthen relationships and dialogue between government, Aboriginal and Torres Strait Islander partners and industry:* Stakeholders identified an opportunity to use the future scenarios outlined in this report as starting points for deeper dialogue with Aboriginal and Torres Strait Islander partners. They recognised that a one-size-fits-all approach to stakeholder engagement is insufficient and that engaging meaningfully with Aboriginal and Torres Strait Islander peoples requires dedicated time and culturally centred methodologies. The opportunity for collaboration to incorporate the knowledge and land management practices of First Nations into future farming systems should be adequately explored and aligned with the goals and objectives of local Indigenous community groups. By committing to the principles of Caring for Country, there is an opportunity to bolster economic strength and enhance food security and nutrition within Aboriginal and Torres Strait Islander communities. Stakeholders acknowledged that these challenges are systemic, not merely procedural, and will need sustained effort and focus to address them to ensure that the voices and perspectives of Aboriginal and Torres Strait Islander peoples are not just acknowledged but intrinsic to long-term strategies for the future of Australian farming systems and foster meaningful collaboration for the benefit of current and future generations.

Ultimately, achieving the most optimistic future is plausible for Australian agriculture. However, it will require significant action and long-term strategic planning across the five fundamental shifts: climate adaptation, land and water, industry and regions. Several of the action areas described above have been proposed in other strategy reports.[194] Therefore, this report intends to emphasise the importance and urgency of these action areas.

Achieving the more positive outcomes described in this report extend beyond any single organisation. They require significant expertise, experience, energy and a collaborative effort across both public and private sector organisations. This report does not address every trend, challenge or plausible future, nor offer all the solutions. Instead, it aims to motivate discussion and identify questions for further research and exploration.

194 EY (2019) Agricultural innovation: a national approach to grow Australia's future. <https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF> (accessed 8 February 2024); Rural RDC (2018) Vision 2050. <https://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf> (accessed 8 February 2024); Woodward et al. (2020) Our Knowledge Our Way in Caring for Country: Indigenous-led Approaches to Strengthening and Sharing Our Knowledge for Land and Sea Management. Best Practice Guidelines from Australian Experiences. NAILSMA and CSIRO, Cairns, Australia.

Appendix – Driver and driver outcome definitions

The 14 drivers and their outcomes for 2050 are the foundational building blocks of the scenarios described in this report. The drivers, their definitions and the outcomes for 2050 shown below were developed and tested based on recent literature, guidance from the co-design participants and the assistance of internal researchers from CSIRO.

Global context

Table 2: Drivers and outcomes for global context

GEOPOLITICAL UNCERTAINTY	
The unpredictability and instability arising from political, social and economic factors at the global, regional or national level that impact the relationships between countries, including diplomatic tensions and increasing risks to liberalised trade, business and stability. Geopolitical uncertainty impacts the prevalence and influence of multilateral forums and international institutions such as the World Trade Organisation.	
Outcome 1	**Outcome 2**
Significantly increased geopolitical volatility and tensions impact major trade and supply chain routes, limiting Australian farmers' reliability and access to crucial agricultural inputs such as fertilisers and chemicals; increasing protectionist trade barriers erode norms in international trade; Australian agricultural exporters must navigate increasingly volatile and destabilised supply chains and market settings.	Geopolitical uncertainty between nations continues to increase but is balanced by strengthening cooperation across nations; protectionist trade policies reduce and lead to increasing international collaboration on biosecurity management, global supply chains and sustainability frameworks; policy measures are designed to safeguard domestic interests while ensuring minimal disruption to international trade.
GLOBAL CLIMATE ACTION	
The pace and effectiveness of collaborative actions from major global powers to mitigate further climate change and the resulting change in weather and climate for Australia.	
Outcome 1	**Outcome 2**
Global action on climate change is fragmented and the average global temperature rises to over 2°C above pre-industrial levels in 2050;[195] extreme weather events are more frequent as a result and competition for dwindling resources, such as water and arable land, intensifies.	Global action on climate change is fragmented and the average global temperature rises to over 2°C above pre-industrial levels in 2050;[196] and allow the goal of net-zero carbon dioxide emissions to be achieved on a global scale by 2075.
CONSUMER DEMAND	
The growth of global consumer populations and incomes and subsequent shifts in consumer preferences for agricultural goods, including considerations for dietary patterns, consciousness of sustainability, animal welfare and nutrition and demands for provenance and tracking.	
Outcome 1	**Outcome 2**
Global population growth begins to stagnate at 9 billion by 2050; slowing global population growth is paralleled by a growing middle class in regions such as Asia; growing demand for higher volume and quality of food and fibre goods as middle-class consumers shift to a more diversified diet and increased protein consumption, with rising expectations for health, provenance, sustainability and ethics.	The global population reaches 10 billion in 2050 driven mainly by growth from regions such as the Middle East and Africa, leading to a sustained increase in the demand for essential bulk commodities; growth of the middle class slows down, leading to demand for higher-value agricultural products growing at a lower rate than expected.

195 Lee et al. (2021) Future global climate: scenario-based projections and near-term information. <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-4/> (accessed 24 Jan 2024); Matches IPCC scenarios for SSP3-7.0.

196 Lee et al. (2021) Future global climate: scenario-based projections and near-term information. <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-4/> (accessed 24 Jan 2024); Matches IPCC scenarios for SSP1-1.9.

Environment and climate

Table 3: Drivers and outcomes for environment and climate

CLIMATE CHANGE ADAPTATION		
The process of adjusting and modifying agriculture and natural systems to adapt production to the negative impacts of climate change, including changes to the types of agricultural production and the locations in which they can occur.		
Outcome 1	**Outcome 2a**	**Outcome 2b**
Slow and uncoordinated adaptation to changing climate conditions across Australia leads to decreasing climate resilience, declining yields, profits and productivity, increased biosecurity threats and increased stress for farming businesses and regional communities; productivity and viability of various industries and regions become threatened.	Proactive adaptation driven by coordinated policy and institutional efforts leads to climate-resilient farming systems, protects yields, profits and productivity, and ensures farming systems are transformed cost-effectively and equitably; includes migration of farms to more appropriate geographical locations, and supportive insurance models.	In addition to the outcomes described in 2a, proactive mitigation strategies are integrated.

NATURAL RESOURCE AND LANDSCAPE STEWARDSHIP		
The extent to which agricultural management practices and institutional settings support and improve outcomes for natural resource health and high-quality ecosystem services, including soil, biological biodiversity, air and waters and seas.		
Outcome 1	**Outcome 2**	**Outcome 2b**
Policy, institutional and farm management settings lead to declining natural resource health; the highest biodiversity loss among OECD nations; the shrinking proportion of land and waters dedicated to conservation and restoration; declining quality of ecosystem services; increasing biosecurity risk; time-consuming and complex reporting requirements for capturing biodiversity benefits for farmers.	Policy, institutional and farm management settings lead to sustainable intensification of agricultural production; the quality of ecosystem services and the health of natural resources in proximity to farming systems are well maintained; some promotion of biodiversity conservation and management of landscapes and waterways, which minimises further negative impacts; restoration of landscapes and biodiversity is minimal.	Policy, institutional and farm management settings lead to increasing restoration of land and waters; improving quality of ecosystem services, air and water quality, increasing biological biodiversity and decreasing biosecurity risk; new industries for sustainability and natural resource management are leading to streamlined reporting requirements.

AGRICULTURAL EMISSIONS REDUCTION			
The rate and pace of absolute emissions and emissions intensity reduction for the agriculture sector. The extent to which net zero emissions have or have not been achieved. Includes the use of carbon offsets and is related to carbon offsets sold by the agriculture sector to other industries.			
Outcome 1	**Outcome 2**	**Outcome 3**	**Outcome 4**
Plateauing emission intensities as incremental gains offset the impact of more intensified practices; increase of absolute emissions from livestock numbers; and continued net emissions with incentives to maintain food and fibre productivity.	Slight decrease in emissions intensity from efficiency gains; and slight absolute emissions increase mainly driven by livestock numbers; low-quality carbon sequestration is used as insets, while high-quality offsets are sold.	Significant decreases in emissions intensity and absolute emissions remain within historical levels as agritech and efficiency gains offset any emission increase from production and livestock numbers; little to no market or policy incentives to access carbon offsets to reduce net emissions.	Significant decrease in emissions intensity and absolute emissions; carbon sequestration is a growing agricultural industry providing insets that enable agriculture to meet net zero and offsets to support other industries' decarbonisation.

Land and water

Table 4: Drivers and outcomes for land and water

LAND AND SEA USE COMPETITION AND VALUE	
Land and seas competition refers to the level of competition from different activities for farming land and access to seas and marine landscapes, including the production of food and fibre, energy production, carbon sequestration, tourism and conservation. Land and seas value refers to the demand and economic worth of farmland and marine landscapes.	
Outcome 1	**Outcome 2**
There is minimal change in the use of land for agricultural purposes (crops and livestock) and for carbon and environmental plantings. Land and sea producers focus on maintaining outputs of food and fibre. The use of marine landscapes and seas is competitive between fisheries, the energy sector and conservation. Policy settings, such as a low carbon price, and funding mechanisms do not provide incentives for shifting away from food and fibre commodities. Urban expansion is poorly managed, resulting in increasing sprawl around Australia's major cities.	The scope of agriculture expands to include new land and sea uses such as carbon and environmental plantings, bioenergy, conservation and agritourism. Producers opt to increase variation in land use to continue to enable food and fibre production, balanced by carbon sequestration and improved biodiversity. Policy settings, such as a high carbon price, land use policies supporting multifunctional use of peri-urban land, sea use policies supporting licencing to diversify activities, zoning laws and funding mechanisms make both traditional and new uses of land and seas equally economically attractive for producers. Population growth results in very little increase in land used for urban developments with urban density increasing across Australian cities.

PRODUCTION MIX AND INTENSITY		
Production mix refers to the combination and variety of crops, livestock or other agricultural productions cultivated on a unit of farmland or in Australian waters. Production intensity refers to the amount of input, including capital, fertilisers, energy etc., and output generated per unit of farmland or water area.		
Outcome 1	**Outcome 2a**	**Outcome 2b**
Land and seas are devoted to the sustainable intensification of food and fibre production. Production methods that decouple from land and sea emerge, such as protected cropping and land-based aquaculture. These promote climate, environment and input-controlled methods that further intensify and minimise land and sea use.	Arable land undergoes sustainable intensification, while some marginal land is diverted to other uses. Diverse, mixed farming systems (including mixed crop–livestock, agroforestry and integrated marine aquaculture) are employed instead of monoculture in some areas. Crop selection considers nitrogen fixation ability, such as legumes.	Arable land undergoes sustainable intensification, while all other land is diverted to other uses. Diverse, mixed farming systems (including mixed crop–livestock, agroforestry and integrated marine aquaculture) are increasingly employed instead of monoculture. Rich crop species selection considers nitrogen fixation ability such as legumes. The changing interface between livestock and wildlife sees new biosecurity practices adopted.

WATER ACCESS AND USE	
The availability of water, water management and the efficiency and methods of utilising water across Australia.	
Outcome 1	**Outcome 2**
Water access remains competitive and sparse; water availability for dryland agriculture is often unreliable, impacting crop outputs and ecosystem health; rising demand for irrigation leads to increasing competition and cost for available water; water use requires increasing regulation, to the point of determining production type and growth locations.	Improved water management, capture and storage lead to water efficiency gains of up to 20%, offsetting the impacts of climate change and increasing demand, and resulting in a positive water balance. Some water savings are used to improve environmental flows; irrigated agriculture can expand; desalinated water becomes an additional or emergency source for farms while recycled and grey water use becomes the norm across Australia.

Innovation and productivity

Table 5: Drivers and outcomes for innovation and productivity

TECHNOLOGY DRIVEN PRODUCTIVITY	
The rate of Total Factor Productivity growth for on-farm or pre-farm gate activities due to management practices, agritech and biotechnologies and the extent to which these are fit-for-purpose for Australian contexts.	
Outcome 1	**Outcome 2**
Incremental innovation and adoption of new tools, technologies, business models and farming practices lead to a widening productivity gap between Australian agriculture and comparable sectors overseas, and stagnating total factor productivity rates for Australia's agriculture sector; the agriculture innovation system structure is not fit-for-purpose; investment in R&D is declining; challenges remain from limited connectivity, data sharing and digitisation.	Step-changes in technology innovation and adoption lead to increasing total factor productivity growth exceeding industry targets and putting Australia at the global frontier; the agritech industry is growing, powered by a fit-for-purpose agriculture innovation system and well-established collaboration channels between researchers and farmers; investment in R&D is increasing.

HUMAN CAPITAL			
The collective capability, capacity and expertise available in the agriculture workforce, including knowledge and skills, and describes where the majority of the workforce is based.			
Outcome 1	**Outcome 2**	**Outcome 3a**	**Outcome 3b**
Policy and institutional settings lead to an increasing human capital gap; diverse and skilled workers are attracted to other sectors; there is poor access in both the regions and cities to education and career pathways into agriculture; digital skills are lagging compared to other sectors, creating growing barriers to adoption for new technologies including advanced robotics; poor connectivity and access to social services in regional Australia impacts attracting and retaining skilled labour for agriculture.	Policy, the education system and institutional settings lead to some diverse and skilled workers joining the agriculture sector but with several barriers to entry still in place; digital literacy and skills increase, enabling the integration of AI-driven robotics and augmenting some on-farm roles; investment in infrastructure and connectivity leads to more workers commuting to the regions or working remotely; human capital gap remains.	Policy and institutional settings lead to improved education and career pathways into agriculture; a growing diverse and skilled workforce; AI-driven robotics and technology platforms complement the skills of workers and on-farm roles; many workers commute into regional Australia or work in cities monitoring and managing farm activities remotely; there is steady demand for construction, transportation and technology and services industries for agriculture in the regions.	As described in 3a, but most workers are based in a select few regions that have benefited from investment and growth of multiple sectors including agriculture, advanced manufacturing and energy; construction, transportation and technology and services industries for agriculture are also steadily growing.

INTEGRATION AND CONSOLIDATION	
Integration refers to the rate and pace of businesses expanding up and down the agriculture value chain or across into different industries at the same stage of the supply chain. Consolidation refers to the rate and pace of farming businesses merging or acquiring other businesses, reducing the number of competitors and creating larger businesses.	
Outcome 1	**Outcome 2**
The rate and pace of integration and consolidation across agriculture businesses follows past trends; policies and robust extension services support smaller farms to compete domestically and internationally, leading to an inclusive agricultural sector that enables both large and small farms to co-exist.	The rate and pace of integration and consolidation across agriculture businesses significantly exceeds past trends, leading to oligopolies across agricultural industries, with large influence over policies and legislation; smaller businesses struggle to survive, with increasing barriers to entry and challenges accessing credit.

Trade and market access

Table 6: Drivers and outcomes for trade and market access

TRADE BARRIERS	
The government-imposed restrictions or policies that limit the free flow of agricultural goods between Australia and other countries, including tariffs, NTMs and subsidies in other countries affect the competitiveness of Australian agricultural goods.	
Outcome 1	**Outcome 2**
Australia fails to effectively advocate for action through bilateral and multilateral forums, which leads to the imposition of new biosecurity measures and NTMs that are ideologically led and not suited to Australian contexts; trade barriers do not align with the nation's interests, driving up compliance costs for exporters and impacting the international competitiveness of Australian agricultural exports.	Australia actively influences trade negotiations, achieving outcomes that align with the nation's interests and are accepted by key regions, including broad acceptance of Australian-led science-based sustainability frameworks; efforts are reinforced by government and industry collaboration aimed at eliminating unjustified trade barriers; enhanced and digitised provenance and tracking systems assist agricultural exporters in complying with regulatory requirements.
TRADE RELATIONSHIPS	
The strength and diversity of Australia's relationships with trading partners, including the strength of Australian influence overseas to establish favourable trading dynamics, access to new markets, FTAs and supply chains.	
Outcome 1	**Outcome 2**
Reliance on only a few bilateral trading partners exposes Australian agriculture to increasing supply chain vulnerabilities and economic risks; limited building of connections and interactions with emerging and growing markets leads to missed opportunities to establish valuable new relationships and market share.	Efforts by the government and the agriculture industry lead to strong relationships with a diverse range of export markets and suppliers of critical agricultural inputs; the government proactively develops FTAs with strategic partners; industry and government proactively manage supply chains, increasing supply chain and economic resilience.

As Australia's national science agency, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Creating a better future for everyone.

Contact us
1300 363 400
+61 3 9545 2176
csiro.au/contact
csiro.au

For further information

CSIRO Futures
Katherine Wynn
katherine.wynn@csiro.au

Yasmin Morgan
yasmin.morgan@csiro.au

csiro.au/futures

Agriculture and Food
Jen Taylor
jen.taylor@csiro.au

Rose Roche
rose.roche@csiro.au

csiro.au/about/people/business-units/agriculture-and-food

B&M | 24-00100