Horticulture impact assessment program 2020-21 to 2022-23 (MT21015)

Annex 4: Impact assessment of the project *Building a genetic foundation for Australia's citrus future* (CT15017)

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Executive summary

What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in CT15017 *Building a genetic foundation for Australia's citrus future*. The project was funded by Hort Innovation over the period August 2016 to May 2021.

Methodology

The investment was first analysed qualitatively within a logical framework that included activities and outputs, outcomes, and impacts. Actual and/or potential impacts then were categorised into a triple bottom line framework. Principal impacts identified were then considered for valuation in monetary terms (quantitative assessment). Past and future cash flows were expressed in 2020-21 dollar terms and were discounted to the year 2020-21 using a discount rate of 5% to estimate the investment criteria and a 5% reinvestment rate to estimate the modified internal rate of return (MIRR).

Results/key findings

CT15017 continued the citrus industry breeding program conducted by the Queensland Department of Agriculture and Fisheries (DAF) which sought to develop improved and high quality varieties for the Australian citrus industry. During CT15017 two new mandarin varieties released, known as 'Premier Murcott' (2019) and 'CB Murcott' (2021), which combined improved consumer desired traits including low-seed, easy-peal, and good colour.

The impact(s) valued were:

- [Economic] Increased production of mandarins target consumer quality preferences, including in Australia's major export markets, thereby helping Australia to differentiate its product, increase demand, and support industry growth.

Additional economic and social outcomes were identified but could not be valued due to a lack of data. These have the potential to provide additional industry impact above what has been identified.

Investment criteria

Total funding from all sources for the project was $4.17 million (2021 equivalent value). The investment produced estimated total expected benefits of $14.24 million (2021 equivalent value). This gave a net present value of $10.07 million, an estimated benefit-cost ratio of 3,41 to 1, an internal rate of return of 11% and a modified internal rate of return of 7%.

Conclusions

New varieties that target consumer preferences and allow product differentiation have the potential to generate increased demand. Higher demand can increase both prices and production levels, depending on the relative supply and demand elasticities; however, the CRRDC impact assessment Guidelines focuses only on first round impacts, which calculate shifts in the supply or demand curves with no price effect. As such, this analysis quantified increased mandarin plantings and production (above current levels) at constant prices.

Sensitivity testing was conducted that showed a BCR ranging from.

With adoption of the new mandarin varieties starting 2020, an assessed adoption period over 11 years, and a tree life of 21 years, the calculated citrus benefits extend to 2050, resulting in 29 years of discounting, and making the results particularly sensitive to changes in the discount rate, with a BCR range of 2.03 to 5.68 (for a 7.5% and 2.5% discount rate, compared to the 5% basreline).

Keywords

Impact assessment, cost-benefit analysis, citrus, mandarin, murcott, breeding

Introduction

Evaluating the impacts of levy investments is important to demonstrate to levy payers, Government and other industry stakeholders the economic, social and environmental outcomes of investment for industry, as well as being an important step to inform the ongoing investment agenda.

The importance of ex-post evaluation was recognised through the Horticulture Innovation Australia Limited (Hort Innovation) independent review of performance completed in 2017, and was incorporated into the Organisational Evaluation Framework.

Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. The assessments were required to meet the following Hort Innovation evaluation reporting requirements:

- Reporting against the Hort Innovation's Strategic Plan and the Evaluation Framework associated with Hort Innovation's Statutory Funding Agreement with the Commonwealth Government.
- Reporting against strategic priorities set out in the Strategic Investment Plan for each Hort Innovation industry fund.
- Annual Reporting to Hort Innovation stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

As part of its commitment to meeting these reporting requirements, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015). This program consisted of an annual impact assessment of 15 randomly selected Hort Innovation RD&E investments (projects) each year.

Project CT15017 *Building a genetic foundation for Australia's citrus future* was randomly selected as one of the 15 investments in the 2020-21 sample. This report presents the analysis and findings of the project impact assessment.

General method

The 2020-21 population was defined as an RD&E investment where a final deliverable had been submitted in the 2020-21 financial year. This generated an initial population of 175 Hort Innovation investments, worth an estimated $101.14 million (nominal Hort Innovation investment). The population was then stratified according to the Hort Innovation RD&E research portfolios and five, pre-defined project size classes. Projects in the Frontiers Fund, and those of less than $80,000 Hort Innovation investment being removed from the sample. From the remaining eligible population of 59 projects, with a combined value of $39.51 million, a random sample of 15 projects was selected worth a total of $9.7 million (nominal Hort Innovation investment), equal to 25% of the eligible RD&E population (in nominal terms).

The impact assessment followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. The approach included both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2018).

The evaluation process involved reviewing project contracts, milestones, and other documents; interviewing relevant Hort Innovation staff, project delivery partners, and growers and other industry stakeholders where appropriate; and collating additional industry and economic data where necessary. Through this process, the project activities, outputs, outcomes, and impacts were identified and briefly described; and the principal economic, environmental, and social impacts were summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were valued in monetary terms. Where impact valuation was exercised, the impact assessment uses cost-benefit analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for individual investments potentially represent an underestimate of the performance of that investment.

Background and rationale

Industry background

The Australian citrus industry, including oranges, mandarins, lemons and grapefruit, has approximately 1500 growers. Mandarins (the focus of project CT15017) are mostly grown along the eastern coastline of Australia, with Queensland being the largest producing state. Major varieties include Imperial, Murcott and Afourer (Hort Innovation 2022a).

Over the 5-years to June 2021, mandarin production has had the strongest growth in the citrus industry, increasing at a trend compound annual growth rate of 2% per year. The 5-year average, mandarin production was 161,591 tonnes, and farmgate value of $316.8 million (nominal) (Hort Innovation, 2022b). Over the same period, an average 62% of mandarin production went to the domestic fresh market, and 38% to the fresh export market with export volume growing at a trend average of 5% per year.

Producers in the citrus industry pay levies to the Department of Agriculture, Fisheries and Forestry (DAFF)), who is responsible for the collection, administration and disbursement of levies and charges on behalf of Australian agricultural industries. Levy is payable on citrus that are produced in Australia and either sold by the producer or used by the producer in the production of other goods. Hort Innovation manages the citrus levy funds which are directed to R&D and marketing.

Rationale

The citrus industry's levy investments are guided by a Strategic Investment Plan (SIP). The citrus SIP 2017-21 (under which CT15017 was delivered) identified "undertaking R&D and extension to enhance product quality (such as flavour and juiciness)" and to "developing new varieties and rootstocks in line with consumer preferences, especially for appearance and juiciness" as a key opportunities for Australia's citrus industry.

Despite being a relatively high-cost producer in global terms, Australian citrus producers have successfully maintained and grown a strong export presence based on quality. Key to maintaining this maintaining a competitive edge in the production of fruit that meets changing consumer preferences relating to appearance and quality, while also ensuring that varieties meet Australia's unique and varied growing conditions.

In line with this, CT15017 aimed to continue the industry breeding program conducted by the Queensland Department of Agriculture and Fisheries (DAF) to develop improved and high quality varieties for the Australian citrus industry.

Alignment with the Citrus Strategic Investment Plan 2017-2021

With a focus on developing new varieties, CT15017 was closely aligned to the Outcome 3 – Improved product quality and increased productivity from the application of innovation. 3.2 Undertake R&D and extension to enhance product quality (such as flavour and juiciness).

Alignment with national priorities

The Australian Government's National RD&E priorities (2015a) and Science and Research Priorities (2015b) are reproduced in Table 1. The project outcomes and related impacts will contribute to RD&E Priority 4, and to Science and Research Priority 1.

Table 1. National Agricultural Innovation Priorities and Science and Research Priorities

Australian Government	
National RD&E Priorities (2015a)	**Science and Research Priorities (2015b)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D.	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health.

Project details

Summary

Table 2. Project details

Project code	CT15017
Title	*Building a genetic foundation for Australia's citrus future through targeted breeding*
Research organization	The Queensland Department of Agriculture and Fisheries
Project leader	Malcolm W. Smith
Funding period	August 2016 to May 2021

Logical framework

A logical framework is shown in Table 3 to highlight the connection between the project activities, outputs, outcomes, and impact.

Table 3. Project logical framework

Activities	• Mutation breeding, selection and propagation of unique hybrids representing different genetic combinations aimed at addressing all the traits required for commercially successful new citrus varieties, with a particular focus on seedlessness in mandarins. • Undertake major field plantings of new mandarin varieties on commercial properties, supporting evaluation under specific Australian growing conditions, and supporting two-way communication with industry to keep selection criteria relevant and the breeding project commercially focused. • Validate more effective and efficient techniques to capture desirable traits. With a particular focus on demonstrating that a single gene for seedlessness works under local conditions and can be transmitted between generations. • Investigate seed contamination in commercial Afourer mandarin orchards. • Identify and collate data on the genetics of acidity developed in ancestral taxa. • Develop and apply efficient screening for bioactive compounds. • Collaborate with international research partners. • Apply of molecular markers to protect against theft prior to future commercialization.
Outputs	• Two new mandarin varieties released, known as 'Premier Murcott' (2019) and 'CB Murcott' (2021), combining low-seed, easy-peal, and good colour, and tested in Australian research and semi-commercial conditions. • Backcross populations established incorporating the newly identified single gene for seedlessness. • Validated techniques to identify the cause of seed contamination in Afourer orchards. • Data identifying a number of very low-acid citrus ancestors as well as some with extremely high Brix (26°) to support future breeding. • Newly established hybrids that are all screened and culled for Alternaria brown spot and Citrus scab.

Outcomes	• Immediate outcomes from new variety releases:
	  ○ Australian citrus growers have access to two new mandarin varieties ('Premier Murcott' and 'CB Murcott'), combining attractive fruit appearance with good eating quality to support increased consumer appeal and demand in domestic and export markets.
	  ○ Australian citrus growers face reduced risk when considering new varieties as the Australian developed varieties have been bred for Australian conditions and trialled in research and semi-commercial conditions.
	• Longer term outcomes from the continued development and improvement of the industry breeding program
	  ○ The industry has improved techniques to identify the cause of seed contamination in Afourer orchards which can now be applied commercially.
	  ○ The industry has made progress towards overcoming the low productivity of '15C001'.

	○ The industry has a better understanding of the domestication of citrus and which genes are involved in determining important commercial traits such as acidity and sugars. ○ The industry has adopted more effective and efficient techniques to capture the seedlessness trait. ○ The industry's field plantings increased by approximately 25% to 40,000 hybrids in the field at Bundaberg at the completion of the project, reflecting the use of more than 130 different seed parents and almost 200 different pollen parents. ○ Future selections in the industry breeding program will have greater resistance to diseases including Alternaria brown spot and Citrus scab. ○ A greater access to technical support for growers to enhance productivity compared to overseas bred varieties who are more difficult to contact and don't understand Australian production systems. Also helping ongoing research.
Impacts	• Impacts from the release of the new 'Premier Murcott' and 'CB Murcott' mandarin varieties: ○ [Economic] Increased production of mandarins that target consumer quality preferences, including in Australia's major export markets, thereby helping Australia to differentiate its product, and increase overall demand for Australian citrus. ○ [Economic] Increased production of mandarins that are bred to perform in Australia's specific growing conditions, enhancing the productivity of the industry. ○ [Economic] Decreased reliance on overseas varieties, generating royalties for Australian breeding program stakeholders that can be re-invested in citrus breeding and related R&D. ○ [Social] Increased contribution to regional community wellbeing from more profitable citrus growers. ○ [Social] A greater selection of citrus varieties combining attractive fruit appearance with good eating quality supporting increased consumer appeal, and thereby supporting increased fruit consumption with associated health and wellbeing outcomes. • Impacts from the continuation and improvement of the industry breeding program: ○ [Economic, social, environmental] New hybrid populations derived from the highest quality progeny-tested parents and families will be deployed enabling ongoing genetic progress targeting consumer preferences (seedlessness, sweetness, appearance) supporting increased demand, as well as resistance to significant diseases, which will decrease production costs, improve pack-outs, and address international and domestic trade issues associated with chemical use and residue levels.

Project costs

Nominal investment

Table 4. Project nominal investment

Year end 30 June	Hort Innovation ($)	Q DAF ($)	Total ($)
2017	100,000	224,145	324,145
2018	110,000	246,559	356,559
2019	371,498	832,694	1,204,193
2020	260,000	582,776	842,776
2021	221,260	495,943	717,203
Total	1,062,758	2,382,117	3,444,875

In-kind costs

Where in kind costs have been provided as a single whole-of-project figure, these have been apportioned based on the Hort Innovation annual costs to reflect the underlying investment delivery.

Program management costs

R&D costs should also include the administrative and overhead costs associated with managing and supporting the project. The Hort Innovation overhead and administrative costs were calculated for each project funding year based on the data presented in the *Statement of Comprehensive Income* in the *Hort Innovation Annual Report* for the relevant year.

Where the overhead and administrative costs were equal to the total expenses, less the research and development and marketing expenses. The overhead and administrative costs were then calculated as a proportion of combined project expenses (RD&E and marketing), averaging 15.7% for the CT15017 funding period (2017-2021). This figure was then applied to the nominal Hort Innovation investment shown in Table 4.

Real Investment costs

For purposes of the investment analysis, the investment costs of all parties were expressed in 2020-21 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2022).

Extension costs

Outputs and varietal results from CT15017 were extended through the industry communication project (CT18000), with ongoing extension through the industry communication program and technical forums (Citrus Technical Forums 2022-2024 (CT20000). Communication and extension costs were 7.7% of total investment in the Citrus SIP 2017-2021 (Hort Innovation 2021). This figure has been added to the total Hort Innovation cost.

Project impacts

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when quantifying impacts, particularly when some uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Impacts valued

The impact(s) valued were:

- Impacts from the release of 'Premier Murcott' and 'CB Murcott' mandarin varieties:
  - [Economic] Increased production of mandarins that target consumer quality preferences, including in Australia's major export markets, thereby helping Australia to differentiate its product, and increase overall demand for Australian citrus.

New varieties that target consumer preferences (appearance and quality) have the potential to generate increased mandarin demand in both the Australian domestic market and overseas markets. Higher demand for the new varieties would encourage both a shift from existing to new varieties in orchard re-plantings, and also encourage additional planted area to meet the increased demand. While the higher demand has the potential to increase both prices and production levels, depending on the relative supply and demand elasticities, the CRRDC impact assessment Guidelines focus on first round impacts, which calculate shifts in the supply or demand curves with no price effect. As such, this analysis focussed on the increase in industry mandarin plantings and production (above current levels) from increased demand, but at constant prices. The increased production was then valued at the annual net cashflow for new plantings (orchard income minus costs).

Impacts not valued

Not all of the impacts identified in Table 4 could be valued in the assessment, particularly where lack of data made it difficult to confidently quantify the impact pathway.

The impacts identified but not value were:

- Impacts from the release of 'Premier Murcott' and 'CB Murcott' mandarin varieties:
  - [Economic] Decreased reliance on overseas varieties, generating royalties for Australian breeding program stakeholders that can be re-invested in citrus breeding and related R&D.
  - [Economic] Increased production of mandarins that are bred to perform in Australia's specific growing conditions, enhancing the productivity of the industry.
  - [Social] Increased contribution to regional community wellbeing from more profitable citrus growers.
  - [Social] A greater selection of citrus varieties combining attractive fruit appearance with good eating quality supporting increased consumer appeal, and thereby supporting increased fruit consumption with associated health and wellbeing outcomes.

- Impacts from the continuation and improvement of the industry breeding program:
  - [Economic] New hybrid populations derived from the highest quality progeny-tested parents and families will be deployed enabling ongoing genetic progress targeting consumer preferences (seedlessness, sweetness, appearance) supporting increased demand, as well as resistance to significant diseases, which will decrease production costs, improve pack-outs, and address international and domestic trade issues associated with chemical use and residue levels.

Public versus private impacts

The impacts identified from the investment are predominantly private impacts accruing to citrus growers. However, some public benefits also have been produced in the form of capacity built and spill-overs to regional communities from enhanced grower income.

Distribution of private impacts

The private impacts will have been distributed between growers, processor/packers, wholesalers, exporters, and retailers. The share of impact realised by each link in the supply chain will depend on both short- and long-term supply and demand elasticities in the citrus markets. In addition, while the analysis quantified private benefits accruing to citrus growers, additional private impacts would be generated in the wider economy. Changes in farm input costs (increase or decrease) would result in spillover changes (increase or decrease) in income for businesses providing those goods and services.

Impacts on other Australian industries

While CT15017 released two new mandarin varieties, the broader breeding program works on the genetic improvement of a wide range of citrus varieties.

Impacts overseas

The project had a focus on Australian citrus stakeholders. However, with international collaboration, and average citrus exports of 33% of production (and 38% for mandarins) additional overseas impacts may be generated. This includes the potential for overseas licensing of Australian bred varieties.

Data and assumptions

A summary of the key impact data and assumptions is provided in Table 5.

Table 5. Summary of data and assumptions

Variable	Assumption	Source / comment
Discount rate	5%	Impact assessment guidelines (CRRDC 2018)
Pre-existing mandarin production area (ha)	3,591 (± 5%)	Hort Stats Handbook (Hort Innovation 2022b) 5-year average production and standard deviation, divided by an average 45 t/ha mature crop production from stakeholder consultation.
Net increase mandarin production area with demand for new varieties (ha)	5% (± 25%)	Discussion with industry stakeholders indicated the Australian mandarin market could diversify and expand with new varieties. These could eventually account for 25% of total murcott production, which is the primary export mandarin and also growing in domestic market share. With total mandarin production trend growth of 2% per year (2017-2021) (Hort Innovation 2022b), it was assumed the new murcott varieties would have the potential to account for 25% of this annual increase going forward. Based on a mature crop yield of 45 t/ha (NSW DPI 2018) and an 11 year adoption curve (Appendix A), this equates to an additional mandarin

		production area of 5% (180 ha) above pre-existing levels. Tested at plus and minus 25%.
First year of new variety adoption	2020	Commercial budding from 2020 (Hort Innovation and Research provider).
Time to peak adoption	11 years (± 18%)	ADOPT model output. See Appendix A.
Mandarin total life	21 years from planting	Citrus Budget Handbook (NSW DPI 2018)
Last year of impact	2050	From above data with adoption starting 2020, an adoption period over 11 years, and a productive life of 21 years. Only a single production cycle was evaluated given the uncertainty of new varieties being developed over the 30 year period.
First year of fruit production from planting	Year 3	Citrus Budget Handbook (NSW DPI 2018)
Mature yield (year 9)	45 t/ha (± 11%)	Citrus Budget Handbook (NSW DPI 2018) and stakeholder consultation.
Farmgate price	$2.05/kg (± 3%)	Hort Stats Handbook (Hort Innovation 2022b) 5-year average and standard deviation. Adjusted to 2020-21 equivalent values.
Average gross margin from new plantings	Average 23% over 21 year tree life, with negative margins from planting to year 3, reaching mature gross margin (35%) in year 11.	Reflecting the net benefit of the increased production. Based of Citrus Budget Handbook (NSW DPI 2018) net-cashflows relative to maximum orchard income. Cashflows include establishment (adoption) costs and ongoing orchard management costs.
Attribution of outcome (new varieties) to CT15017	67% (± 25%)	Citrus breeding programs require a long investment period to identify a range of potentially suitable hybrids and conduct trials to ensure the variety traits are stable. Based on the variety codes of the two new varieties (11C017 and 12C007) the breeding period was identified as starting in 2011-2012 in *Early season replacement for imperial mandarin* (CT09014). The extent to which the new varieties should be attributed to early-stage breeding (CT09014) or later stage breeding (CT15017) is relatively subjective. CT15017 accounted for 84% of the total inflation adjusted costs (taken as the upper value of attribution), with an assumed lower value of 50% and baseline of 67%.
R&D counterfactual	75% (± 33%)	In discussion with stakeholders it was assumed that there was only a small likelihood the investment and outcomes would have been delivered without Hort Innovation levy contribution and coordination.

Results

All costs and benefits were discounted to 2020-21 using a real discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment (2020-21) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment criteria

Table 6 shows the impact metrics estimated for different periods of benefit for the total investment. The present value of benefits (PVB) attributable to the Hort Innovation investment, shown in Table 7, has been estimated by multiplying the total PVB by the Hort Innovation proportion of real investment (35%).

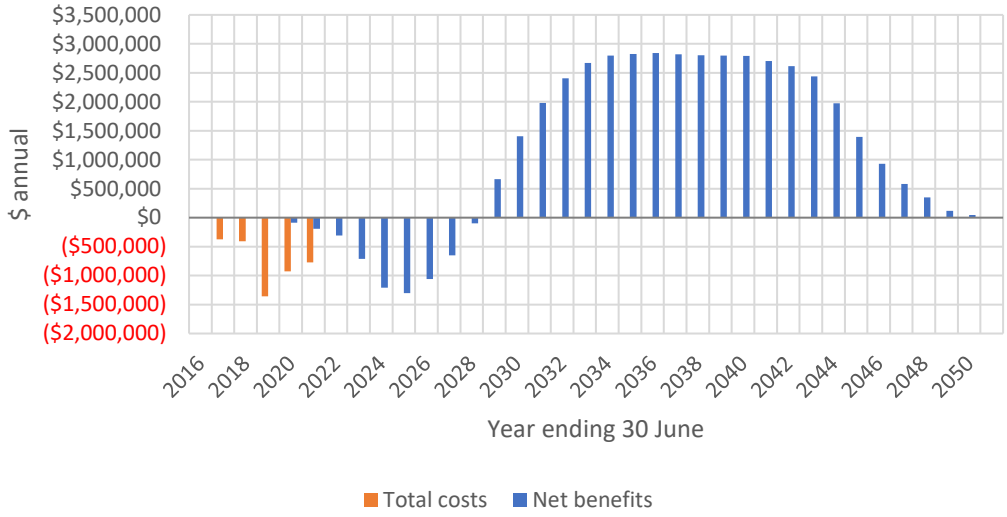
Table 6. Impact metrics for the total investment in project CT15017

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	4.17	4.17	4.17	4.17	4.17	4.17	4.17
PVB ($m)	-0.28	-4.17	-2.15	5.02	10.82	13.94	14.24
NPV ($m)	-4.45	-8.34	-6.32	0.85	6.65	9.77	10.07
BCR	-0.07	-1.00	-0.52	1.20	2.59	3.34	3.41
IRR	Negative	Negative	Negative	6%	10%	11%	11%
MIRR	Negative	Negative	Negative	5%	7%	8%	7%

Table 7. Impact metrics for the Hort Innovation Investment in project CT15017

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	1.48	1.48	1.48	1.48	1.48	1.48	1.48
PVB ($m)	-0.10	-1.48	-0.76	1.78	3.83	4.94	5.04
NPV ($m)	-1.58	-2.95	-2.24	0.30	2.35	3.46	3.57
BCR	-0.07	-1.00	-0.52	1.20	2.59	3.34	3.41
IRR	Negative	Negative	Negative	6%	10%	11%	11%
MIRR	Negative	Negative	Negative	5%	7%	8%	7%

Figure 3. Annual cash flow of undiscounted total benefits and total investment costs



Sensitivity analysis

A sensitivity analysis was carried out on key variables identified in the analysis where a data range was identified, or there was a level of uncertainty around the data. Data ranges and sources are described in Table 5.

Table 8. Impact BCR sensitivity to changes in key underlying variables

Variable		Low	Baseline	High
Discount rate	Variable range	3%	5%	8%
	BCR range	5.68	3.41	2.03
Pre-existing mandarin production area (ha)	Variable range	3,430	3,591	3,752
	BCR range	3.26	3.41	3.57
Net increased production area with new varieties (ha)	Variable range	3.75%	5.00%	6.35%
	BCR range	2.56	3.41	4.27
Time to peak adoption (years)	Variable range	9	11	13
	BCR range	3.30	3.41	3.51
Farmgate price ($/kg)	Variable range	2.00	2.05	2.11
	BCR range	3.32	3.41	3.51
Attribution of outcome (new varieties) to CT15017	Variable range	50%	67%	84%
	BCR range	2.55	3.41	4.28
R&D counterfactual	Variable range	50%	75%	100%
	BCR range	2.28	3.41	4.55

Discussion and conclusions

The analysis showed that the quantified benefits were greater than the investment cost for CT15017, with a BCR 3.41:1. The results reflect the benefits of the release and adoption of 'Premier Murcott' and 'CB Murcott' mandarin varieties, with the potential to generate increased demand relative to existing varieties due to increased consumer appeal, and thereby encouraging additional planted area.

To account for the uncertainty in some of the variables, sensitivity testing was conducted that showed a BCR ranging from 2.03 to 5.68. The results were most sensitive to the tested ranges of the discount rate. The discount rate reflects the time value of money, with a dollar earned (or spent) in 2021 worth more than a dollar earned (or spent) in 2031. The longer the impact period, the greater discounting effect. With adoption starting 2020, an adoption period over 11 years, and a tree life of 21 years the calculated citrus benefits extend to 2050, resulting in 29 years of discounting.

A lack of underlying data meant that there were economic and social outcomes identified but not quantified which had the potential to provide additional impact to the citrus industry. These included royalty benefits accruing to Australian breeding program investors, increased citrus breeding capacity, and social and economic spillovers from a more productive and profitable citrus industry.

The spillover impacts include increased demand for goods and services from upstream (orchard inputs) and downstream (transport, marketing) supply chain participants as a result of expanded mandarin production. The increased input costs would result in corresponding changes in income for employees and businesses providing those goods and services generating additional impact a

Investment that support increased demand have the potential to increase both production and prices. However, the CRRDC impact assessment Guidelines focus only on first round impacts, which calculate shifts in the supply or demand curves with no price effect. As such, this analysis focussed on the increase in industry mandarin plantings and production (above current levels) from increased demand, but at constant prices. Including second round price effects would effectively shift benefits between producers and consumers depending on the slope of the supply and demand curves.

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Glossary of economic terms

Cost-benefit analysis	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Modified internal rate of return	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits	The discounted value of benefits.
Present value of costs	The discounted value of investment costs.

Abbreviations

ADOPT The Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Adoption & Diffusion Outcome Prediction Tool (Kuehne et al 2017)

CRRDC Council of Rural Research and Development Corporations

DAFF Department of Agriculture, Fisheries and Forestry (Australian Government)

GDP Gross Domestic Product

GVP Gross Value of Production

IRR Internal Rate of Return

MIRR Modified Internal Rate of Return

PVB Present Value of Benefits

PVC Present Value of Costs

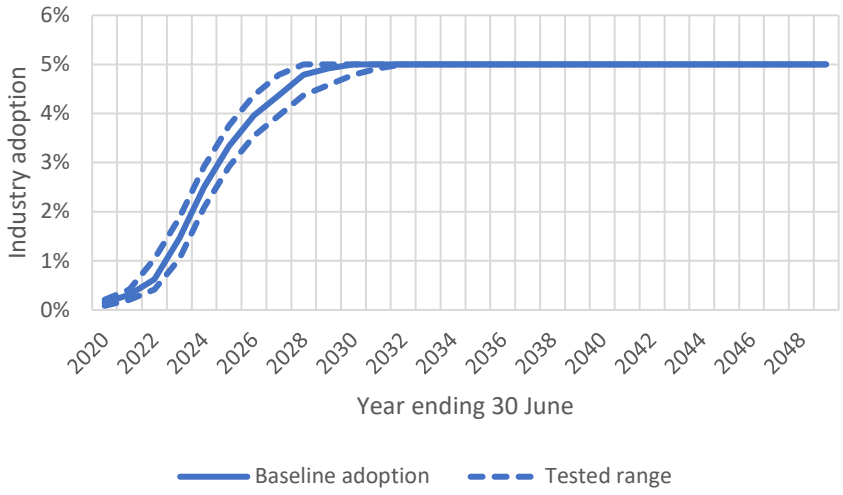
RD&E Research, Development and Extension

SIP Strategic Investment Plan

Appendix A. ADOPT questions and answers for CT15017 impact assessment

Appendix A includes the data inputs for the ADOPT model (Kuehne et al 2017) used in this analysis. The adoption curve and tested ranges can be seen in Figure 2. The tested range was based on changes in industry awareness of the new mandarin varieties supporting faster and slower rates of adoption across the industry (Q13). The resulting curve was applied to the assumed 5% increase in industry plantings.

Figure 2. Change in adoption and diffusion curve from CT15017 new mandarin varieties. Includes sensitivity testing of ±50% of the baseline yearly change.



1. What proportion of farmers have maximising profit as a strong motivation?
A majority have maximising profit as a strong motivation

2. What proportion of farmers has protecting the natural environment as a strong motivation?
About half have protection of the environment as a strong motivation

3. What proportion of farmers has risk minimisation as a strong motivation?
About half have risk minimisation as a strong motivation

4. On what proportion of farmers is there a major enterprise that could benefit from the technology?
A majority of the target farms have a major enterprise that could benefit

5. What proportion of farmers have a long-term (greater than 10 years) management horizon for their farm?
About half have a long-term management horizon

6. What proportion of farmers are under conditions of severe short-term financial constraints?
A minority currently have a severe short-term financial constraint

7. How easily can the innovation be trialled on a limited basis before a decision is made to adopt it on a larger scale?
Easily trialable

8. Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?
Not at all difficult to evaluate effects of use due to complexity

9. To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?
Not observable at all

10. What proportion growers use paid advisors capable of providing advice relevant to the project?
A majority use a relevant advisor

11. What proportion of growers participate in farmer-based groups that discuss farming?
A majority are involved with a group that discusses farming

12. What proportion of growers will need to develop substantial new skills and knowledge to use the innovation?
A minority will need new skills or knowledge

13. What proportion of growers would be aware of the use or trialling of the innovation in their district?
A minority are aware of the use or trialling of the innovation in their district
About half are aware of the use or trialling of the innovation in their district
A majority are aware of the use or trialling of the innovation in their district

14. What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?
A moderate initial investment required

15. To what extent is the adoption of the innovation able to be reversed?
Difficult to reverse

16. To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?
No profit advantage in years that it is used (planted)

17 To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?
Moderate profit advantage in the future

18 How long after the innovation is first adopted would it take for effects on future profitability to be realised?
3 to 5 years before the effects on future profitability are realised

19. To what extent would the use of the innovation have net environmental benefits or costs?
No environmental advantage

20. How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?
Not applicable

21. To what extent would the use of the innovation affect the net exposure of the farm business to risk?
No change in risk

22. To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?
No change in ease and convenience