Value of honey bee pollination to the Australian economy

by Dr Rob Gillespie, Michael Clarke
and Elizabeth Frost
February 2024

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Foreword

Since the mid-1980s, economists have made numerous attempts at estimating the value of honey bee pollination to the Australian economy. The exercise is not straightforward, and a variety of valuation methods have been used in the past.

The purpose of this research was to review previous studies and the economic theory underpinning them, and use the results to prepare an authoritative valuation framework. The resultant framework, which incorporates the concepts of consumer and producer surplus and a partial equilibrium model, was then used to estimate the value of honey bee pollination to the Australian economy.

The study has delivered an updated, defendable and transparent estimate of the economic value of honey bee pollination. The estimate was prepared using 2020-21 gross value of production data and showed that crops worth $12.9 billion are at least partially reliant on honey bee pollination. The economic contribution (consumer and producer surplus) attributable to honey bee pollination is $4.6 billion.

This estimate is less than that of a previous and widely quoted study. It has been concluded that the different estimates produced by the two studies is due to application of estimation techniques, rather than any diminution in the contribution made by honey bee pollination. Researchers acknowledge growth in honey bee pollination-dependent cropping since the previous study and have expanded model coverage to include a record 67 crops.

The conceptual framework and the spreadsheet model have been provided to AgriFutures Australia so we can continue estimating the value of pollination to the Australian economy. AgriFutures Australia intends to update the estimate every three to five years.

This project was completed as part of the AgriFutures Honey Bee & Pollination Program, which invests in research, development and extension to foster a productive, sustainable and more profitable Australian beekeeping industry, and to secure the pollination of Australia's agricultural and horticultural crops. For more information and resources, visit https://agrifutures.com.au/honey-bee-pollination/.

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Dr Rob Gillespie is the Principal of Gillespie Economics, an environmental and resource economics consulting firm that has worked across agriculture, conservation, forestry, tourism and recreation, energy generation and transmission, energy storage, mining, extractive industry, water, and urban development. Its core areas of expertise are environmental and resource economics, benefit-cost analysis, non-market valuation, regional economic impact assessment (input-output analysis), financial appraisal, pricing policies, economic and financial instruments, and policy analysis, development and review. In 2017, Rob contributed input-output analysis to Rural Industries Research and Development Corporation project *Regional economic multiplier impacts, potential pollinator deficits across crops*.

Michael Clarke is an experienced agricultural economist whose work includes economic evaluation, policy analysis, strategic planning and research in agriculture and natural resource management. Michael has worked with the Australian beekeeping industry researching and analysing resource access, biosecurity, industry R&D plans, policy, honey bee product markets and industry levy issues since 1995. In 2024, he co-authored the report *Size and scope of the Australian honey bee and pollination industry* with Danny Le Feuvre. A year prior, Michael and Danny completed a comprehensive analysis of the number of honey bee hives required to pollinate horticultural crops.

Elizabeth Frost is Technical Specialist Bees with the New South Wales Department of Primary Industries. Liz's research interests include pollination of crops using European honey bees. Liz co-manages the National Honey Bee Genetic Improvement Program (Plan Bee), which was federally funded through the Rural Research and Development for Profit program. For the past 15 years, she has immersed herself in US bee research lab work, US/Australian commercial queen breeding and honey production seasonal labour, and Australian RD&E. She has worked across the public and private sectors delivering projects for agencies and beekeepers. Liz works to increase beekeeping business viability, queen breeding efficiency and food security through RD&E in collaboration with industry and research partners.

Acknowledgements

Gillespie Economics would like to thank Steve Fuller, President of the Crop Pollination Association of Australia, and Annelies McGaw, Honey Bee & Pollination Program Manager with AgriFutures Australia, for their contributions to and support for this project.

Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AHBIC	Australian Honey Bee Industry Council
CIE	Centre for International Economics (consultants)
DAFF	(Australian Government) Department of Agriculture, Fisheries and Forestry
FAO	Food and Agriculture Organization (of the United Nations)
GVP	gross value of production
PEM	partial equilibrium model
RDC	Research and Development Corporation
RD&E	research, development and extension
RIRDC	Rural Industries Research and Development Corporation (now AgriFutures Australia)
UK	United Kingdom
US	United States

Contents

Executive summary

Since the mid-1980s, economists have made numerous attempts at estimating the value of honey bee pollination to the Australian economy. The exercise is not straightforward, and a variety of valuation methods have been used in the past.

The purpose of this research was to review previous studies and the economic theory underpinning them, and use the results to prepare an authoritative valuation framework. The resultant framework, which incorporates the concepts of consumer and producer surplus and a partial equilibrium model (PEM), was then used to estimate the value of honey bee pollination to the Australian economy.

The study has delivered an updated, defendable and transparent estimate of the economic value of honey bee pollination. The estimate was prepared using 2020-21 gross value of production data and showed that crops worth $12.9 billion are at least partially reliant on honey bee pollination. The contribution (consumer and producer surplus) attributable to honey bee pollination was $4.6 billion.

The previous investigation of the value of honey bee pollination was undertaken in 2018 using 2014-15 data. Since the release of this research, managed hive pollination has increased, and the value of agricultural and horticultural crops has also increased, prompting this latest research.

Who is the report targeted at?

The report is targeted at honey bee and pollination peak industry bodies, AgriFutures Australia, other Research and Development Corporations, pollination-dependent industries, and decision makers, including policy analysts in both the Australian Government and state and territory jurisdictions.

Where are the relevant industries located in Australia?

Honey bee pollination using managed and unmanaged honey bees takes place in all Australian states and territories. Honey bee pollination is important to a range of tree crops, broadacre crops, vine crops, annual horticulture and seed production.

Methods used

Research to understand the contribution that honey bee pollination makes to the Australian economy was completed using the concepts of consumer and producer surplus and a PEM. Data to populate the model included current knowledge on crop dependency on honey bees for pollination, estimates of the farmgate elasticity of supply and demand for honey bee-dependent crops, and 2020-21 data on crop farmgate prices and production by state and territory.

Key findings

Australian crops with a gross value of production (GVP) of $12.9 billion are at least partially reliant on honey bee pollination. The economic contribution (consumer and producer surplus) attributable to honey bee pollination is $4.6 billion.

Study differences that require communication to beekeepers include:

1. The GVP of honey bee-pollinated crops is about 30% greater than it was in 2014-15, when the previous economic value of pollination study (Karasiński 2018a) was completed.

2. The approach used in this study and Karasiński (2018a) was the same, i.e. a PEM measuring changes in producer and consumer surplus following loss of honey bee pollination services.

3. The two studies produced different estimates of the value of honey bee pollination to the Australian economy; the $4.6 billion estimate of the current study is in contrast to the $14.2 billion of Karasiński (2018a). This is due to different modelling assumptions, especially those used to estimate demand elasticity.

4. Elasticity of demand measures the relationship between a change in the quantity of crop available and a change in its price. In this instance, the assumed change in price is due to loss of yield and quality of a crop following loss of honey bee pollination.

5. This study has sourced up-to-date elasticity of demand estimates from published literature.

Recommendations

Findings from the research should be used by AgriFutures Australia to prepare a value of honey bee pollination infographic that highlights the economic contribution of each state and territory, and each pollination-dependent crop.

The conceptual framework and the spreadsheet model have been provided to AgriFutures Australia to enable routine update of the estimate. AgriFutures Australia is recommended to update the estimate every three to five years in light of changes in demand for honey bee pollination.

Introduction

This study was commissioned to inform AgriFutures Australia, other Research and Development Corporations (RDCs), pollination-dependent industries, and decision makers about the current economic value of European honey bee (*Apis mellifera*) pollination to the Australian economy.

Pollination is the movement of male pollen grains from the anthers of a flower to the female stigma of the same or a different flower. Once on the stigma, the pollen grain must germinate, and the resulting pollen tube must break through the stigmatic tissue and down through the style to reach the ovule. The genetic material in the pollen tube then combines with an ovule to create a fertilised seed. For a commercial crop, this needs to happen reliably and often (Goodwin 2012).

Some flowers will be pollinated by movement of pollen in wind, but for many crops the pollination rate is much higher when insects visit flowers and move pollen on their bodies. Honey bees are important flower visitors, but a range of other native bees, flies and beetles can also be important. A few crops benefit from bird or bat pollination (Clarke *et al*. 2017).

Honey bee pollination can be achieved in a variety of ways. These include the crop grower paying beekeepers to provide pollination services, beekeepers providing honey bees at no cost to the grower in exchange for a honey crop, or by unmanaged, wild European honey bees with colonies adjacent to crops providing pollination services of their own volition.

Pollination is a service of incontrovertible economic value linked to human wellbeing through agricultural production and food supply. There is both technical and economic literature pertaining to the benefits of honey bee pollination. However, the methodological approaches adopted for estimating the economic benefits of pollination are as varied as the resultant estimates.

An international review by Porto *et al*. (2020) identified six distinct methods of economic valuation of pollination services without drawing distinctions or critiquing the approaches. A review of Australian studies found valuation approaches that included output value, willingness to pay, replacement cost, producer surplus, combined producer and consumer surpluses using both partial and general equilibrium analysis, and regional economic impacts. These methods are not substitutes for each other and are not equally valid. Even studies that seem to adopt the correct valuation method provide little transparency and so limit the ability for replicability and updating. This project aimed to remedy this situation.

Project objectives and approach

The objective of the project was to provide an updated, defendable, and transparent estimate of the economic value of honey bee pollination to the Australian economy, that can be replicated over time. The project was discharged through the completion of the following tasks:

1. Project launch meeting with the AgriFutures Honey Bee and Pollination Program Manager and a project steering committee to clarify any outstanding issues with the Gillespie Economics proposal and review preliminary research. Preliminary research included a draft set of pollination-dependent crops and estimated honey bee dependency factors. Comments were provided on this draft by Elizabeth Frost and Steve Fuller.

2. Review of previous studies and the methods used. This included both Australian and overseas studies. The results of studies were summarised, and the method used to estimate values were identified.

3. Development of a conceptual economic framework for the valuation of changes in agricultural crop supply as a result of honey bee pollination. The conceptual framework was founded in the microeconomic theory of welfare economics which is the basis for economic valuation of goods and services. The conceptual framework was used to further evaluate and categorise studies from the literature and provide a basis for an updated valuation of honey bee pollination services in Australia.

4. Identification of relevant data sources (including, but not limited to, the Australian Bureau of Statistics (ABS) and previous research funded by the Rural Industries Research and Development Corporation/AgriFutures Australia). The conceptual framework for valuation identified a variety of data requirements and where these were not readily available, “second best” approaches were used to synthesis essential information. Critical data requirements included the price and quantity of all relevant crops by state and territory, share of crop exported (to estimate changes in Australian consumer surplus), dependency of crop production on honey bee pollination, as well as demand, and supply elasticities by crop.

5. Implementation of the conceptual framework to estimate both producer surplus and consumer surplus economic values by agricultural crop, state/territory, and for the whole of Australia. This required the development of a series of spreadsheet models with clear documentation of all assumptions/data and calculations. This study can now be updated at regular intervals on a “like-for-like” basis.

6. Preparation of both a draft and final report. The results of the study, the approaches used, data employed, and a plain English summary were documented in a draft report for assessment by the AgriFutures Honey Bee and Pollination Advisory Panel. Data limitations and suggestions for future research to fill data gaps were also identified. A final report incorporating Advisory Panel feedback, was then prepared, and submitted to AgriFutures.

Literature review findings

Issues with determining the value of honey bee pollination

The Australian Government's Department of Agriculture, Fisheries and Forestry (DAFF), in a submission to a 2014 Senate Inquiry, identified the following issues with determining the value of honey bee pollination:

1. Uncertainty about the extent to which crops benefit under Australian field conditions from pollination by honey bees. This is particularly applicable to broadacre crops and pastures, which do not generally benefit from the addition of managed honey bees for pollination.

2. Distinguishing the contribution to crop pollination made by honey bees from the contribution made by other insects. Cross-checking of estimates from the literature with pollination experts and growers was used to 'firm up' estimates employed in this study.

3. Apportioning crop value to a single input when there are several critical inputs to crop yield, including but not limited to crop nutrition, irrigation and grower management.

4. Uncertainty about the ability of the agriculture industry to adjust, or partially adjust, to maintain economic returns in the absence of honey bee pollination.

In addition to the issues identified by DAFF, it is also noted that estimates that focus only on changes in crop yield ignore the positive impact honey bee pollination has on crop quality. Superior crop quality achieved with optimal pollination can have a major impact on the price growers receive, or whether there is even a market for their product (Gordon and Davis 2003; Keogh *et al*. 2010).

Previous studies, economic value of honey bee pollination

A review of previous Australian and overseas studies of the economic value of honey bee pollination was completed; the results are summarised in Table 1.

Table 1: Previous studies on the economic value of honey bee pollination

Country	Measurement technique	Number of crops	Pollinator type	Estimated value	Reference and comments
Australia	Gross value of production, pollination-dependent crops	N/A	Managed and wild honey bees	$158.6 million	Victorian Department of Agriculture 1984
Australia	Replacement cost of commercial pollination services (i.e. additional pollination fees paid to beekeepers)	Not stated	Managed and wild honey bees	$0.545 million	Industries Assistance Commission 1985
Australia	Partial equilibrium model estimating producer and consumer surplus	25	Managed and wild honey bees	$0.6 billion to $1.2 billion	Gill 1989
Australia	Partial equilibrium model estimating producer and consumer surplus	25	Managed and wild honey bees	$1.2 billion; used upper estimate of Gill (1989)	Gibbs and Muirhead 1998
Australia	Partial equilibrium model estimating producer and consumer surplus (also employment and flow-on multipliers)	35	Managed and wild honey bees	$1.7 billion ($3.7 billion when flow-on multipliers are included)	Gordon and Davis 2003
Australia	Net present value of lost producer surplus from honey bee-dependent crops	35	Managed and wild honey bees	$0.02 billion to $0.05 billion	Cook *et al*. 2007

Australia	Partial equilibrium model estimating producer and consumer surplus	41	Managed and wild honey bees	The price impact of varroa mite calculated on a per-hive basis	Monck *et al*. 2008; study estimated cost due to an exotic pest (varroa) destroying hives
Australia	Gross value of production of honey bee-dependent horticultural crops	25	Managed and wild honey bees	$4.0 billion to $6.0 billion	Barry *et al*. 2010; study to determine surveillance needs
Australia	Replacement cost of commercial pollination services	35	Managed and wild honey bee	Not estimated	Keogh *et al*. 2010
Australia	Quoting Gill (1989) and Gordon and Davis (2003)	35	Managed and wild honey bees	$0.6 billion to $1.7 billion (previous estimates)	DAFF submission to the Senate Honey Bee and Pollination Inquiry in 2014
Australia	Partial equilibrium model estimating consumer surplus; study does not appear to have estimated changes in producer surplus	53, no livestock impacts	Managed and wild honey bees	$8.35 billion to $19.97 billion; mid-point estimate of $14.2 billion	Karasiński 2018a
Shepparton, Victoria	Regional economic impact of pollination deficit (output, value added, income, employment and associated multipliers)	13, including livestock	Managed and wild honey bees	$0.78 billion	Clarke *et al*. 2017
New Zealand	Economic value of lost production, i.e. changes in producer surplus	Not stated	Managed and wild honey bees	NZ$3.1 billion in 1992	Estimate reported in Gordon and Davis 2003
United States	Partial equilibrium model estimating only consumer surplus	Not stated	Managed and wild honey bees	US$1.6 billion to US$5.7 billion	Southwick and Southwick 1992
United States	Economic value of lost production – changes in the gross value of production	Not stated	Managed and wild honey bees	US$14.6 billion in 2000	Morse and Caldone 2000
United States	Economic value of lost production – changes in the gross value of production	Not stated	Insects	US$34.0 billion in 2012	Jordan *et al.* 2021
Whole world	Partial equilibrium model estimating consumer surplus. Producer surplus not estimated	>50 crops	Insects	€150 billion	Gallai *et al*. 2008
Whole world	Increase in crop area required to offset yield loss	>50 crops	Insects and animals	Opportunity cost of additional crop land	Aizen *et al*. 2009
Whole world	Output value, willingness to pay, replacement cost, producer surplus, combined producer and consumer surplus, regional economic impact	"Full set of globally grown crops"	Insects and animals	US$195 billion to US$387 billion per annum	Porto *et al*. 2020

Source: Karasiński (2018a) and project research

Economic evaluation frameworks and concepts of value

There are a range of economic assessment frameworks and associated economic values and indicators that are referred to the literature in the context of bee pollination.

These are summarised in Table 2 and discussed in detail in Attachment 1.

Table 2: Summary of frameworks and value types.

Assessment type	Typical value type
Partial equilibrium	Consumer surplus Producer surplus Output/revenue
General equilibrium	Gross regional output Gross regional income Employment Other indicators, including terms of trade, gross regional product, etc. Multipliers of the above
Regional economic impact	Output Value added Income Employment Multipliers of the above
Other	Replacement cost of pollination services Increase in crop area required to offset yield Willingness to pay for pollination services

Source: Project research

Previous attempts to determine the value of honey bee pollination to the Australian economy, including Gill (1989), Gordon and Davis (2003), and Karasiński (2018a), employed the concept of consumer and producer surplus to measure economic value using a partial equilibrium modelling (PEM) approach.

Both Gill (1989) and Gordon and Davis (2003) included both producer surplus and consumer surplus values. However, Gordon and Davis (2003) extended the PEM framework to allow for adjustments in exports and imports within quarantine constraints. They also included assessment of second-round impacts using input-output analysis. Karasiński (2018a) appears to only measure consumer surplus, assuming a horizontal or infinitely elastic supply curve. No supply elasticity assumptions are reported.

The PEM framework and the concept of consumer and producer surplus are considered the most appropriate measures of economic value. These measures of value are consistent with the net economic values used in benefit-cost analysis, including of agricultural research and priority setting. Alternative concepts of value are discussed in Attachment 1.

The conceptual framework for understanding consumer and producer surplus is the static supply and demand, or market, model.

Consumer surplus is the difference between what an individual is willing to pay (demand) for a good or service (the total benefit to the consumer) and what they have to pay (the cost to the consumer, i.e. consumer expenditure or price times quantity). In Figure 1, the consumer surplus at the initial equilibrium price (P_0) and quantity (Q_0) is the area is P_0AB.

Producer surplus is the difference between the revenue (consumer expenditure) received for a good or service (the total benefit to the producer) and the costs (supply) of the inputs used in the provision of the good or service (the economic cost to the producer). In practical terms, it is the net revenue (before tax) earned by the grower of honey bee pollination-dependent crops. In Figure 1, the producer surplus at the initial equilibrium price (P_0) and quantity (Q_0) is P_0BC_0.

Reductions in honey bee pollination levels can be conceptualised as a leftward shift in the supply curve of pollination-dependent fruit, nuts, vegetables, seeds or oilseeds. The economic values (producer and consumer surpluses) of crops reliant on honey bee pollination can then be estimated by the loss in producer and consumer surpluses because of the supply shift.

With a supply shift, the new equilibrium price and quantity is P_1 and Q_1, and the change (loss) in total surplus (ΔTS) is equal to the area beneath the demand curve and between the two supply curves (area C_1DBC_0). Alternatively, the impact can be partitioned into the costs to consumers in the form of changes in consumer surplus (ΔCS = area P_1DBP_0) and the costs to producers in the form of the change in producer surplus (ΔPS = area P_0BFG).

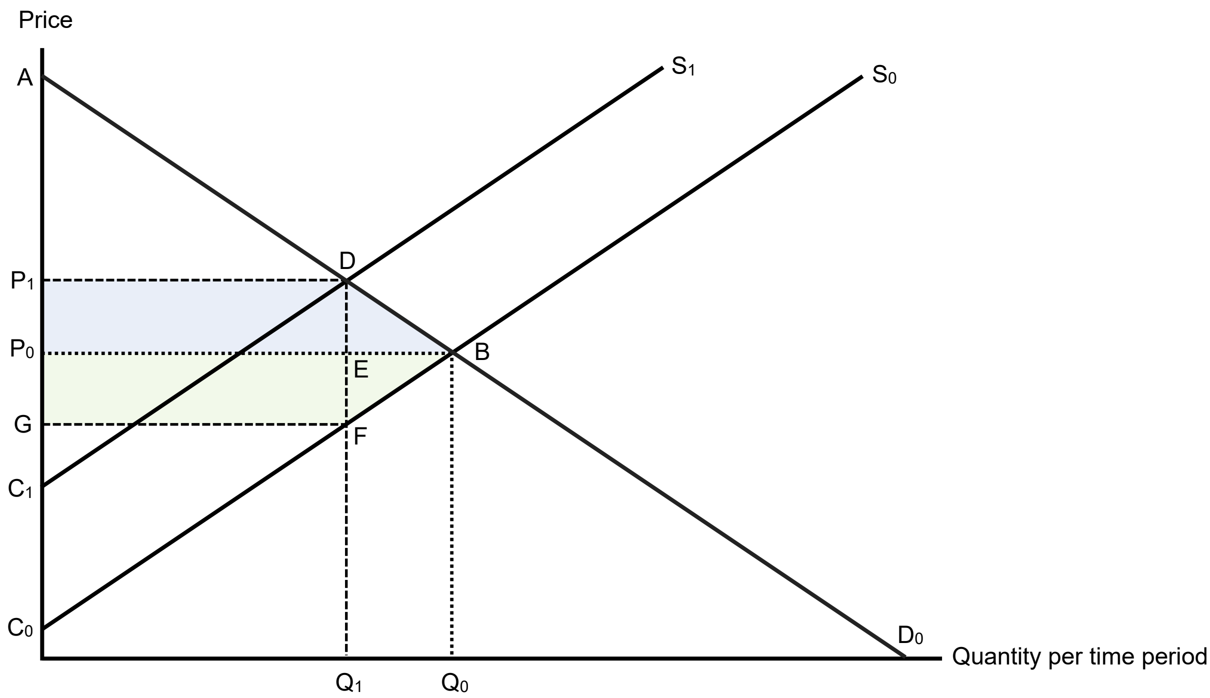

Figure 1: Economic value changes from a supply shift.

Implementing this approach requires the following data:

- Identification of crops that are dependent on honey bee pollination.
- The starting price (P_0) per unit and quantity (Q_0) for each agricultural product that is at least partially dependent on honey bee pollination.
- The horizontal shift in the supply function ($Q_0 – Q_1$) – i.e. the dependency of the agricultural product on honey bee pollination.
- The elasticity of supply (Es) at the farm gate for each agricultural product.
- The elasticity of demand (Ed) at the farm gate for each agricultural product.

Data sources for this information are identified in the following section.

Crops reliant on honey bee pollination

Determining the honey bee dependency factor

Agricultural crops can be pollinated by wind, a range of animals (birds, bats, possums, reptiles) and insects, including native bees, flies, beetles, moths and butterflies. Approximately one-third of Australia's food crops are insect pollinated (Gibbs and Muirhead 1998). Introduced, insect-pollinated food crops, most of which originated in Europe or the Americas, tend to rely on European honey bees for pollination.

Gill (1989) sourced honey bee dependency factors for crops from American literature, and McGregor's encyclopedia-like tome *Insect Pollination of Cultivated Crop Plants* (McGregor 1976), spanning 845 pages, was particularly relevant. Gordon and Davis (2003) applied the same honey bee dependency factors as used by Gill (1989) in their analysis. Monck *et al*. (2008) revised Gill's dependency factors using advice from the Australian Crop Pollination Association. Keogh *et al*. (2010) revised Monck's reliance factors in light of more recent research completed in Australia.

Karasiński (2018a) reviewed pollination dependency factors reported in the Australian literature and updated the information with advice from Western Australian honey bee researcher Dr Rob Manning. Unfortunately, Karasiński (2018a) did not provide published dependency factors in his report. Somerville and Frost 2018 provided general information on 64 Australian crops that may or may not make use of honey bees for pollination (e.g. olive, which they note as principally wind pollinated).

Since 2018, additional research has been completed on Australian crop reliance on honey bee pollination. For example, Clarke and Le Feuvre (2023) reviewed all literature relevant to 10 economically significant horticultural crops and interviewed growers of these crops on their use of both managed and unmanaged honey bees for pollination. Some honey bee pollination dependency factors were revised down following this research (e.g. mango revised from 90% dependence on honey bees for pollination to 10%, with other tropical insect species being dominant).

In this study, estimates from all these sources were compiled and the consensus position was reviewed with Australian experts, including Elizabeth Frost, Technical Specialist Bees with the New South Wales Department of Primary Industries (NSW DPI), and Steve Fuller, President of the Australian Crop Pollination Association.

Australian crops reliant on honey bees

This study has collated data on 67 economically significant honey bee-dependent Australian crops, including 22 vegetable and broadacre seed crops. A decision to include a crop in the analysis was made on the basis of it having both a credible honey bee dependency factor and reliable data on production value and volume. Crops included in the analysis and their estimated dependency factors are summarised in the tables below.

Crops considered but excluded from the analysis include:

- Native foods, such as Davison plum, finger lime, and lilly pilly – emerging industries with some use of wild honey bees but mostly native insects.
- The permaculture sector – its GVP may be as high as $18 million and it makes use of managed honey bees, but tends to rely on barter rather than cash payments for pollination services.

Table 3: Tree crops reliant on managed and wild honey bee pollination.

Crop	Reliance for yield (%)	Reference and comments
Almond	100	Clarke and Le Feuvre 2023. Almond requires managed honey bees to secure a commercial crop.
Apple	100	Clarke and Le Feuvre 2023. Apple makes use of both managed and unmanaged honey bees for pollination.
Apricot	70	Keogh *et al*. 2010.
Avocado	100	Clarke and Le Feuvre 2023. Avocado makes use of both managed and unmanaged honey bees for pollination.
Blueberry	100	Clarke and Le Feuvre 2023. Blueberry requires managed honey bee pollination.
Cherry	90	Clarke and Le Feuvre 2023. Cherry is highly reliant on unmanaged honey bees for crop yield.
Coffee	20	Keogh *et al*. 2010. Coffee is pollinated by a range of insects, including unmanaged honey bees.
Grapefruit	80	Keogh *et al*. 2010.
Lemon/lime	20	Keogh *et al*. 2010.
Lychee	80	McGregor 1976; Somerville and Frost 2018.
Macadamia	90	Clarke and Le Feuvre 2023. Macadamia makes use of both managed and unmanaged honey bees for pollination.
Mandarin	30	Keogh *et al*. 2010.
Mango	10	Clarke and Le Feuvre 2023. Some pollination completed by unmanaged honey bees.
Nashi	100	Keogh *et al*. 2010.
Orange	30	Keogh *et al*. 2010.
Papaya/pawpaw	20	Keogh *et al*. 2010. Tropical insects provide most of the pollination needs of papaya and pawpaw.
Peach/nectarine	60	Keogh *et al*. 2010.
Pear	75	Keogh *et al*. 2010. Depends on the variety; unmanaged honey bees are attracted to pollen.
Persimmon	80	Keogh *et al*. 2010.
Plum	70	Keogh *et al*. 2010.
Prune	70	Keogh *et al*. 2010.
Pomegranate	20	Somerville and Frost (2018) noted that crop increases are approximately 20% due to the impacts of insects.

Source: Project analysis

Table 4: Vine and annual horticulture crops reliant on managed and wild honey bee pollination.

Crop	Reliance for yield (%)	Reference and comments
Capsicum	10	Keogh *et al*. 2010.
Cucumber	100	Keogh *et al*. 2010.
Dragon fruit/pitaya	30	Gallai *et al*. 2008. Insect pollination reliance depends on the variety, however honey bee pollination can increase the fruit size across common species. A dependence factor was estimated by this study.
Kiwi	80	Keogh *et al*. 2010.
Passionfruit	80	Somerville and Frost 2018.
Pumpkin	100	Clarke and Le Feuvre 2023. Growers rely on unmanaged honey bees.
Rubus (raspberry/ blackberry)	100	Keogh *et al*. 2010; Somerville and Frost 2018.
Muskmelon (rockmelon, honeydew)	100	Keogh *et al*. 2010; Clarke and Le Feuvre 2023. Includes rockmelon and muskmelon.
Watermelon	70	Keogh *et al*. 2010.
Strawberry	40	Gordon and Davis 2003.
Zucchini	10	Keogh *et al*. 2010; estimate is also for squash.

Source: Project analysis

Table 5: Broadacre crops reliant on managed and wild honey bee pollination.

Crop	Reliance for yield (%)	Reference and comments
Buckwheat	100	Estimate made by this study following discussion with Steve Fuller, President, Crop Pollination Association of Australia, August 2023.
Canola	15	Keogh *et al*. 2010. Beekeepers bring their hives to canola at no cost to the grower to secure a honey crop.
Faba bean	20	Somerville and Frost (2018) noted yield increases of between 20% and 50%.
Field pea	20	Estimated at 20% by this study (same as for faba bean).
Cotton lint	20	Keogh *et al*. (2010), updated with Crop Pollination Association advice. Newer varieties are less reliant on insecticides and more reliant on insect pollination.
Lucerne and clover cut for hay and silage	15	Monck *et al*. (2008) noted that self-seeding of lucerne and clover stands will be less without honey bees. This study estimates a 15% long-term average yield loss.
Lupin	20	Somerville and Frost (2018) quote literature that estimated an 18.5% increase in yield attributable to honey bees.
Soybean	35	This study estimates a yield loss of 35% in the absence of unmanaged honey bees. Somerville and Frost (2018) noted yield improvements of up to 40% with honey bees placed in the crop. Jordan *et al*. 2021 also noted an insect dependency of 40%.
Sunflower	65	Keogh *et al*. (2010) noted that yield loss can be between 30% and 100%. Jordan *et al*. 2021 also noted an insect dependency of between 70% and 100%.
Opium poppy	20	Somerville and Frost (2018) noted that honey bees readily visit this crop. Attribution factor estimated by this study.
Peanut	10	Gordon and Davis 2003.
Safflower	10	Somerville and Frost (2018) quote literature that estimated increased yield attributable to honey bees. Yield attribution estimate made by this study.

Source: Project analysis

Table 6: Seed production reliant on managed and wild honey bee pollination.

Seed crop	Reliance for yield (%)	Reference and comments
Vegetable seed		
Asparagus	90	Coles and Willmott 2008.
Beans	10	Keogh *et al*. 2010.
Broccoli	100	Keogh *et al*. 2010.
Brussel sprout	100	Keogh *et al*. 2010.
Cabbage	100	Keogh *et al*. 2010.
Capsicum	10	Keogh *et al*. 2010.
Carrot	100	Keogh *et al*. 2010.
Cauliflower	100	Gordon and Davis 2003; Keogh *et al*. 2010.
Celery	100	Keogh *et al*. 2010.
Chinese cabbage	100	Keogh *et al*. 2010.
Cucumber	100	Keogh *et al*. 2010.
Kale	100	Coles and Willmott 2008.
Lettuce	100	Coles and Willmott 2008.
Onion	100	Keogh *et al*. 2010 and Jordan *et al*. 2021.
Radish seed	100	Coles and Willmott 2008.
Broadacre seed		
Canola seed	100	Keogh *et al*. 2010.
Mustard	100	Keogh *et al*. 2010.
Clover	100	Keogh *et al*. 2010.
Subclover	10	Somerville and Frost (2018) noted that subclover is mostly self-pollinating.
Lucerne	100	Gill 1989; Keogh *et al*. 2010.
Medics	10	Estimate made by this study after considering Somerville and Frost (2018).
Serradella	20	Estimate made by this study after considering Somerville and Frost (2018).

Source: Project analysis

Estimates of the elasticity of supply and demand

Where possible, supply and demand elasticities were obtained from published research. However, for many of the crops listed in the previous tables, elasticity estimates for Australian supply and demand were not available. Deriving elasticities requires comprehensive and reliable time series data which was not available to the study.

The absence of published elasticity estimates and/or necessary underlying data has meant that elasticities have had to be approximated for different groups of crops. To the extent possible, elasticities reported in published research have been used as benchmarks. Factors influencing the elasticity of supply and demand are discussed below.

Elasticity of supply

The price elasticity of supply measures the change in quantity supplied by producers following a change in product price. The price elasticity of supply depends on a range of factors – the extent of spare capacity and surplus stock, ease of substitution between production factors, ease of grower entry/exit and the time being considered.

When supply is inelastic, factors limit the supply response in each period. When supply is elastic, firms can respond quickly to a change in price. Agricultural production depends on land, which is a fixed factor. Faced with a price increase, producers will want to expand production. However, increasing production depends on the availability of additional land (in addition to other production factors, such as capital, labour and water), which is not readily available in the short term (the time period we are considering). As land cannot be substituted with other production factors, the price elasticity of supply is assumed to be relatively inelastic for all crops (Gordon and Davis 2003).

Table 7: Elasticity of supply for honey bee pollination-reliant crops.

Crop type	Elasticity of supply estimate	Reference and comments
Tree crops	1.25	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Growers locked into current supply, with lags of five years for yield from alternative tree crops.
Vine/annual horticulture	0.75	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Growers have more capacity to switch between quickly grown crops in response to price signals.
Broadacre crops	1.00	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Growers have more capacity to switch between quickly grown, annual broadacre crops.
Seed production	0.75	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Seed production is an annual crop.

Source: Project analysis

Elasticity of demand

The price elasticity of demand is defined as the percentage change in the quantity of demand resulting from a 1% change in price of that good. The greater the response to a price change, the more elastic the demand. The price elasticity of demand is determined by a range of factors – the availability of substitutes, the period of adjustment to price changes and the share of the consumer budget allocated to the product.

Goods that are more essential to everyday living, and that have fewer substitutes, typically have lower elasticities (staple foods are a good example). However, there are undoubtedly many vegetables and fruits that can offer consumers the same benefits (health and taste) as those vegetables and fruits reliant to some extent on honey bee pollination services. Goods with many substitutes, or that are not essential, have higher elasticities (Gordon and Davis 2003).

Table 8: Elasticity of demand for honey bee pollination-reliant crops.[1]

Crop type	Elasticity of demand estimate (absolute)	Reference and comments
Tree crops – staple (e.g. apple, orange)	2.00	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008).
Tree crops – discretionary (e.g. mango, macadamia)	2.50	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Supply chain more likely to consider these as luxury items.
Vine/annual horticulture – staple (e.g. lettuce)	2.00	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008).
Vine/annual horticulture – discretionary (e.g. kiwi)	2.50	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). Supply chain more likely to consider these as luxury items.
Broadacre crops	2.00	Estimates sourced from Gordon and Davis (2003) and Monck *et al.* (2008). There are ample substitutes for mostly oilseed crops reliant on honey bees for pollination.

Source: Project analysis

[1] Note that Karasiński (2018) uses two price elasticities, 1.049 and 0.053 (also reported as 0.53).

Price and quantity data

The crop price and quantity data used in the PEM were obtained from a variety of sources, including the ABS, Hort Innovation and project estimates. Farmgate estimates of crop values were used. Crop production was sourced and reported at the national level, as well as for the six states and the Northern Territory. This data is reported in Attachment 3. Estimates of the share of product exported were also collected.

Tree crop, vine crop and annual horticulture data

Tree crop, vine crop and annual horticulture data was sourced in the first instance from the ABS for the financial year 2020-21. These data were available by state/territory and can be readily sourced for future model updates. For less-significant tree crops, vine crops and annual horticulture not reported by the ABS, data was sourced from the *Australian Horticulture Statistics Handbook* (Hort Innovation and Fresh Logic 2023), and reported for the year 2020-21. For minor horticultural crops, such as coffee and pomegranate, that are not reported by either the ABS or Hort Innovation, data was sourced from the literature and, where necessary, estimated by the researchers.

Broadacre crop data

For the major Australian broadacre crops, ABS data for 2020-21 was used. Where necessary, this information was supplemented with data from the *Australian Crop Report* for 2020-21 (ABARES 2023). Estimates for minor and specialty broadacre crops, such as opium poppy, were sourced from the literature and, where necessary, estimated by the researchers.

Seed production data

Seed production data was sourced from a variety of reports, including the *AgriFutures Pasture Seeds Program RD&E Plan 2018-2023* (GHD 2023) and IBISWorld's *Seed Production in Australia – Industry Data, Trends and Statistics* (IBISWorld 2023). There is no national, consistent reporting of data for this sector.

Economic value of honey bee pollination

Australia, states and territories

In Australia, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $12.9 billion; $5.0 billion of farmgate output value of crops is directly dependent on honey bee pollination (Table 9).

Farmgate output value refers to the gross value to producers. In Australia, the net economic value (to producers and consumers) of crops directly dependent on honey bee pollination is estimated at $4.6 billion (Table 9). Producer surplus accounts for 67% of the total surplus value. This is a function of the price elasticity of supply for each honey bee pollination-dependent crop generally being more inelastic than the price elasticity of demand.

The largest net economic values are associated with New South Wales, Victoria and Queensland (Table 9). These states make up 70% of the net economic value of honey bee pollination-dependent crops. The largest economic value from honey bee pollination is associated with canola, lucerne and clover, apple, cotton (lint) and almond (Figure 2).

The main crops benefiting from honey been pollination varies by state/territory. This is reported in the following sections.

Table 9: Economic value ($, million) of honey bee pollination in Australia, states and territories.[2]

State/territory	Gross economic values		Net economic values		
	Farmgate output value of crops at least partially dependent on honey bee pollination	Farmgate output value of crops dependent on honey bee pollination	Producer surplus	Consumer surplus	Total surplus
New South Wales	3,819	1,366	841	423	1,263
Victoria	2,917	1,364	754	394	1,148
Tasmania	407	270	137	68	205
South Australia	1,308	582	355	173	528
Western Australia	2,156	524	391	194	585
Northern Territory	156	38	29	12	41
Queensland	2,111	871	557	260	817
Australia	**12,883**	**5,013**	**3,063**	**1,523**	**4,587**

[2] Note that Karasiński (2018) uses two price elasticities, 1.049 and 0.053 (also reported as 0.53).

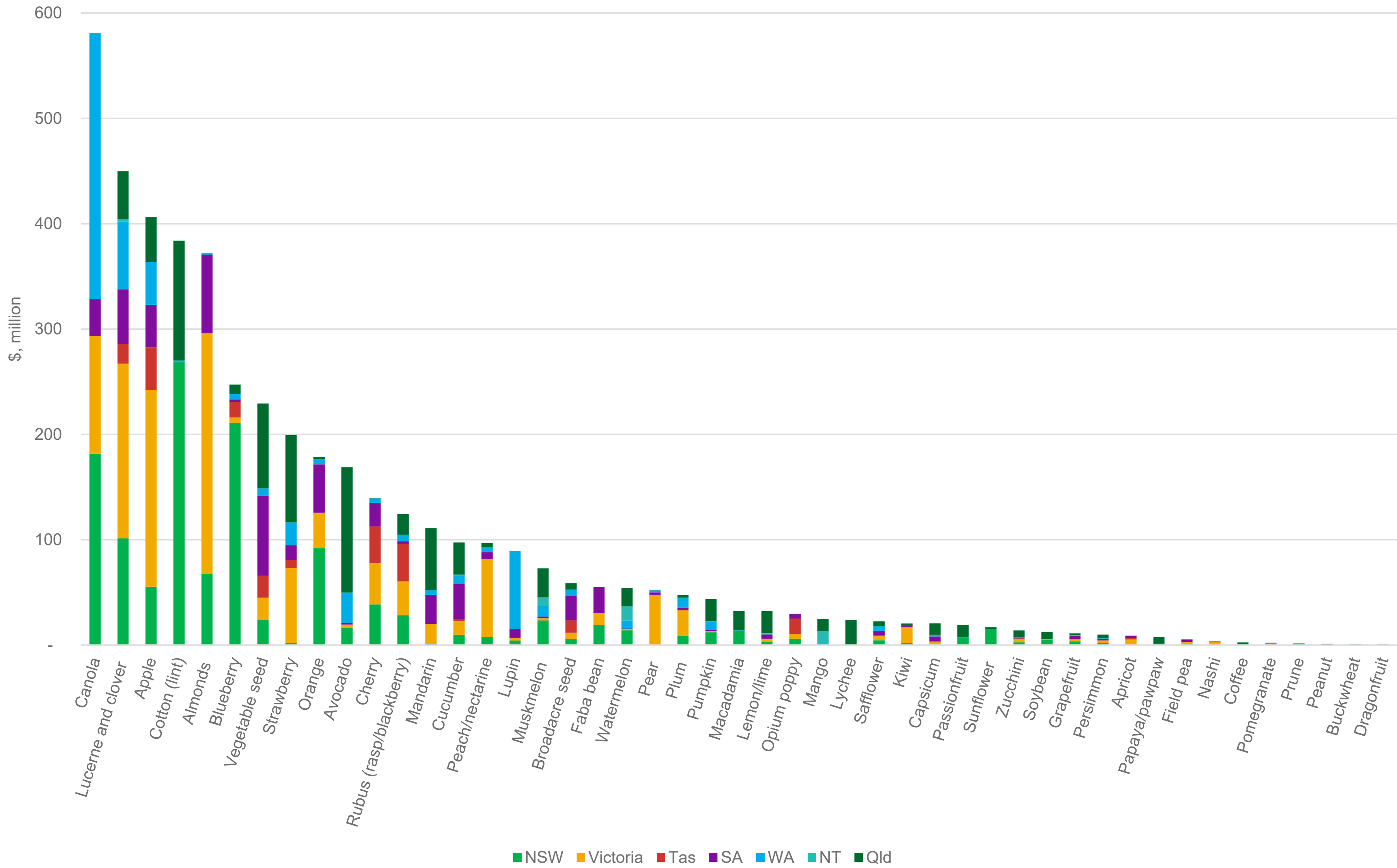

Figure 2: Economic value of honey bee pollination by crop and state/territory.

New South Wales

In New South Wales, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $3.8 billion; $1.4 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $1.3 billion.

The largest net economic value from honey bee pollination is associated with cotton (lint), blueberry and canola (Figure 3).

Tasmania

In Tasmania, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $0.4 billion; $0.3 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $0.2 billion.

The largest net economic value from honey bee pollination is associated with blueberry, zucchini and almond (Figure 4).

Queensland

In Queensland, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $2.1 billion; $0.9 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $0.8 billion.

The largest net economic value from honey bee pollination is associated with avocado, cotton (lint), strawberry and vegetable seed (Figure 5).

Victoria

In Victoria, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $2.9 billion; $1.4 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $1.1 billion.

The largest net economic value from honey bee pollination is associated with almond, apple, and lucerne and clover (Figure 6).

South Australia

In South Australia, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $1.3 billion; $0.6 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $0.5 billion.

The largest net economic value from honey bee pollination is associated with vegetable seed and almonds (Figure 7).

Western Australia

In Western Australia, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $2.2 billion; $0.5 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $0.6 billion.

The largest net economic value from honey bee pollination is associated with canola, lupin, and lucerne and clover (Figure 8).

Northern Territory

In the Northern Territory, the farmgate output value of crops at least partially dependent on honey bee pollination is estimated at $0.2 billion; $0.04 billion of farmgate output value of crops is directly dependent on honey bee pollination.

The net economic value of crops (producer and consumer surplus) directly dependent on honey bee pollination is estimated at $0.4 billion.

The largest net economic value from honey bee pollination is associated with watermelon, mango and muskmelon (Figure 9).

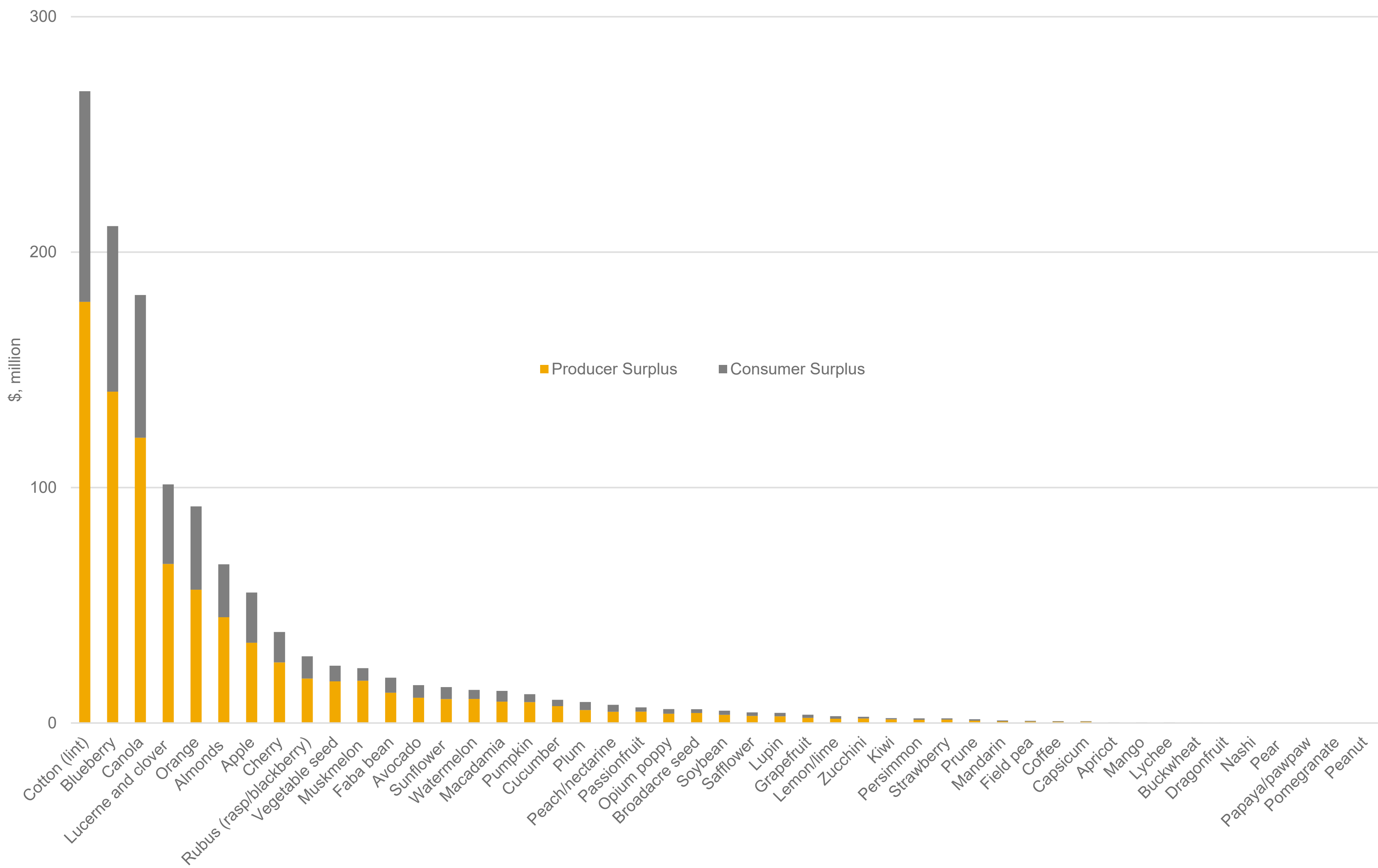

Figure 3: Economic value of honey bee pollination by crop in New South Wales.

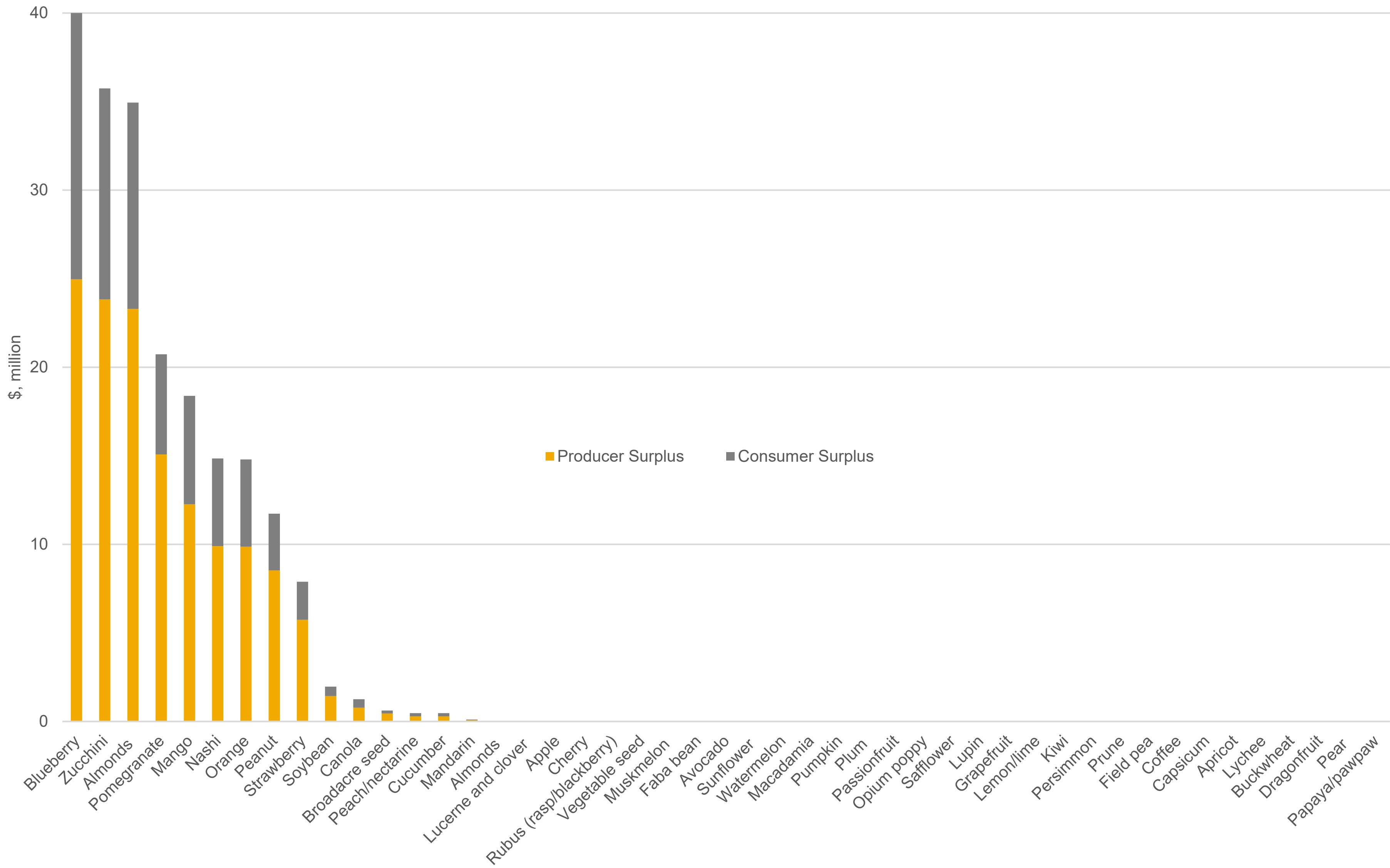

Figure 4: Economic value of honey bee pollination by crop in Tasmania.

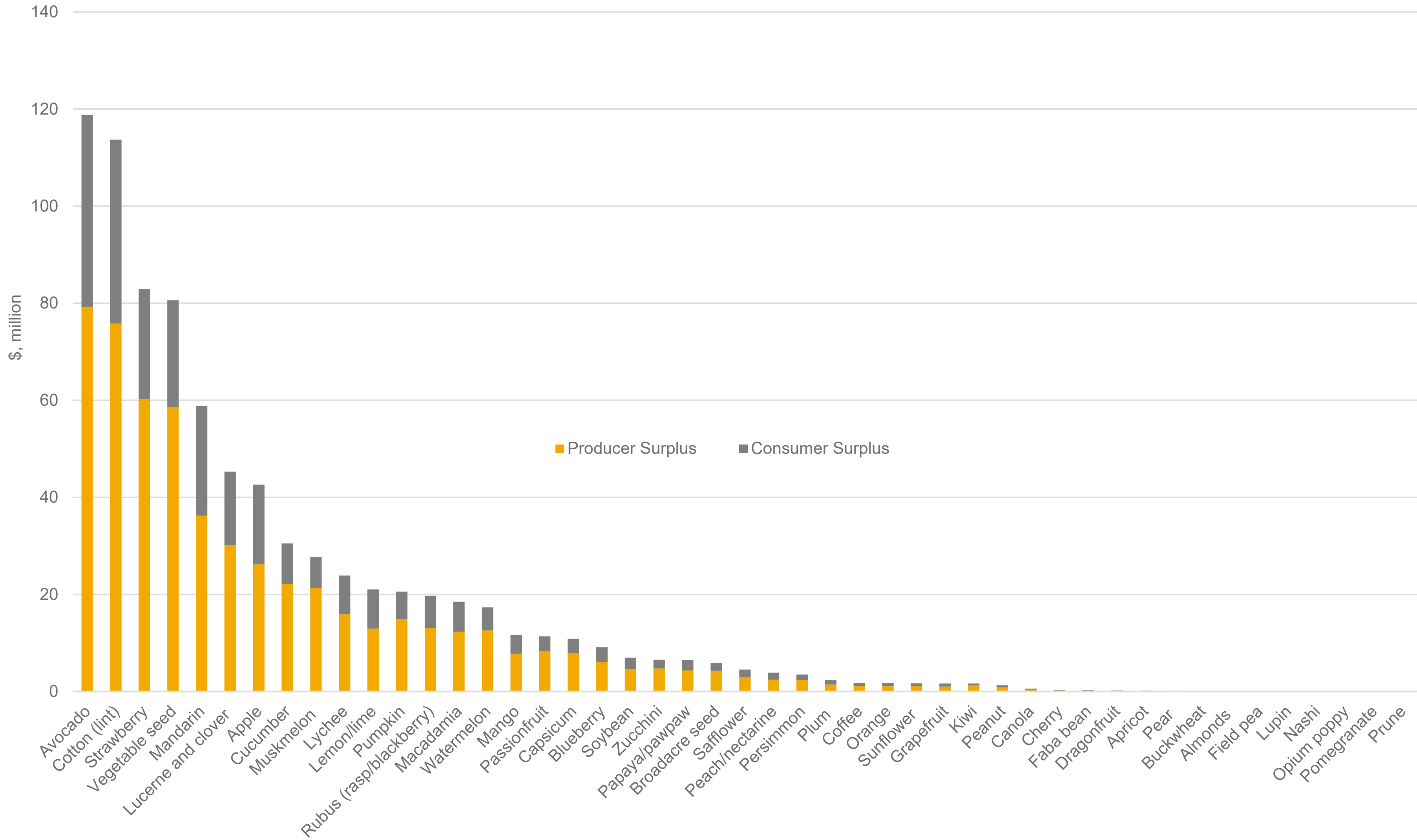

Figure 5: Economic value of honey bee pollination by crop in Queensland.

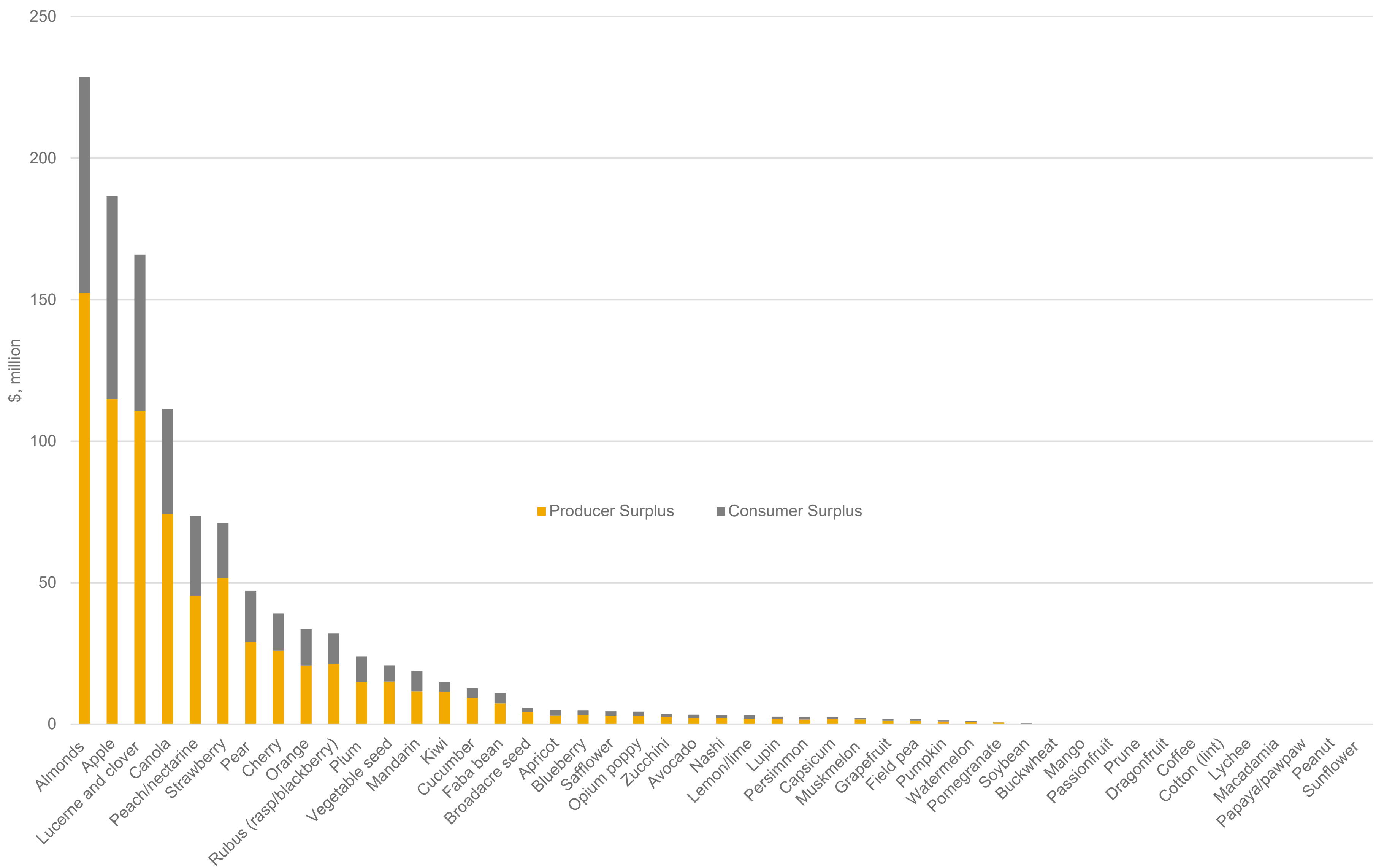

Figure 6: Economic value of honey bee pollination by crop in Victoria.

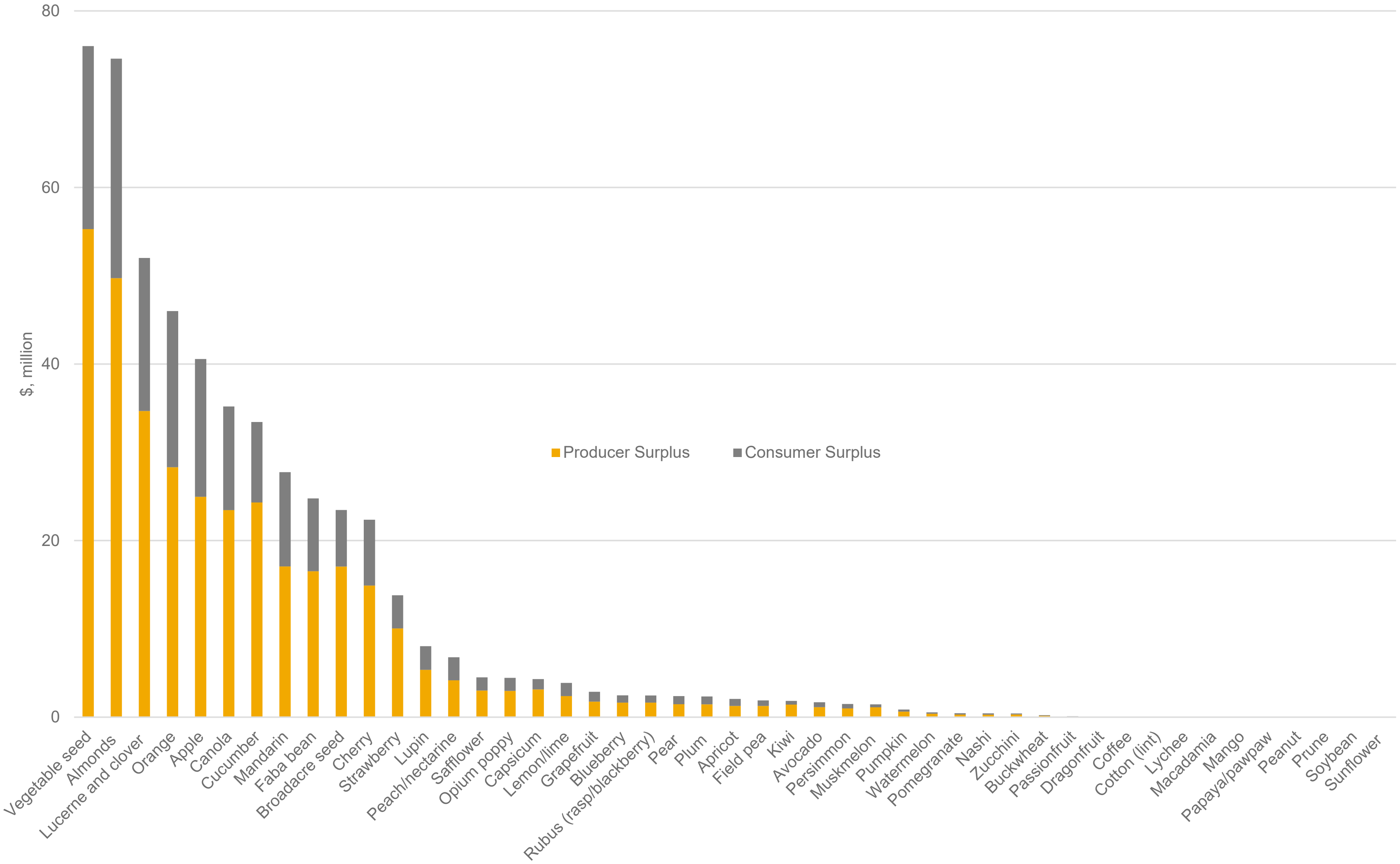

Figure 7: Economic value of honey bee pollination by crop in South Australia.

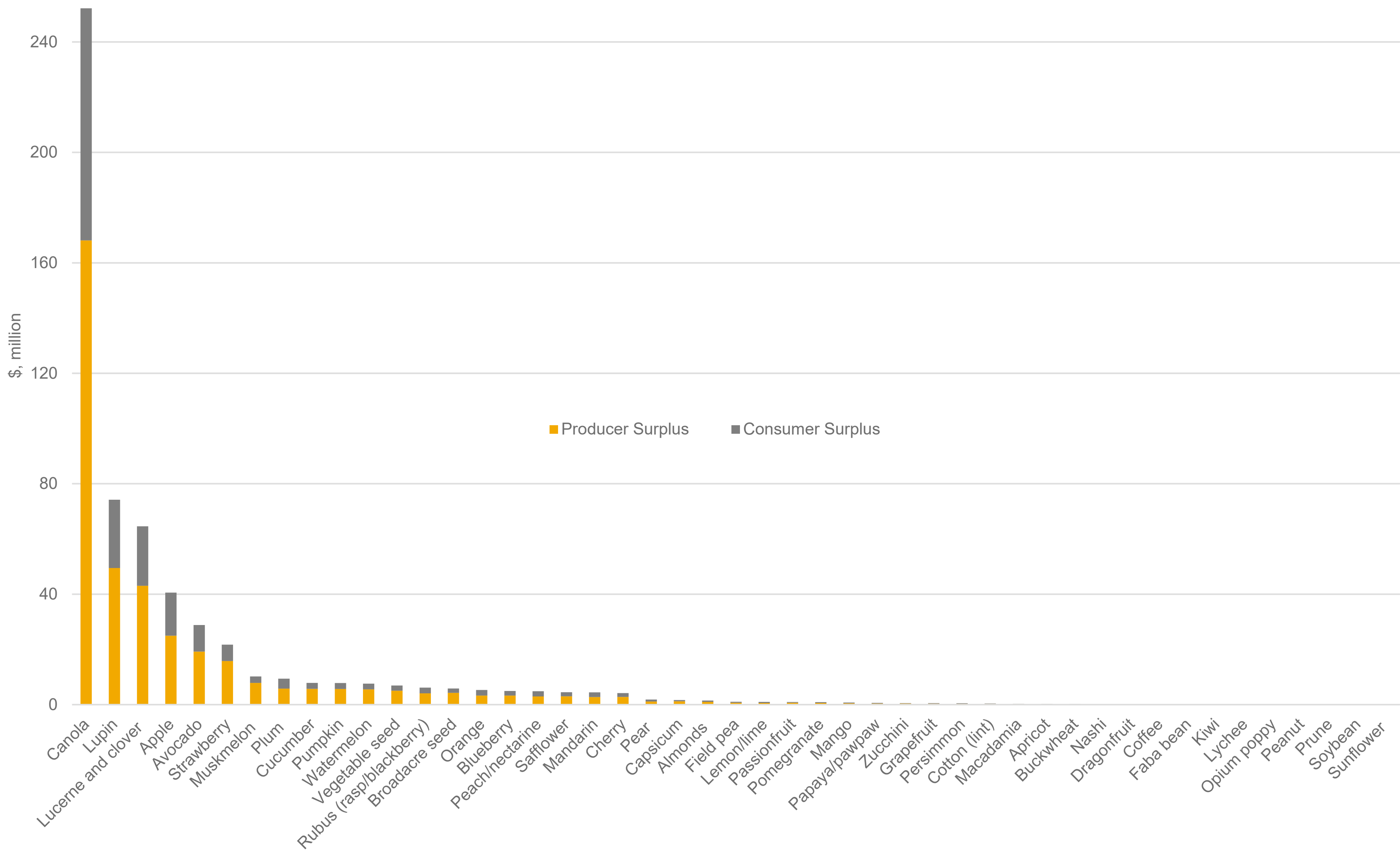

Figure 8: Economic value of honey bee pollination by crop in Western Australia.

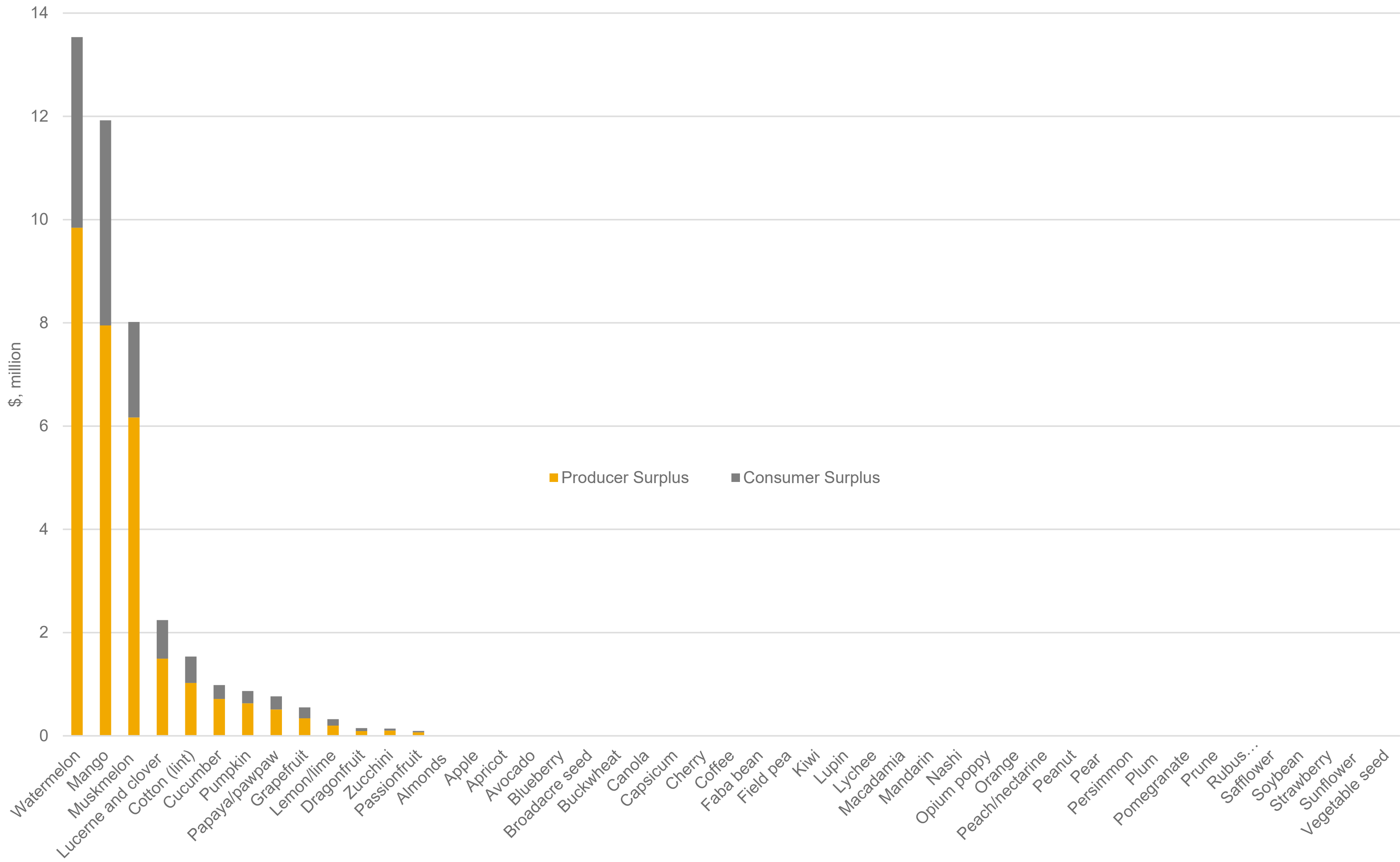

Figure 9: Economic value of honey bee pollination by crop in Northern Territory.

Conclusions

Honey bee pollination in Australia is important for the production of numerous crops. For some crops, honey bee pollination is essential, while for others, it raises yield and quality. These pollination services have an economic value to both producers and consumers.

A number of studies, both in Australia and overseas, have estimated the value of honey bee pollination services. These have used a range of different economic assessment frameworks and associated economic values and indicators. This study uses the partial equilibrium framework and the economic value concepts of producer surplus and consumer surplus. In this framework, a reduction in honey bee pollination can be conceptualised as a leftward shift in the supply curve (reduction in the quantity) of pollination-dependent fruit, nuts, vegetables, seeds or oilseeds, and associated losses in surpluses.

Using this approach for 67 crops, the economic value of crops reliant on honey bee pollination is estimated at $4.6 billion per year, comprising $3.1 billion in producer surplus and $1.5 billion in consumer surplus. Producer surplus accounts for 67% of the total surplus value. This is a function of the price elasticity of supply for each honey bee pollination-dependent crop generally being more inelastic than the price elasticity of demand.

This is a partial equilibrium estimate of economic value and hence is gross of any subsequent adjustments by consumers and producers following the initial supply shift. It represents the value/cost if farmers were unable to adjust, as would be the case if there was, say, a sudden disease outbreak.

The largest net economic values are associated with New South Wales, Victoria and Queensland. These three states make up 70% of the net economic value of honey bee pollination-dependent crops.

The main crops benefiting from honey been pollination varies by state/territory. However, at the national level, the largest economic value from honey bee pollination is associated with canola, lucerne and clover, apple, cotton (lint) and almond.

The net economic value estimate from this study can be compared to that generated by Gill (1992) of $0.6 to $1.2 billion, and Gordon and Davis (2003) of $1.7 billion (using Gill's approach and elasticity assumptions). These estimates used a similar modelling approach, albeit Gill used different price elasticity of supply and demand assumptions. Adopting Gill's price elasticity of demand (-2) and supply (0.5) assumptions for all crops gives a value of $4.9 to $9.8 billion. The estimate of the value of crops dependent on honey bee pollination produced by Karasiński (2018a) for 2014-15 of $8.3 to $20.0 billion (average of $14.2 billion) is an outlier, partially explained by large differences in assumed elasticities.

The estimates in this study of the economic value of crops reliant on honey bee pollination is based on a range of data and assumptions. These include data on farmgate price and quantity for each relevant crop, the price elasticity of supply and demand for each crop, and the degree of dependence of crops on honey bee pollination. A spreadsheet of assumptions and calculations has been provided that will enable data and assumptions to be varied over time as new information becomes available or alternative assumptions arise from the literature. The estimates can therefore be readily updated over time.

Recommendations

Findings from the research should be used by AgriFutures Australia to prepare a value of honey bee pollination infographic that highlights the economic contribution of each state and territory, and each pollination-dependent crop.

The conceptual framework and the spreadsheet model have been provided to AgriFutures Australia to enable routine update of the estimate. AgriFutures Australia is recommended to update the estimate every three to five years in light of changes in demand for honey bee pollination.

The following messages should be communicated to the honey bee and pollination industry:

1. The GVP of honey bee-pollinated crops is about 30% greater than it was in 2014-15, when the previous economic value of pollination study (Karasiński 2018a) was completed.

2. The approach used in this study and Karasiński (2018a) was the same, i.e. a PEM measuring changes in producer and consumer surplus following loss of honey bee pollination services.

3. The two studies produced different estimates of the value of honey bee pollination to the Australian economy; the $4.6 billion estimate of the current study is in contrast to the $14.2 billion of Karasiński (2018a). This is due to different modelling assumptions, especially those used to estimate demand elasticity.

4. Elasticity of demand measures the relationship between a change in the quantity of crop available and a change in its price. In this instance, the assumed change in price is due to loss of yield and quality of a crop following loss of honey bee pollination.

5. This study has sourced up-to-date elasticity of demand estimates from published literature.

Appendices

Appendix 1: The conceptual framework

Concept of economic value

The net economic value to the community of market goods, such as crops, is measured by consumer and producer surplus – the net benefit to consumers and producers. Previous attempts to determine the value of honey bee pollination to the Australian economy, including Gill (1989), Gordon and Davis (2003) and Karasiński (2018a), employed the concept of consumer and producer surplus to measure economic value. Alternative concepts and why they are inappropriate have been reviewed by this study.

The conceptual framework for providing an understanding of consumer and producer surplus is the static supply and demand, or market, model (Figure 10).

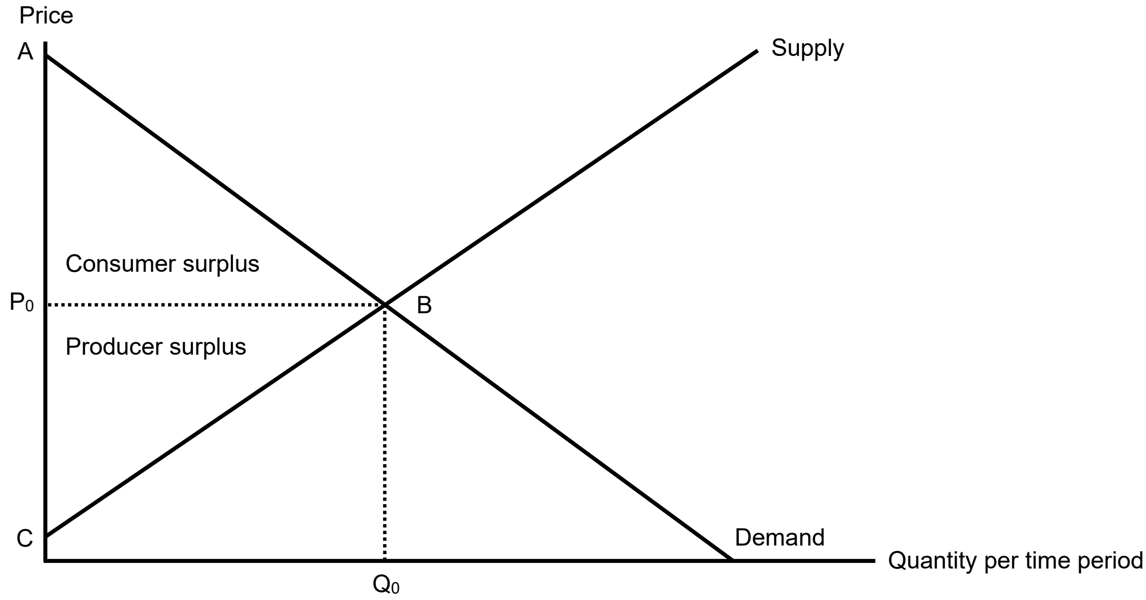

Figure 10. Supply and demand and economic value.

The market supply curve (which in this instance comprises the summation of the supply curves of individual producers who grow crops at least partially dependent on honey bee pollination) indicates the costs of extra production, i.e. the costs to society of producing an extra unit of a good or service. Producers aim to operate on the upward sloping part of their marginal cost curve above the minimum average variable cost; this upward slope reflects diminishing returns to inputs (production costs), and hence it costs more to produce each additional unit of output.[3] The area under the supply curve is the total cost of production.

The market demand curve (which comprises the summation of individual demand curves of buyers of crop products) indicates the maximum amount that buyers are willing to pay for incremental increases in the quantity of a fruit, nut, vegetable, seed or oilseed. The demand curve is normally downward sloping because the more someone consumes of a good, the less they are willing to pay. This concept is generally known as diminishing marginal utility. The area under the demand curve is the total willingness to pay for a good.

[3] If the marginal cost of producing an extra unit of output is less than the market price, it is still profitable to produce.

The interaction of demand and supply determines the market price for a good (P) and the quantity (Q) that is produced and consumed in any given period.

This market model provides the basis for identifying and estimating the net economic values to consumers and the net economic values to producers, referred to as consumer surplus and producer surplus, respectively.

Consumer surplus is the difference between what an individual is willing to pay (demand) for a good or service (the total benefit to the consumer) and what they have to pay (the cost to the consumer, i.e. consumer expenditure or price times quantity). In Figure 10, this is the area between the demand curve and the price line (P_0AB).

Producer surplus is the difference between the revenue (consumer expenditure) received for a good or service (the total benefit to the producer) and the costs (supply) of the inputs used in the provision of the good or service (the economic cost to the producer). In practical terms, it is the net revenue (before tax) earned by the grower of honey bee pollination-dependent crops. In Figure 10, this is the area between the price line and the supply curve (P_0BC).

The above conceptual framework is the economic framework to identify and estimate the economic value, producer surplus and consumer surplus, at current levels of production. These are the economic values relevant when estimating an industry's contribution to a community's economic welfare.

Alternative concepts of economic value and why they are inappropriate for this analysis

Other concepts of 'value' inappropriate for determining an industry's economic contribution to the Australian economy include:

- Output/revenue – the gross value of business turnover. In Figure 10, this is equivalent to the area under the price line (P_0BQ_0). However, this is not a net value concept and includes costs of production (CBQ_0). Costs of production should be excluded when estimating economic value because they are resources that could be allocated to the creation of value in other industries and do not represent a net addition to the community's welfare.

- Value-added – the difference between the gross value of business turnover and the costs of the inputs of raw materials, components and services bought in to produce total industry output. These costs exclude wage costs. In Figure 10, value-added is equivalent to the producer surplus plus some of the area under the supply curve, i.e. some production costs, such as wages. Value-added overestimates industry's net contribution to the economy.

- Income – the wages paid to employees, including imputed wages for self-employed and business owners. Wages are a cost of production and in Figure 10 are represented by part of the area under the supply curve.

- Employment – the number of people employed (including self-employed, full-time, and part-time) in an industry. Employment is a resource used as an input to production, the cost of which (wages) is represented by part of the area under the supply curve.

None of these concepts are measures of net economic value and can best be thought of as overestimates of net economic value (output, value-added), costs only (wages) or indicators of economic activity (output, income, value-added, employment).

Replacement costs reflect the cost of replacing a good or service, e.g. replacing no-cost unmanaged pollination services with paid pollination services. However, there are a number of problems with this as an approach to valuation, including that:

- It does not measure producer or consumer surplus, as per Figure 10. Producer and consumer surplus are standard measures of net economic value. Replacement cost is, at best, a cost of replacement rather than a measure of net economic value.

- It assumes that the benefits from replacement would exceed the market costs.

- It assumes producers would pay the replacement costs.

Opportunity cost of offsets, including additional land required to ‘offset’ lost yield as a result of a lack of pollination in some crops[4] is also not a measure of net economic value and suffers the same shortcomings as the replacement cost approach.

Willingness to pay for pollination services can be conceptualised in a similar framework to Figure 10, but for pollination services themselves, rather than honey bee pollination-dependent crops. There is a cost of supplying honey bee pollination services – an upward sloping supply curve – and a downward sloping demand for these services. In this market, there is a producer surplus that accrues to people supplying the service, and a consumer surplus that accrues to farmers who demand this service. However, this PEM would be relevant to the question of the value of commercial honey bee pollination services, rather than the value of honey bee pollination to the Australian economy.

Partial equilibrium model

Changes in honey bee pollination levels can be conceptualised as a shift in the supply curve of pollination-dependent fruit, nut, vegetables, seeds or oilseeds. The economic values (producer and consumer surpluses) of crops reliant on honey been pollination levels can then be estimated by the loss in producer and consumer surpluses because of the supply shift. These changes in economic values are given in the following comparative static PEM[5] (Figure 11).

The initial equilibrium price and quantity are P_0 and Q_0, and after the supply shift they are P_1 and Q_1.

[4] For some crops, like almond, there is zero yield in the absence of honey bee pollination.

[5] It is comparative static model in that two (static) equilibrium situations – before and after a change or with and without a honey bee pollination – are compared. It is a partial equilibrium model (as opposed to a general equilibrium model) because it focuses on one part of the economy, e.g. production of a certain crop, and treats other economic variables as being constant (exogenous) in the analysis, i.e. ceteris paribus.

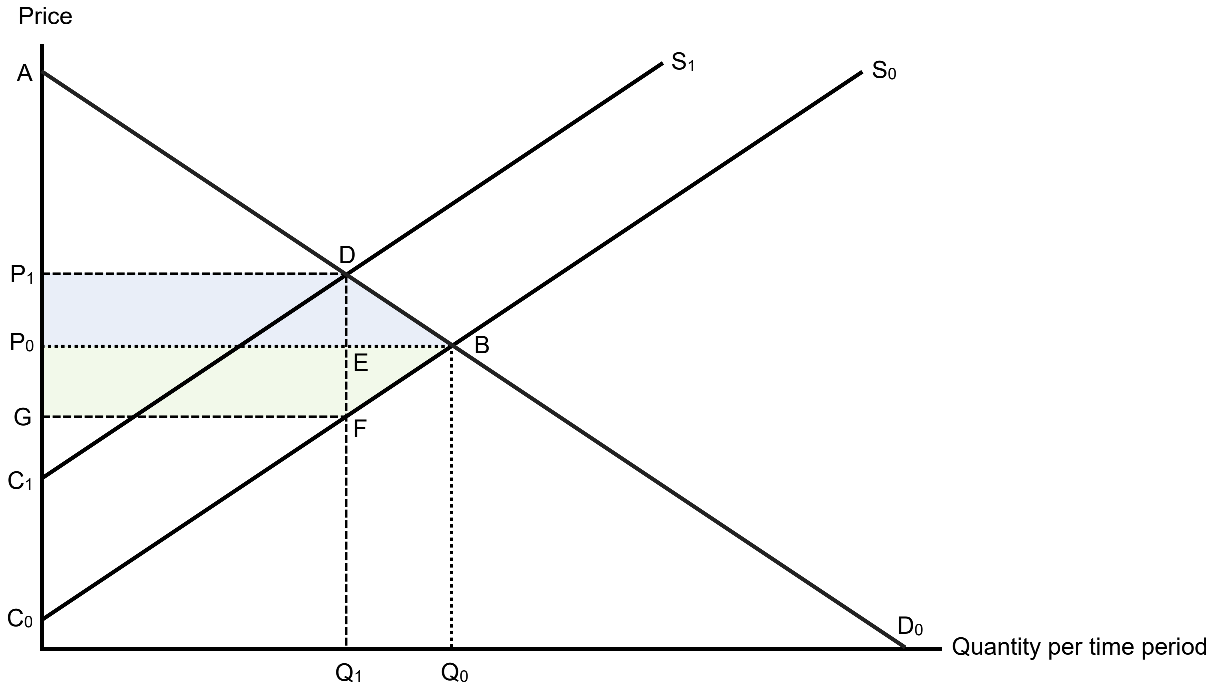

Figure 11: Economic value changes from a supply shift.

The total annual impact (change in producer surplus and consumer surplus, i.e., ΔTS) from the supply shift is equal to the area beneath the demand curve and between the two supply curves (area C_1DBC_0). Alternatively, the impact can be partitioned into the costs to consumers in the form of changes in the consumer surplus (ΔCS = area P_1DBP_0) and the costs to producers in the form of the change in the producer surplus (ΔPS = area P_0BFG). These reductions in producer surplus and consumer surplus can be expressed algebraically based on the following information:

- Starting price (P_0) per unit and quantity (Q_0) for each agricultural product.
- The horizontal shift in the supply function ($Q_0 - Q_1$) – the dependency of the agricultural product on honey bee pollination.
- The elasticity of supply at the farm gate for each agricultural product.
- The elasticity of demand at the farm gate for each agricultural product

The above PEM integrates the contribution made by honey bee pollinators (via the individual honey bee dependency factors), along with the farmgate prices of pollinated agricultural crops and the empirically derived price elasticity of demand for fruit, nuts, vegetables, broadacre crops and seeds to determine economic value.

Change in consumer surplus is calculated using the following formula:

$$\Delta CS = P_0Q_0Z(1 + 0.5ZN)$$

Change in producer surplus is calculated using the following formula:

$$\Delta PS\ (K - Z)P_0Q_0(1 + 0.5ZN)$$

Where:

P_0 = the initial price at the farm gate per unit

Q_0 = the initial quantity of the product

Z = the relative increase in price; in Figure 11, this is $(P_1 - P_0) / P_0$

= KE / (E + N)

K = k / P_0

k = the increase in production cost per unit

= $(((Q_1 - Q_0) / (N \times Q_0)) \times (E + N) \times P_0) / E$

E = the elasticity of supply

N = the elasticity of demand

(Derived from Alston *et al*. 1998)

Key assumptions of the above PEM model as it is generally applied and applied in this study are:

- Linear demand and supply curves
- The assumption of a parallel shift in supply
- Single elasticity of supply and single elasticity of demand
- Producer surplus and consumer surplus estimates
- No substitution effects
- No reinvestment of freed resources.

Linear demand and supply curves: Accurate measurement of ordinary demand and supply curves, particularly along their entire length, is difficult, time consuming and expensive. Alternative assumptions on the shape/functional form of the demand and supply curves can be used. However, in the absence of empirical information on the shape of these curves, there is little to justify alternative function forms. Assumptions of linearity also simplify consumer and producer surplus calculations, and have been used for this reason in most studies of research benefits to agriculture (Alston *et al*. 1998). Alston and Wohlgenant (1990) suggest that when a parallel shift is used, the function form is largely irrelevant, and that a linear model provides a good approximation regardless of the true function form of supply.

The assumption of a parallel shift in supply: Alternatives include convergent, divergent and pivotal shifts of the supply curve. The assumption of parallel shifts can have large impacts on estimates, with parallel shifts in supply producing larger impacts than pivotal shifts. However, information to inform an assumption of pivotal shifts in supply is simply not available (Alston *et al*. 1998). In the absence of the information required to choose a particular type of shift, a parallel shift in supply is assumed. An additional advantage of this approach is that it simplifies some calculations and permits consistency in evaluation across different crops (Alston *et al*. 1998).

Single elasticity of supply and single elasticity of demand: The model calculations use a single elasticity of supply and a single elasticity of demand for each honey bee pollination-dependent crop. However, elasticities of demand may vary between small changes in supply and large changes in supply – with elasticity of demand increasing as prices increase (Gordon and Davis 2003). Notwithstanding, there is insufficient empirical information on elasticities at different levels of price change to incorporate this into the PEM. The analysis thus undertakes sensitivity testing of different elasticity assumptions.

Producer surplus and consumer surplus estimates: All producer surpluses and consumer surpluses are estimated regardless of to whom they accrue. The above PEM is essentially for a closed economy where all production is produced and consumed by Australians. However, some producer surplus and consumer surplus will accrue to foreign entities, e.g. foreign-owned producers and foreign consumers (in the case of crop exports). The distinction between economic values that accrue to Australia and to the rest of the world is commonly drawn in the application of evaluation methods, such as benefit-cost analysis. Data has been collected on export percentages by crop, but no data was available on foreign ownership of production. Consequently, for simplicity of calculation and consistency (between producer and consumer surplus calculations), no apportionment of producer surplus or consumer surplus is undertaken here.

No substitution effects: Following a loss of honey bee pollination, crop prices will increase and partially offsetting imports may increase. However, this is inconsistent with the partial equilibrium framework that holds all other things constant. Even in a general equilibrium framework that allows for substitution effects, strong biosecurity measures are in place in Australia to prevent imports of most pollination-dependent crops. With this said, some pollination-dependent crops are imported in small quantities. These crops include apricot, avocado, cherry, citrus, mango, papaya, pear, peanut, kiwi, beans and carrot (Monck *et al*. 2008).

No reinvestment of freed resources: With reduced supply of honey bee pollinated crops, inputs that would otherwise be used for crop production will be available for reinvestment in other agricultural activity, which will itself generate producer and consumer surpluses. However, this is inconsistent with the PEM approach, which focuses on a single supply shift, holding all other variables constant.

Application of the PEM therefore estimates losses arising from a sudden absence of honey bee pollination services – 'the morning after' shock. To the extent that all production costs are committed (sunk), the estimated impact using the PEM is the immediate impact (a snapshot). The longer-term costs depend on the capacity of honey bee pollination-dependent crop producers to switch out of these crops to alternative non-honey-bee-dependent products, and the ability of overseas crop suppliers to export their produce to Australia.

This PEM is soundly grounded in economic theory and has been used in one form or another to estimate economic value since the late 1800s. The above PEM, with a single shift in the supply curve, is consistent with the approach used in benefit-cost analysis to evaluate policies and investment generally, as well as to evaluate agricultural research and development programs.

As evident from the literature review, Gill (1989), Gordon and Davis (2003) and Karasiński (2018a) used a PEM to calculate the economic value of honey bee pollination in Australia. Southwick and Southwick (1992) used the same technique to estimate the economic value of honey bee pollination in the United States, and Gallia *et al*. (2008) used a PEM to estimate the worldwide contribution of insects to agricultural crop production.

Other models

The PEM and its net economic values of producer surplus and consumer surplus are the appropriate measures of economic value to determine an industry's contribution to a community's economic welfare. In this framework, only direct changes in producer and consumer surpluses are estimated.

Other approaches to modelling impacts (of economic activity rather than economic value) include the general equilibrium model and the regional economic impact assessment (input-output analysis). These impact assessment methods tend to focus on different economic measures (as identified above), and include direct and indirect effects (multipliers). These indirect effects arise from expenditure on inputs to production (with associated economic activity, e.g. output, income, value-added, employment), which in turn requires inputs to production (with associated economic activity, e.g. output, income, value-added, employment) etc.

Input-output analysis can be ‘bolted on’ to a PEM analysis to provide ‘second round’ contributions of an industry to the Australian economy (as per Gordon and Davis 2003), but this was beyond the scope of the current study.

Assessment types and values estimated across a range of modelling alternatives are shown in Table 10.

Table 10: Summary of frameworks and value types.

Assessment type	Typical value type
Partial equilibrium	Consumer surplus Producer surplus Output/revenue
General equilibrium	Gross regional output Gross regional income Employment Other indicators, including terms of trade, gross regional product, etc. Multipliers of the above
Regional economic impact	Output Value added Income Employment Multipliers of the above
Other	Replacement cost of pollination services Increase in crop area required to offset yield Willingness to pay for pollination services

Appendix 2: Gross value and quantity of production for honey bee pollination-dependent crops

Table 11: Gross value ($) and quantity of production (tonnes) for honey bee pollination-dependent crops.

	Australia		New South Wales		Victoria		Tasmania		South Australia		Western Australia		Northern Territory		Queensland	
Crop	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity	Gross value	Quantity
Almond	621,603,884	129,028	112,323,822	23,315	381,142,637	79,115	-	-	124,320,777	25,806	2,486,416	516	-	-	-	-
Apple	624,082,368	284,897	85,249,651	38,917	287,077,889	131,052	62,408,237	28,490	62,408,237	28,490	62,408,237	28,490	-	-	65,528,649	29,914
Apricot	15,200,000	3,447	456,000	103	8,512,000	1,930	2,128,000	483	3,496,000	793	456,000	103	-	-	304,000	69
Avocado	282,450,792	85,986	26,832,825	8,169	5,649,016	1,720	-	-	2,824,508	860	48,016,635	14,618	-	-	197,998,005	60,276
Blueberry	411,000,000	23,451	351,816,000	20,074	8,220,000	469	24,660,000	1,407	4,110,000	235	8,220,000	469	-	-	15,207,000	868
Cherry	235,288,595	21,310	65,057,296	5,892	65,880,806	5,967	58,822,149	5,327	37,646,175	3,410	7,058,658	639	-	-	470,577	43
Coffee	11,000,000	1,600	3,437,500	500	-	-	-	-	-	-	-	-	-	-	7,590,000	1,104
Grapefruit	17,700,000	11,190	5,664,000	3,581	3,186,000	2,014	-	-	4,602,000	2,909	885,000	560	885,000	560	2,655,000	1,679
Lemon/lime	138,300,000	65,920	12,447,000	5,933	13,830,000	6,592	-	-	16,596,000	7,910	4,149,000	1,978	1,383,000	659	89,895,000	42,848
Lychee	41,900,000	2,071	414,810	21	-	-	-	-	-	-	-	-	-	-	41,481,000	2,050
Macadamia	284,749,001	49,276	119,594,580	20,696	-	-	-	-	-	-	2,847,490	493	-	-	162,306,931	28,087
Mandarin	334,927,094	181,893	3,315,778	1,801	56,937,606	30,922	-	-	83,731,773	45,473	13,397,084	7,276	-	-	177,511,360	96,403
Mango	217,900,000	68,600	2,179,000	686	1,089,500	343	-	-	-	-	6,537,000	2,058	104,592,000	32,928	102,413,000	32,242
Nashi	6,500,000	1,551	195,000	47	5,460,000	1,303	-	-	715,000	171	65,000	16	-	-	-	-
Orange	533,757,049	435,409	277,553,666	226,413	101,413,839	82,728	-	-	138,776,833	113,206	16,012,711	13,062	-	-	5,337,570	4,354
Papaya/pawpaw	35,400,000	16,772	-	-	-	-	-	-	-	-	2,832,000	1,342	3,540,000	1,677	30,090,000	14,256
Peach/nectarine	177,466,067	88,016	14,197,285	7,041	134,874,211	66,892	-	-	12,422,625	6,161	8,873,303	4,401	-	-	7,098,643	3,521
Pear	85,455,024	90,187	170,910	180	77,336,797	81,619	769,095	812	3,930,931	4,149	2,990,926	3,157	-	-	256,365	271
Persimmon	17,300,000	3,462	3,460,000	692	4,325,000	866	-	-	2,595,000	519	865,000	173	-	-	6,055,000	1,212
Plum	79,500,000	31,798	15,097,050	6,038	40,545,000	16,217	795,000	318	3,975,000	1,590	15,900,000	6,360	-	-	3,975,000	1,590
Prune	2,800,000	1,829	2,687,720	1,756	112,000	73	-	-	-	-	-	-	-	-	-	-
Pomegranate	10,400,000	5,200	-	-	4,160,000	2,080	-	-	2,080,000	1,040	4,160,000	2,080	-	-	-	-
Capsicum	117,893,360	55,150	4,479,948	2,096	14,147,203	6,618	3,536,801	1,655	24,757,606	11,582	9,431,469	4,412	-	-	62,483,481	29,230
Cucumber	107,294,264	58,207	10,729,426	5,821	13,948,254	7,567	2,145,885	1,164	36,480,050	19,791	8,583,541	4,657	1,072,943	582	33,261,222	18,044
Dragon fruit	2,250,000	750	675,000	225	112,500	38	-	-	225,000	75	112,500	38	450,000	150	675,000	225
Kiwi	24,700,000	6,903	2,470,000	690	18,031,000	5,039	-	-	2,223,000	621	-	-	-	-	1,976,000	552
Passionfruit	21,500,000	4,787	7,525,000	1,675	107,500	24	-	-	107,500	24	1,075,000	239	107,500	24	12,900,000	2,872
Pumpkin	47,303,863	91,710	13,339,689	25,862	1,419,116	2,751	-	-	946,077	1,834	8,514,695	16,508	946,077	1,834	22,469,335	43,562
Raspberry/blackberry	205,400,000	9,631	47,239,946	2,215	53,404,000	2,504	59,566,000	2,793	4,108,000	193	10,270,000	482	-	-	32,864,000	1,541
Muskmelon	84,100,000	67,598	26,911,159	21,631	2,523,000	2,028	-	-	1,682,000	1,352	11,774,000	9,464	9,251,000	7,436	31,958,000	25,687
Watermelon	64,900,000	114,974	16,874,000	29,893	1,298,000	2,299	-	-	649,000	1,150	9,086,000	16,096	16,225,000	28,744	20,768,000	36,792
Strawberry	336,372,093	56,843	3,363,721	568	121,093,953	20,464	13,454,884	2,274	23,546,046	3,979	37,000,930	6,253	-	-	141,276,279	23,874
Zucchini	80,000,000	38,849	15,200,000	7,381	20,800,000	10,101	-	-	2,400,000	1,165	3,200,000	1,554	800,000	388	37,600,000	18,259

	Australia		New South Wales		Victoria		Tasmania		South Australia		Western Australia		Northern Territory		Queensland	
Crop	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**	**Gross value**	**Quantity**
Buckwheat	1,500,000	3,000	300,000	600	300,000	600	150,000	300	300,000	600	300,000	600	-	-	150,000	300
Canola	2,817,877,619	4,756,388	873,542,062	1,474,480	535,396,748	903,714	-	-	169,072,657	285,383	1,211,687,376	2,045,247	-	-	2,817,878	4,756
Faba bean	204,000,000	680,000	71,400,000	238,000	40,800,000	136,000	-	-	91,800,000	306,000	-	-	-	-	1,020,000	3,400
Field pea	27,700,000	22,200	4,501,250	3,608	8,864,000	7,104	-	-	9,141,000	7,326	4,986,000	3,996	-	-	-	-
Cotton (lint)	1,422,809,274	566,067	993,832,278	395,398	-	-	-	-	-	-	1,422,809	566	5,691,237	2,264	421,151,545	167,556
Lucerne and clover	2,154,668,100	7,182,227	486,954,991	1,623,183	797,227,197	2,657,424	88,341,392	294,471	249,941,500	833,138	310,272,206	1,034,241	10,773,341	35,911	217,621,478	725,405
Lupin	331,194,696	865,619	15,897,345	41,550	9,935,841	25,969	-	-	29,807,523	77,906	274,891,598	718,463	-	-	-	-
Soybean	28,100,000	40,200	12,043,660	17,230	843,000	1,206	-	-	-	-	-	-	-	-	16,045,100	22,954
Sunflower	25,900,000	25,900	23,206,400	23,206	-	-	-	-	-	-	-	-	-	-	2,590,000	2,590
Opium poppy	110,000,000	5,000	22,000,000	1,000	16,500,000	750	55,000,000	2,500	16,500,000	750	-	-	-	-	-	-
Peanut	9,000,000	18,000	-	-	-	-	-	-	-	-	-	-	-	-	9,000,000	18,000
Safflower	158,500,000	288,097	31,700,000	57,619	31,700,000	57,619	-	-	31,700,000	57,619	31,700,000	57,619	-	-	31,700,000	57,619
Vegetable seed	251,300,000	115,000	26,552,358	12,151	22,617,000	10,350	22,617,000	10,350	82,929,000	37,950	7,539,000	3,450	-	-	87,955,000	40,250
Broadacre seed	64,000,000	24,165	6,400,000	2,416	6,400,000	2,416	12,800,000	4,833	25,600,000	9,666	6,400,000	2,416	-	-	6,400,000	2,416
Total	**12,882,943,141**	**16,700,158**	**3,819,288,128**	**4,360,354**	**2,917,220,614**	**4,374,487**	**407,194,443**	**357,176**	**1,308,146,817**	**1,900,825**	**2,156,407,584**	**4,014,089**	**155,717,097**	**113,157**	**2,110,855,417**	**1,566,672**

Appendix 3: Total economic value (producer surplus and consumer surplus) by state and crop

Table 12: Total economic value (producer surplus and consumer surplus) ($, million) by state and crop.

Crop	Australia	NSW	VIC	TAS	SA	WA	NT	QLD
Canola	586	182	111	-	35	252	-	1
Lucerne and clover	448	101	166	18	52	65	2	45
Apple	406	55	187	41	41	41	-	43
Cotton (lint)	384	268	-	-	-	0	2	114
Almond	373	67	229	-	75	1	-	-
Blueberry	247	211	5	15	2	5	-	9
Vegetable seed	230	24	21	21	76	7	-	81
Strawberry	197	2	71	8	14	22	-	83
Orange	177	92	34	-	46	5	-	2
Avocado	169	16	3	-	2	29	-	119
Cherry	140	39	39	35	22	4	-	0
Raspberry/blackberry	123	28	32	36	2	6	-	20
Mandarin	111	1	19	-	28	4	-	59
Cucumber	98	10	13	2	33	8	1	30
Peach/nectarine	97	8	74	-	7	5	-	4
Lupin	89	4	3	-	8	74	-	-
Muskmelon	73	23	2	-	1	10	8	28
Broadacre seed	59	6	6	12	23	6	-	6
Faba bean	55	19	11	-	25	-	-	0
Watermelon	54	14	1	-	1	8	14	17
Pear	52	0	47	0	2	2	-	0
Plum	47	9	24	0	2	9	-	2
Pumpkin	43	12	1	-	1	8	1	21
Macadamia	32	14	-	-	-	0	-	19
Lemon/lime	32	3	3	-	4	1	0	21
Opium poppy	30	6	4	15	4	-	-	-
Mango	25	0	0	-	-	1	12	12
Lychee	24	0	-	-	-	-	-	24
Safflower	23	5	5	-	5	5	-	5
Kiwi	21	2	15	-	2	-	-	2
Capsicum	21	1	2	1	4	2	-	11
Passionfruit	19	7	0	-	0	1	0	11
Sunflower	17	15	-	-	-	-	-	2
Zucchini	14	3	4	-	0	1	0	7
Soybean	12	5	0	-	-	-	-	7
Grapefruit	11	4	2	-	3	1	1	2
Persimmon	10	2	2	-	1	0	-	3
Apricot	9	0	5	1	2	0	-	0
Papaya/pawpaw	8	-	-	-	-	1	1	6
Field pea	6	1	2	-	2	1	-	-
Nashi	4	0	3	-	0	0	-	-
Coffee	3	1	-	-	-	-	-	2
Pomegranate	2	-	1	-	0	1	-	-
Prune	2	2	0	-	-	-	-	-
Peanut	1	-	-	-	-	-	-	1
Buckwheat	1	0	0	0	0	0	-	0
Dragon fruit	1	0	0	-	0	0	0	0
Total surplus	**4,587**	**1,263**	**1,148**	**205**	**528**	**585**	**41**	**817**

References

ABARES (2023) *Agricultural commodities and trade data: Australian crop report data*. https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data#australian-crop-report-data

Aizen, M. A., Garibaldi, L. A., Cunningham, S. A. and Klein, A. M. (2009). How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103, 1579-1588.

Alston, J., Norton, G. and Pardey, P. (1998) *Science Under Scarcity: Principles and Practice for Agricultural Research and Priority Setting*. CABI, Boston, USA.

Alston, J. and Wohlgenant, M. (1990) Appendix 2: Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models. In: Mullen, J. and Alston, J. (eds), *The Returns to the Australian Wool Industry from Investment in R&D*, Rural & Resources Economics Report No. 10. New South Wales Department of Agriculture and Fisheries, Sydney, Australia.

Australian Bureau of Statistics. (2022). *Agricultural Commodity Estimates by Australian Statistical Geographic Standard Edition 3 regions – 2020-21*. https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/2020-21

Barry, S., Cook, D., Duthie, R., Clifford, D. and Anderson, D. (2010). *Future Surveillance Needs for Honeybee Biosecurity*. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/future-surveillance-needs-for-honeybee-biosecurity/

Clarke, M., Gillespie, R. and Cunningham, S. (2017). *Regional Economic Multiplier Impacts, Potential Pollinator Deficits across Crops*. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/regional-economic-multiplier-impacts-potential-pollinator-deficits-across-crops/

Clarke, M. (2021). *Australian Pomegranate Industry Strategic Plan 2021-2026*. AgriFutures Australia. https://agrifutures.com.au/product/australian-pomegranate-industry-strategic-plan-2021-2026/

Clarke, M. and Le Feuvre, D. (2023). *Australian Pollination Service Statistics*. Hort Innovation. https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/ha21005/

Coles, R. and Willmott, P. (2008). *Potential impact of Varroa mite on major crops pollinated by honey bees in South Australia*. Primary Industries and Regions South Australia.

Cook, D. C., Thomas, M. B., Cunningham, S. A., Anderson, D. L. and De Barro., P. J. (2007). Predicting the Economic Impact of an Invasive Species on an Ecosystem Service. *Ecological Applications* 17(6), 1832-1840.

Cunningham, S., FitzGibbon, F. and Heard, T. A. (2002). The Future of Pollinators for Australian Agriculture. *Australian Journal of Agricultural Research* 53(8), 893-900.

Gallai, N., Salles, J. M., Settele, J. and Vaissiere, B. E. (2008). Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline. *Ecological Economics* 68(3), 810-821.

GHD. (2023). *AgriFutures Pasture Seeds Program RD&E Plan 2023-2028*. AgriFutures Australia. https://agrifutures.com.au/product/agrifutures-pasture-seeds-program-rde-plan-2023-2028/

Gibbs, D. M. H. and Muirhead, I. F. (1998). *The Economic Value and Environmental Impact of the Australian Beekeeping Industry.* Australian Honey Bee Industry Council. https://honeybee.org.au/doc/Muirhead.doc

Gill, R. A. (1989). *The Social Value of Commercially Managed Honey Bee Pollination Services in Australia*.

Goodwin, M. (2012). *Pollination of Crops in Australia and New Zealand*. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/pollination-of-crops-in-australia-and-new-zealand/

Gordon, J. and Davis, L. (2003). *Valuing Honeybee Pollination*. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/valuing-honeybee-pollination/

Hogendoorn, K., Rader, R., Cunningham, S., Oldroyd, B., Latty, T., Brown, J., Holmes, M., Gellie, N., Groom, S., Tokmakoff, A., O'Connor, P., van Dijk, K. and Lowe, A. (2021a). *Securing pollination for more productive agriculture: Guidelines for effective pollinator management and stakeholder adoption.* AgriFutures Australia. https://agrifutures.com.au/product/securing-pollination-for-more-productive-agriculture-guidelines-for-effective-pollinator-management-and-stakeholder-adoption/

Hogendoorn, K., Rader, R., Cunningham, S., Oldroyd, B., Latty, T., Brown, J., Holmes, M., Gellie, N., Groom, S., Tokmakoff, A., O'Connor, P., van Dijk, K. and Lowe, A. (2021b). *Securing pollination for more productive agriculture: Guidelines for effective pollinator management and stakeholder adoption.* Hort Innovation. https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/ph16004/

Hort Innovation and Fresh Logic. (2023). *Australian Horticulture Statistics Handbook 2021/22*. https://www.horticulture.com.au/globalassets/hort-innovation/australian-horticulture-statistics-handbook/ahsh-2021-22-intro-r3.pdf

IBISWorld. (2023). *Seed Production in Australia – Industry Data, Trends and Statistics*. https://www.ibisworld.com/au/industry/seed-production/4209/

Industries Assistance Commission. (1985). *Industries Assistance Commission Report on Biological Control of Echium Species (Including Paterson's Curse/Salvation Jane)*. Report no. 371. Australian Government Publishing Service.

Jordan, A., Patch, H. M., Grozinger, C. M. and Khanna, V. (2021). Economic Dependence and Vulnerability of United States Agricultural Sector on Insect-Mediated Pollination Service. *Environmental Science and Technology* 55(4), 2243-2253.

Karasiński, J. M. (2018a). The economic valuation of Australian managed and wild honey bee pollinators in 2014-15, Curtin University. https://www.wheenbeefoundation.org.au/wp-content/uploads/2020/02/Karasinski-JM-2018_The-Economic-Valuation-of-Australian-Managed-and-Wild-Honey-Bee-Pollinators-in-2014-2015.pdf

Karasiński, J. M. (2018b) The economic valuation of Australian non-honey bee pollinators in 2014-15. Curtin University. https://aussiepollination.com.au/pdf/Karasinski%20JM%202018%20The%20Economic%20Value%20of%20Aust%20Non-Honey%20Bee%20Insect%20Pollinators%20in%202014-2015.pdf

Keogh, R. C., Anthony, P. W., Robinson, A. P. W. and Mullins, I. J. (2010). Pollination Aware: The Real Value of Pollination in Australia. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/pollination-aware-the-real-value-of-pollination-in-australia/

McGregor, S. E. (1976). *Insect Pollination of Cultivated Crops Plants*. United States Department of Agriculture.

Monck, M., Gordon, J. and Hanslow, K. (2008). *Analysis of the market for pollination services in Australia*. Rural Industries Research and Development Corporation. https://agrifutures.com.au/product/analysis-of-the-market-for-pollination-service-in-australia/

Morse, R. A. and Calderone, N. W. (2000). *The value of honey bees as pollinators of U.S. Crops in 2000*. https://www.beyondpesticides.org/assets/media/documents/pollinators/documents/ValueofHoneyBeesasPollinators-2000Report.pdf

Oliver, J. R., Orchard, C. and Bradley, M. (2018). *Pasture Seeds Program RD&E Plan 2019-2023*. AgriFutures Australia. https://agrifutures.com.au/product/pasture-seeds-program-rde-plan-2019-2023/

Parliament of Australia. (2014). *Submissions to the Senate Standing Committee inquiry 'Future of the beekeeping and pollination service industries in Australia'*. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/Beekeeping/Submissions

Porto, R., Fernandes de Almeida, R., Cruz-Neto, O., Tabarelli, M., Viana, B. F., Peres, C. A. and Lopes, A. V. (2020). Pollination ecosystem services: A comprehensive review of economic values, research funding and policy actions. *Food Security* 12(2), 1425-1442.

Somerville, D. and Frost, E. (2018). *Pollination using honey bees*. AgGuide. NSW Department of Primary Industries. https://shop.regional.nsw.gov.au/products/pollination-using-honey-bees-b974

Southwick, E. E. and Southwick, L. (1992). Estimating the Economic Value of Honey Bees (Hymenoptera: Apidae) as Agricultural Pollinators in the United States. *Journal of Economic Entomology* 85(3), 621-633.

Thomson, M. (2007). Footnote 2: Transcript of Evidence. In: *Standing Committee of Primary Industries and Resources*. Parliament of Australia.

United States Department of Agriculture. (2023). *Australian Peanut Area, Yield and Production*. https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=AS&crop=Peanut

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