Deloitte
Access Economics

Economic contribution of crop protection products in Australia

August 2023

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Short name	Full name
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
APVMA	Australian Pesticides and Veterinary Medicines Authority
CPP	Crop protection product
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPI	Department of Primary Industries (NSW Government)
FTE	Full-time equivalent
GDP	Gross Domestic Product
GRDC	Grains Research and Development Corporation
IO	Input-output
UNFAO	Food and Agriculture Organization of the United Nations
USDA	United States Department of Agriculture

Executive summary

Deloitte Access Economics has been engaged by CropLife Australia to estimate the contribution of the crop protection industry to the Australian economy, and the Australian agricultural output attributable to the use of crop protection products (CPPs). This report represents an update to a report released in 2013 and 2018 by Deloitte Access Economics.

CPPs include herbicides, fungicides and insecticides, and are widely used in many sectors of the economy. For industry — particularly agriculture — it is a means of increasing the productivity of land. Governments also use CPPs to control invasive or non-native species on public land (such as roadsides and in national parks). They are also widely used by households for backyard gardening and pest control, in commercial buildings, on sporting fields and in maritime applications. This report focuses on the contribution of the CPP industry to value added in the Australian economy (as an employer and purchaser of inputs from other industries), and the contribution of CPP use to crop production. The value and importance of CPPs to public land and other environmental land managers has been discussed qualitatively in this report.

The approach used in this study is two-fold:

- First, the direct and indirect economic contributions of the CPP industry to the economy (in terms of contribution to Gross Domestic Product (GDP) and employment) are estimated.
- Second, the share of crop production in Australia attributable to CPPs is estimated. This utilises previous work undertaken for the United States, with adjustments made to reflect differences in Australian production systems.

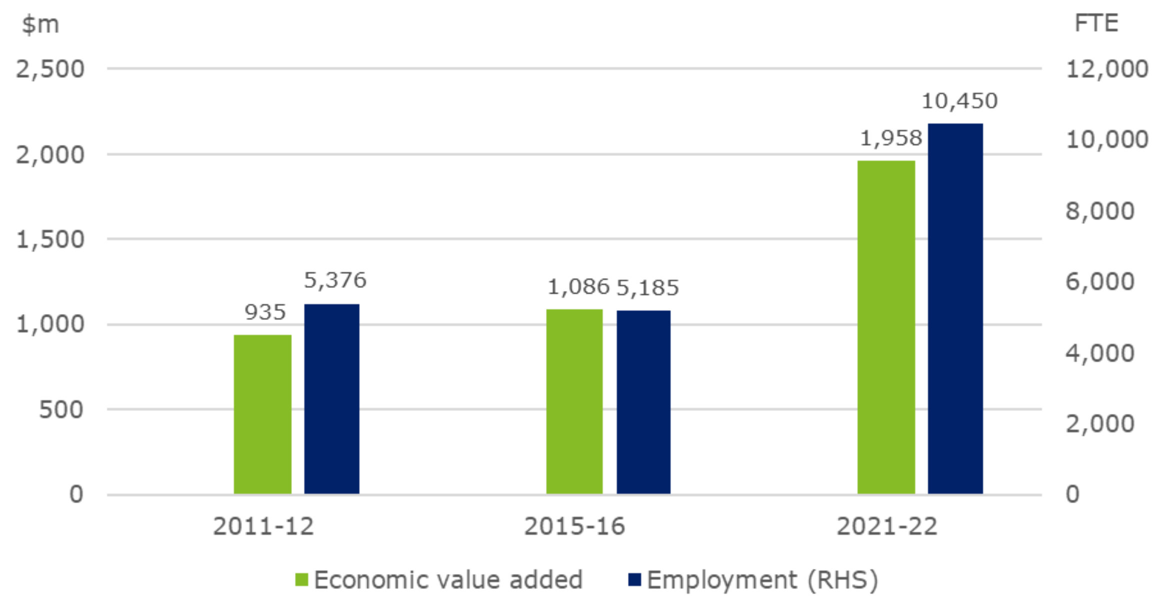
Economic contribution

$5.1 billion of CPPs were used in Australia in 2021-22.[i] This output was associated with an economic contribution of $2.0 billion of value-added to GDP, which consists of a direct economic contribution of $955 million and indirect economic contribution of $1,003 million in sectors supplying the CPP industry with intermediate inputs. These value-added contributions comprise both gross operating surplus and wages.

In terms of employment, the CPP industry contributed 10,450 full time equivalent (FTE) employees in 2021-22, which consists of 4,615 directly in the CPP manufacturing sector and 5,835 in the sectors that supply inputs to the CPP industry. The primary industries contributing employment include Professional, Scientific and Technical Services, Wholesale Trade and Road Transport.

The contribution of the CPP industry to the Australian economy has grown significantly since it was last estimated in 2015-16, the year for which Deloitte Access Economics last undertook this study. Over this 5-year period, it is estimated that total employment generated by the sector has more than doubled to 10,450, whilst value-added from the sector has increased by 80 per cent to nearly $2 billion in 2021-22 compared with 2015-16.

Chart i: Contribution of the CPP industry to the Australian economy, 2011-12, 2015-16 and 2021-22



Source: Deloitte Access Economics

Note: The approach used for the 2021-22 estimates has changed from previous editions to better reflect the role of imports in the sector. The 2011-12 and 2015-16 results have been revised to reflect this approach and allow direct comparison.

Crop production attributable to CPPs

The total value of Australian crop production attributable to CPPs is estimated as the sum of the attributable value of production for field crops (broadacre), vegetables, fruits and nuts and other crops (mostly forage crops). The output attributable to CPPs is based on current farming practices and assumes that all other necessary production inputs (sufficient water, nutrients, etc.) are available. The analysis does not consider the impact if all CPPs suddenly become unavailable, which would necessitate significant changes to farming practices (and likely involve significant changes in crop mix and land use).

Updated modelling shows that $31.6 billion of Australian crop output in 2020-21 was attributable to the use of CPPs, or 73 per cent of the total value of crop production in that year. This represents nominal growth of 53 per cent on the previous estimate in 2015-16, driven primarily by the increased value of production. Over half of this contribution is from fungicides, reflecting their significant contribution to the value of production of vegetables, fruits and nuts.

Broader benefits of CPPs

CPPs offer broader social benefits to Australia outside of the economic and agricultural values outlined above. These include:

- **Community benefits from non-agricultural uses –** 15 per cent of CPPs are used for non-agricultural uses such as gardens, sports ovals and public spaces. This provides a variety of benefits such as accessibility, amenity and health benefits.
- **Environmental and climate benefits –** The use of CPPs by Australian farming system reduces tillage and deforestation in other parts of the world to accommodate the required increase in food production. In turn, this avoids any greenhouse gas emissions and nature loss that would be associated with this land use change around the world.
- **Food security and biosecurity –** CPPs increase agricultural productivity, thus increasing the amount of food available to consume domestically or export. CPPs also protect Australia's environment by helping to control invasive pests and diseases.
- **Spillover benefits to scientific research and development –** Existing CPPs provide a foundation for extensive research on pests and diseases affecting Australian crops. For example, herbicides enable innovation in modern farming practices such as minimum- or no-

till farming, which provide a range of indirect benefits outside of the cropping industry (e.g to broader plant and animal science).

1 Background

Deloitte Access Economics has been engaged by CropLife Australia to estimate the economic contribution of crop protection product (CPP) use in the Australian economy, and the Australian agricultural output attributable to the use of CPPs. This report is an update of a similar piece of work that Deloitte Access Economics produced for CropLife Australia in 2013 and 2018. This report also includes a summary of published literature on the broader qualitative benefits of CPP usage, outside of agriculture.

This report presents estimates of the CPP industry's economic contribution and of the share of cropping output attributable to the use of CPPs in Australia. A summary of qualitative research on the broader benefits of CPPs is also presented. This study is not a cost-benefit analysis and does not consider or compare the relative magnitudes of costs in relation to the benefits; for example, potential costs to the environment or health implications of their consumption.

The CPP industry's economic contribution (the amount of value added involved in the production and sale of CPPs) is a different concept to the amount of cropping output that is attributable to the use of CPPs. The two concepts are different ways of looking at economic value, but they are not additive and hence should not be combined.

1.1 Crop protection products

Conventional synthetic CPPs include herbicides, fungicides and insecticides, which are widely used in many sectors of the economy. For industry – particularly agriculture – it is a means of increasing the productivity of land. Governments often use CPPs to control invasive or non-native species on public land (such as roadsides and in national parks). They are also widely used by households for backyard gardening and pest control, in commercial buildings and maritime applications.

Crop protection products and organic produce

The scope of CPPs is broad and includes chemical products that are naturally occurring as well as chemicals which are synthetic. CPPs generally contain at least one active substance that protects plants and plant products from pests, weeds and disease. These active substances can be from plant extracts, chemicals, pheromones, or micro-organisms. As such, any chemicals derived from naturally occurring substances, as used by the organic agriculture sector, are included as CPPs.

The three main groups that contribute to this part of the chemical industry are herbicides, fungicides and insecticides, contributing a total of 85 per cent of product sales for the 2021-22 financial year.[ii]

In addition to traditional chemical CPPs, there are also several non-chemical measures for protecting crop products – such as mechanical methods and farm practices which can include traps, fences, crop rotation and irrigation practices. Non-chemical controls can also refer to pest products that are derived from a biological origin such as animals, plants, bacteria, or minerals.[iii] CPPs in varying forms have improved the efficiency of the agriculture sector for over 150 years.[iv]

In Australia, agricultural chemicals are regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA) up until the point of final retail sale. This includes pre-market risk assessment, approval and registration of products as well as defining the content of labels describing instructions for safe and responsible use. States and territories control the use of products after this point including creating and administering rules for access to products, training and licensing of users, as well as any additional requirements for use such as record keeping or other restrictions.

As more products have been registered in recent years, the value of chemical CPP sales has continued to grow, highlighting the agricultural sector's acceptance of new chemical innovation, as shown in Chart 1.1 and Chart 1.2. In the 2021-22 financial year, around $5.1 billion was spent on 10,100 registered crop protection products in Australia.

Chart 1.1: Number of registered CPPs in Australia, 2011-12 – 2021-22

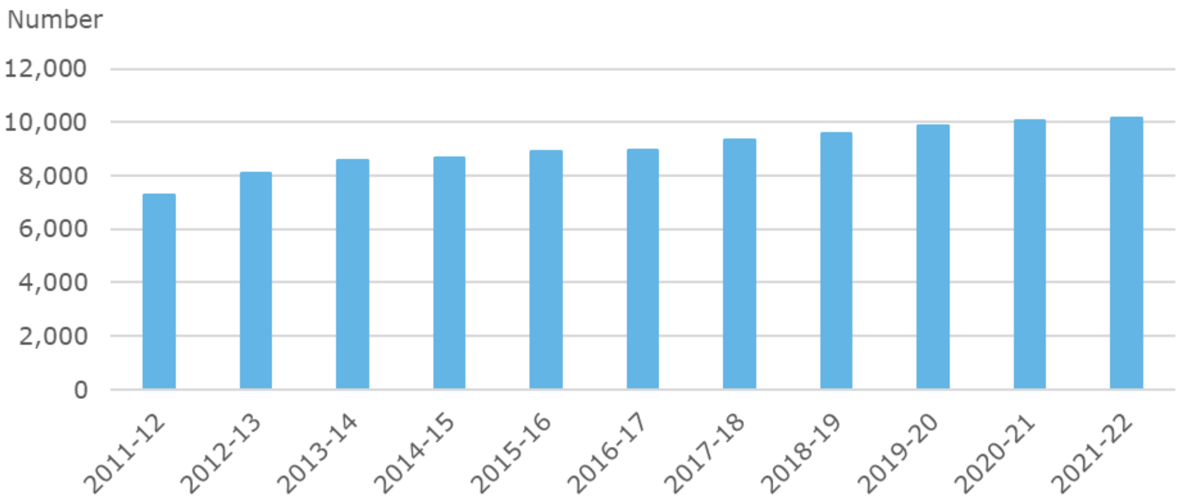
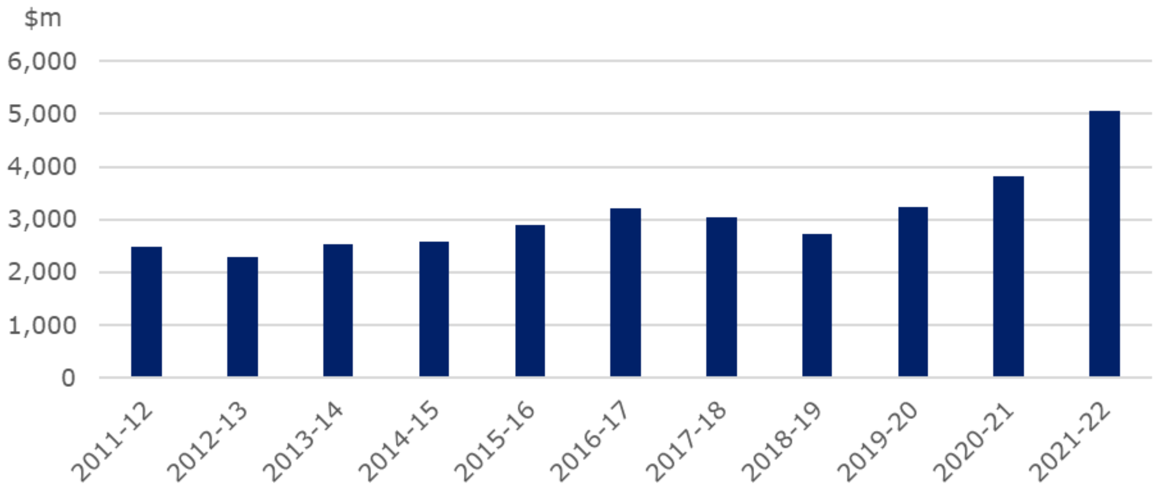


Chart 1.2: Annual CPP sales in Australia, 2011-12 – 2021-22



Source: APVMA, 2023.

CPPs can be classified into four broad categories:

- Herbicides – products intended to prevent or reduce the growth of weeds. These can be either:
  - selective (chemicals which kill weeds specifically without harming crops); or
  - non-selective (chemicals which stop the growth of plants indiscriminately).
- Insecticides – chemicals which aim to control insects in plants and crops.
- Fungicides – products whose purpose is to prevent or manage fungal diseases in plants.
- Other – includes other pesticides (such as miticide, molluscicide, vertebrate poison) as well as chemical agents (adjuvants and surfactants).

Key reasons for use of CPPs include to:

- decrease and control pests and diseases;
- reduce the need for crops and plants to compete with weeds and other invasive plants;
- increase the yield of crops;

- increase the quality of crops
- protect biodiversity;
- improve amenity; and
- protect and maintain infrastructure such as buildings and roads through pest or weed control.

For this report, APVMA data on agricultural (pesticides) product sales are used as indicative of CPP industry revenue. This includes all of the major categories of chemical products used in crop production, as well as some products that may not be used in crop production (for example, household insecticides, pool products/algicide) but these make up a small share of total sales (see Table 2.1). The total value of agricultural (pesticide) product sales is used in the calculation of the economic contribution of the CPP industry because of the close links in the production and sale of all of those products, and the fact that the industry exists, by and large, to service the crop production sector.

1.2 Previous studies into the economic value of crop protection products

Although CPPs are well established worldwide, there is limited research on their economic contribution. This section details a few key studies.

The most comprehensive study undertaken to date is Mark Goodwin Consulting's 2011 report "The Contribution of Crop Protection Products to the United States Economy". The Goodwin study was commissioned by CropLife America, and it details the value of selected crops which is attributable to CPPs.

The study adopted a three-stage methodology. For each crop identified, Goodwin Consulting:

1. determined the proportion of crop value attributable to herbicides, insecticides and fungicides, using previous studies published by the Crop Protection Research Institute[1];
2. determined the total value of the crop by state; and
3. determined the total economic value attributable to agrochemical use by multiplying (1) and (2).

Aggregating, Goodwin concludes that that the direct contribution of CPPs to the US economy is $81.8 billion, with flow-on benefits amounting to $166.5 billion across 20 industries, and approximately one million jobs across the country.

This study was followed by a similar report, "Cultivating a vibrant Canadian economy", published by CropLife Canada in 2011. This report considered the contributions of CPPs as well as plant biotechnology. After evaluating several potential methodologies, the Canadian report quantifies the contribution of agrochemicals by comparing yields between conventional and organic crops. It then calculates the value of crops attributable to CPPs as the difference in yields multiplied by the price of crops. The report concludes that, for the most commonly grown crops in Canada, the value generated by the increased yields associated with the use of agrochemicals and plant biotechnology is almost CA$8 billion.[2]

In Australia, the AECgroup published a report on the "Economic Impact of State and Local Government Expenditure on Weed and Pest Animal Management in Queensland" in 2002. The report conducted a cost benefit analysis of state and local government spending on a set of pest and weed management initiatives. One of the initiatives examined was the eradication of Siam Weed. The study found that every $1 spent on this program (including spraying, maintenance and border protection costs) resulted in $3.70 in benefits. Another study from the Local Government Association of Queensland found that each dollar spent on weed and pest animal management initiatives in Queensland can deliver $6.40 in benefits.

A Deloitte Access Economics study from 2013 based on the methodology of the CropLife America report, adjusted appropriately for the Australian context, estimated that $17.6 billion of Australian crop production in 2011-12 could be attributed to the use of CPPs. A 2018 update of this estimate

[1] Gianessi, L., and Regier, N., 2006; Gianessi, L., and Regier, N., 2005; Gianessi, 2009.
[2] Including 16 field crops, 29 vegetable crops, 13 fruit crops and potatoes.

found that this value had risen to $20.6 billion in 2015-16. The economic contribution section of this report follows a revised version of the methodology used in the 2013 and 2018 Deloitte Access Economics study, which is detailed further in the following chapters. These two previous studies are used throughout this report in presenting time series results for the economic value of CPPs.

2 Economic contribution of CPPs

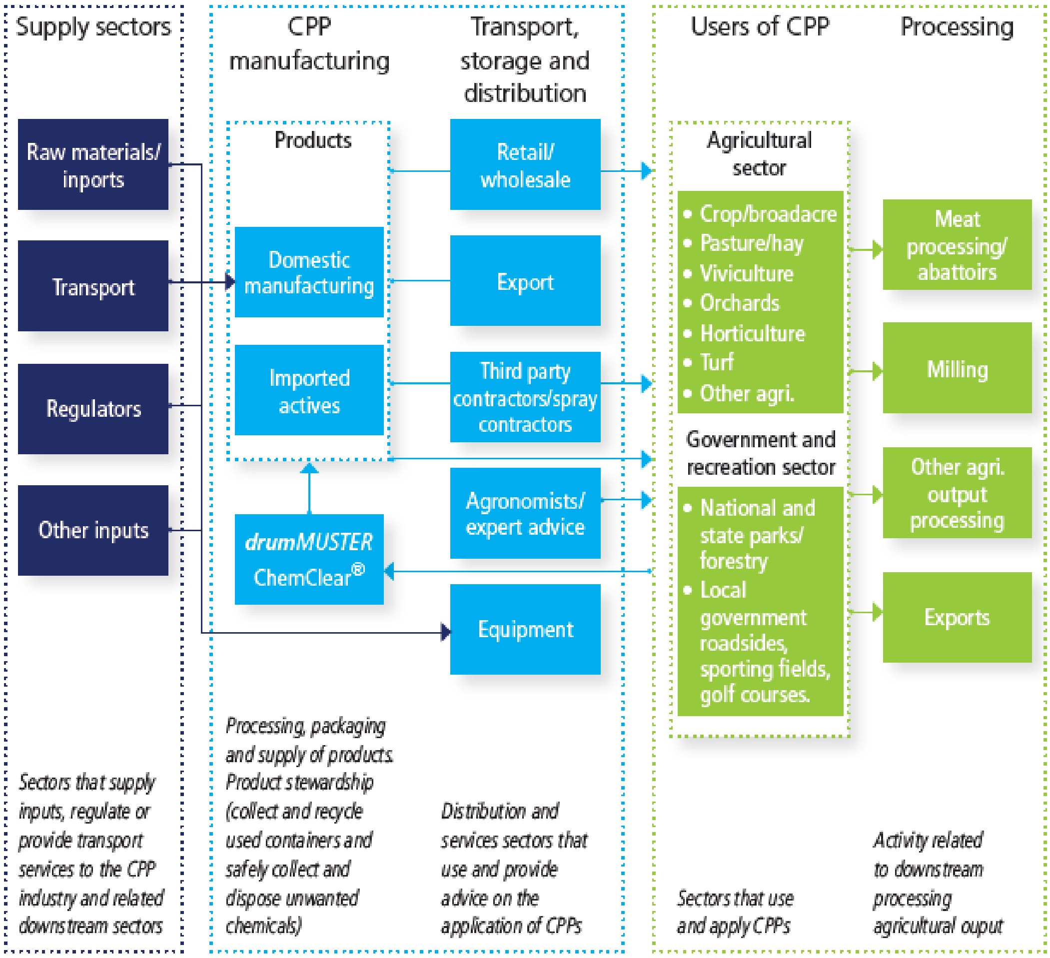
This section outlines the economic contribution of CPP production and use in Australia in 2021-22.[3] This includes the direct economic contribution of the CPP industry, in gross value added and full time equivalent (FTE) employment terms, and the indirect contribution associated with its purchases of intermediate inputs, as illustrated in Figure 2.1.

2.1 CPP industry linkages and relationships

The CPP supply sectors includes the suppliers of raw materials from which CPPs are manufactured, as well as third-party contractors and the agronomists that service the sector and help to optimise farm practices. It is noted that there are several types of agronomists. Some are employed by CPP companies (distribution agronomists), hence have their costs embedded in the retail cost of CPPs as employees of chemical resellers. Private agronomists, on the other hand, independently generate revenue (over and above sales of CPPs) through their work as consultants.

Figure 2.1 provides an overview of the value chain associated with CPP use, including the intermediate suppliers, producers, importers and end users.

Figure 2.1: CPP industry linkages and relationships



[3] To reflect the role that CPPs play across the entire Australian economy, both local production and imports are deemed to contribute to the economy and agriculture sector for the purposes of this study.

2.2 CPP use in Australia

In 2021-22, $5.1 billion worth of CPPs were sold in Australia.[v] This figure has increased from the $3.0 billion figure measured in 2017-18, representing a compound average growth rate of 14 per cent over this period. Herbicide sales (the largest product type by level of sales) grew by an average of 16 per cent over this period. This level of growth is higher than that seen in the agricultural sector – the value of crops produced in Australian grew at an average of seven per cent over the same period.[vi]

Herbicides, insecticides and fungicides making up 86 per cent of sales. Herbicides alone account for 60 per cent of sales, worth nearly $3.1 billion in 2021-22. Insecticides accounted for 15 per cent of sales (with 80 per cent of these being insecticides for use on farms and 20 per cent for use in households). Fungicides made up nearly 10 per cent of sales.

The sector also provides a number of chemical products that are used in non-crop production processes, such as dairy cleanser, seed treatments and wood preservatives. Collectively, these other agricultural products comprise six per cent of total sales.

This dataset also includes a number of products that are used in aquatic applications, for example anti-fouling marine paints and water sanitisers for use in pools and spas. APVMA data also outlines that the sector produces $2 million in dog and bird repellents, this is an increase from 2017-18 figures which report $1.4 million. The value of production of these products has been included in the calculation of the economic contribution of the CPP industry. The reasons are twofold: firstly, because of the close links between the production and sale of the various types of products, and secondly because the industry as a whole exists, by and large, to service the crop production industry.

Table 2.1: CPP industry output by type of product $m, 2021-22

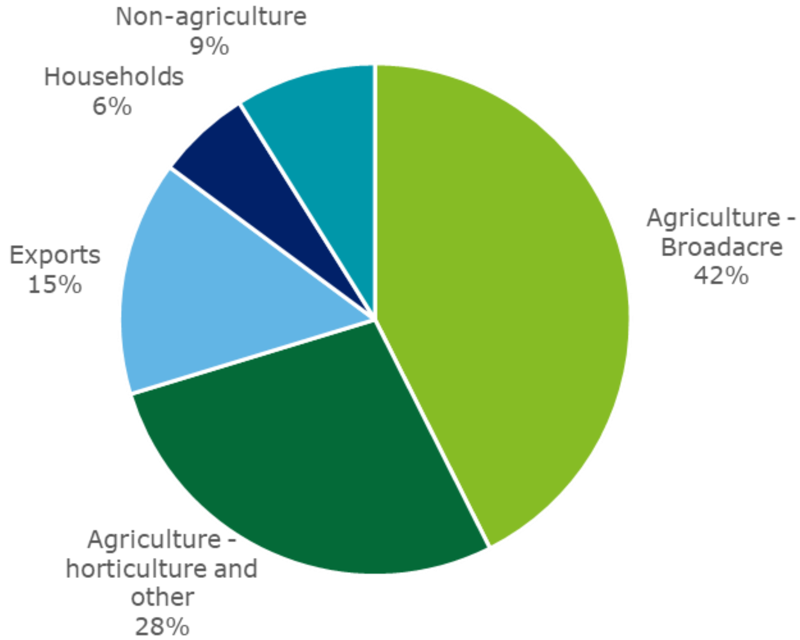
Output	$m	Share of total
Adjuvants / Surfactants	187.3	3.7%
Antifouling - Boat	19.5	0.4%
Dairy Cleanser	14.3	0.3%
Disinfectant / Sanitiser	15.0	0.3%
Fungicide	496.5	9.8%
Growth promoters / Regulators	78.9	1.6%
Herbicide	3,085.8	60.9%
Household Insecticide	158.0	3.1%
Insecticide	599.5	11.8%
Miscellaneous	10.2	0.2%
Miticide	32.7	0.6%
Mixed Function Pesticide	32.2	0.6%
Molluscicide	28.3	0.6%
Nematicide	3.6	0.1%
Pool Products / Algicide	80.5	1.6%
Repellent – Dogs / Birds etc.	2.1	0.04%
Seed Treatments	89.4	1.8%
Vertebrate Poison	62.4	1.2%
Wood Preservative	71.5	1.4%
Total	5,067.5	100%

Source: APVMA, 2023.

2.3 Where are CPPs used?

As outlined above, actives are formulated into products and then distributed to a number of consumers. The agriculture sector remains the highest consumer, accounting for 70 per cent total consumption. Of this, 43 per cent is used in broadacre industries. Within these industries, the relative importance of various herbicides, fungicides and insecticides depend on the crop being grown. Horticulture and other agricultural industries then consume 27.5 per cent of Australia's CPPs, with 14.5 per cent of CPPs being exported, and the remaining used by households and other non-agricultural users (Chart 2.1).

Chart 2.1: Major Australian CPP market segmentation, 2022



Source: IBISWorld, 2022.

Note: Non-agriculture uses include local government for weed and other pest-control programs.

2.4 Industry economic contribution

This section provides estimates of the CPP industry's total economic contribution to the national economy in 2021-22. Economic contribution refers to value added, which is equal to the sum of gross operating surplus and wages. The sum of value added across all industries in the economy equals GDP. The industry's total economic contribution is made up value added within the industry (its direct economic contribution), and value added generated in other industries through the supply of intermediate inputs to the CPP industry (its indirect economic contribution).

The CPP industry's total economic contribution is estimated using information on the value of CPP production, imports and the most recent 2020-2021 Australian Bureau of Statistics (ABS) Input-Output tables.[vii] Locally manufactured products were separated from imports to represent the different ways in which the CPP sector contributes to the Australian economy. As such, the results presented in Table 2.2 are not directly comparable with those presented in previous editions of this report. For a detailed overview of the approach used in this section, refer to Appendix A.

Table 2.2: Economic contribution of CPP industry, 2021-22

	Direct	Indirect	Total
Value added ($m)			
Gross operating surplus	400	510	910
Wages	555	493	1,048
Total	955	1,003	1,958
Employment (FTE)	4,615	5,835	10,450

Source: Deloitte Access Economics.

The CPP industry contributed a total of $1.96 billion in value added to the Australian economy in 2021-22. Of this figure, $1.05 billion was in the form of wages (or returns to labour), and $910 million was gross operating surplus, otherwise known as returns to capital. In 2021-22, the CPP industry also contributed a total of 10,450 FTE employees, 4,615 of whom are directly employed in the industry. The remaining 5,835 jobs supported by the industry are in downstream suppliers.

The CPP industry also indirectly supports economic activity in upstream sectors through its demand for and use of intermediate inputs. In 2021-22, the CPP industry indirectly contributed $1.0 billion to value added, and supported a further 5,835 FTE jobs in Australia.

A breakdown of indirect value added by industry is given in Table 2.3. Professional, scientific and technical services capture the largest share of indirect value added resulting from CPP demand for intermediate inputs, at 11.2 per cent, or $112.7 million. The same sector indirectly employs the most FTEs (863), contributing 14.8 per cent of total indirect employment attributable from upstream expenditure by the CPP industry.

Table 2.3: Indirect contribution of CPP industry, 2021-22

Industry value added	$m	Share of indirect contribution (%)
Professional, Scientific and Technical Services	112.7	11.2
Oil and gas extraction	98.3	9.8
Finance	64.9	6.5
Wholesale trade	48.2	4.8
Employment, travel agency and other administrative services	48.2	4.8
Other industries	630.8	62.9
Total	1003.2	100
Industry employment contributions	**FTE**	**Share of indirect contribution (%)**
Professional, Scientific and Technical Services	863	14.8
Employment, Travel Agency and Other Administrative Services	533	9.1
Road Transport	345	5.9
Wholesale Trade	324	5.6
Non-Residential Property Operators and Real Estate Services	264	4.5
Other industries	3,506	60.0
Total	5,835	100

Source: Deloitte Access Economics

2.4.1 Comparison with previous estimates

To demonstrate the change in size of the CPP industry over time, Table 2.4 presents the key results from 2021-22 alongside comparable figures from the 2013 and 2018 reports. It shows that the CPP industry's contribution to GDP has increased by 80% since 2015-16, and employment has more than doubled.

Table 2.4: Estimates of CPP contribution to Australian economy over time

Value added ($m)	2011-12	2015-16	2021-22
Direct - CPP	366	525	955
Indirect - supply sector	570	561	1003
Total	935	1,086	1,958
Employment	**2011-12**	**2015-16**	**2021-22**
Direct	1,804	1,838	4,615
Indirect	3,572	3,347	5,835

Total	5,376	5,185	10,450

Source: Deloitte Access Economics

Note: The 2011-12 and 2015-16 estimates have been revised to reflect the approach taken in the 2021-22 estimates.

2.5 Market dynamics and trends

Several supply- and demand-side factors explain the significant rise in the CPP sector's economic contribution, as well as the increase in aggregate CPP sales value over the past five years. Price factors include increases in energy costs, manufacturing disruptions, and reliance on CPP imports, while demand-side drivers include wetter than average seasonal growing conditions across Australia in 2020-2022. These drivers are explained in further detail below.

2.5.1 Supply-side drivers

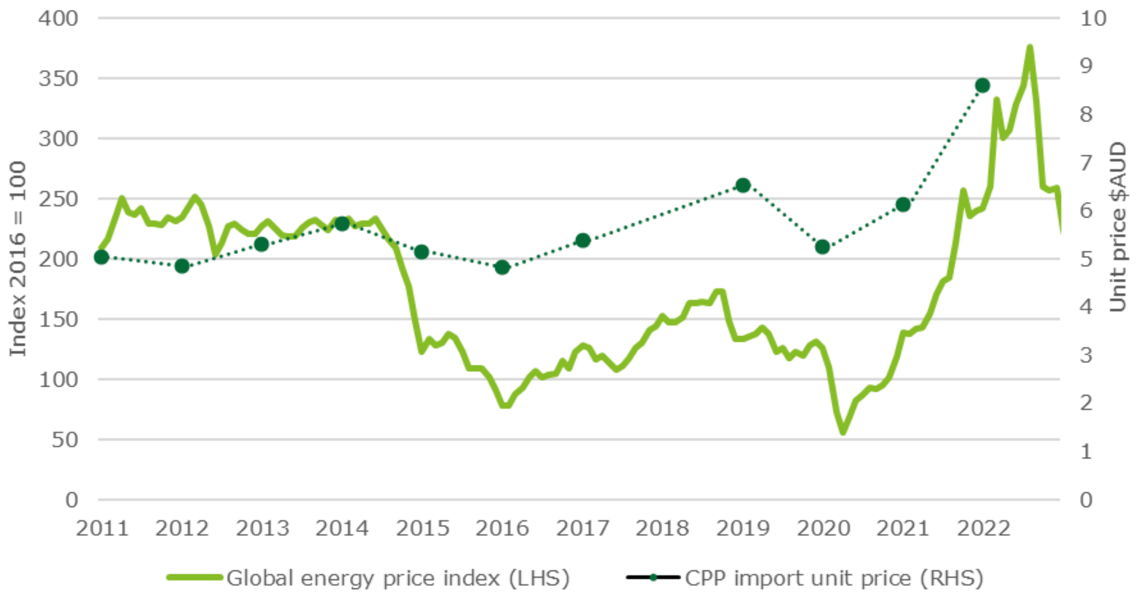
2.5.1.1 Rise in global energy prices

Focussing on CPP imports, the average per-unit of price of imported CPPs rose 60 per cent from 2020 to 2022, from $5.6/kg to $8.6/kg, shown in Chart 2.2. A key driver of the average price increase in CPP imports has been an increase in the price of glyphosate.[4] The sharp price rise at the beginning of 2022 was in part caused by China's industrial policy in the lead-up to the Winter Olympics.[viii] The reduction in Chinese production had a material impact on global supply and therefore price, since China manufactures about 65 per cent of the world's glyphosate. Additionally, a mechanical failure on the production line of a key glyphosate raw material supplier further reduced global supplies and placed upward pressure on price.[ix]

The global energy shortage driven by Russia's invasion of Ukraine in March 2022 also drove up glyphosate prices and CPP prices more broadly. The price of gas increased by 150 per cent from January to August 2022[x], which fed into higher glyphosate prices, since gas is a key input in glyphosate manufacturing.[xi] Additionally, China reduced production of yellow phosphate, a raw material used in the production of glyphosate in the second half of 2021, due to energy restrictions driven by tight coal supplies and high prices.[xii] The combination of high energy prices and electricity rationing in China likely pushed up glyphosate and other CPP prices from 2020 to 2022.

[4] The wholesale price of CPP imports, as well as glyphosate (herbicide) prices can be used as proxies to explain trends in aggregate CPP prices, given that data on the per-unit price of CPPs sold in Australia does not exist. CPP import prices are a suitable proxy for the per-unit price of domestic retail sales, since a large proportion (just over 50 per cent) of CPPs used in Australia are imported. Additionally, the price of broad-spectrum herbicide glyphosate can also be used to help explain trends in CPP expenditure, since glyphosate (and other herbicides) comprise around 61.5 per cent of total CPP use in Australia.[4]

Chart 2.2: CPP import unit price and global energy price index.



Source: Comtrade (2022); Federal Reserve Economic Data (FRED, 2023)

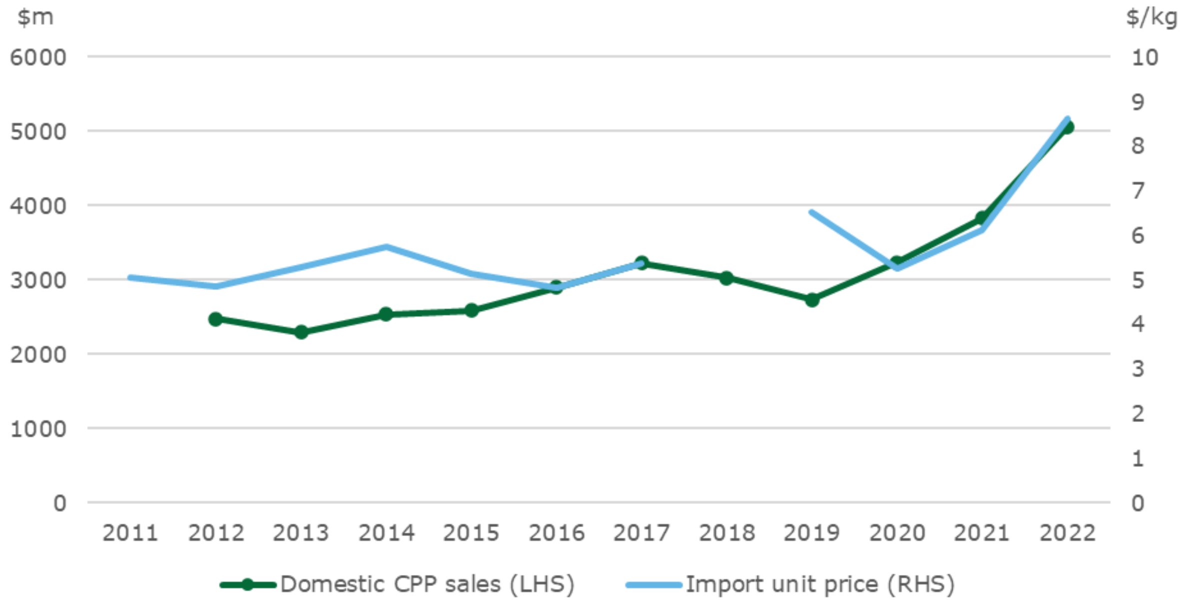
Note: The data encompasses "insecticides, rodenticides, fungicides, anti-sprouting agents, plant growth regulators, disinfectants and the like, put up in forms or packings for retail sale or as preparations for articles."

Domestic producers of agrichemicals have also faced rising energy and other input costs. ABS data indicated that chemical manufacturers recorded input price rises of 23.9 per cent for the year end June 2022. Robust demand and tight supply of natural gas was a key contributor to this trend.[xiii]

2.5.1.2 Trade exposure of the CPP industry

The high level of international trade in the CPP industry has meant that international price shocks (described in Chapter 2.5.1.1) are transmitted to the domestic CPP market. Imports play an important role in meeting domestic demand (primarily from agriculture), with around 50 per cent of CPPs being imported.[xiv] As shown in Chart 2.3, there is a positive correlation between the per-unit price of imports, and domestic CPP sales data. Despite one CPP manufacturer doubling its domestic chemical manufacturing footprint in the last two years, the import share of CPP use in Australia has remained relatively steady.[xv]

Chart 2.3: CPP sales data and import unit prices, Australia, 2011-2022



Source: APVMA; Comtrade (2022).

Note: Comtrade import data is not available in 2017.

2.5.2 Demand drivers

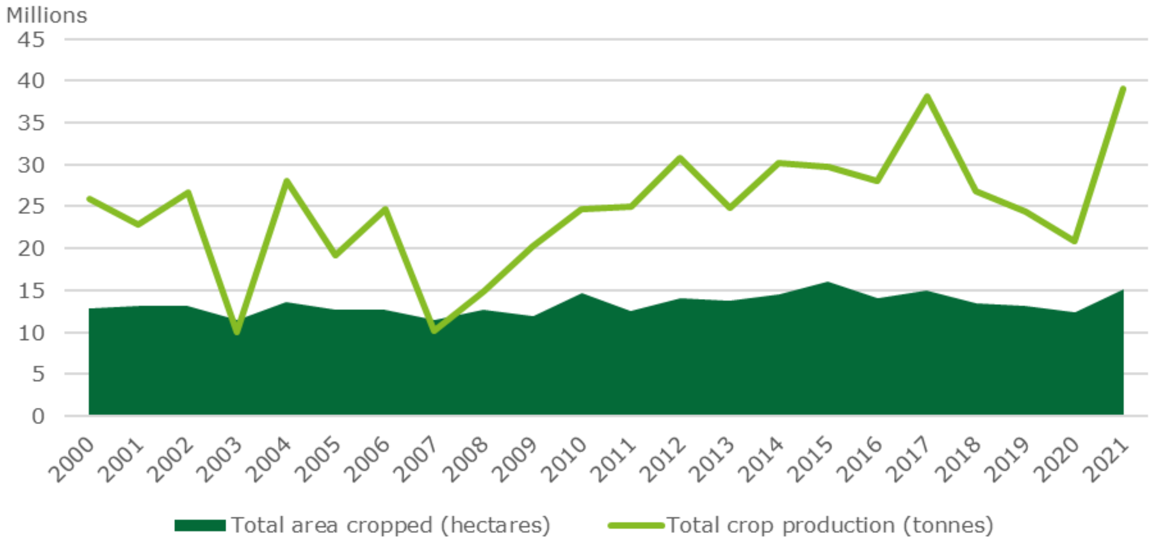
In addition to supply-side shocks, heightened demand for CPPs since 2020 have also placed upward pressure on CPP prices, and in turn, aggregate CPP sales value. Two primary demand drivers discussed below are favourable seasonal conditions and historically high prices for broadacre crop commodities.

2.5.2.1 Wetter seasonal conditions from 2020-2022

Above-average rainfall recorded across much of Australia from 2020-2022 increased variables such as weed growth, disease pressure, areas cropped and crop yield potential, all collectively acting to fuel strong demand for CPPs over the period. Three consecutive La Nina events, combined with a negative Indian Ocean Dipole in the winter and spring of 2022, and a persistently positive phase of the Southern Annular Mode from mid-autumn onwards were the main climate influences of wetter conditions.[xvi] In 2022, nationally averaged rainfall was 26 per cent above the 1961-1990 average at 587.8mm, while rainfall was very much above average for key cropping and horticulture regions in the south-eastern quarter of the mainland (Figure 2.2).[xvii]

It is likely that farmers increased use of CPPs over this period to take advantage of more favourable seasonal conditions to sow more areas and produce higher yields, as well as sowing more land into crop. Chart 2.4 shows total broadacre cropped area rebounded from 13.2 million hectares during the drought year of 2019 to 15.1 million hectares in 2021. Accordingly, aggregate broadacre crop production (grains and oilseeds) jumped from 24.3 million tonnes in 2019 to 39 million tonnes in 2021.

Chart 2.4: Total area cropped and total crop production, Australia, 2000-2021

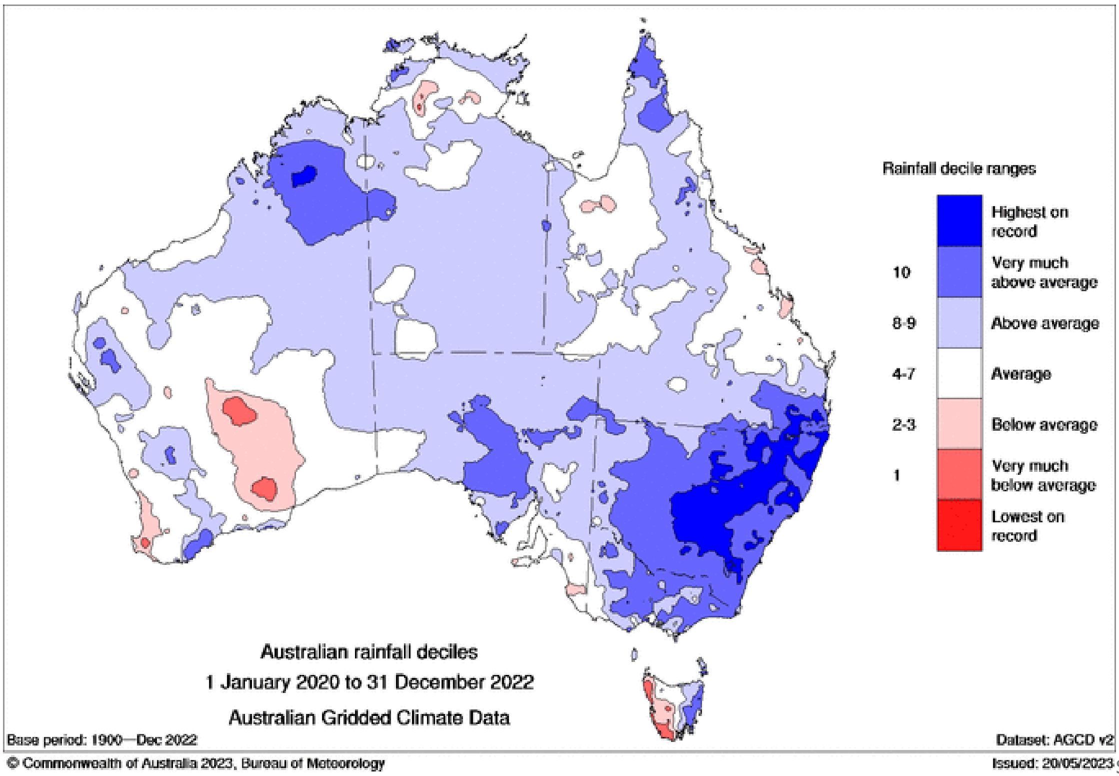


Source: ABARES

Note: Data pertains to the 'wheat and other crop' industry.

Greater demand for CPPs also would likely have stemmed from increased weed and disease pressure due to wetter conditions. Strong La Niña conditions particularly during the winter and spring of 2022 contributed to greater incidence of disease in crops, such as fungal diseases, which stimulated sales of post-emergent fungicides to reduce impact on yield and quality. Weed pressure was also elevated, resulting in higher demand for pre- and post-emergent herbicides. While generally wetter seasonal conditions likely contributed to greater demand for CPPs (and indirectly higher prices) over the last 2-3 years, the end of La Nina and possible declaration of El Niño in 2023 could result in CPP demand returning to more normal long-run levels, or even be temporarily lower should drought conditions prevail.[xviii]

Figure 2.2: Australian Rainfall deciles, 2020-2022



Source:

Source: Bureau of Meteorology (2023)

2.5.2.2 Strong commodity prices

Despite recent elevated prices for CPPs, high agricultural commodity prices (particularly grains and oilseeds) and robust demand for Australian agricultural production has further supported expenditure on CPPs. The disruption of Ukrainian exports of cereal crops in early 2022, combined with drought conditions in some northern hemisphere cropping regions pushed grain and other commodity prices to highest-on-record levels (Chart 2.5).[xix] Historically high prices across a range of commodities enabled farmers to increase crop planting and CPP use while maintaining or increasing profitability. Agricultural commodity prices have since eased with resumed trade flows from Ukraine and increased southern hemisphere production boosting supply.

Chart 2.5: Producer Price Index – Grains

Source: Federal Reserve Economic Data (2023)

2.5.3 Summary of recent market dynamics

The coinciding of demand- and supply-side shocks has caused CPP prices (and aggregate expenditure on CPPs) to rise substantially since 2020. On the supply side, sharp increases in energy input prices and manufacturing disruptions reduced supply and increased per-unit production costs. On the other hand, wetter seasonal conditions in Australia from 2020-2022 due to consecutive La Nina events stimulated demand for CPPs, particularly herbicides and fungicides.

The combination of multiple local and global shocks forcing CPP prices to record levels is an exceptional circumstance which is unlikely to reoccur in the short term. The gradual return of global energy prices to more normal levels will reduce pressure on manufacturing costs. Additionally, the predicted occurrence of El Nino in 2023 may reduce weed and disease pressure and therefore dampen demand for CPPs in Australia. CPP prices are therefore likely to moderate in the short- to medium-term.

2.5.4 Market trend: Increasing prevalence of natural CPPs

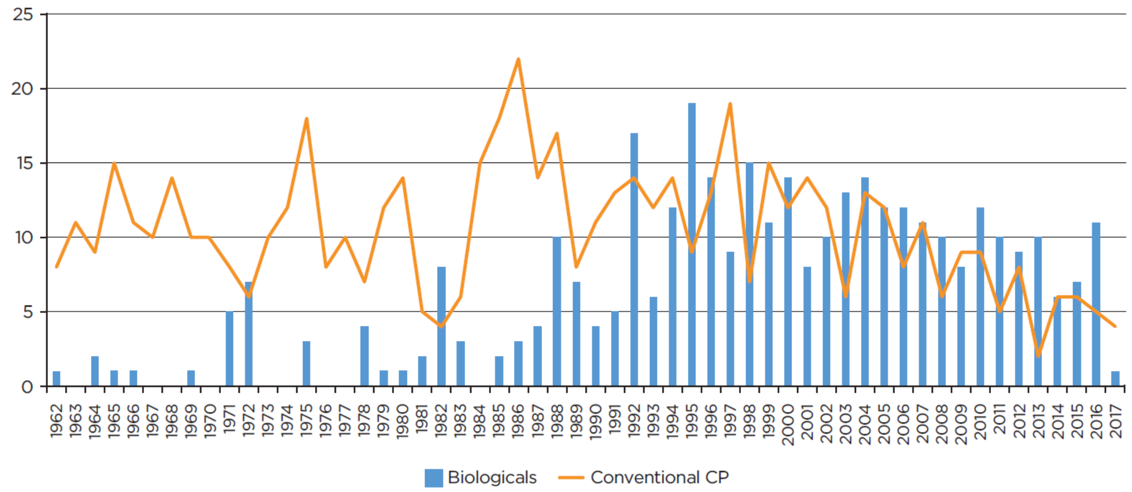
Another recent market trend within the CPP industry is the increasing interest in naturally derived CPPs, also known as biological agricultural products (biologicals), biopesticides, or biocontrol products.[xx] According to the APVMA, a biological product is defined by having an active constituent that is derived from a living organism (plant, animal, micro-organism, etc). There are four main groups of biological products:[xxi]

1. Biological chemicals, which contain naturally occurring substances with indirect toxicity or modifying effects in target species. Substances include potassium carbonate, phosphorus acids, pheromones for insect mating disruption, enzymes and vitamins.
2. Plant and other extracts, including botanic oils.
3. Microbial agents, including bacteria, insect viruses, fungi, actinomycetes, protozoa, etc. that function as bio-control agents, affect the target species directly or indirectly through the compounds they produce.
4. Other living organisms, including microscopic insects, plants and animals, as well as some organisms that have been genetically modified.

Biologicals are associated with several advantages relative to chemical CPPs. Notwithstanding some challenges discussed shortly, they can help improve crop yield and quality when used in addition to synthetic CPPs, although efficacy is highly location-specific. This is partly because of improved resistance management, as biologicals have different modes of action to chemical CPPs.[xxii] Another advantage is related to their safety of use in agroecosystems. Biologicals generally only affect the target pests or plant pathogens, and pose little to no risk to birds, fish, beneficial insects, pollinators, mammals, and other non-target organisms. They pose minimal risks to workers, and as readily biodegradable products, do not pollute air and water.[xxiii]

The rate of introduction of biological products has grown significantly since 1960 (Figure 2.3).Over the last 20 years, the rate of new biological product introduction has frequently exceeded that of conventional products. Increasing interest in biologicals has in part been encouraged by a less demanding regulatory process faced by manufacturers, the growth of integrated pest management (IPM) approaches (discussed further in Section 3.5.1), and farmers' demand for a more diverse range of tools to manage insects and disease. Other drivers include restrictions on chemical pesticides, increasing incidence of pesticide resistance, and residue management.[xxiv]

Figure 2.3: Annual new product introduction for biological products and conventional CPPs



Source: Phillips McDougall (2018)

Commercially available biological crop protection product – NPV

Nucleopolyhedrovirus (NPV) is a commercially available biopesticide used to manage the Helicoverpa and Heliothis species of insects in a variety of field crops, including sorghum, chickpeas, cotton and maize. NPV is a virus which occurs naturally in the Australian environment. It was first available to Australian farmers in the 1990s, however subsequent research has produced newer products that utilise the local virus strain.

The virus works by infecting and killing the larvae of target pests following ingestion of the virus particles. Commercial NPV products only kill target species, and do not harm other insects, wildlife or humans. Insect resistance to insecticides and greater understanding of integrated pest management (IPM – see Section 3.5.1) is leading to increased use of technologies such as NPV in Australian agriculture.

However, there are challenges to the uptake of biologicals. Biological products are best integrated into crop production and pest management programs, rather than used as complete substitutes for synthetic CPPs. A lack of awareness and understand in how to deploy the unique modes of action of biological CPPs in integrated programs can be a barrier for farmers. Perceptions (whether real or not) of higher cost and lesser efficacy also exist.[xxv] Consequently, the biological share of the overall global CPP market is small, around US$3-4 billion of the US$61.3 billion CPP market.[xxvi] Despite these challenges, the growth of biological products is projected to outpace that of chemical CPPs in coming decades.[xxvii]

3 Australian crop production attributable to CPPs

This chapter presents the methodology and estimation of the Australian crop production attributable to CPPs. This estimate is conceptually different to the contribution to GDP discussed in the previous chapter. This chapter highlights the value of the *output* of crop production that is attributable to CPPs, as distinct from the contribution to GDP of the previous chapter. For many agricultural crops (particularly some horticultural and tree crops) it would not be possible to produce a crop without the use of CPPs, for other crops yields would decline without the use of CPPs. The estimate of crop production attributable to CPPs captures this reality.

Importantly, the value of crop production attributable to CPPs is not the same as the 'economic impact' that would occur in a scenario where all CPPs became unavailable – such a scenario may involve changes in behaviour and changes in farm practices that partly offset the absence of CPPs. Rather, this report estimates the current production attributable to CPPs (in 2020-21[5]) based on current farm practices.

The methodology for estimating the contribution of CPPs is based on work by Mark Goodwin Consulting (2011) and the scientific literature on attributions of different crops that underpinned that report. The report was commissioned by CropLife America, and detailed the value of selected crops attributable to CPPs (specifically herbicides, insecticides and fungicides). This methodology is a replication of previous iterations to allow for consistency and a time series comparison of results. An update of the literature on this topic since the last estimate was developed is also discussed. Note that this method captures most of the value of CPPs to agriculture, but not all. Importantly it doesn't capture the use of CPPs in the livestock industry, most notably through the use of herbicides in pasture management.

Deloitte Access Economics has adjusted previous estimates of the contribution of CPPs to the production of different crops in the USA to reflect salient features of Australian production practices. Differences in crop mix between the USA and Australia also impact the value of Australian crop production attributable to CPPs. Each of these is discussed in Sections 3.1 and 3.2. The value of CPPs to Australian crop production in 2021-22 is discussed in Section 3.3.

3.1 The Island Factor

The Australian and American cropping industries utilise different agricultural systems and practises due to a number of factors:

- Australia is an island continent – Geographic isolation from other countries and a rigorous quarantine system limit the prevalence of overseas crop pests and diseases. On the other hand, there are some pests and diseases unique to Australia, such as the native Queensland fruit fly.
- Climate and rainfall – Australia generally has a warmer, drier climate, which affects growth of weeds as well as crops.
- Soils – Australia is an old continent, with soils older and less fertile than those in the USA. This has implications for fertiliser use and plant competition from weeds and hence the use of CPPs.
- Agricultural practices – Minimum tillage and GPS controlled cropping systems have been adopted more quickly in Australia than in the USA (Australian Farm Institute, 2012) which can have an effect on soil-borne pests and diseases and need for pesticides. American agricultural production has a greater penetration of genetically modified crops (such as corn and soy)

[5] ABS crop production data for FY22 and CY22 were available, but not used, due to a reduced set of statistics being available for Australia. This is due to lower quality responses to the Rural Environment and Agricultural Commodities Survey, a major data input to this publication. As such, FY21 data (the latest year with a full set of statistics) were used as the basis for these estimates.

which can reduce the requirement of CPP inputs into these farming systems, particularly where crop varieties are resistant to specific pests and diseases.

- Labour costs – Australian agricultural sector wages are around double those in the United States, which could make farmers more likely to use CPPs in Australia to reduce reliance on labour (Australian Farm Institute, 2012).

An effect of these differences in agricultural industries is different use of CPPs in production. For example, application rates of particular pesticides vary, which entails differences in the use of CPPs per unit of production and per unit of cropping area.

A factor is applied to the USA data to make it applicable to the Australian context. This Island Factor takes into account the differences in crop production outlined above through a ratio comparing CPP use in Australia and the USA. This is summarised in Table 3.1 below.

Table 3.1: The Island Factor, 2016-2021

	Australia	USA
Total CPP use ($m)	3,158	19,682
Total crop area (million ha)	29	396
Total crop production ($m)	32	263
CPP use/ha (AUD/ha)	89	50
CPP use/$ production (USD)	83	75
Island factor (ha)	1.80	
Island factor (production)	1.10	
Average Island Factor	1.45	

Source: APVMA (2022), ABARES (2022) ABS (2022), USDA (2022), UNFAO (2023). Note: All dollar values used have been converted to 2021 Australian dollars.

Note: Data on CPP use is presented in expenditure terms, and therefore does not necessarily reflect the relative volume of CPP used, due to varying prices and disparate product selection across regions.

Data for Australian spend on CPPs, crop area and the value of total crop production was collected for 2013-14 to 2021-22 inclusive. Using the average across these years allows the methodology to account for differences in the use of CPPs across different growing conditions.

All values were converted to USD using yearly average exchange rates to make them comparable across countries. CPP use per hectare and CPP use per dollar of production were then estimated from the above data. Australian CPP use per hectare was divided by American CPP use per hectare to derive an Island Factor of 1.10. Similarly, Australian CPP use per dollar of production was divided by American CPP use per dollar of production to derive an Island Factor of 1.80. The average of these provided an Island Factor of 1.45.

The Australian farming system has been advanced in its adoption of newer farming practices that maximise soil moisture[xxviii] and reduce soil erosion. This has included the adoption of no-tillage and minimum tillage technologies that are enabled through the use of chemical weed control. The adoption of chemical weed control has also been incentivised as a way for Australian farmers to manage labour shortages and relatively high labour costs[xxix] compared to international competitors.

As discussed in the following section, the relative crop mix also affects the use of pesticides in agriculture, with horticulture representing a greater proportion of production Australia compared to the USA.

The Island Factor used in this report is equivalent to the value of 1.45 calculated for use in the 2018 report. However, the per-hectare component of the Island Factor has increased, while the per-dollar value has decreased.

3.2 The crop mix

In addition to the differences accounted for in the previous section, the Australian crop mix also differs from production in the USA. To some degree, the factors outlined above affect the relative proportions of crops produced in both countries.

Crops can be categorised into four broad categories:

- broadacre crops;
- vegetables;
- fruits and nuts; and
- other crops (mostly forage crops produced for livestock consumption).

The relative proportions of these crop groups have implications for the contribution of CPPs. In particular, higher applications of CPPs are generally used in high-value horticultural production compared to broadacre cropping. The Australian crop mix has a higher share of horticultural production compared to the USA (Table 3.2).

The share of production attributable to CPP use varies among individual crops within each category. For example, the proportion of production attributable to CPPs is higher for potatoes than it is for barley. These differences are accounted for in the calculation of the proportion of the total value of production of each broad category attributable to CPP use.

Table 3.2: Crop production mix, Australia and USA (A$m)

	Australia (2020-21)		USA (2021)	
Crop type	A$m	%	US$m	%
Field crops (broadacre)	22,948	53.1%	213,003	83.2%
Vegetables	6,900	16.0%	30,163	11.8%
Fruit and nuts	11,070	25.6%	12,974	5.1%
Other crops	2,293	5.3%	-	-
Total crops	43,211	100.0%	256,139	100.0%

Source: ABARES (2022), USDA (2022).

3.3 Value of CPPs to Australian crop production

Gianessi (2005, 2006 and 2009) conducted a series of studies on the contribution of fungicides, herbicides, insecticides to crop production in the USA. These studies presented data by crop, for the share of value attributable to each CPP. A summary of this data is provided at Appendix A.

Mark Goodwin Consulting combined the findings of these studies in their 2011 report to provide an overall estimate of the contribution of CPPs for the USA. This was done by adding the herbicide, insecticide and fungicide percentage contributions to provide a total CPP contribution. These totals were capped at 100 per cent even if the sum of herbicide, insecticide and fungicide contributions exceeded this amount.

For this study, the crops were split into the four crop categories of: field crops, vegetables, fruit and nuts, and other crops. Average herbicide, insecticide and fungicide contributions to the production for each crop category were then estimated based on the mix of individual crops. This is separately described for each crop group below.

These averages were then multiplied by the Island Factor to determine the Australian contribution to production. Finally, these contributions were multiplied by the value of crop production in the four groups (field crops (broadacre), vegetables, fruit and nuts, and other crops) to calculate the value of Australian crop production attributable to CPP use.

Field crops (broadacre)

Field crops include barley, canola, cotton, sorghum, sugarcane and wheat, among other crops. The full list of crops in this category is shown in Appendix A.

Within this category of crops, the proportion of value attributable to herbicide ranges from 16 per cent for sunflowers up to 53 per cent for rice. Overall, corn and sorghum are relatively hardy, with a smaller proportion of total production being attributable to CPPs (23 per cent and 34 per cent of value attributable to CPPs, respectively).

The value contribution of herbicide, insecticide and fungicide was estimated based on data from Gianessi (2005, 2007 and 2009), weighted for the Australian crop mix by value of production. Wheat and sugarcane combined make up over half of the value of these broadacre crops in Australia.

Adjusting for differences in use of CPPs in Australian agriculture, these weighted average contributions were then multiplied by the Island Factor. This produces an overall contribution to the value of Australian broadacre production of 54 per cent. Herbicides make up more than half of this, with a contribution of 35 per cent of crop value. In dollar terms, the contribution of CPPs to Australian broadacre production is estimated at $12.3 billion.

Table 3.3: Australian field crop production attributable to CPP use

	Herbicide	Insecticide	Fungicide	Total CPP
Weighted average contribution (%)	24%	6%	11%	39%
Australian contribution (%)	35%	9%	16%	54%
Value to Australia ($m)	7,141	1,914	3,236	12,292

Source: Mark Goodwin Consulting 2011, Deloitte Access Economics, ABS, ABARES.

Vegetables

Crops included in this category include broccoli, carrots, lettuce and onions, with a full list included in Appendix A. For the purposes of estimation, herbs have been included in this category.

Vegetable crops have a relatively high dependence on CPPs, in particular fungicides. Onions, for example, attribute 100 per cent of their production to fungicides, and CPPs account for 95 per cent and 92 per cent of crop value for carrots and celery respectively. That is, these vegetables would be very difficult to grow commercially without the use of CPPs.

In the absence of sufficiently detailed data to weight the mix of vegetable crops by value or volume of Australian production, an average was taken of the contribution of herbicides, insecticides and fungicide contributions for the range of crops analysed by Gianessi (2005, 2006 and 2009).

The contribution of each type of CPP to vegetable production was calculated by multiplying the total value of vegetable production by the average percentage of production attributable to CPP use across the range of crops for which Giannessi provided estimates (multiplied by the Island Factor).

Calculating the contribution of CPP use as a whole to vegetable production first requires summing the percentage of production attributable to each CPP category, which in many cases is greater than 100 per cent. The simple average of these is taken, which equals 83 per cent, and then multiplied by the Island Factor of 1.45 to calculate the contribution of CPP use as a whole to Australian vegetable production.

Using this method produces the result that 100 per cent of Australian vegetable production – $6.9 billion in 2020-21 – is attributable to the use of CPPs. The increase over the estimate produced for

2015-16 is solely due to the increase in the value of vegetable production (because, as in the 2018 analysis, 100 per cent of the value of vegetables is attributed to the use of CPPs).

Along with CPPs, vegetables also require water, labour and land to produce a crop. The use of (say) water could also be attributed with 100 per cent of onion output, as without water there would be no production. As such, the estimates here should be interpreted as the amounts of production attributable to CPPs, assuming all other requisites for production (water, labour, etc.) are readily available.

Table 3.4: Australian vegetable production attributable to CPP use

	Herbicide	Insecticide	Fungicide	Total CPP
Weighted average contribution (%)	21%	34%	54%	83%
Australian contribution (%)	30%	49%	78%	100%
Value to Australia ($m)	2,059	3,379	5,385	6,900

Source: Mark Goodwin Consulting 2011, Deloitte Access Economics, ABS, ABARES, IBISWorld.

Fruits and nuts

The fruits and nuts category includes apples, almonds, bananas, grapes, oranges and peanuts among others. The full list is presented in Appendix A.

Similar to vegetables, the value of fruits and nuts are more dependent on fungicides than other CPPs, and have a relatively small contribution from herbicides. Grapes and papaw are particularly reliant on fungicides, with 100 per cent of their value attributed to their use according to the Gianessi estimates. Peanuts and almonds attribute 92 per cent and 70 per cent of production to fungicide use, respectively.

The weighted average contribution of herbicides, insecticides and fungicides was estimated using data on the value of production of the relevant crops. This is preferred to the approach of using a weighted average based on volume (which had to be used in the 2013 report due to insufficient value data) or a simple average (which has been used for vegetables due to insufficient volume or value data).

Multiplying by the Island Factor provides the estimate for the contribution of CPPs to Australian crop production. While fungicide alone accounts for 100 per cent of fruits and nuts production on average, and the contribution of all CPPs is capped at 100 per cent, herbicides and insecticides also contribute to the value of production.

As with vegetables, 100 per cent of the value of fruit and nuts production is attributed to the use of CPPs under the methodology used. This is primarily due to the important role of insecticides in the production of a number of major crops, including apples and grapes.

The total value of CPP use on fruits and nuts production in Australia is estimated to be valued at $11.1 billion (the total value of fruit and nut production). As with vegetables, the increase over the figure in 2013 is entirely due to the increase in the value of fruit and nut production.

Table 3.5: Australian fruit and nut production attributable to CPP use

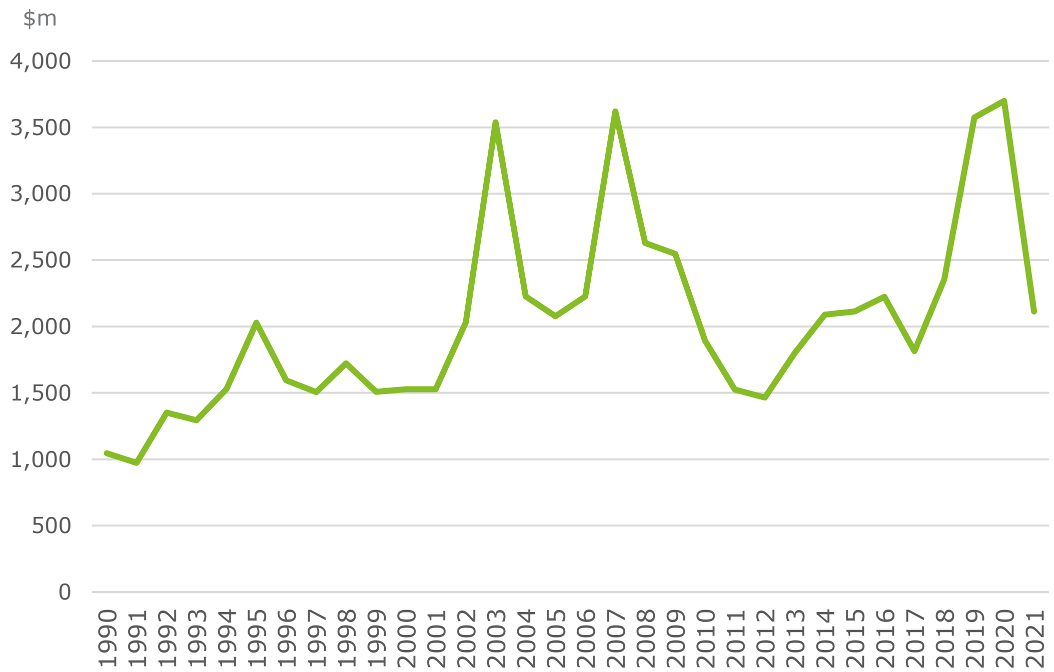
	Herbicide	Insecticide	Fungicide	Total CPP
Weighted average contribution (%)	7%	46%	75%	93%
Australian contribution (%)	10%	67%	100%	100%
Value to Australia ($m)	1,052	7,387	11,070	11,070

Source: Mark Goodwin Consulting 2011, Deloitte Access Economics, ABS, ABARES, IBISWorld.

Other crops

This category of crops is mainly comprised of forage crops; those grown to be grazed directly from the field by livestock, or harvested and conserved as hay or silage. These crops support a broad range of livestock production, including dairy cattle, beef, lamb and white meat – particularly in drought years where availability of pasture is limited. As shown in Chart 3.1, spending on fodder across Australian farms can vary significantly from year to year, and has reached over $3.5 billion in recent dry years.

Chart 3.1: Annual fodder costs, all farms, Australia



Source: Australian Bureau of Agricultural Resource Economics and Sciences (2023)

The proportional contribution of CPPs to value of production for these crops is assumed to be the same as for broadacre crops. Adjusting by the Island Factor suggests a contribution of 58 per cent of the value of production. In dollar terms, this is estimated at $1,300 million, a slight increase over the figure of $934 million estimated in 2018. Note that these figures only capture the value of CPPs to forage crops harvested and sold. It does not capture the value of CPPs to either forage crops grown and consumed on the same farm (i.e without any forage sale), or the wider value of CPPs in pasture management for the livestock industry.

Table 3.6: Australian other crop production attributable to CPP use

	Herbicide	Insecticide	Fungicide	Total CPP
Weighted average contribution (%)	24%	6%	11%	39%
Australian contribution (%)	35%	9%	16%	57%
Value to Australia ($m)	798	214	362	1,300

Source: Mark Goodwin Consulting 2011, Deloitte Access Economics.

3.4 Results summary

The total value of CPPs to Australian crop production is calculated as the sum of their contribution to each of the four categories of crops discussed in Section 3.3.

In aggregate, it is estimated that $31.6 billion of cropping production is attributable to the use of CPPs, or 73 per cent of the total value of crop production in 2020-21. Over half of this contribution is from fungicides, reflecting their significant contribution to the production of vegetables, fruit and nuts. This is equivalent to the 73 per cent estimated in 2015-16. A summary of the results discussed in Section 3.3 is shown in Table 3.7.

Table 3.7: Australian crop production attributable to CPP use

	Herbicide	Insecticide	Fungicide	Total CPP	% of total
Field crops (broadacre) ($m)	7,141	1,914	3,236	12,292	53.7%
Vegetables ($m)	2,059	3,379	5,385	6,900	92.0%
Fruit and nuts ($m)	1,052	7,387	11,070	11,070	93.5%
Other crops ($m)	798	214	362	1300	56.7%
Total ($m)	**11,050**	**12,894**	**20,053**	**31,562**	**73.0%**

Source: Mark Goodwin Consulting 2011, Deloitte Access Economics.

Note: Subtotals do not add to total due to the use of multiple CPPs in some crops.

The value of Australian crop production attributable to CPPs in 2021 is 53 per cent higher than the equivalent that was calculated for 2015-16. This result is primarily driven by an increase in the value of production (58% higher than 2015-16).

3.5 Additional research relating to CPP attributable production

Various crop protection technologies have had a considerable influence on long-term agricultural production in Australia and overseas. Synthetic and non-synthetic products have enabled significant gains in agricultural productivity, and are the dominant tool for maintaining consistently high yields in the absence of alternative farming systems or methods.[xxx] CPPs are often the first line of defence against insects and diseases that can damage crops, and generally contribute to higher crop yields at a lower cost to farmers. Without CPPs or other integrated strategies (outlined in 3.5.1 below), farmers could face challenges in managing pests and diseases that reduce crop yield and quality.

The importance of CPPs to crop production and supply is not limited to the farming process, as the integrity of crop quality needs to be maintained after harvesting. There is evidence to suggest that throughout the entirety of agricultural production and storage, pests (including invertebrates, weeds, and plant pathogens) cause nearly 40 per cent of global crop yield loss, with a further 20 per cent destroyed by postharvest pests and diseases.[xxxi] Natural disasters including flooding and drought, labour shortages and changing commodity prices are other factors that contribute to crop losses and waste.[xxxii]

In the Australian context, limited empirical literature presents differing outcomes for farm production and profitability resulting from CPPs no longer being available. A 2021 study estimated the economic impacts of the loss of herbicides glyphosate and paraquat on mixed-enterprise farms in the Central Wheatbelt region of Western Australia. The results showed that there would be a decline in farm profits if these herbicides were unavailable, and the average Central Wheatbelt farm could lose as much as $250,000 in revenue per year.[xxxiii] Another study used a bioeconomic model to simulate crop yields and profitability generated by southern Australian cropping farms in the context of no glyphosate use.[xxxiv] In contrast to the 2021 study, the model showed that it is possible to maintain crop yields and profitability without glyphosate. The authors emphasised that various cultural management practices appropriately tailored to specific agricultural contexts, for example early seeding, and strategic use of mechanical weed control to minimise detrimental soil disturbance are necessary in the absence of glyphosate use prior, during and after cropping. The divergent outcomes predicted in the literature suggests that the loss of key CPPs such as herbicides could present challenges to productivity and profitability of magnitude that differs across regions.

The impact of reduced CPP use on the agriculture sector has also been estimated in other markets. In response to incoming legislation restricting the use of certain pesticides in Europe, studies have measured the potential impact on the European agriculture industry and international trade. One study reported a potential decline in agricultural production of seven per cent globally to 12 per cent in the EU. This decline would tighten the food supply, and consequently would see a rise in household consumer spending. This was also found to exacerbate international food insecurity.[xxxv] While there is limited academic literature mirroring these tests in an Australian context, it does illustrate the potential disruptions to the industry that could occur without CPP use.

3.5.1 Emerging trends: agroecological systems and CPP use

Despite the dominance of CPPs in modern Australian agriculture, alternative agricultural systems which use CPPs more strategically (or in some cases, not at all) to produce food and fibre have existed since the early 20th Century.[xxxvi] Interest in such systems has grown over the past five to ten years, in part due to the recent increase in prices for CPPs and mineral fertilisers[xxxvii] (See Section 2.5), greater focus on the environmental sustainability of agricultural production,[xxxviii] as well as farmers' demand for a more diverse toolkit to deal with insect, weed and disease issues.[xxxix]

One such system is Integrated Pest Management (IPM).[6] The United Nations Food and Agriculture Organisation (UNFAO) defines IPM as 'the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms, and only using pesticides when needed'.[xl] It focuses on managing insects, weeds and diseases through a combination of cultural, physical, biological and chemical methods that are cost effective, environmentally sound and socially acceptable. It is important to note that IPM involves the careful consideration of all pathogen management techniques, including chemical and biological products (Section 2.5.4), and subsequent integration of appropriate measures.[xli]

A diverse range of practices are used under IPM to manage insect and weed pressure while reducing reliance on CPPs. In general, practices must be tailored to specific farming contexts, considering the farm enterprise mix, climate, soil type, topography, as well as the goals of the farm manager (or enterprise). In relation to weeds, practices such as planting multi-species cover crops can help reduce summer weed burdens and reduce reliance on herbicides for winter crop weed control, particularly in summer-dominant rainfall regions such as northern NSW.[xlii] Higher summer rainfall means the risk of reducing starting soil moisture in the winter crop phase is lower, relative to winter-dominant or indeterminate rainfall regions. Summer cover crops have also been evaluated in the Central West region of NSW which is more winter rainfall-dominant. The primary advantage described by Department of Primary Industries (DPI) researchers pertaining to CPP use was reduced herbicide applications over the summer fallow due to lower weed burdens. This was somewhat offset by the high herbicide rate required to terminate the cover crop and establish the following winter crop. Additionally, the risk of starting soil moisture deficiency (and therefore yield penalty) in the Central West region is higher, relative to aforementioned summer rainfall-dominant areas.[xliii] Findings from field trials underscore the importance of context when implementing IPM strategies to manage weeds, insects and diseases.

Furthermore, the biological management of plant diseases is also becoming increasingly recognised as a viable broadacre disease management tool. Promoting diversity of beneficial soil microbiota can help to increase plant health and resilience against disease, and therefore the need for fungicide applications.[xliv] Additionally, integrating livestock such as sheep and cattle into cropping-only systems can help to reduce grassy and broadleaved weeds, reduce herbicide use, and enhance nutrient cycling which benefits crop nutrition.[xlv] The use of 'virtual fencing' to allow grazing in discrete spatial areas (particularly those with high weed burdens) has been trialled by the CSIRO. The results from one trial in South Australia showed that strip-grazing using virtual fencing more than halved the amount of ryegrass seed heads compared to the paddock grazed

[6] There are a range of overlapping systems, each with similar principles, but differing practices, regulatory framework and academic literatures. They include (but are not limited to) agroecology, precision agriculture, permaculture, organic agriculture, biodynamic agriculture and regenerative agriculture.

without virtual fencing, thereby reducing future weed burden and necessary rates of herbicide use.[xlvi]

Various farm management practices can therefore be used to produce crops whilst reducing (but not necessarily eliminating) CPP use. Such practices are not generalisable across the broad range of enterprise types and climatic zones that characterise the Australian agriculture system, but must be specifically developed to suit particular farming contexts. Notwithstanding these developments in the sector, CPPs remain integral to agricultural production.

4 The broader benefits of CPPs

CPPs offer broader social benefits to Australia outside of the economic and crop production values estimated so far in Chapters 2 and 3.

For the purposes of this report, the wider benefits of CPPs are split into four categories: community benefits, environmental protection and climate benefits, food security and biosecurity, and the spillover benefits from Australia's scientific research and development in the CPP space.

While discussed in these distinct headings, these benefits are interrelated. For example, advances in scientific research and development will lead to benefits in food security, environmental protection, and to communities, while the benefits of environmental protection also have a positive externality on communities (and vice versa).

This analysis does not provide a monetary valuation of these benefits but provides a tangible understanding of the broader gains to Australia through CPP use. Furthermore, this chapter does not consider or compare the relative magnitudes of costs in relation to these benefits. For example, costs to the environment and potential health implications of their use are not covered in this report.

4.1 Community benefits from non-agricultural uses

Approximately 15 per cent of all CPPs are used by households, local councils and other non-agricultural users.[xlvii] Primarily, households use CPPs for gardening and lawn maintenance purposes. Other non-agricultural users include sporting facilities (golf courses, football ovals etc) and local government bodies, who use CPPs to control weeds and other invasive species.

Cooper and Dobson[xlviii] provide a comprehensive overview of benefits of non-agricultural use of CPPs. They contend that pests can have a negative impact on human activity, infrastructure, and the materials of everyday life unless they are controlled (by CPPs or other techniques).

CPP use on public council areas helps to provide secondary benefits to local community through the maintenance and accessibility of urban facilities and green spaces, which have been found to reduce stress and improve quality of life.[xlix]

Urban environments can influence the health of its residents through providing exercise and recreation areas that are accessible and neatly maintained. Herbicides are utilised by local councils to ensure that community facilities remain unspoiled from weeds.[l] For example, railways can be susceptible to weeds, and keeping tracks free of weeds is required to maintain good traction and braking distance of trains on the tracks. In Australia, Horticulture Innovation has established a Green Cities Fund which is undertaking research into science-based solutions to incorporating green spaces into urban development. Given the unique constraints of urban environments, CPPs could help ensure the establishment and ongoing maintenance of any urban greening initiatives.[li]

Households primarily implement CPPs for gardening and lawn maintenance. Urban and rural gardens play an important role in human wellbeing and sustainable urban development. Gardening is often cited as a beneficial activity as it combines physical activity with exposure to nature and sunlight.[lii] Increased gardening and greenspaces in urban areas can contribute to lower energy usage as more shade is planted and can also have a positive impact on local biodiversity and at-home food production.[liii] Having access to house-hold friendly herbicides and pesticides is essential for sustainable gardening by households and communities. The use of CPPs by governing bodies, communities and households can positively contribute to environmental protection and to offset the impacts of climate change in urban areas.

4.2 Environmental Protection and Climate Benefits

The global demand for food will continue increasing and Australia is a key contributor to global food supply chains. The agricultural industry can be a significant emitter, but CPPs can help reduce the impact. CPPs contribute to environmental protection and climate benefits in three ways:

- the benefits gained from reduced tillage practices
- minimising the prevalence of invasive species
- the avoidance of deforested land for agricultural purposes.

The use of CPPs by Australian farming system reduces deforestation in other parts of the world to accommodate the required increase in food production. In turn, this avoids any greenhouse gas emissions and nature loss that would be associated with this land use change around the world.[liv]

Tillage is a method used to prepare soil for planting which can be conducted by digging, stirring, and overturning and often requires machinery. As well as preparing soil for planting, tillage is often used to control weeds in between crops being planted. Conversely, no-till or reduced-till planting is where a new crop is planted directly into where the previous crop was planted, without any ploughing. For no or reduced-tillage practices to be implemented, CPPs such as herbicides are often employed to control weeds in the crops. Australia is one of the leading countries of conservation tillage practices, with 74 per cent of Australia's grain crop area using these practices in 2016.[lv]

There are several benefits of herbicide enabled no-tillage practices, including minimised soil degradation, enhanced water conservation and nutrient retention.[lvi] Herbicide enabled no-till farming has been found to reduce soil erosion by 80 per cent, which consequently protects water quality by preventing sediment run-off.[lvii] Another key benefit is that it can lead to fewer greenhouse gas emissions being released into the atmosphere. This is done through avoiding burning fossil-fuels to power machinery required for tillage, and it also lessens the amount of greenhouse gases that are released from the soil.[lviii] In Australia, there was a significant uptake of minimum tillage practices during the 1990s and 2000s spanning approximately 33.7million hectares of Australia's croplands. This resulted in approximately 5 million metric tonnes of carbon dioxide being sequestered in the soil annually, relative to what would have occurred if these practices were not implemented.[lix]

Furthermore, research has found that if glyphosate — a commonly used herbicide — use was restricted by farmers, the global environmental impact would be equivalent to adding over 11 million cars to the roads. This is due to the decreased soil carbon sequestration and additional carbon emissions from fuel usage by farm equipment.[lx] This figure is likely to be an underestimate as it pertains only to CPPs which use glyphosate and does not capture the equivalent if use of all CPPs was restricted. In addition, this estimate only considers the use of glyphosate on herbicide tolerant crops. This is a small subset of herbicides applied to crops in Australia, compared to North America where these crops are more widely deployed.

Invasive weeds would have a significant impact on Australian agricultural production if left unmanaged, with research estimating they generate an average annual cost of nearly $5 billion across Australia.[lxi] These weeds can also harm areas that are difficult to quantify such as ecosystems, wildlife and community areas. Invasive species can lead to a loss or alteration of native habitat and even extinction of native species. For example, the Chytrid fungus, which was introduced to Australia in the 1970s, directly contributed to the extinction of four native frog species, and the decline of many others.[lxii] CPPs such as herbicides and fungicides can be used to control the spread of these invasive weed species, helping to preserve Australian crops as well as native flora and fauna.

Case Study – Gamba Grass in the Northern Territory[lxiii]

Gamba grass (Andropogon gayanus) is an African pasture grass that can grow very tall and provides more feed for livestock than native grasses. Gamba grass was introduced to the Northern Territory in 1931 and has since been introduced and naturalised in parts of Queensland and Western Australia. It was declared a Weed of National Significance once it became evident that it was displacing native pasture species, contributing to intense bushfires, and altering soil-nutrient cycles.

Gamba grass is tolerant to fire and infested pastures have up to eight times higher fuel loads than native forest and pastures, and the presence of gamba grass has increased the season of extreme fire weather in the Northern Territory by six weeks. It is particularly prevalent around Darwin where the costs of fire-fighting have increased 9-fold since its introduction. In addition to the fire danger, Gamba grass is a highly invasive species that is displacing existing eucalypts and is dramatically altering native plant communities.

Gamba grass will never be fully eradicated in the Territory, but it can be effectively managed through the application of glyphosate, the only known effective herbicide. While Gamba grass can be removed manually, they have extensive root systems. Physically removing these weeds from the roots can disturb the soil, making it more susceptible to rain and wind erosion. Disturbed soil is often unsuitable for native plant seedlings. Given this, spraying with herbicides is the most effective option for minimising the impact of Gamba grass in national parks and reserves. Other non-chemical methods of control, such as steam spraying, can be used effectively in small areas (such as city recreational facilities) but is not effective when the weed is spread over a larger area, such as farms, nature reserves and national parks.

4.3 Food Security and biosecurity

By 2050, the world population is expected to reach 10 billion people, with a large concentration of them in developing countries. Historical population increases can be partially attributed to the rising availability and stability of global food crops, however, by 2050 it is estimated that the demand for food will be 56 per cent greater than in 2010.[lxiv] Developing countries are also more susceptible to the impacts of climate change, however Australian farmers are not without climate risks themselves. Extreme weather events that are increasing due to climate change bring with them a higher number of agricultural pests. This can be due to changing temperatures and precipitation patterns expanding the geographical distribution of pests and increasing the risk of invasion by migratory pests and the increased incidence of insect-transmitted plant diseases.[lxv] The subsequent losses to crop yields can have drastic impacts on food security. CPPs can help mitigate climate change risks and can also alleviate domestic and global food security pressures.

Given advances in agriculture, over the last century there are fewer individuals farming while producing greater yields. For example, 98 per cent of the population in the USA and Canada relies on the remaining 2 per cent of their population to produce food.[lxvi] CPPs allow for increased productivity per hectare, as they help to eliminate pests and pathogens that contribute to crop losses. Evidence suggests that without implementing CPPs in some key crops, there could be a global decline by 78 per cent in fruit production, 54 per cent in vegetable production, and 32 per cent in cereal production.[lxvii] The use of CPPs is necessary to combat food and nutritional insecurity, especially in the face of climate change impacts to crop yields.

Maintaining Australia's biosecurity is essential to protect the unique biodiversity in the country, as well as promoting ongoing food security. A biodiverse environment is better suited to withstand pest outbreaks, and Australia's biosecurity agencies look to protect food crops and livestock from pests as well as protecting ecosystems from invasive species.

Case Study – Sri Lanka's pesticide ban exacerbating food insecurity[lxviii] [lxix]

In April 2021, the Sri Lanka Government imposed a ban on importing and using conventional agricultural chemicals including pesticides. Since the 1960s, Sri Lanka has utilised synthetic CPPs in agricultural production, and this has made the country largely self-sufficient in rice crops. From a food security perspective, being sufficient in a staple crop such as rice is essential. The ban was implemented quickly, and it was not staggered to allow farmers time to switch to non-synthetic CPPs.

A direct result of this ban was increased challenges to purchasing the conventional products that were used in farming inputs. 80 per cent of farmers had to pay higher prices for conventional pesticides and 79 per cent were not able to purchase products at all.[lxix] Consequently, most farmers had to change their existing farming practices. These included reducing the dose rate (which has a direct impact on crop yield) and delaying or bringing forward when these products would be applied to crops.

The swift ban of these products led to a 20 per cent reduction in rice production; and the production of tea (one of Sri Lanka's largest exports) fell by 18 per cent. Overall, there were reports of Sri Lankan farmers losing over half of their normal crop yield throughout the season due to significantly higher weed, disease and pest infestations. Over 80 per cent of farmers reported a higher weed infestation, over 70 per cent noticed higher insect activity and 77 per cent experienced a higher disease infestation in their crops. These were noted across the country and were observed in multiple crops including tea, vegetables and maize.

This decrease in crop yields, in conjunction with other ongoing political and economic factors of the country, led to large inflation of food prices (at around 30 per cent for rice), a decrease in exports, and an increase in food insecurity for the nation, particularly those at the lower end of the income distribution. While some farmers were able to sell their produce at a higher price due to these shortages, it was not enough to offset lower crop yields and higher input costs. The strain was felt across with the sector and 25 per cent of Sri Lankan farmers have noted they would have resigned farming if the ban continued.

The drop in crop yields caused by the lack of CPPs also contributed to high domestic food prices. These high food prices exacerbated existing inflation which was already high due to COVID-19 economic disruptions, high fuel-costs and prevailing political conditions. Food crops that were previously produced locally now needed to be imported, including staple crops like rice. A majority of the country relies on their own agricultural output to meet their daily food requirements as well as for an income stream.

Food inflation reached 95 per cent in September of 2022, ranking Sri Lanka among the top five countries for high food price inflation. This has led to 37 per cent of the Sri Lankan population experiencing food insecurity in August 2022. This figure has since reduced to 32%, but it remains a large increase over the 9 per cent recorded in 2019. To manage this crisis, nearly 80 per cent of households in Sri Lanka are adopting food-based coping strategies as a result which include reducing the number of meals or skipping them entirely. The increasing food insecurity has exacerbated existing inequalities in the country, with poorer households and female-led households being more food insecure on average, largely attributable to their higher reliance on food-based coping strategies.

4.4 Contributions to Scientific Research and Development

Existing CPPs provide a foundation for extensive research on pests and diseases affecting Australian crops. Although the primary objective of CPP development and use is for agricultural productivity (see Section 3), it can also provide spillover benefits to other related industries. For example, CPP research enables innovation in adjacent fields, such as biosecurity and pest control.

Broad use of CPPs has been associated with increased pest resistance, particularly when the same product is used multiple times in the same area.[lxx],[lxxi] Additionally, Australia is one of the countries with the highest cases of herbicide resistant weeds and it is expected that the level of insecticide resistance in major grain growing regions of Australia will increase in the coming years.[lxxii] Consequently, an area of ongoing research globally and within Australia, is the development of alternative CPPs that can replace pest-resistant products. By understanding pest and disease dynamics, researchers can develop new practices. This includes integrated pest management (IPM), which combines a range of practices to control insect pests in agricultural production and innovate new forms of CPPs that can target specific pests while mitigating any negative impacts of chemical use.

There are several research institutions and organisations across the country participating in the conducting or funding the research and development of CPPs. This includes the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Horticulture Innovation Australia, Cotton Research and Development Corporation and the Grains Research and Development Cooperation, who have targeted research and funding areas for key Australian crops such as cotton, grains, and horticulture.[lxxiii] Their research investigates methods to protect these crops as well as native plants from threats from pathogens, pests and weeds, as well as understanding disease resistance genes. The development of innovative practices and CPPs because of this research will have positive contributions to Australia’s environment, food security and agricultural sustainability. Research and development of CPPs is also undertaken at various universities across the country.

The importance of conducting research into CPPs and the adjacent industries (i.e., agriculture) is also felt directly by the research institutions. Conducting this research can create revenue streams that contribute to the overall operation of the institute as well as providing opportunities for innovation and new products and businesses. DemAgtech in Western Australia provides a recent example. A newly established business, DemAgtech have commercialised herbicides that were researched and developed at the University of Western Australia, and aim to continue to develop products that address increasing herbicide resistance in Australia.[lxxiv] This joint venture demonstrates the value and importance of research into CPPs to the wider community as well as various institutions.

Concerns over the negative impacts of chemical CPPs on human health and the environment has encouraged intensive research and development in the CPP industry, spurred by changes in registration requirements of CPPs. For example, the European Union made changes to their registration requirements on active ingredients found in CPPs, and this led to the removal of over half of the CPP active ingredients in the 1990s.[lxxv] There has been a high rate of new biological products being registered as CPPs since the 1960s, and in 2016 there were more patents lodged for biological products compared to conventional CPPs.

Case Study - Australia Research Council Hub: Sustainable Crop Protection and BioClay™

The Australian Research Council supports a research hub focusing on Sustainable Crop Protection, in partnership with Nufarm and The University of Queensland.[lxxvi] The research being conducted aims to develop and commercialise a biological alternative to chemical fungicides that are targeting broad-acre and horticultural crop diseases. This research can address fungicide resistance, chemical residues in food, and environmental harm. Consequently, the broader benefits of this research to the Australian community are immense. By reducing crop losses due to fungal pathogens in an environmentally sustainable way, this can protect Australia’s biodiversity as well as increasing crop productivity, reducing the risk of residue remaining on food products, and have positive impacts on domestic and global industries.

While based at the University of Queensland, this ARC Hub has partnerships with universities and research institutes around the country, as well as in the United States. Such partnerships foster knowledge exchange and contribute to advancements in crop protection science and technology, and result in collaboration. For instance, the CPP being developed at this hub, BioClayTM, targets fungal pathogens that affect globally significant crops such as strawberries, grapes, chickpeas, canola, cotton and cereals.[lxxvii] The Tasmanian Institute of Agriculture based out of the University of Tasmania is currently working with BioClayTM to investigate its use in suppressing botrytis disease in wine grapes. If successful, this could hold significance to the wine industry, as it offers growers an innovative alternative to chemical fungicides.[lxxviii] This is just one example of innovation in this space, but it is indicative of the wide-reaching gains that could be harnessed from ongoing research and development of CPPs. The development and findings of this research have the capacity to have a global reach beyond Australia's borders.

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Appendix A : Economic contribution methodology

A.1. Analysis introduction

Economic contribution studies are intended to quantify measures such as value added, exports, imports and employment associated with a given industry or firm, in a historical reference year. The economic contribution is a measure of the value of production by a firm or industry.

All direct, indirect and total contributions are reported as gross operating surplus (GOS), labour income, value added and employment (with these terms defined in Table A.1).

Table A.1: Definitions of economic contribution estimates

Estimate	Definition
Gross operating surplus (GOS)	GOS represents the value of income generated by the entity's direct capital inputs, generally measured as the earnings before interest, tax, depreciation, and amortisation (EBITDA).
Labour income	Labour income is a subcomponent of value add. It represents the value of output generated by the entity's direct labour inputs, as measured by the income to labour.
Value added	Value added measures the value of output (i.e. goods and services) generated by the entity's factors of production (i.e. labour and capital) as measured in the income to those factors of production. The sum of value added across all entities in the economy equals GDP. Given the relationship to GDP, the value added measure can be thought of as the increased contribution to welfare.
Employment (FTE)	Employment is a fundamentally different measure of activity to those above. It measures the number of workers (measured in full-time equivalent terms) that are employed by the entity, rather than the value of the workers' output.
Direct economic contribution	The direct economic contribution is a representation of the flow from labour and capital committed in the economic activity.
Indirect economic contribution	The indirect contribution is a measure of the demand for goods and services produced in other sectors as a result of demand generated by economic activity.
Total economic contribution	The total economic contribution to the economy is the sum of the direct and indirect economic contributions.

Source: Deloitte Access Economics, 2018

A.2. Definitional notes

When calculating the GOS for a typical for-profit firm or industry, income streams from government (such as transfers or production subsidies) are excluded as they are a transfer of public funds, not reflective of income generated by the activities of the firm or industry.

Similarly, value added is typically calculated as GOS plus labour income net of subsidies; under the ABS Australian System of National Accounts (ASNA) (ABS 2013):

> *A subsidy on a product is a subsidy payable per unit of a good or service. An enterprise may regard a subsidy as little different from sales proceeds. However, in the national accounts, subsidies are regarded as transfer payments from general government, enabling enterprises to sell their output for less than would otherwise be the case.*

A.3. Value added

The measures of economic activity provided by this contribution study are consistent with those provided by the Australian Bureau of Statistics. For example, value added is the contribution the sector makes to total factor income and gross domestic product (GDP).

There are a number of ways to measure GDP, including:

- expenditure approach – measures expenditure: of households, on investment, government and net exports; and
- income approach – measures the income in an economy by measuring the payments of wages and profits to workers and owners.

Below is a discussion measuring the value added by an industry using the income approach.

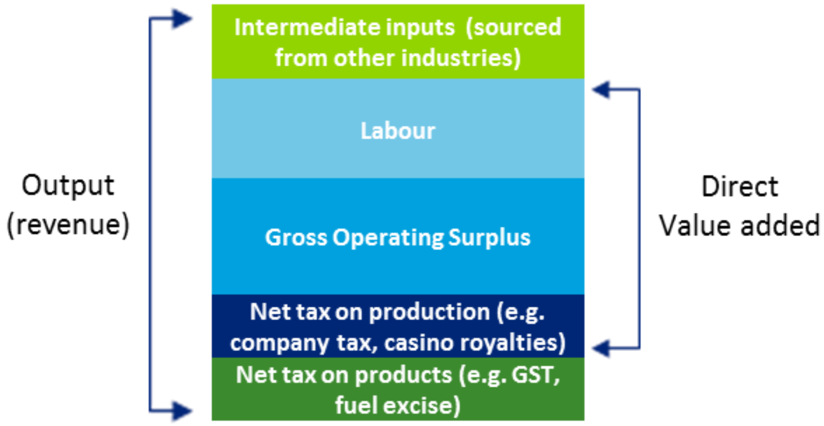
A.4. Measuring the economic contribution – income approach

There are several commonly used measures of economic activity, each of which describes a different aspect of an industry's economic contribution:

- Value added measures the value of output (i.e. goods and services) generated by the entity's factors of production (i.e. labour and capital) as measured in the income to those factors of production. The sum of value added across all entities in the economy equals gross domestic product. Given the relationship to GDP, the value added measure can be thought of as the increased contribution to welfare.
  Value added is the sum of:
  - Gross operating surplus (GOS) represents the value of income generated by the entity's capital inputs, generally measured as the earnings before interest, tax, depreciation and amortisation (EBITDA).
  - Tax on production less subsidy provided for production. Note: given the manner in which returns to capital before tax are calculated, company tax is not included or this would double-count that tax. In addition it excludes goods and services tax, which is a tax on consumption (i.e. levied on households).
  - Labour income is a subcomponent of value added. It represents the value of output generated by the entity's direct labour inputs, as measured by the income to labour.

Figure A.1 shows the accounting framework used to evaluate economic activity, along with the components that make up output. Output is the sum of value added and the value of intermediate inputs used by the firm or industry. The value of intermediate inputs can also be calculated directly by summing up expenses related to non-primary factor inputs.

Figure A.1: Economic activity accounting framework



Source: Deloitte Access Economics.

Contribution studies generally outline employment generated by a sector. Employment is a fundamentally different measure of activity to those above. It measures the number of workers that are employed by the entity, rather than the value of the workers' output.

A.5. Direct and indirect contributions

The direct economic contribution is a representation of the flow of labour and capital to businesses in the CPP industry.

The indirect contribution is a measure of the demand for goods and services produced in other sectors as a result of demand generated by the direct economic activity of the CPP industry. Estimation of the indirect economic contribution is undertaken in an input-output (IO) framework using Australian Bureau of Statistics IO tables which report the inputs and outputs of specific sectors of the economy (ABS 2023).

The total economic contribution to the economy is the sum of the direct and indirect economic contributions.

Other measures, such as total revenue or total exports are useful measures of economic activity, but these measures alone cannot account for the contribution made to GDP. Such measures overstate the contribution to value added because they include activity by external firms supplying inputs. In addition, they do not discount the inputs supplied from outside Australia.

A.6. Limitations of economic contribution studies

While describing the geographic origin of production inputs may be a guide to a firm or industry's linkages with the local economy, it should be recognised that these are the type of normal industry linkages that characterise all economic activities.

Unless there is unused capacity in the economy (such as unemployed labour) there may not be a strong relationship between a firm's economic contribution as measured by value added (or other static aggregates) and the welfare or living standard of the community. The use of labour and capital by demand created from the industry comes at an opportunity cost as it may reduce the amount of resources available to spend on other economic activities. This is not to say that the economic contribution, including employment, is not important. As stated by the Productivity Commission in the context of Australia's gambling industries: (Productivity Commission 1999):

> *Value added trade and job creation arguments need to be considered in the context of the economy as a whole … income from trade uses real resources, which could have been employed to generate benefits elsewhere. These arguments do not mean that jobs, trade and activity are unimportant in an economy. To the contrary they are critical to people's well-being. However, any particular industry's contribution to these benefits is much smaller than might at first be thought, because substitute industries could produce similar, though not equal gains.*

In a fundamental sense, economic contribution studies are simply historical accounting exercises. No 'what-if', or counterfactual inferences – such as 'what would happen to living standards if the firm or industry disappeared?' – should be drawn from them.

The analysis – as discussed in the report – relies on a national IO table modelling framework and there are some limitations to this modelling framework. The analysis assumes that goods and services provided to the sector are produced by factors of production that are located completely within the state or region defined and that income flows do not leak to other states.

The IO framework and the derivation of the multipliers also assume that the relevant economic activity takes place within an unconstrained environment. That is, an increase in economic activity in one area of the economy does not increase prices and subsequently crowd out economic activity in another area of the economy. As a result, the modelled total and indirect contribution can be regarded as an upper-bound estimate of the contribution made by the supply of intermediate inputs.

Similarly the IO framework does not account for further flow-on benefits as captured in a more dynamic modelling environment like a Computerised General Equilibrium (CGE) model.

A.7. Input-output analysis

Input-output tables are required to account for the intermediate flows between sectors. These tables measure the direct economic activity of every sector in the economy at the national level. Importantly, these tables allow intermediate inputs to be further broken down by source. These detailed intermediate flows can be used to derive the total change in economic activity associated with a given direct change in activity for a given sector.

A widely used measure of the spill-over of activity from one sector to another is captured by the ratio of the total to direct change in economic activity. The resulting estimate is typically referred to as 'the multiplier'. A multiplier greater than one implies some indirect activity, with higher multipliers indicating relatively larger indirect and total activity flowing from a given level of direct activity.

The IO matrix used for Australia is derived from the ABS 2020-21 IO tables, the latest available IO data at the time of the analysis. The industry classification used for IO tables is based on the Australian and New Zealand Standard Industrial Classification (ANZSIC), with 114 sectors in the modelling framework.

A.8. Change in methodology from previous reports

The methodology employed to calculate the economic contribution of the CPP industry to the Australian economy was altered from previous reports. The method was necessarily changed because of an adjustment in the multipliers underpinning the ABS IO tables, and an improved approach to capture the economic contribution of imported CCP products and their sales to Australian farmers.

In the revised approach, Deloitte Access Economics partitioned the contribution of domestic CPP manufacturing to GDP and employment, as well as the contribution of imported CPPs that are retailed in Australia.

To achieve this, the contribution of domestic CPP manufacturing and CPP imports were entered separately in the IO model. The value of domestic pesticide manufacturing was obtained from ABS datasets. The total value of imports was calculated by subtracting the value of domestic CPP manufacturing from the APVMA sales data. The total imported value was scaled down to capture the logistics contribution of the imported goods.

Acknowledging that imports are mostly handled by the wholesale and retail trade industries in Australia, the scaled value of imports figure was split across these two industries. Data from Table 2 – Merchandise importers, by industry of importer and state of final destination of imported commodity was used to inform the relative shares.

The inclusion of CPP imports into the model marginally increased the direct share of value added, relative to shares in the 2018 and 2013 reports. This can be attributed to the wholesale and retail trade industries which handle and distribute imported CPPs to end users. These industries utilise relatively more labour than manufacturing, which is reflected in a higher ratio of wages to total value added. Overall, despite imported CPPs accounting for approximately 25 per cent of total CPP income, around 30 per cent of direct value added can be attributed to imports.

Appendix B : Attributable production estimates (USA)

Table B.1: Share of yield attributable to CPPs, USA (%)

Crop	Herbicide	Insecticide	Fungicide	Total CPP	Category*
Alfalfa		5		5	V
Almond	5	43	70	100	FN
Apple	15	93	86	100	FN
Artichoke	16	60	35	100	V
Asparagus	55	67	22	100	V
Avocado		48		48	FN
Banana			75	75	FN
Barley			9	9	FC
Blueberry	67	69	75	100	FN
Broccoli	14	75		89	V
Cabbage		64	65	100	V
Canola	45			45	FC
Cantaloupe			60	60	FN
Carrot	48	10	95	100	V
Celery	0	48	92	100	V
Cherries		84	92	100	FN
Citrus	0		88	88	FN
Collard			78	78	V
Corn	20	3		23	FC
Cotton	27	30	12	69	FC
Cranberry	50	50	87	100	FN
Cucumber	66	34	77	100	V
Date		85		85	FN
Dry bean	25			25	FC
Eggplant		25		25	V
Garlic			61	61	V
Grape	1	35	100	100	FN
Green bean	20	58	65	100	V
Green pea	20	22		42	FC
Hazelnut		45	60	100	FN
Hop	25	100	100	100	FC
Hot pepper	0		44	44	V
Kiwi			33	33	FN
Lettuce	13	50	85	100	V
Mint	58	54	16	100	V
Nectarine		64	89	100	FN
Olive		90	84	100	FN
Onion	43	22	100	100	V
Orange		77		77	FN
Papaya			100	100	FN
Parsley			66	66	V
Peach	11	51	91	100	FN
Peanut	52	55	92	100	FN
Pears		85	89	100	FN
Pecan		56	72	100	FN
Pistachio		64	39	100	FN

Crop	Herbicide	Insecticide	Fungicide	Total CPP	Category*
Plums and prunes			66	66	FN
Potato	32	29	94	100	FC
Raspberry	0	55	97	100	FN
Rice	53	13	54	100	FC
Sorghum	26	8		34	FC
Soybean	26	5	3	34	FC
Spinach	50	16	71	100	V
Strawberry	30	56	97	100	FN
Sugar beet	29	23	78	100	V
Sugarcane	25	22		47	FC
Sunflower	16	50		66	FC
Sweet corn	25	28	36	89	FC
Sweet peppers		53	80	100	V
Sweet potato	20	45		65	V
Tomato	23	53	77	100	FN
Walnut		36	54	90	FN
Wheat	25	3	9	37	FC
Wild Rice	50		20	70	FC

Sources: Gianessi 2005, 2006 and 2009. *Note: categories FC=field crop (broadacre), V = vegetables (includes herbs), FN = fruits and nuts. Blanks indicate no data was available.

Limitation of our work

General use restriction

This report is prepared solely for the use of CropLife Australia. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose set out in the engagement letter dated 15 March 2023. You should not refer to or use our name or the advice for any other purpose.

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