ACIL ALLEN

6 April 2023

Report to GRDC

International benchmarking study

Final report

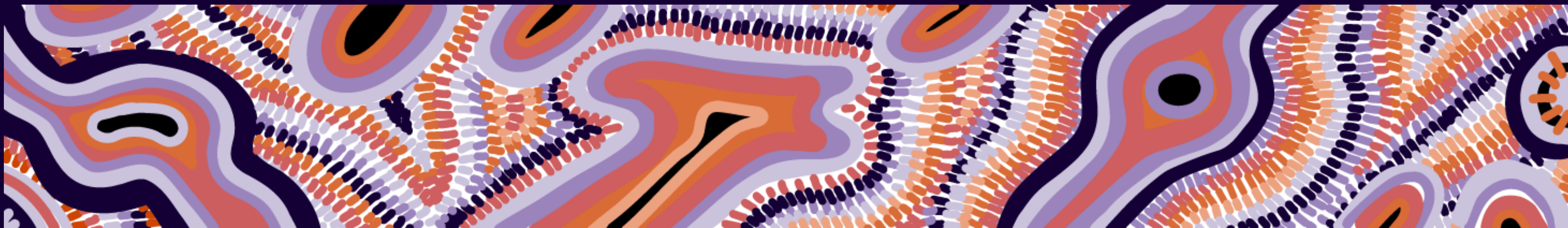
About ACIL Allen

ACIL Allen is a leading independent economics, policy and strategy advisory firm, dedicated to helping clients solve complex issues.

Our purpose is to help clients make informed decisions about complex economic and public policy issues.

Our vision is to be Australia's most trusted economics, policy and strategy advisory firm. We are committed and passionate about providing rigorous independent advice that contributes to a better world.

ACIL Allen acknowledges Aboriginal and Torres Strait Islander peoples as the Traditional Custodians of the land and its waters. We pay our respects to Elders, past and present, and to the youth, for the future. We extend this to all Aboriginal and Torres Strait Islander peoples reading this report.



Goomup, by Jarni McGuire

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Executive Summary

Context

In May 2022, GRDC engaged ACIL Allen to undertake a data-driven international benchmarking study for major GRDC grain crops and producing nations. This summary report provides key messages from the analysis.

The report provides comparative data and analysis (stretching back over three decades) assembled from different sources. A range of international and country-based organisations and experts in the field have supported data collection.

GRDC and its stakeholders can use the report for various purposes. This report is not intended to advocate for changes to Australia's grains R&D funding or production systems or to infer one production system is superior to another.

Key findings

Australia invests approximately 1.5% of the gross value of grain production in RD&E each year including Government contributions. Funding from research partners increases RD&E investment to around 2.5% of GVP. This investment is funded through commodity levies and matching Australian Government R&D contributions. State Governments, public research bodies, universities, and other private entities also contribute to research outcomes for grain growers.

Other grain-producing countries undertake research activities suited to their production environment. The public RD&E structure in those countries is vastly different from the Australian system. Australia's levy-based rural funding has some advantages over the mechanisms used by the other countries analysed in this study. Mainly levy-based funding provides certainty and stability, allowing GRDC to allocate RD&E funding against priorities across the entire grains industry.

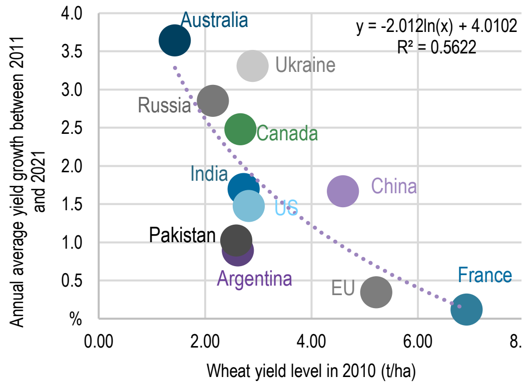
Scientific advances in biotechnology, globalisation of food and agricultural markets, stronger legal protection for intellectual property (IP), and changes in agricultural and regulatory policies affect private industry incentives to invest in agricultural RD&E. This study has identified a growing trend in private-sector investment across all countries analysed, and the data collected suggests that private-sector investment broadly complements public RD&E in most countries. This investment has focused mainly on seeds, biotechnology, agricultural chemicals, fertilisers and farm machinery.

Public sector investment in grain crops (primarily through GRDC) has focused on genetic improvements; agronomic and farming systems; crop protection (pests, weeds and disease management); crop nutrition; automation; market access; climate change; biosecurity and others.

Most of Australia's grain production increase over the past 30 years has come from raising yield growth, as shown for wheat (**Figure ES 1**).

This growth has occurred within the context of significant drought in growing regions and an unprecedented rate of technology-driven grain production that has supported yield increases under water-limited circumstances (see Hochman et al., 2017).

Figure ES 1 Wheat yield level and growth rate

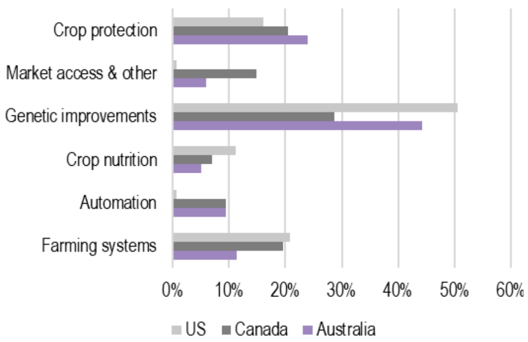


Source: Based on USDA PSD Database and FAO database

This study examined RD&E funding across selected countries by theme over the past 5 years. While comparing the investment mix across nations is difficult, it is possible to conclude that Australia's research allocation is broadly comparable to the US and Canada (**Figure ES 2**). For example, the average percentage of research spending on genetic improvements is more than 50% in the US, 44% in Australia, and 29% in Canada.

The next most significant RD&E investment theme is crop protection (weeds, pests, and disease management). This study has identified that Australia ranks first amongst top grains producing countries, with 24% of its funding allocated towards crop protection.

Figure ES 2 A comparison of current public research priorities (average last five years)



Source: GRDC, Agri-Food Canada and USDA

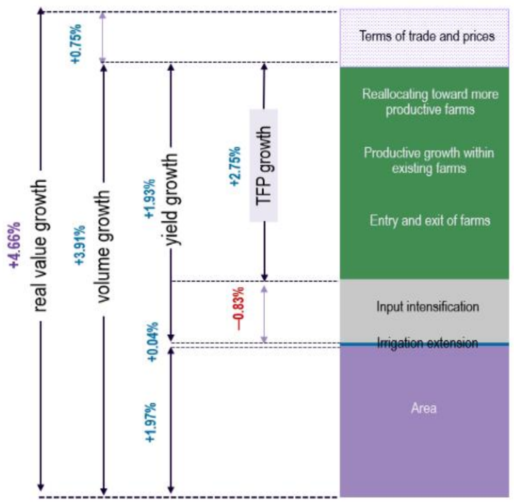
The third major category is agronomic and farming systems research. Australia ranks lowest, with 12% of funding allocated to this theme.

Australia's RD&E spending on automation is comparable with Canada's expenditure. The US reported the lowest share of automation spending among these three countries.

RD&E expenditure on market access is lower for Australia than for Canada but higher than in the US.

This report examines a range of yield growth and productivity measures (in particular, Total Factor Productivity or TFP) across countries and crops. It finds that yield growth in wheat is mainly attributable to TFP growth rather than input intensification over the past 30 years in Australia (**Figure ES 3**). Over the past 30 years, the Australian wheat crop TFP growth was 2.8% per year. This growth is higher than the other countries analysed in this study.

Figure ES 3 Australian wheat value growth over the past 30 years



Source: Various

Table ES 1 summarises Australia's relative position against the benchmarks assembled for six other countries in this study.

The US is the largest economy, dominates agriculture RD&E and ranks top in most of the indicators analysed.

Australia ranks higher on research intensity than on agricultural and grains RD&E expenditure. Australia ranks higher on grains research priorities in crop protection and automation.

Table ES 1 Comparative RD&E benchmarks and rankings

	Aus	Arg	Bra	Can	Fra	Ind	US
Agriculture RD&E	5th	7th	4th	6th	3rd	2nd	1st
Grains RD&E	5th	7th	3rd	4h	6th	2nd	1st
Indicative current grain research priorities							
Farming systems	3rd			2nd			1st
Automation	1st			1st			3rd
Crop nutrition	3rd			2nd			1st
Genetics	2nd			3rd			1st
Market access	2nd			1st			3rd
Crop protection	1st			2nd			3rd

Source: Various

1

Introduction

1.1 Context and scope

In May 2022, GRDC engaged ACIL Allen to undertake a data-driven international benchmarking study for major GRDC grain crops. The study sought to demonstrate the position of Australia's grain industry relative to selected grain-producing nations across key macro and farm-level economic indicators. In particular, it aimed to compare Australia's RD&E private, industry, and public investment mix to its international competitors. This study compared RD&E investment relative to productivity growth in Australia and elsewhere.

This study's benchmarking outcomes provide valuable information to support GRDC's investment decision-making, engagement with key stakeholders (including industry and governments), and longer-term strategy formation. This study's scope includes an analysis of major GRDC's crops over the past 30 years to 2021. The crops analysed include:

— Wheat (US, Canada, France, Argentina, Australia)
— Barley (US, Canada, France, Australia)
— Maize (US, Brazil, Australia)
— Canola (Canada, Australia)
— Soybean (US, Canada, Brazil)
— Pulses (peas, lentils and chickpeas) (India, Australia)
— Other cereals (sorghum/millet) (US, Argentina, Australia).

The study's scope included an analysis of funding sources (private sector, public sector, industry, public sector government departments and other organisations) by country. The study also included a thematic analysis of RD&E expenditure encompassing: genetic improvement; agronomic and farming systems innovation; preventative/readiness research; market access and education; automation translation and extension; market information; and consumer analysis.

1.2 Approach

This study was undertaken as a collaboration between ACIL Allen and GRDC. This collaboration was essential to overcome the challenges of collecting and analysing country-based data. The study was undertaken through five key stages:

1. A *planning* stage that included the identification of data sources and potential stakeholders who may hold data in different countries.
2. A *refinement* stage that involved a recalibration of the data collection activities following a preliminary search and planning.
3. A *consultation and engagement* stage involved meetings and correspondence with representatives from selected countries to understand better the data sources that could be used to support the benchmarking and analysis (see **Appendix A** for a list of organisations that endorsed the consultation and engagement process).
4. A *full data search and collection* stage based on the outcomes of the engagement.
5. A *production, productivity, funding, expenditure and productivity analysis/benchmarking* stage based on the data collected from different sources.

1.3 How to read this report

This study has a large range of potential use cases. However, it is not intended to infer changes to Australia's RD&E grains funding arrangements or level are required. It is also not meant to infer that Australia or other countries perform at higher or lower levels than others. Many complex factors underpin the longer-term performance of a country's agricultural and grain-producing system, which are beyond the reasonable scope of this analysis.

We have assembled these benchmarks from a large range of public and privately held sources. Some of these sources are based on the work of country specialists, government bodies and international organisations.

This approach has been necessary because, to our knowledge, there is no internationally comparable and consolidated database on grain RD&E and productivity. While every attempt has been made to collect the data required for benchmarking, it is important to note there are some unavoidable gaps in this analysis. Where possible we have attempted to address these gaps through assumptions based on published research and academic studies.

Production and yield analysis

2

2.1 Production environment

This study has considered the production environments of Australia and other grain-producing countries and the key metrics of those environments.

It is important to note that many factors influence grain crop production and yield, and exploring them in detail over an extended timeframe is impossible. In the sections below, we discuss the most significant factors underpinning production.

2.1.1 Grain producing regions

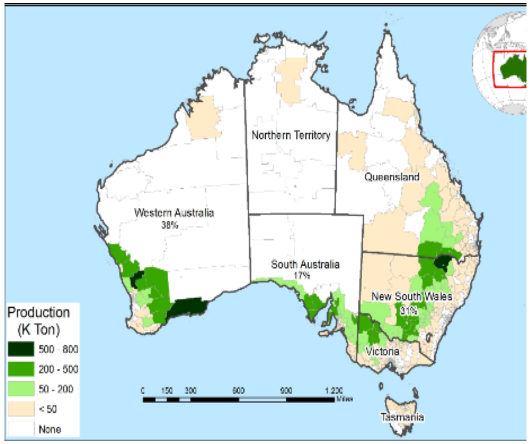
Grains are produced in northern (US, Canada, France, and India) and southern (Brazil, Argentina, and Australia) hemispheres, irrigated and rainfed, and varying climatic conditions and zones in each country. Even within irrigated and rainfed settings, there are different production systems and a continuum of technologies from full irrigation to total rainfed production.

Most of the world's grain crops are grown under rainfed systems.

Figure 2.1 shows the wheat production areas in Australia. The map shows higher-intensity production in Central and Southern Queensland, Northern, Central, and Southern New South Wales, North Western Victoria, Southern South Australia, and Western Australia's Southern, Western and Central regions.

Maps of the other grain-producing regions examined in this study are provided in Appendix B.

Figure 2.1 Wheat growing areas in Australia



Source: USDA

2.1.2 Crops and production factors

Wheat is the major (winter) crop grown in Australia, with sowing starting in autumn and harvesting, depending on seasonal conditions, occurring in spring and summer.

Making more productive use of farming inputs, especially water, reduces inputs and increases grain crop yields.

Australia has reported the lowest annual mean rainfall of all the prominent grain crop-producing countries, which has widely varied from year-to-year.[1] To address this, water use efficiency has been an important focus of R&D in the Australian grains system. A range of research papers examined for this study suggests that this focus has contributed to average yield growth, even in the face of significant decadal drought.[2]

As noted, all countries examined in this study have vastly different production systems. These differences are based on economic development or maturity levels, climate and environment suitability, R&D and adoption systems, domestic needs, and export potentials. Australia is catching up on yield potentials of significant grain crops, including wheat and barley, as a nation with relatively high climate variability. Over the past three decades, Australia has become a significant producer and exporter of canola and is steadily growing its production and exports of pulses.

[1] FAO (2020), The State of Food and Agriculture 2020. Overcoming water challenges in agriculture. Rome.

[2] Hochman, Z., Gobett, D. and Horan, H. (2017) 'Climate trends for stalled wheat yields in Australia since 1990', Global Change Biology, vol. 23.

2.2 Production and yield

This section discusses the key findings from the crop-based benchmarking undertaken for this study.

2.2.1 Wheat

Figure 2.2 shows the top 10 wheat-producing countries (by volume).

Global wheat production grew by an average of 2.1% per year from 233 million tonnes (MT) in 1961 to 776 MT in 2021. China and India accounted for over 30% of the world's wheat production in 2021. That same year, the top 5 producing countries grew over half the total global quantity of wheat produced, with just ten countries accounting for almost 82% of the world's wheat production.

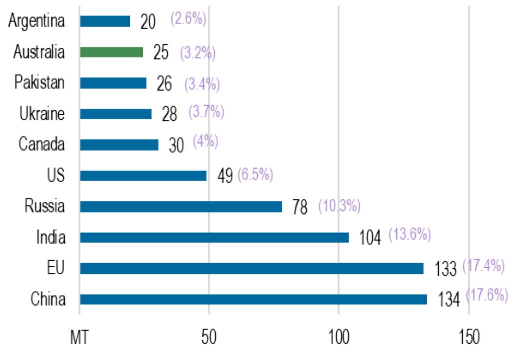
China is the world's largest wheat producer, with 134 MT per year (or 17.6% of the world's annual production volumes), followed closely by the EU. India is third, with over 100 MT produced yearly. Russia, the US, Canada, Ukraine, and Pakistan follow this.

Wheat accounts for most of Australia's grain production. Australia produces around 3% of the world's wheat (about 25 million tonnes annually).

Russia was a major exporter of wheat in 2021. However, it is unclear what impact Russia's war with Ukraine will have on grain production and exports. Nearly half of Russia's production was exported, which accounts for over 19% of global wheat exports.

Australia's wheat industry is export-oriented, shipping about 68% of its production to more than 50 countries. Australia ranks sixth in wheat exports based on the 5-year average and third based on current-year export volumes.

Figure 2.2 Top 10 wheat countries



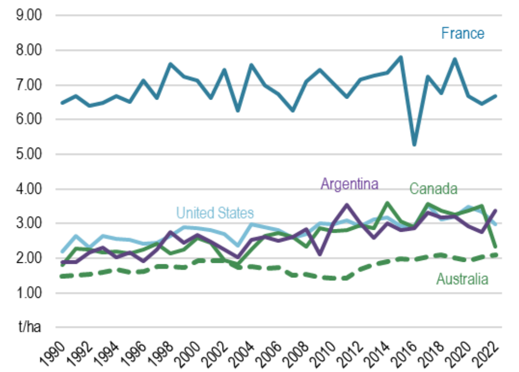
Source: USDA PSD Database

Figure 2.3 shows yield trends in 5 wheat-producing countries, including Australia. Wheat yield (tonnes/ha) varies yearly due to several factors, including soil conditions, temperature variations, rainfall, climate conditions, fertiliser and pesticide use intensity, and wheat varieties.

Figure 2.3 also shows that Australian wheat yield is trending at similar levels to other major wheat-producing countries like Canada, Argentina, and the US. However, Australia has experienced continuous growth over the past decade, whereas similar countries have experienced volatility in their growth levels.

That said, Australia's average yield levels over time are significantly below France, which has had the highest wheat yield over the past forty years, at around 7 tonnes/ha.

Figure 2.3 Wheat yield (t/ha)

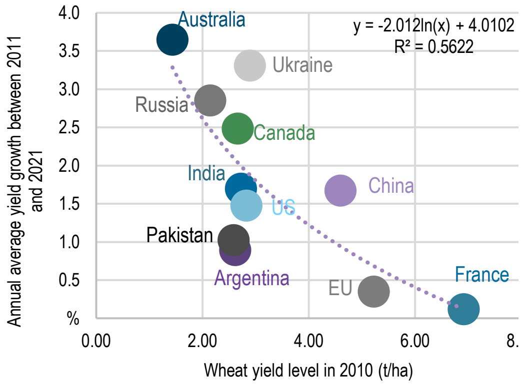


Source: USDA PSD Database

Figure 2.4 provides another way of illustrating yield growth against yield levels over the past 40 years. This Figure shows there has been convergence in yield levels amongst top wheat-producing countries, with established and traditionally high-yielding countries growing slower than the new wheat-growing countries.

The yield convergence may be explained by countries with lower initial yield levels being more likely to increase their yields faster than countries with higher initial yield levels. This explanation appears supported by a downward trend among the selected wheat-producing countries in **Figure 2.4**.

Figure 2.4 Wheat yield convergence

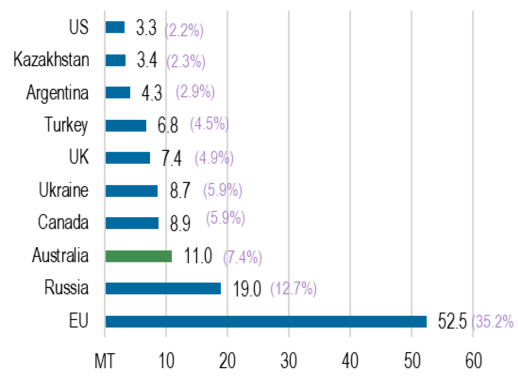


Source: Based on USDA PSD Database and FAO database

2.2.2 Barley

Globally 70% of barley production is used as animal fodder, while 30% is used as a fermentable material for beer, certain distilled beverages, and food processing. In 2021, barley was the fourth most produced grain in the world (149 million tonnes) behind maize, rice, and wheat. **Figure 2.5** shows the top ten barley-producing countries. Worldwide nearly 150 MT of barley is produced annually. The EU is the largest barley producer in the world, with 52.5 MT or 35% of the world's production volume per year, followed closely by Russia and Australia. Australia ranks third in barley production based on the 5-year average production volumes. The top 10 counties produced 84% of global barley production.

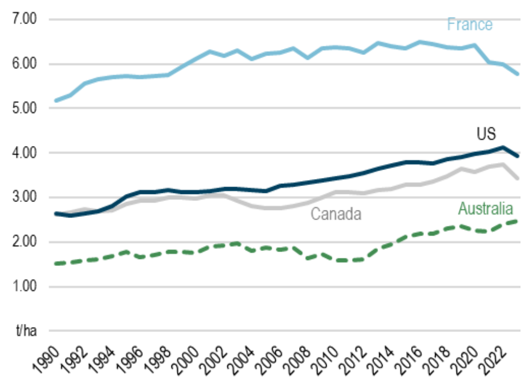
Figure 2.5 Top 10 barley countries



Source: Based on USDA PSD Database and FAO database

Yield trends in major barley-producing countries are provided in **Figure 2.6**.

Figure 2.6 Barley yield (t/ha)



Source: Based on USDA PSD Database and FAO database

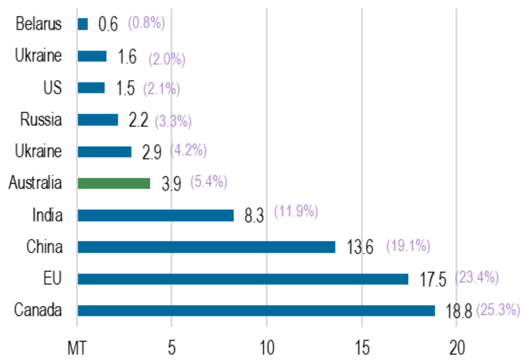
Australia's barley yield was lower than other major barley-producing countries. It averaged around 1.6t/ha until 2012 and increased to 2.5t/ha in 2022. However, Australia ranks first in annual average yield growth of 4.1% over the past decade, followed by Ukraine and Kazakhstan.

2.2.3 Canola

Figure 2.7 shows the top ten canola-producing countries. These countries account for 98% of global canola production.

Worldwide nearly 73 MT of canola is produced per year. Canada is the largest canola producer in the world, with 18.8 MT (or 25.3% of the world's production), followed closely by the EU, China, India, and Australia. Australia ranks fifth in canola production based on the 5-year average production volumes.

Figure 2.7 Top 10 canola countries



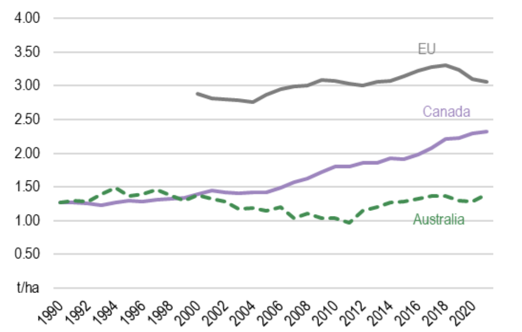
Source: Based on USDA PSD Database and FAO database

Figure 2.8 compares Australian canola yield trends with the major canola-producing countries.

The EU reported the highest canola yield on average, around 3t/ha. Australia's canola yield was comparable to Canada's in the early 1990s. However, they have diverged in yield levels since the early 2000s.

Both Australia and Canada averaged around 1.4/ha in 2000 and Australia increased to 1.4t/ha by 2021 while Canada increased to 2.3t/ha by 2021.

Figure 2.8 Canola yield (t/ha)



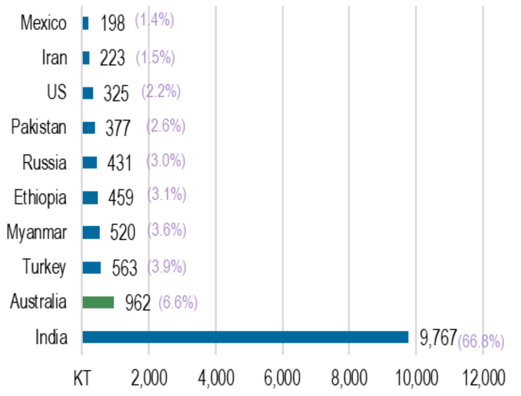
Source: Based on USDA PSD Database and FAO database

2.2.4 Chickpea

The top 10 chickpea-producing countries are shown in **Figure 2.9**. These countries account for 95% of global chickpea production.

Worldwide, over 15 MT of chickpeas are produced per year. India is the largest chickpea producer in the world, with nearly 10 MT (or 66.8% of world production volume per year), followed by Australia, Turkey, Myanmar and Ethiopia. Australian production based on the 5-year average production volumes was 962 KT.

Figure 2.9 Top 10 chickpea countries

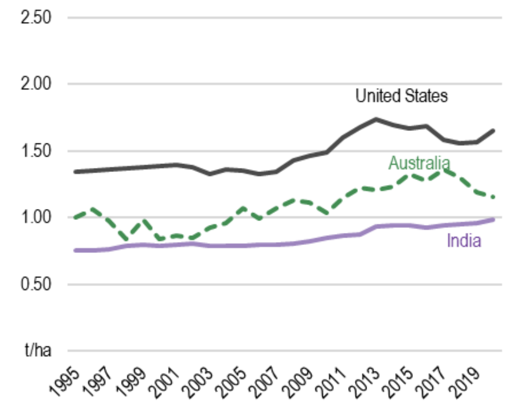


Source: Based on USDA PSD Database and FAO database

Australian chickpea yield trends are compared with the major producing countries in **Figure 2.10**.

Australia's chickpea yield was higher than India's yield and lower than the US. This is mainly due to the varietal differences and different agronomic practices. Australian growers practice narrower rows, higher plant populations, and earlier sowing to yield more than Indian chickpea growers. Most chickpea crop is grown under irrigated conditions in the US, resulting in higher average yields.

Figure 2.10 Chickpea yield (t/ha)



Source: Based on USDA PSD Database and FAO database

2.3 How does Australia's production rank internationally?

Table 2.1 summarises Australia's ranking against the top 10 countries in production, exports, and yield of major grain crops over the past ten years.

The table shows that Australia ranks top in some measures but not in all indicators for all grain crops.

For example, Australian average wheat yield levels are lower among the top ten wheat-producing countries. Still, Australia's 10-year yield growth rates are higher than other major producing countries.

Similarly, Australia ranks second in chickpea production (a minor crop) and first in export. Still, yield levels and growth rates are moderate compared to the countries analysed in this study.

Australia's chickpea production and exports have decreased recently due to the import tariff introduced by India in 2017. India applied tariffs of 33% to both lentils and chickpeas in 2017. India imposed tariffs on lentils and chickpeas over the past eight years.

Table 2.1 Australia's production rankings

Crop	Global production (tonnes)	Exports (tonnes)	Yield level in 2021 (tonnes/ha)	10yrs growth (% in yield growth)
Wheat	9th	6th	10th	1st
Barley	3rd	2nd	8th	1st
Oats	4th	2nd	9th	2nd
Canola	5th	2nd	9th	2nd
Lupins	1st		9th	2nd
Triticale				4th
Chickpea	2nd	1st	6th	4th
Maize			6th	5th
Rye	10th			5th
Lentils	3rd	2nd	7th	5th
Millet			4th	8th
Sorghum		3rd	6th	
Canary	5th		9th	9th
Sunflower			9th	
Peanuts			5th	
Soybeans			9th	

Source: Based on USDA PSD Database and FAO database

3

Wheat TFP analysis

3.1 Total factor productivity growth

The yield trends provided in Chapter 2 are a type of productivity level representing the tonnes of wheat produced per hectare of land. However, yield alone does not capture all the inputs used to produce a tonne of grain.

Productivity growth helps growers offset the impact on the profitability of a declining trend in terms of trade (output prices relative to input prices). Improving productivity is the primary way grain growers can meet the challenges of uncertain seasonal conditions and other macroeconomic and trade factors beyond their control.

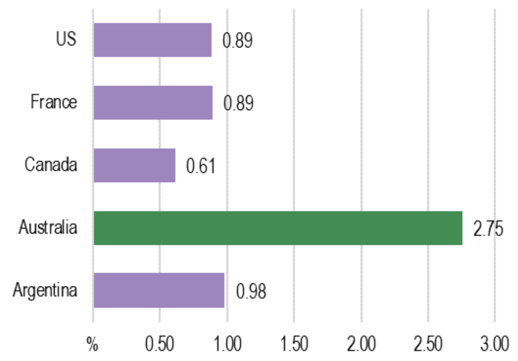
Productivity growth is analysed two main ways in the literature: 1) by considering all inputs; or 2) by considering primary factor inputs (such as land, labour and capital). The former is termed total factor productivity (TFP) and later multifactor productivity (MFP).

TFP considers all of the land, labour and capital, and material resources employed in production and compares them with the total gross output of a crop. If the total production is growing faster than the total inputs, this is an improvement in TFP. TFP differs from wheat yield per hectare or agricultural value-added per worker because it considers a broader set of inputs used in production. Therefore, TFP growth measures the output growth that cannot be explained by input growth alone.

3.2 Wheat TFP growth

Australian wheat TFP growth over the past 30 years is compared with the other major wheat producers, as shown in **Figure 3.1**. Compared with wheat TFP measures, yield, labour productivity, and water productivity are of limited use for summarising the overall productivity performance of wheat crop production.

Figure 3.1 Annual average wheat TFP growth rate over the past 30 years



Source: ACIL Allen estimates based on various data sources

The estimated Australian wheat TFP growth rate was higher than the five countries analysed in this study. This outperforming TFP growth can be attributable not only to economies of scale, as farms are getting bigger and using inputs more efficiently, but also RD&E focus and institutional arrangements for grain crops RD&E in Australia.

3.3 Wheat value growth

A decomposition of Australian wheat production value over the past 30 years (compared with other selected countries) is provided in **Figure 3.2**. The Figure shows that wheat production value growth in various countries is attributable to different drivers in different periods.

Australia

TFP growth was the main driver for Australia over the past 30 years.

Annual average wheat output value growth in Australia over the past 30 years indicate that real value growth of 4.7% was contributed by:

- 3.9% growth in volume
- 0.8% growth in relative prices

Volume growth of 3.9% was contributed by:

- 1.93% growth in yield (t/ha)
- 1.97% growth in area
- 0.04% growth in irrigated land

Yield growth was mainly attributable to TFP growth of 2.8% per year. Australia also uses lower inputs per unit of land on average while maintaining the output level. TFP growth includes the efficiency of input use.

Argentina

For Argentina and Canada, key drivers for wheat value growth were input intensification (more units of inputs used on land) and favourable terms of trade.

Wheat output value growth in Argentina over the past 30 years indicates that:

Growth in wheat prices contributed 35% of wheat output value growth (or 1.27%). Wheat volume growth of 2.40% was contributed by:

— 2% growth in yield
— 0.4% growth in area

Nearly 50% of yield growth was from the TFP growth and the other 50% was from higher use of other inputs (capital, labour, fertilizers, seed and others) in wheat production.

Based on the World Bank data, fertilizer use in arable land increased in Argentina, from 6kg/ha in 1990 to over 50kg/ha in 2020.

Canada

Annual average wheat output value growth in Canada over the past 30 years indicates that real value growth of 2.5% was contributed by:

— 0.31% growth in volume
— 2.19% growth in prices

Volume growth of 0.31% was contributed by:

— 1.77% growth in yield
— -1.43% growth in the area
— -0.03% growth in irrigated land

Yield growth is mainly attributable to input intensification on wheat cropping land.

Based on the World Bank data, fertilizer use in arable land increased in Canada, from 53kg/ha in 1990 to over 132kg/ha in 2020.

France

France reported negative value growth mainly attributable to input extensification (less input use on existing wheat production land) and unfavourable terms of trade.

Annual average wheat output value growth in France over the past 30 years indicates that real value growth of -0.70% was contributed by:

— 0.25% growth in volume
— -0.95% growth in prices

Volume growth of 0.25% was contributed by:

— 0.17% growth in yield
— 0.08% growth in the area

Yield growth was mainly attributable to TFP growth.

Based on the World Bank data, fertilizer use in arable land decreased in France, from over 300kg/ha in 1990 to under 170kg/ha in 2020.

The United States

For the US, the favourable terms of trade did not fully offset the decline it experienced in wheat area harvested.

The annual average wheat output value growth in the US over the past 30 years indicates that real value growth of 0.63% was contributed by:

— -0.61% growth in volume
— 1.26% growth in prices

Volume growth of -0.61 % was contributed by:

— 0.86% growth in yield
— -1.46 % growth in the area

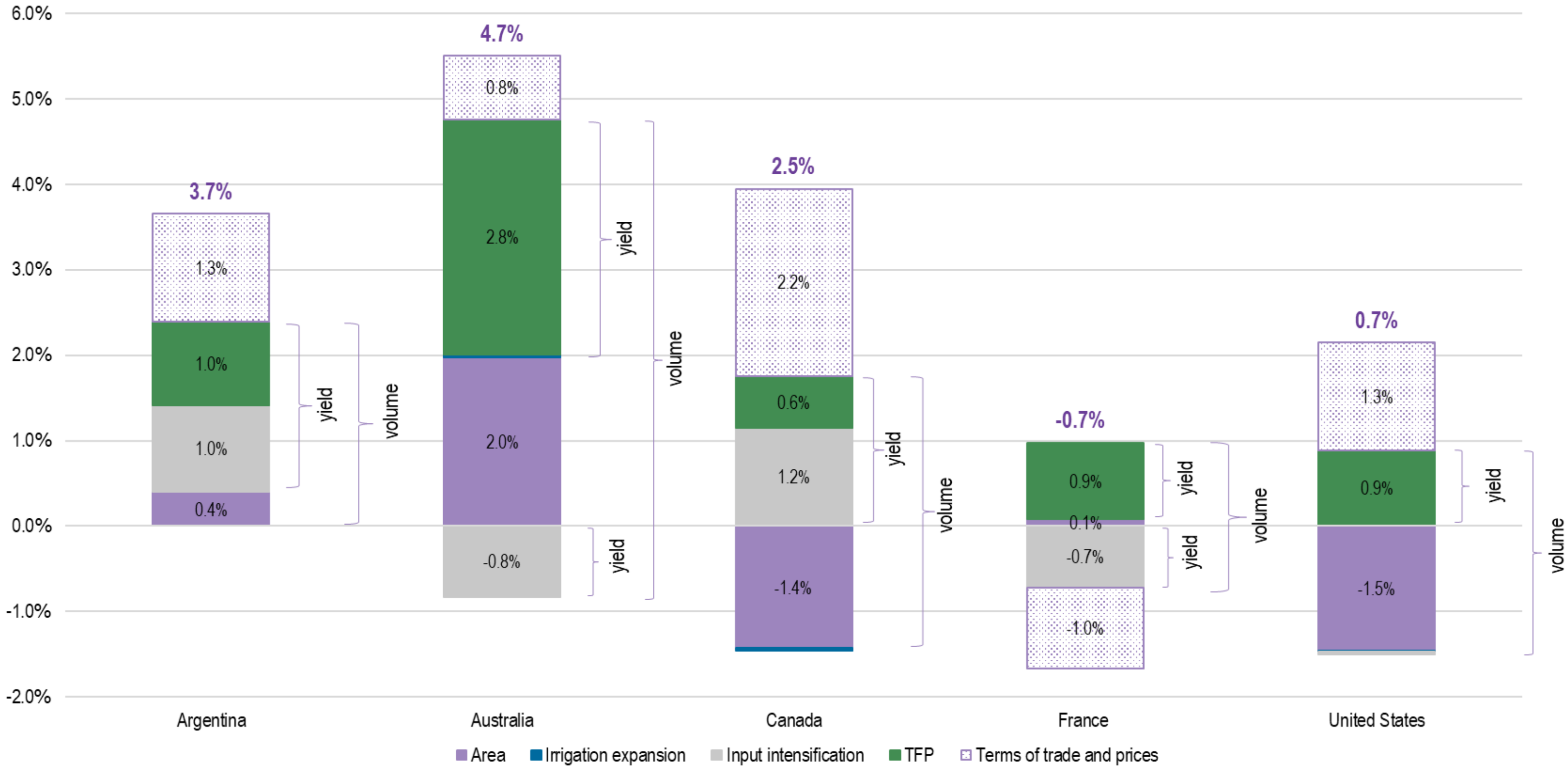
Yield growth is mainly attributable to TFP growth of 0.9%.

The decomposition of TFP estimates reveals a key element, without land expansion, all increases in output are attributable to yield improvements.

Moreover, yield improvements can be due to the more intense use of inputs and growth in TFP. Both of these can be affected by changes in commodity or input prices. For example, higher crop prices or real wages will increase the use of existing farmland and land improvement investments. But, in the short term, the ability to raise yields through intensification is primarily confined to existing technology and subject to diminishing returns.

Changes in TFP, on the other hand, are driven by innovations and changes in technology. Moreover, through investment in RD&E, incremental improvements to productivity can be sustained over the long term. Institutional frameworks that provide a constructive ‘enabling environment’ can stimulate investment in innovation and adoption.

Figure 3.2 A comparison of wheat annual average output value growth over the past 30 years



Source: ACIL Allen estimates based on various data sources

Australian average wheat production costs are slightly higher than Canada and lower than the US.

Australia's growth in wheat production value over the past 30 years has been 4.7% per year. This growth has occurred within the context of GRDC's investment period, significant drought (between 2013-2019), and favourable terms of trade (on average, wheat prices in US$ are slightly higher than the inputs costs in US$). Our analysis has shown that TFP has significantly contributed to wheat volume growth in Australia over the past 30 years. On average, wheat growers achieved 2.8% of yearly productivity growth over the past 30 years. The area harvested also contributed positively to the wheat value growth at around 2% per year. Irrigation expansion contributed 0.04% to the value growth. Australian wheat value growth has been higher than the other four countries analysed in this study over the past 30 years.

4

RD&E expenditure analysis

4.1 Agriculture RD&E expenditure

Predictions for growth in demand for food over the coming 20–40 years, combined with the rise of biofuels and a changing climate, have raised renewed concerns about whether the world is investing enough in R&D that delivers crop improvement, soil, water, and environmental sustainability, and disease and pest-resistant varieties. Such investment is significant for staple food grains (such as wheat), which have important economic, population health, and even social roles in our societies.

ACIL Allen has sought to collect information about government investment in agricultural research as part of this benchmarking study. We have observed a general trend that government investment has declined in several developed countries over the past decades. This decline is due to many economic and public policy assessments (at the national and multi-country levels), which have demonstrated consistently high returns from publicly funded research.[3]

By contrast, the proportion of private sector research funding investment has grown over the past decades. While it is difficult to document and account for much of this funding internationally, it appears that it has grown and is likely to continue (in some countries) over the coming decades.

4.1.1 Public investment in RD&E

Figure 4.1 summarises the annual average level of public agriculture RD&E expenditure by country over the past five years.[4]

The US is a significant investor in agriculture RD&E, investing nearly US$5.6 billion per year. The high level of yearly investment in the US is mainly due to the size of the agriculture sector.

The US is followed by India, which invested around US$1.8 billion annually. India ranks second among the seven selected countries for public agricultural R&D expenditure.

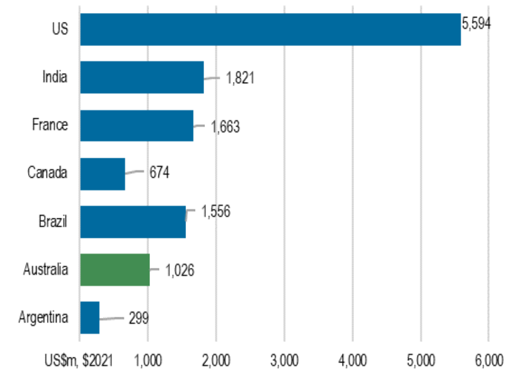
France lies in third place with investments of US$1.7 billion.

Canada invested the least of the selected developed economies analysed in this report, at around US$674 million annually.

Argentina was the lowest among the selected countries, with only US$299 million of public agricultural R&D expenditure.

Australia ranks fifth of selected countries in total public agriculture RD&E expenditure.

Figure 4.1 Annual level of agriculture public RD&E expenditure (average last five years)



Source: ACIL Allen estimates based on various sources

4.1.2 Trends in public RD&E

The countries examined in this study have used various policy instruments to address the under-investment problem in agriculture research.

For example, Australia adopted a commodity-based levies model to fund research investments for which the primary beneficiaries are the producers and consumers of the commodity. This approach is called in the literature a *collective industry goods approach*. An alternative approach adopted by Canada is to use more substantial intellectual property rights (IPRs) to attract private investment into

[3] Alston, J M (2010), "The Benefits from agricultural Research and Development, Innovation, and Productivity Growth", OECD Food, Agriculture and Fisheries Papers, No. 31, OECD Publishing, Paris.

[4] Grower levies spend by public organisations are included in the public agriculture expenditure.

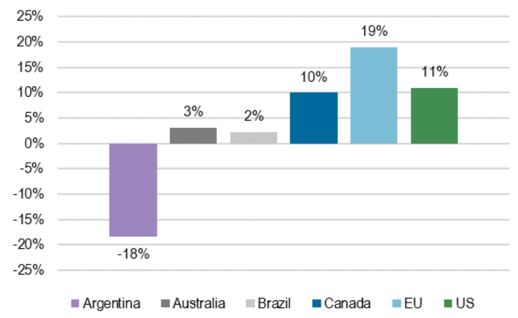
crop breeding. This is called *a private goods approach*. Both of these approaches rely on private funding rather than government funding. However, they have different implications for the total level of investment in RD&E made in each country. They also have implications for distributing the benefits arising from that investment. The Australian system has undergone significant transformation over the past 30 years. It has moved from a predominantly publicly funded and managed system (that provided wheat varieties to growers free of charge) into an approach centred on levy-based funding and, more recently, to predominantly royalty-based funding for new wheat varieties. This transformation has significantly increased the total funding for wheat varietal improvement (currently around 44% of GRDC's funding allocation).

Farm Bills primarily govern agricultural policy in the US. Farm Bills authorise agricultural and food policies in nutrition assistance, crop insurance, commodity support, conservation, and agricultural research.

Agriculture research funding in Argentina comes directly from the Secretary of Agriculture and is highly volatile and determined by the government's priorities of the day. Brazil has one of the most well-developed and well-funded agricultural research systems in the developing world, ranking third in public agricultural RD&E investments after China and India. Brazil's agricultural research system is complex because of its size, the number of agencies involved, and the dual role the federal and state governments play in the system.

Governments choose various policy instruments to assist the agriculture sector. Australia's support to agricultural producers (PSE) is among the lowest in the OECD, estimated at 3% of gross farm receipts for 2019-21, as shown in **Figure 4.2**. The support given to agriculture research, innovation, and research infrastructure is around 3% of the value of agricultural production in Australia,[5] with approximately one-quarter of total public expenditure for agriculture directed to support rural research.

Figure 4.2 Producer support estimates, 2019-21



Source: OECD (2022) Agricultural Policy Monitoring and Evaluation 2022

Support to producers in Argentina has been negative since the beginning of the 2000s, reflecting export taxes that decrease domestic prices producers receive. Brazil is a competitive agricultural exporter, reflected in its relatively high exports and low levels of support and protection to the sector. Producer support as a share of gross farm receipts fell from 7.6% in 2000-02 to 2.3% in 2019-21.

Canada has significantly reduced support for agriculture since the late 1980s. Producer support as a share of gross farm receipts was halved from 1986-88 to 2000-02 primarily due to the discontinuation of market price support in 1995. Producer support was halved again by the early 2010s and averaged about 10% of gross farm receipts in 2019-21.

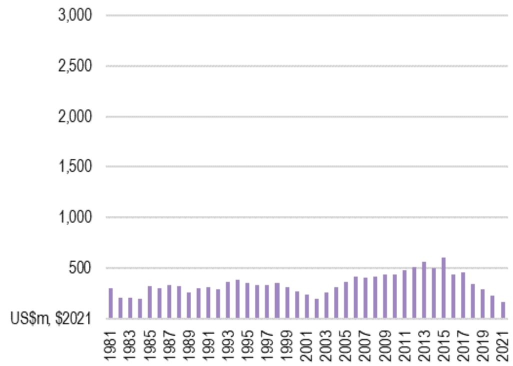
US producer support averaged 11% of gross receipts in 2019-21. While market price support has declined, budgetary support has increased over time, covering mainly risk management, crop insurance, and, more recently, compensation for the effects of the COVID-19 pandemic. The counter-cyclical nature of budgetary support links it to market price developments, such that periods of high commodity prices, as in 2012-13 and 2021-22, typically see lower levels of support.

The levy system appears to provide a relatively stable level of RD&E funding in Australia (compared to other countries) over a long period. However, this observation is difficult to test or prove empirically.

Figure 4.3 to **Figure 4.9** shows trends in public agriculture RD&E of selected countries between 1980 and 2021.

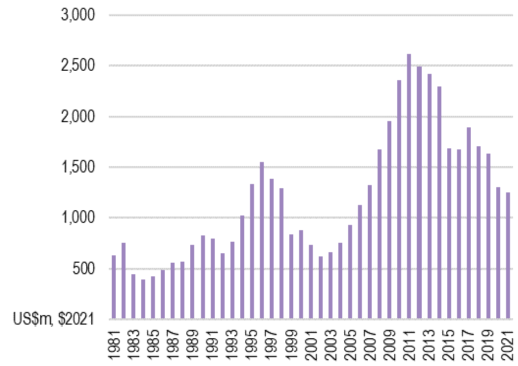
[5] With the agriculture production value of A$70bn, the value of PSE is around A$2bn.

Figure 4.3 Argentina: public agriculture research expenditure



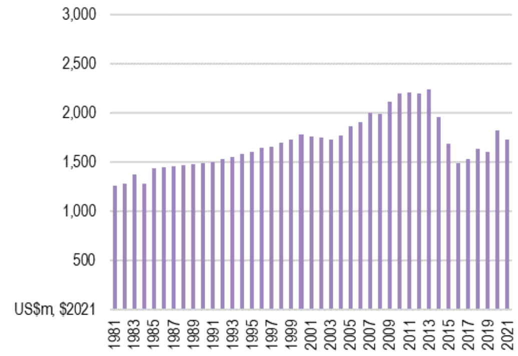
Source: Various

Figure 4.5 Brazil: public agriculture research expenditure



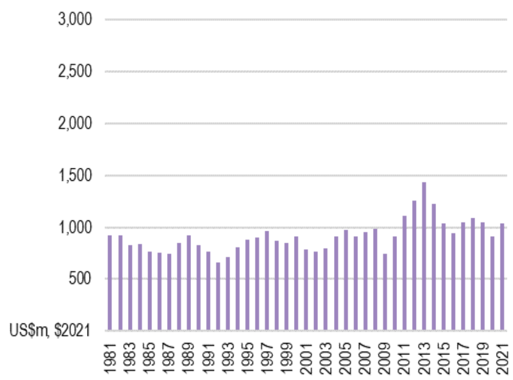
Source: Various

Figure 4.7 France: public agriculture research expenditure



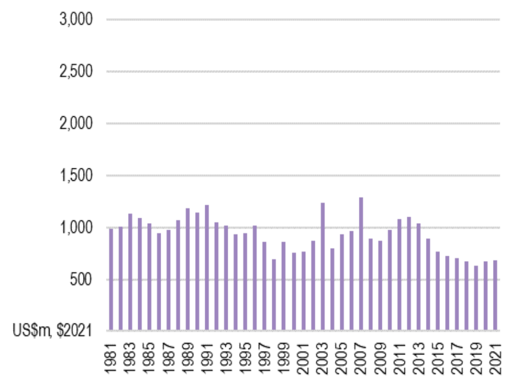
Source: Various

Figure 4.4 Australia: public agriculture research expenditure



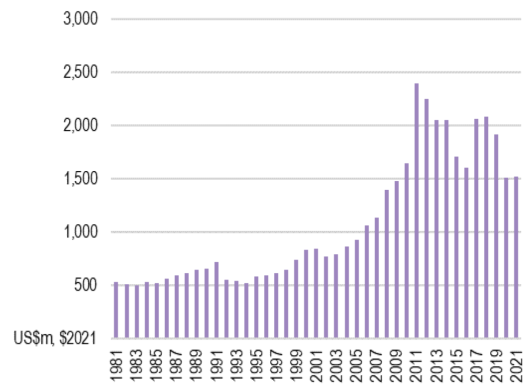
Source: Various

Figure 4.6 Canada: public agriculture research expenditure



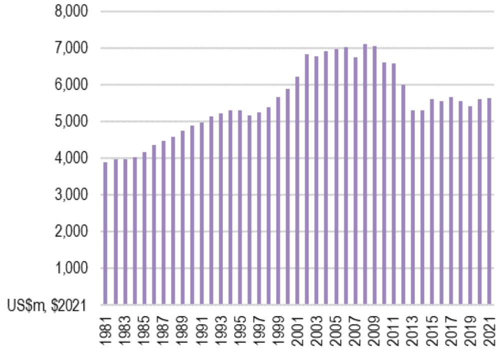
Source: Various

Figure 4.8 India: public agriculture research expenditure



Source: Various

Figure 4.9 The US: agriculture research expenditure



Source: Keith Fuglie

Scientific advances in biotechnology, globalisation of food and agricultural markets, more robust legal protection for intellectual property, and changes in agricultural and regulatory policies affected the incentives for private industry to invest in food and agriculture RD&E. Not only has private agricultural spending increased, as shown in the figures above for several countries, but the industries that supply agricultural inputs (seeds, chemicals, and machinery) to farmers have undergone significant structural transformations in recent years. Although most private agricultural RD&E spending is by companies based in high-income countries (the US and Germany) essential changes have also occurred in developing countries. These changes are partly due to investments in multinational corporations (MNCs) and the emergence of significant local technological capacities in countries like India and Brazil.

Total Canadian public agriculture RD&E spending has declined as successive governments redirected funding to other national priorities. This is consistent with Canada's overall economy-wide public RD&E decline over the past decades. Other budget demands have seen some research funding re-allocated to address other economic and societal issues (such as the environment and food safety). The private sector has been active since Canada introduced the Canadian Plant Breeders' Rights Act in 2015. The Act has encouraged private sector investment (mainly in canola) by providing more certainty about intellectual property rights.

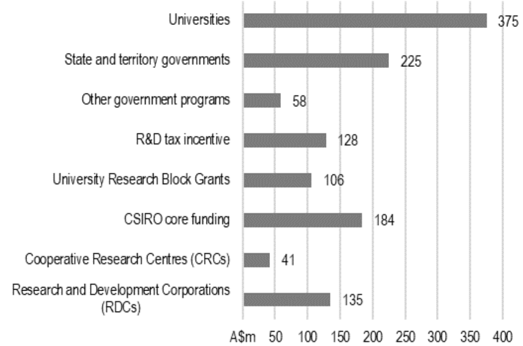
Figure 4.10 shows the public funding sources for agriculture research in Australia.[6] Australian Government contributions to GRDC is included in the total RDC's funding of A$135 million. On average, Australian Government contributed around A$68 million to the grain crops.

4.2 Grains RD&E expenditure

In most cases, published national RD&E data does not clearly distinguish grains RD&E from other sectors. This makes comparative analysis using publicly available data problematic because funding mechanisms and funding sources differ in each country for grains and other crops.

To illustrate the relative funding levels for grain crops, ACIL Allen undertook a comprehensive data search and literature review. This was further supported by directly contacting relevant organisations for unpublished funding sources and expenditure-type data. The lack of a systematic database for grains RD&E spending means that estimates have been either proxied by expenditure data or pieced together from various sources. Therefore, the RD&E expenditure estimates for grains in this report are only indicative.

Figure 4.10 Public agriculture research funding in Australia (average last five years)



Source: ABARES 2023. The data is in nominal Australian dollars. This public funding data excludes levies collected by RDCs on behalf of growers.

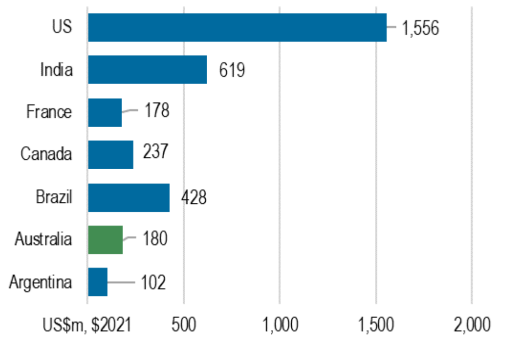
Figure 4.11 summarises the annual level of estimated grains public RD&E expenditure by country.[7] It shows that the US is a major investor

[6] Grower levies are not included under public funding.

[7] Grower levies spend by public organisations are included in the public grains RD&E expenditure.

in grains RD&E. It invested nearly US$1.6 billion annually from public sources, and private companies in the US performed significant research related to farm inputs and farm machinery. India ranks second in the annual grains RD&E investments, followed by Brazil and Australia.

Figure 4.11 Annual grains public RD&E expenditure (last five years)



Source: Various

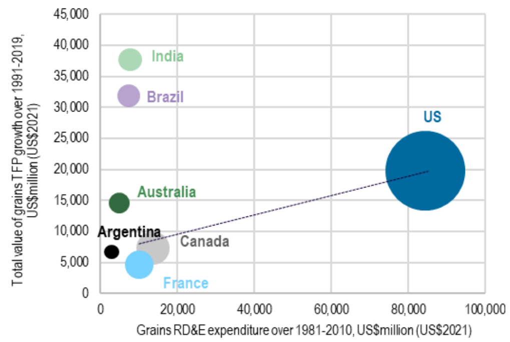
4.3 Grains TFP and RD&E expenditure

Figure 4.12 shows the investment in grains RD&E and the value of grains productivity growth in seven grain-producing countries. The Figure illustrates how improvements to agricultural productivity affected agricultural output. Even in countries where agricultural output stagnated, TFP growth freed up resources for use elsewhere in the economy. The Figure plots a simple correlation between the value of TFP improvements (y-axis) and the RD&E investment (x-axis). TFP benefits are the cumulative totals between 1991 and 2019 of nearly 30 years measured in constant 2021 US dollars (real dollars).

RD&E is the cumulative total between 1981 and 2010, measured in constant 2021 US dollars. This indicates an investment lag of 10 years. Agriculture research expenditures estimated in this study are summed over 1981-2010 and USDA and ABARES (Australia) productivity improvements over 1991–2019 to account for the lag between the time that research is initiated and the time it is likely to affect farm productivity. ACIL Allen's analysis suggests that the value of productivity improvements exceeded the cost of RD&E for India, Brazil, and Australia. For India and Brazil this is mainly due to the spillover benefits received from the investment in research by other developed countries.

The analysis also suggests that countries investing more in RD&E achieved remarkable productivity growth. This can be illustrated by the Figure's upward-sloping line, which is the average relation between RD&E spending and the value of TFP growth benefits.

Figure 4.12 Investment in grains RD&E and value of grains productivity growth



Source: ACIL Allen estimates

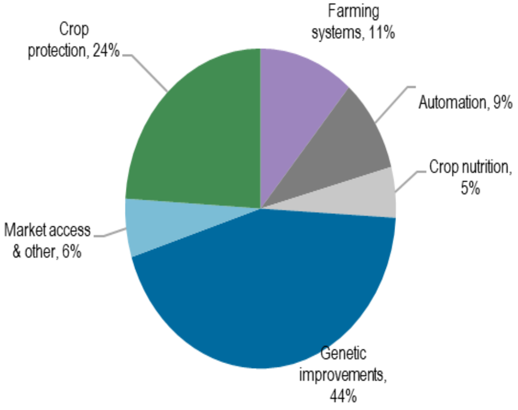
4.4 Research priorities for grain crops

Public research funding, spending, and prioritisation of grain research projects vary across the countries analysed in this study. Unfortunately, much of the data needed to compare countries is unavailable. So ACIL Allen has only reported grain-focused RD&E in Australia, Canada, and the US.

4.4.1 Australia

GRDC's research allocation over the past five years has focused on yield improvements (44%) and weeds, pests, and disease improvements (24%) (**Figure 4.13**). Compared to the previous 5-year Strategic Plan (2013-2017), the current Plan (2018-2022) allocated more investment towards agronomic, farming systems innovation, automation and crop nutrition. In the current GRDC's Strategic Plan, in addition to the above categories, GRDC invested nearly $26 million in climate-related research and almost $18 million in biosecurity-related aspects. These investments demonstrate GRDCs capability and capacity to support these areas, delivering returns to growers. These investments complement GRDC's other crop, disease and pest research where required.

Figure 4.13 GRDC's current research priorities

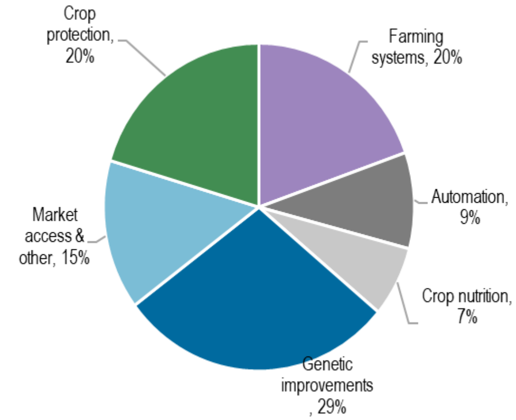


Source: GRDC

4.4.2 Canada

Federal and provincial governments are significant investors and performers of agricultural RD&E, catalysing partnerships across sectors and establishing policies and programs to support research and innovation activities. Agri-Food Canada's recent grains research focus is shown in **Figure 4.14**. They only represent a small part of the entire Canadian system. These priorities focus mainly on sustainable grain production that can adapt to climate change and declining soil conditions (16.6%) and research that delivers increased crop protection (20.4%).

Figure 4.14 Canada's current research priorities

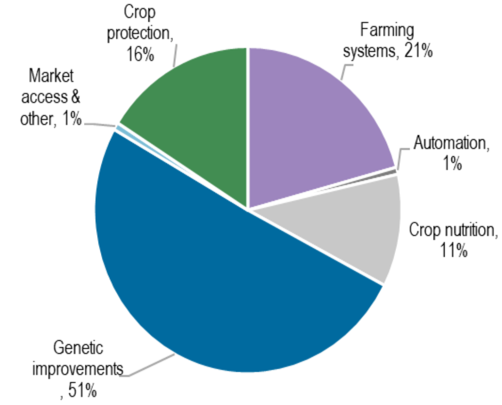


Source: Agri-Food Canada

4.4.3 The US

Figure 4.15 summarises total grain crop RD&E spending in the US by the public sector. In 2019, nearly 51% of grain RD&E spending was on genetic improvements, followed by farming systems (21%). An average percentage of recent grain research on genetic improvements dominates in all three countries – Australia, Canada, and the US. More than 50% of the US's grain research expenditure was allocated to genetic improvements. This category share is around 44% of GRDC funding allocation in Australia and approximately 29% in Canada.

Figure 4.15 The US's current research priorities

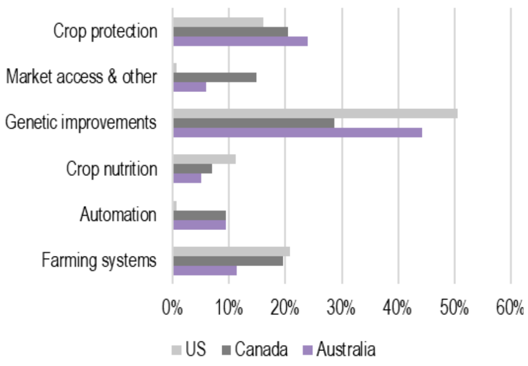


Source: Keith Fuglie USDA

4.4.4 Comparing Australia's portfolio to other countries

At a very high level, it is possible to conclude that GRDC's investment mix (or portfolio funding allocations) is *broadly* comparable to public spending on grain research in Canada and the US, as shown in **Figure 4.16**. The following investment category is crop protection – weeds, pests, and disease management. Australia ranks first, with 24% of GRDC's funding allocated to crop protection. The third major category is agronomic and farming systems research. GRDC's spending on automation is comparable with Canadian spending. The US reported the lowest share of automation spending among these three countries. Research spending on market access is lower for Australia than for Canada but higher than for the US. Data for other countries analysed in this study is unavailable, so comparisons have not been undertaken.

Figure 4.16 A comparison of spending on research priorities



Source: GRDC, Agri-Food Canada, and USDA

4.5 How does Australia's RD&E funding rank internationally?

Table 4.1 summarizes Australia's ranking in agriculture and grains public RD&E, and similarities and differences in the portfolio of investment in Australia compared to the top 10 countries in each category. The US is the largest economy, dominates agriculture RD&E, and ranks top in most key indicators analysed. However, Australia ranks top in agriculture and grains research intensity. The allocation of grain research funding to key Australian research themes in Australia is broadly comparable to Canada and the US.

Table 4.1 Public RD&E rankings

	Australia	Argentina	Brazil	Canada	France	India	US
Agriculture public RD&E	5th	7th	4th	6th	3rd	2nd	1st
Grains public RD&E	5th	7th	3rd	4th	6th	2nd	1st
Indicative current grain research priorities							
Farming systems	3rd			2nd			1st
Automation	1st			1st			3rd
Crop nutrition	3rd			2nd			1st
Genetics	2nd			3rd			1st
Market access	2nd			1st			3rd
Crop protection	1st			2nd			3rd

Source: Various.

A

Data sources and contacts

Supporting information

ACIL Allen contacted 58 organisations, agencies, and individual to collect data for this report. The tables below show the key data sources, and organisations and individuals provided information and data we used to benchmark agriculture and grain RD&E across the selected countries.

Table A.1 Organisations contacted

Organisation	Link
USDA ERS (US Department of Agriculture – Economic Research Service)	https://www.ers.usda.gov/
ABARES (Australian Bureau of Agricultural and Resource Economics)	https://www.agriculture.gov.au/abares
FAO (Food and Agriculture Organization)	https://www.fao.org/home/en
ASTI (Agricultural Science and Technology Indicators)	https://www.asti.cgiar.org/
World Bank	https://www.worldbank.org/en/topic/agriculture
OECD (Organisation for Economic Co-operation and Development)	https://www.oecd.org/
ISTA	https://www.seedtest.org/en/home.html
CIMMYT (International Maize and Wheat Improvement Center)	https://www.cimmyt.org/
INDEC (National Institute of Statistics and Census of Argentina)	https://www.indec.gob.ar/
Statistics Canada	https://www.statcan.gc.ca/
BEA (Bureau of Economic Analysis)	https://www.bea.gov/
EMBRAPA (Brazilian Agricultural Research Corporation)	https://www.embrapa.br/en/international
Horizon Europe	https://research-and-innovation.ec.europa.eu/select-language?destination=/node/1
Alberta Wheat and Barley Commission	https://www.albertawheatbarley.com/alberta-barley
Alberta Canola Producers Commission	https://albertacanola.com/
Sask Wheat Development Commission	https://saskwheat.ca/
Sask Barley Development Commission	https://saskbarley.com/
Sask Canola Development Commission	https://www.saskcanola.com/
Sask Pulses Growers	https://saskpulse.com/
Manitoba Crop Alliance	https://mbcropalliance.ca/
Manitoba Canola Growers	https://canolagrowers.com/
Manitoba Pulse and Soybean Growers	https://www.manitobapulse.ca/
Grain Farmers Ontario	https://gfo.ca/
Ontario Pulse Crop Committee	https://www.gobeans.ca/

Source: ACIL Allen

Table A.2 Stakeholders directly consulted

Name	Organisation
Keith Fugile	USDA ERS (US Department of Agriculture – Economic Research Service)
Andrew Sowell	USDA (US Department of Agriculture)
Fidel Castañeda Nava	CIMMYT (International Maize and Wheat Improvement Center)
Alexandra Bunton	Bayer
Phil Pardey	University of Minnesota
Deborah Rondanini	University of Bueno Aires
Richard Gray	University of Saskatchewan
Holly Mayer & Bruno Lami	Agriculture and Agri-food Canada

Source: ACIL Allen

Production regions

B

Supporting information

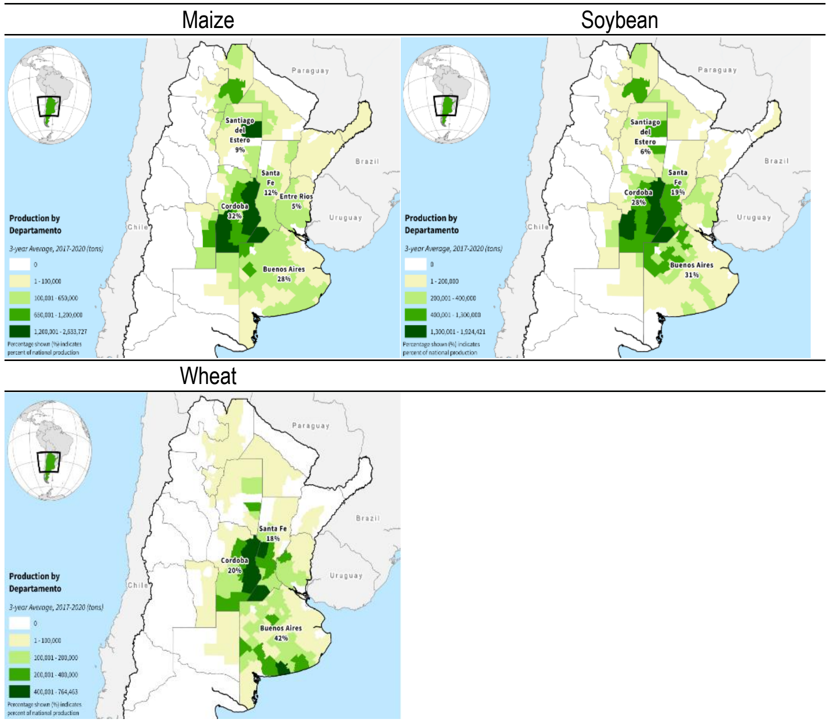
B.1.1 Argentina

Argentina is a major producer of soybeans and ranks third in volume of production and exports after the US and Brazil. Australia competes with Argentina in international markets mainly for wheat, barley, maize, sorghum, safflower, chickpea and peanuts.

The Argentinian economy has experienced sustained economic crises and uncertainty over the past decades.

Agricultural production in Argentina is dominated by extensive farming and mechanisation, and modern technologies in the Pampas region.

Figure B.1 Production regions of Argentina



Source: USDA

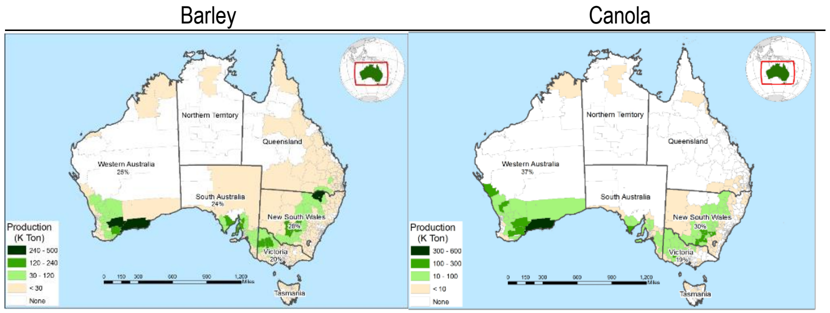
B.1.2 Australia

Agriculture represents a small share of the Australian economy, accounting for just over 2 per cent of GDP in 2021.

Australia is an important producer of agricultural commodities.

Wheat is the major winter crop grown in Australia with sowing starting in autumn and harvesting, depending on seasonal conditions, occurring in spring and summer with most being sold overseas.

Figure B.2 Production regions of Australia



Source: USDA

B.1.3 Brazil

Brazil is among the world's leaders in the production of soybeans, poultry, beef, cotton, corn, and orange juice, being the third biggest exporter of agro-food products after the European Union and the United States.

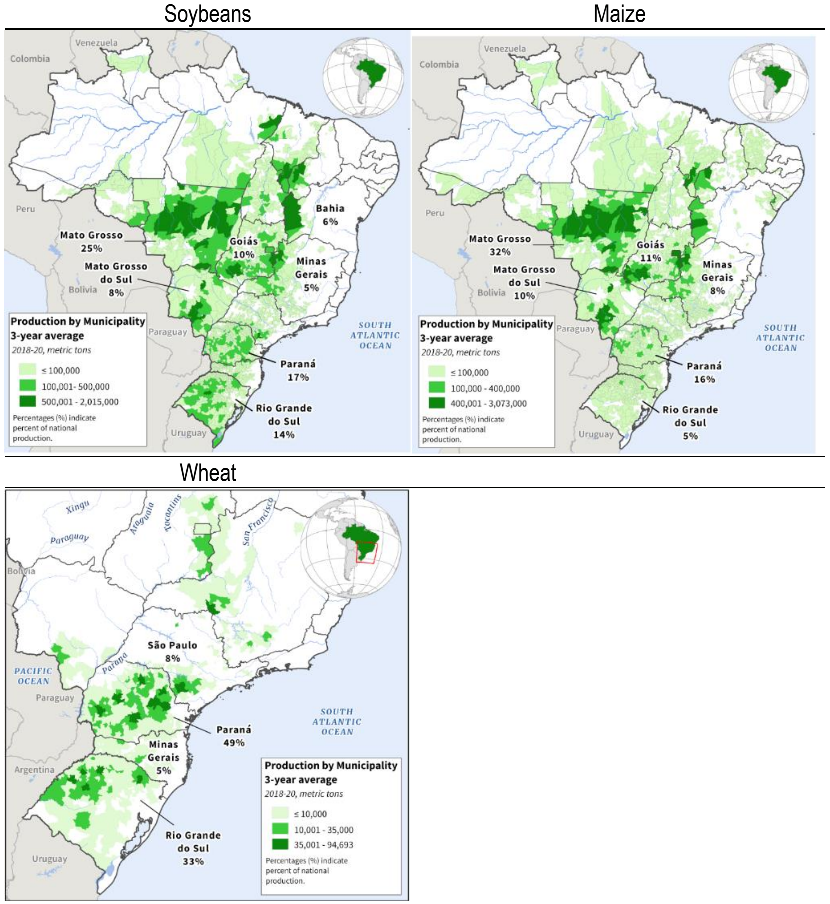
Two-thirds of the total value of agricultural production is crop products and one-third is livestock products.

The main product in Brazilian exports is soybeans (grain, meal and oil), which represent almost 50 per cent of the agro-food exports.

The Brazilian agricultural sector has been transformed from a traditional production system with low use of modern technologies to a world agricultural leader. This transformation occurred as the country moved away from import-substitution policies — which nurtured domestic industrial development at the expense of agriculture — toward market-oriented policy reforms.

These reforms included openness to foreign trade and investment and the use of new technologies, which led to a new growth pattern in the agriculture sector.

Figure B.3 Production regions of Brazil



Source: USDA

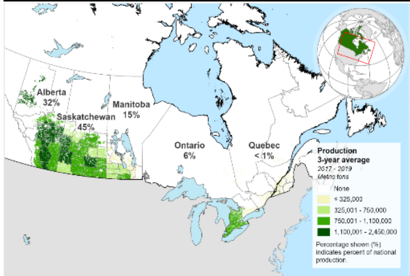
B.1.4 Canada

Primary agriculture accounts for less than 2 per cent of Canada's GDP but contributes to a larger share of economic output in some of the country's regions. Crop production is concentrated in the western prairies, where the typical farm is twice as large as the national average, is highly productive, and is largely for export.

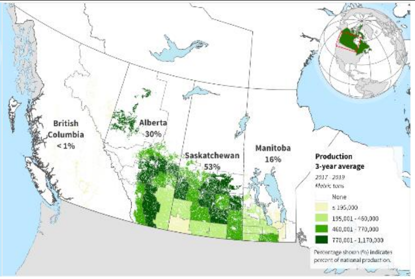
Due to climate conditions, grains are mostly grown in the inland south. Canada is a major producer of canola, canary seed and lentils and ranks first in the global production of these crops

Figure B.4 Production regions of Canada

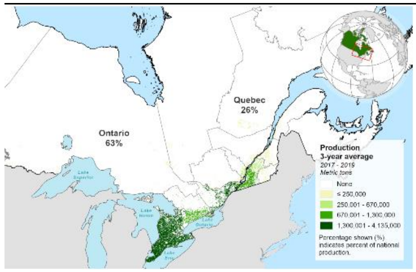
Wheat



Canola



Maize



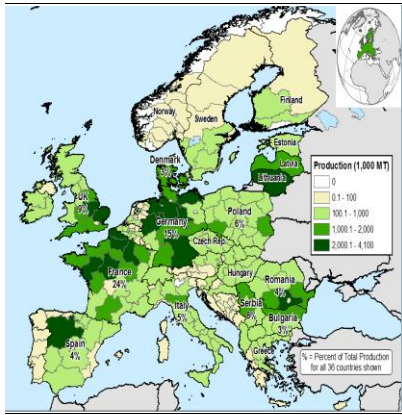
Source: USDA

B.1.5 France

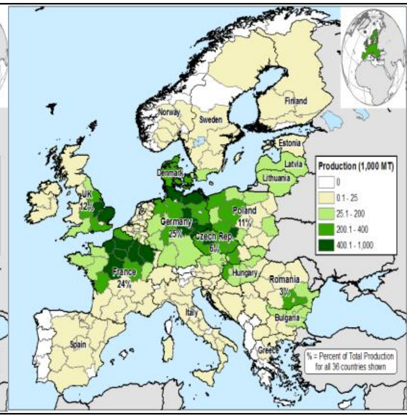
France is a major wheat producer and ranks first in selected major producing crops' global wheat yield levels. France is also the top producer worldwide in oats and rye, and second in wheat. The country also ranks highly in the export of these crops.

Figure B.5 Production regions of Europe

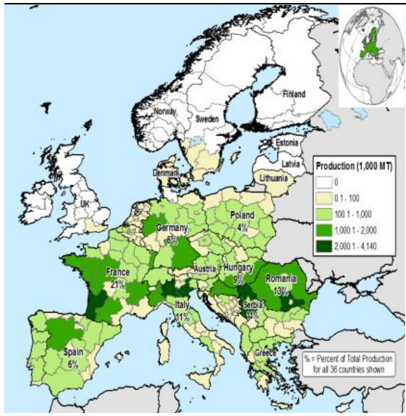
Wheat



Canola



Maize



Source: USDA

B.1.6 India

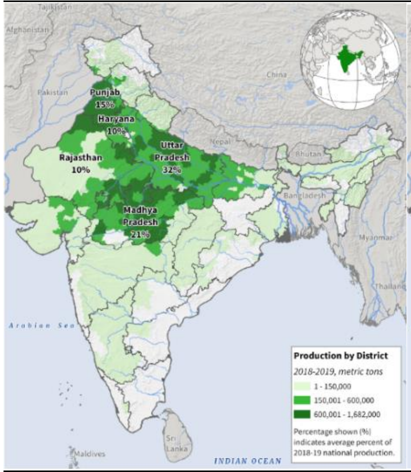
Agriculture accounts for an estimated 40 per cent of India's employment. Still, its 17 per cent share of GDP indicates that labour productivity remains significantly lower than in the rest of the economy.

Agricultural output growth in India averaged 3.2 per cent between 2010 and 2019, well above the world average. This has been driven mainly by a significant increase in TFP, backed by technological progress in the form of improved seeds and better infrastructure

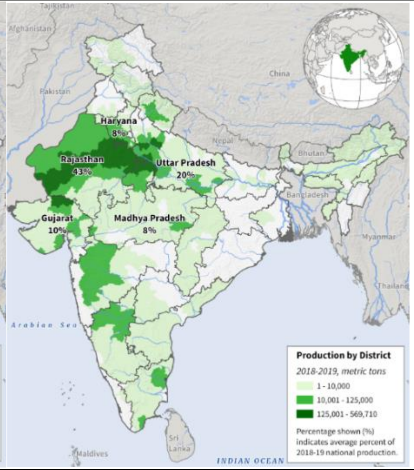
India is a major wheat producer and ranks third in the production volume. It ranks first in millet, chickpea and pigeon pea global production.

Figure B.6 Production regions of India

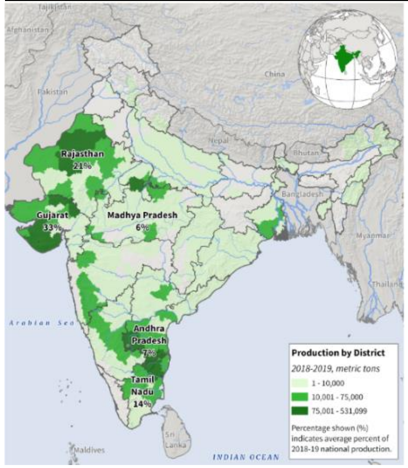
Wheat



Millet



Peanut



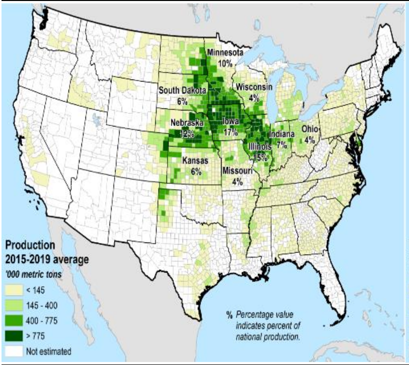
Source: USDA

B.1.7 The US

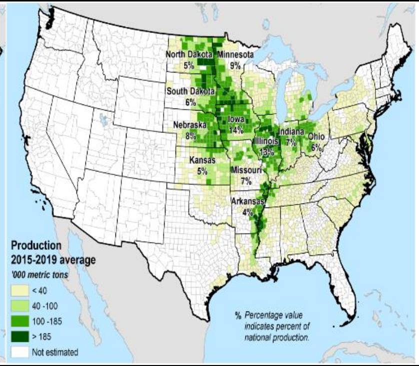
The US agricultural sector benefits from a large domestic consumer market, as well as abundant arable and pasture land and diverse climatic conditions that support the production of a wide range of commodities. In recent years, total agricultural production has been divided relatively equally between crops and livestock. Key industries include grains (maize and wheat), oilseeds (soybeans), cotton, cattle, dairy, poultry and fruits and vegetables.

Figure B.7 Production regions of the US

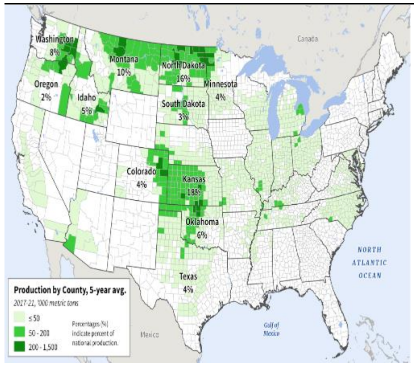
Maize



Soybean



Wheat



Source: USDA

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