Impact assessment of the investment:

Avocado sunblotch viroid survey (AV18007)

*By Adam Briggs, **Ag Econ***
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Hort Innovation

Previous page image courtesy of Avocados Australia Limited 2020.

Disclaimer:

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Level 7
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Telephone: (02) 8295 2300

www.horticulture.com.au

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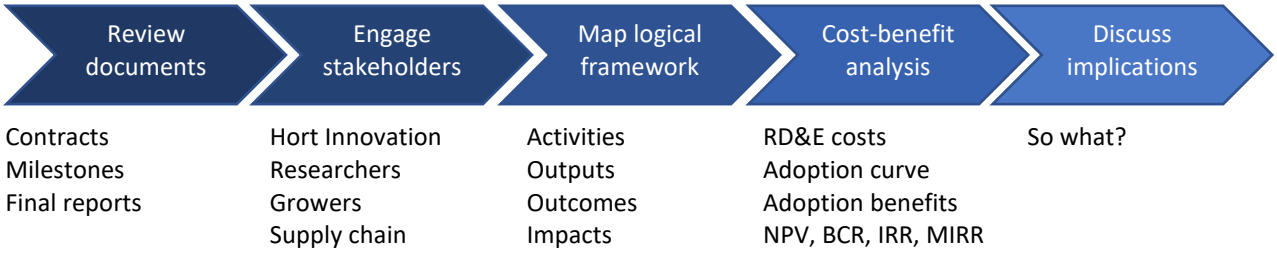
Executive summary

What the report is about

Ag Econ conducted independent analysis determine the economic, social, and environmental impact resulting from delivery of the avocado project *Avocado sunblotch viroid survey (AV18007)*. The project was funded by Hort Innovation over the period June 2019 to February 2023 using the avocado research and development levy and contributions from the Australian Government. The project was delivered by The University of Queensland.

The analysis applied a five step analytical process to understand the impact pathway and collect supporting data.



Research background

The Avocado sunblotch viroid (ASBVd) was detected in Australia over 50 years ago, however is now uncommon following the implementation of an industry wide control program that was established in 1980. While ASBVd remains rare, the industry identified the need to develop a cost-effective survey testing protocol and undertake industry testing given the increasing importance of export markets for industry growth and the potential for trading partners to request evidence at the orchard level that supplied product is free from ASBVd. The program also tested a novel surveillance method which relied on detecting ASBVd through pollen stores from honey bee orchard pollinators, given that the viroid is pollen-transmitted.

Key findings

The nominal investment cost of $0.74 million was adjusted for inflation (ABS, 2024) and discounted (using a 5% real discount rate) to a 2023-24 present value (PV) of costs equal to $0.97 million.

The analysis conducted a detailed evaluation of the AV18007 impact pathway through a logical framework. From this process, economic and social impacts were identified as having the potential to be realised from increased export volume supported by the avocado industry investment in AV18007.

A review of available data and discussions with stakeholders identified sufficient data to model the industry level benefits of increased export volume to new markets.

This generated total PV benefits of $7.61 million, with a benefit cost ratio (BCR) of 7.82:1.

Reflecting the underlying uncertainty for many variables modelled, sensitivity testing showed a wide potential impact range of between 2.58:1 and 74.88:1. As all model simulations showed a BCR greater than 1:1 (i.e. a positive impact), this supports a high level of confidence that the AV18007 investment will generate a positive impact off the farm level benefits alone.

Despite the clear impact pathway for industry level benefits of reduced ASBVd risks (through enforcement of international best practice biosecurity protocol) there was insufficient data identified to confidently quantify the benefits. Improved data relating to these benefits, as outlined in this analysis, would support an estimate of benefit and likely further increase the RD&E impact quantified in this analysis.

The key findings of the AV18007 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, avocado; sunblotch viroid; nursery; export; pollinator; survey; sample

Figure 1. Summary of impact assessment findings

AV18007 Avocado Sunblotch survey

RD&E activities

Outcomes

Impacts

Total RD&E costs:

- $0.74 million (nominal value)
- 100% R&D levy and Government matching.

Research activities:

- Develop a sampling and mapping tool and survey protocol to demonstrate pest freedom in an orchard.
- Develop a new filter paper based method of RNA viroid extraction.
- Nursery and orchard tree testing (n=8,320).
- Collection of bee and hive samples to inform the potential for bee-assisted surveillance of ASBVd.

Extension activities:

- Sampling tool to guide optimisation of the sampling design for detection of ASBVd.
- 4 x Scientific papers.

Outcomes:

- Improved crop protection solutions for ASBVd.
- Adoption of best practices through supply of superior planting material.
- Improved industry knowledge and capacity increasing export market opportunities.
- New knowledge of alternative crop protection solutions
- Improved import risk assessment capacity

Industry adoption:

- Export permits have granted for North Queensland growers into New Caledonia
- Future export volume growth to New Zealand is expected following protocol regonotation, supported by ASBVd survey capacity.

Industry economic impacts:

- Increased industry revenue from export market volume growth realised from improved capacity to meet market access conditions.

Social impacts:

- Improved industry sentiment and confidence influenced by robust biosecurity practices and management capacity.

Total attributable benefits and impact:

- Present value (PV @ 5% discount) RD&E costs of $0.97 million.
- PV estimated benefits of $7.61 million between 2024 and 2053.
- Net PV (NPV) of $6.64 million.
- Benefit cost Ratio (BCR) of 7.82:1 with a 90% confidence of a BCR between 4.70:1 and 24.94:1.

Introduction

Evaluating the impacts of levy investments is important to demonstrate the economic, social and environmental benefits realised through investment to levy payers, Government and other industry stakeholders. Understanding impact is also an important step to inform the ongoing investment agenda.

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. Commencing with MT18011 in 2017-18, the impact assessment program consisted of an annual impact assessment of up to 15 randomly selected Hort Innovation RD&E investments (projects) each year. In line with this ongoing program, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015).

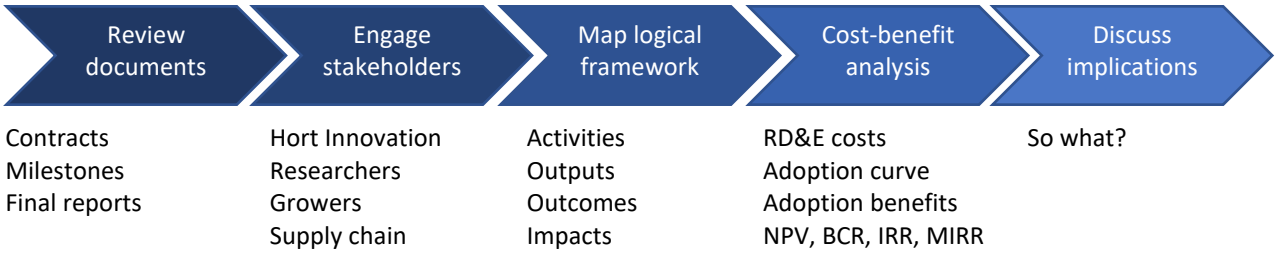
Avocado sunblotch viroid survey (AV18007) was randomly selected in the 2021-22 sample. This report presents the analysis and findings of the project impact assessment.

The report structure starts with the general method of analysis used, followed by the RD&E background and an outline of the impact pathway in a logical framework, then describes the approach used to quantify the identified costs and benefits including any data gaps and limitations to the analysis, presents the results including from the sensitivity analysis, and finally discusses any implications for stakeholders.

General method

The impact assessment built on the impact assessment guidelines of the CRRDC (CRRDC, 2018) and included both qualitative and quantitative analysis. The general method that informed the impact assessment approach is as follows:

1. Review project documentation including project plan, milestone reports, outputs and final report.
2. Discuss the project delivery, adoption and benefits with the Hort Innovation project manager, project researcher/consultant, growers and other relevant stakeholders (see *Stakeholder consultation*).
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, and outcomes to identify the principal economic, environmental, and social impacts realised through the project
4. Collect available data to quantify the impact pathway and estimate the attributable impacts using cost-benefit analysis (over a maximum 30 years with a 5% discount rate), and then sensitivity test the results to changes in key parameters.
5. Discuss the implications for stakeholders.



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program. A more detailed discussion of the method can be found in the *MT21015 2021-22 Summary Report* on Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015).

Project background

The Avocado industry has experienced rapid expansion throughout the 2000's, driven by increased industry plantings in response to growth in consumer demand, with Australians now amongst the highest consumers of avocados globally on a per capita basis (Rabobank 2023). However despite the growth in demand, industry production growth continues as new plantings continue to mature, with industry production forecasts indicating this production will outpace domestic market demand. Therefore, growth in export markets will be required to absorb additional volumes and maintain sustainable industry prices (Hort Innovation 2023, 2024).

Ongoing industry export growth relies on industry capacity to satisfy market access protocols for existing and potential markets. Avocado sunblotch viroid (ASBVd) is one of the smallest disease-causing agents in the world but can reduce the yield of an avocado tree by as much as 80%. ASBVd was initially introduced into the first commercial producing orchards in California via infected seed and budwood, and into Australia through latently infected propagules. While comparatively rare due to an industry control program introduced in 1980 that ensured tree propagation was sourced from clean material, ASBVd has not been demonstrated to be entirely free within Australia. This represents a market access risk for the industry.

Prior to the research, available diagnostic assay testing for ASBVd while accurate, was still relatively costly and time consuming for growers. Furthermore, a definitive sampling methodology sufficient to demonstrate orchard freedom from ASBVd within an accepted level of statistical risk were not available. Therefore the industry sought to improve sampling, testing and capacity at the grower and industry level to demonstrate 'free from' status for ASBVd to ensure that future export market opportunities would could be realised, such as New Zealand.

AV18007 was undertaken to develop a statistically robust sampling approach to demonstrate pest freedom in an orchard that complies with regulatory requirements of trading partners. The project also undertook a widescale survey of existing orchards in major growing regions and across nurseries to determine the presence of ASBVd across Australia. Finally, given that ASBVd is transmitted in pollen, a novel approach to detecting the presence of the viroid in orchards via pollen stores in beehives was tested, with the view to expanding as a low cost method for other disease survey applications.

AV18007 aligned with the Avocado Strategic Investment Plan (SIP) 2022-2026 through:

- Outcome 1: Demand creation. Strategy 4. Improve technical access to high-value markets as identified within the export strategy.

Project details

AV18007 was funded from 2019 to 2023 (Table 1).

Table 1. Project details

Project code	AV18007
Title	Avocado sunblotch viroid survey
Research organisation(s)	The University of Queensland (lead) Commonwealth Scientific and Industrial Research Organisation (CSIRO) South Africa Agricultural Research Council Cambridge University
Project leader	Andrew Geering
Funding period	June 2019 to February 2023
Objective	Survey Avocado sunblotch viroid (ASBVd) in Australia to provide evidence to support a declaration of pest-freedom and facilitate export market growth.

Logical framework

The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework (Table 2).

Table 2. Project logical framework detail

RD&E activities

Sampling and mapping tool

- Software (AgKonnect) was customised by layering the QLUMP national avocado farm data to reflect industry plantings and nurseries to enable sampling.
- Map previous records of ASBVd in Australia, identifying priority list of farms to survey.
- Review the distribution of ASBVd between branches and fruit of symptomatic and asymptomatic trees to inform a sampling strategy to satisfy trade protocols.
- Gather data on rates of spread of ASBVd in South Africa to inform modelling.
- Software developed to inform the survey protocol.
- Engagement with the Department of Agriculture, Water and the Environment to understand protocol requirements to declare and maintain a farm a pest-free production site.
- Development of a survey protocol to demonstrate pest freedom in an orchard.

Avocado nursery diagnostic testing

- Develop new filter paper based method of RNA viroid extraction.
- Nursery testing completed through the Avocado Nursery Voluntary Accreditation Scheme (ANVAS).
- Diagnostic reports produced and provided to participating nurseries to register with the Nursery Industry Accreditation Scheme Australia (NIASA) or to demonstrate ongoing compliance.

Orchard diagnostic testing

- Surveying of farms in major production regions to test for ASBVd.

Bee-assisted surveillance of ASBVd

- Random selection of hives located in producing orchards for sampling (Queensland and South Africa).
- Collection of bee and hive samples (RNA from worker bees, pollen samples).
- Analysis of samples using high throughput RNA sequencing.
- Record and compare reliability of testing with RT-qPCR methods.

RD&E outputs

- **1 x final report** on the Hort Innovation website.
- **4 x Scientific papers:**
  - Pretorius, L.-S., Chandra, KA, Jooste, A.E.C., Motaung, L.C., Parkinson, L.E., Geering, A.D.W., 2022. Adaptation of a filter paper method for RNA template preparation for the detection of avocado sunblotch viroid by reverse transcription qPCR. *Journal of Virological Methods* 301, 114455. https://doi.org/10.1016/j.jviromet.2022.114455
  - Pretorius, L.-S., Geering, A.D.W., 2023. Extreme resilience of avocado sunblotch viroid RNA in sampled avocado leaves and fruit. *Australasian Plant Pathology* 52, 63–66. https://doi.org/10.1007/s13313-022-00898-1
  - Roberts, J.M.K., Jooste, A.E.C., Pretorius, L.-S., Geering, A.D.W., 2023. Surveillance for Avocado Sunblotch Viroid Utilizing the European Honeybee (Apis mellifera L.). Phytopathology 113(3) https://doi.org/10.1094/PHYTO-08-22-0295-R
  - Bonnéry, D.B., Pretorius, L.-S., Jooste, A.E.C., Geering, A.D.W., Gilligan, C.A., 2023. Rational design of a sampling protocol for detection of a subcellular plant pathogen to demonstrate area freedom in commercial orchards. PLoS One 18(4):e0277725. doi: 10.1371/journal.pone.0277725.
- **New high throughput diagnostic protocol developed (online tool)**
- **New survey protocol meeting international biosecurity agency standards.**
- **Survey results of avocado orchard and nursery trees (n=8,320).**

Outcomes

The key end of project outcome for AV18007 was the development of new knowledge and tools that can be used to support claims of freedom from ASBVd to satisfy trade protocols of trading partners.

- **Improved crop protection solutions for ASBVd.** Provision of expert knowledge on distribution of ASBVd to support granting of plant health certificates.
- **Adoption of best practices through supply of superior planting material.** The number of participating nurseries in ANVAS has increased from 3 to 11 as supported by the revised ASBVd testing method.
- **Improved industry knowledge and capacity increasing export market opportunities.** New survey protocol for testing ASBVd can be used to support several export market opportunities, including:
  - Contributing to New Zealand protocol requirements by providing an acceptable method to demonstrate freedom of ASBVd from orchards.
  - Granting export permit to New Caledonia for Queensland avocado growers.
- N**ew knowledge of alternative crop protection solutions** achieved through successful demonstration of bee-assisted surveillance with potential application for cost effective surveillance of other plant disease.
- **Improved import risk assessment capacity** supported by new knowledge of internationally accepted evidence needed to demonstrate pest freedom.

Impacts

The development of internationally accepted survey protocols and low cost testing methods has resulted in the increased capability of the avocado industry to meet requirements of export markets, in turn supporting:

- [Economic] Increased industry revenue from export market volume growth realised from improved capacity to meet market access conditions.
- [Economic] Reduced costs of testing to demonstrate pest freedom in support of satisfying export market protocols.
- [Economic] Reduced orchard and nursery testing and management costs (e.g. removing and replanting disease affected trees).
- [Economic] Reduced risk of ASBVd being imported into Australia through enforcement of international best practice biosecurity protocol.
- [Socio-economic] Improved industry sentiment and confidence influenced by robust biosecurity practices and management capacity.
- [Socio-economic] Avoided loss of industry spillovers that would result from a decline in the avocado industry as a source of employment and economic stimulant to local communities (The CIE 2023).
- [Social] Avoided health and wellbeing costs to farm staff including psychological stress and strains on business and community relationships related to biosecurity events (CSIRO 2020 and CSIRO 2021).

Project costs

The project was funded by Hort Innovation, using the avocado research and development levy and contributions from the Australian Government, with additional funding from research partner University of Queensland

Nominal investment

The project funding period was 2019 to 2023 (Table 3). Hort Innovation overhead costs were added to the direct project cost to capture the full nominal value of the RD&E investment.

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	Other funding ($)[2] (includes overheads)	Total nominal cost ($)
2019	104,710	22,085	13,528	139,323
2020	98,000	18,152	12,783	128,935
2021	83,000	13,482	10,827	107,309
2022	227,129	36,845	29,627	293,601
2023	568,710	10,032	7,418	74,321
Total	**568,710**	**100,595**	**74,184**	**743,489**

1. The overhead and administrative costs were calculated from the Financial Operating Statement of the Avocado Fund Annual Reports, averaging 18.0% for the AV18007 funding period (2019-2023).
2. Other funds from the University of Queensland included in-kind salaries of key staff. These were provided in the contract as a lump sum, so have been apportioned yearly based on Hort Innovation cash costs.

Present Value of investment

The nominal total investment cost of $0.74 million identified in Table 3 was adjusted for inflation (ABS, 2024) into a real investment of $0.84 million (2023-24 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.97 million (2023-24 PV). The results were sensitivity tested changes in the discount rate between 2.5% and 7.5%.

Project impacts

The impact pathways identified in Table 2 were evaluated against available data to determine if their impact could be quantified with a suitable level of confidence.

Impact pathway and available data

The contribution of the revised ASVBd survey methodology and testing protocol in support of meeting export market protocol requirements provided the clearest pathway to impact for AV18007. New Caledonia and New Zealand were identified as the two relevant export markets that require demonstrated freedom of ASBVd is to support trade requirements. Trade had already commenced into New Caledonia over the project period, while the New Zealand protocol is currently under review for renegotiation in relation to other biosecurity considerations. The current and potential trade volumes for each of these markets was informed by trade data supplied by Hort Innovation, against current and future projected market share, market values and industry growth rates. Cost data for completing the ASBVd sampling was supplied by the research team.

Impacts valued and valuation framework

Given the above, the impact assessment focused on the contribution of the ASBVd sampling methodology and testing protocol for supporting export trade into New Caledonia and New Zealand.

A model was developed incorporating current and projected avocado production and export volumes into New Caledonia and New Zealand, which was informed by the Horticulture Statistics Handbook (Hort Innovation 2024), Avocados Australia Facts at a Glance 2022-23 (Hort Innovation 2023b) and the Avocado industry export strategy (confidential) (AAL 2022). Together these data sources provided the foundation for estimating an industry export baseline in the absence of the capacity to demonstrate ASBVd freedom (the “without investment” scenario) and changes to the industry export volumes over time to the New Caledonia and New Zealand markets as a result of AV18007 (the “with investment” scenario). Comparing the “without investment” exports and the “with investment” export scenario generates the net export volume change resulting from the ASBVd diagnostic tool and sampling protocol delivered through AV18007.

Having established the level of export change, the model valued the following economic benefits:

- [Economic] Increased industry revenue from export market volume growth realised from improved capacity to meet market access conditions.

- [Economic] Reduced costs of testing to demonstrate pest freedom in support of satisfying export market protocols.

Finally, the attribution of the total identified impact to AV18007 was considered. The avocado export protocols to the New Zealand and New Caledonia markets stipulate additional treatments beyond the requirement of demonstrated freedom from ASBVd relating to cold treatment. While the current export protocol to New Caledonia is workable, additional negotiation of the New Zealand protocol is required before it will be commercially viable to export avocados to this market. Therefore given the additional investment and activity that is required to support the export protocol, only a portion of the total end benefit of increased export trade is attributable to AV18007. This reflects that the capacity to demonstrate ASBVd freedom is a necessary but not a sufficient condition to export. As protocol requirements are generally revised over time in response to new evidence and knowledge, the general attribution of AV18007 was also considered to decline marginally from 2033/34 onwards (10 years after the conclusion of the research).

Impacts unable to be valued

Additional economic impacts could not be quantified primarily for the following reasons.

- [Economic] Reduced orchard and nursery testing and management costs (e.g. removing and replanting disease affected trees). The extent to which removal and replanting from infected stock would be required is unknown, given the low prevalence of ASBVd in both nursery stock and existing plantings.
- [Economic] Reduced risk of ASBVd being imported into Australia through enforcement of international best practice biosecurity protocol. The relative risk of imprting ASBVd prior to the new testing and treatment protocol developed through AV18007 was not available. Therefore the relative change to risk as influenced by AV18007 could equally not be determined with confidence.

The social impacts identified through the logical framework could not be quantified for the following reasons.

- [Socio-economic] Improved industry sentiment and confidence influenced by robust biosecurity practices and management capacity. A robust non-market valuation methodology reflecting changes to grower sentiment and confidence is not available
- [Socio-economic] Avoided loss of industry spillovers that would result from a decline in the avocado industry as a source of employment and economic stimulant to local communities. The CIE (2023) highlighted the flow-on (spillover) effects of the avocado industry as a source of employment and economic stimulant to regional communities. By supporting market growth capacity, AV18007 supports a corresponding increase in spillovers to local communities. While this analysis quantified the direct impacts for avocado industry production and value, the flow-on effects require additional analysis using economic models that capture regional and national linkages, which are beyond the scope of the R&D impact assessment program (CRRDC 2018). Increased resilience also relates to avoided health and wellbeing costs associated with biosecurity events. These health and
- [Social] Avoided health and wellbeing costs to farm staff including psychological stress and strains on business and community relationships related to biosecurity events (CSIRO 2020 and CSIRO 2021). Wellbeing effects, such as avoided or reduced psychological stress can affect growers and their communities, may be more profound than the direct economic impact (CSIRO, 2020 and CSIRO 2022). The CSIRO research also noted that health and wellbeing affects are harder to quantify than economic impacts, which is consistent with the lack of data identified.

Data and assumptions

The required data relating to the impact pathway was collected from the project documents and other relevant resources (Table 4). Where available, actual data was applied to the relevant years, with estimates applied for any data gaps and projections into the future based on analytical techniques (for example correlations and trend analysis), or stakeholder estimates, or both. A data range was incorporated to reflect underlying risk and uncertainty. This was particularly relevant where estimates were needed due to data gaps, and where projections were made into the future. These ranges were then analysed through sensitivity testing (see *Results*).

Table 4. Summary of data and assumptions for impact valuation

Variable	Value	Source & comment
General data and assumptions		
Discount rate	5% (± 50%)	CRRDC Guidelines (2018)
Annual volume CAGR	7.2% (+11.7%, & -2.4%)	The Australian avocado production model (Avocados Australia 2023) estimates from a 2023-24 volume forecast of 138,711t, the 6 year production CAGR will be 7.2% to 2029-30 (210,000 tonnes). The

		production model forecasts a high growth CAGR of (11.7%) and a low growth of (2.4%) to 2029-30. Production is assumed to flatline after 2029-30.
Export share of production volume	15% (± 50%)	The avocado industry is required to export an increasing share of production volume to maintain a sustainable market supply/demand balance. Guided by the industry export strategy, the export share of production is assumed to reach 15% of total volume (approximately 31,500 tonnes) in 2033-34. This is tested at ±50%
New Caledonia export share (%)	0.20% (-25%, & +50%)	An average of 0.17% of total export volume over the 5 years to 2022-23 was exported to New Caledonia. The future export share to this market is assumed to remain at 0.20% over the impact assessment period, tested at -25% and +50%.
New Zealand export volume share (%)	10.5% (± 33%)	Analysis of the Avocado Export Strategy indicates that trade to New Zealand could peak at 14% of total export volume by 2027-28 (maximum) following protocol renegotiation. A low of 7% (-50%) and midpoint of 10.5% (-33.5%) is assumed. This share of export trade is assumed to apply for the remainder of the analysis period.
Average real unit export price (NZL)	$6.70/kg (±18.6%)	The 5 year average avocado export unit price is assumed to apply to New Zealand once export commenced, tested for sensitivity using standard deviation. Average real unit export prices to New Caledonia ($5.18/kg) were assumed to apply over the analysis period.
New Zealand export volume potential realised	75% (±33%)	The extent to which the potential export volume realised within the New Zealand market is expected to vary each year. A baseline of 75% of the total volume potential was tested at ±33% to account for expected uncertainty.
Year of NZL market access	2033-34 (± 5 years)	Discussions with stakeholders identified that the priority of negotiating a workable export protocol for New Zealand is being balanced with other export markets such that access in the short term is unlikely. The actual timing for market access is highly uncertain, so a sensitivity range of ±5 years from the base year (2033-34) is used.
Outcome attribution (NZL)	10% (5% & 30%)	While a 100% outcome attribution of trade is assumed for New Caledonia for ASBVd testing because other export protocols requirements could already be satisfied by growers, the export protocol to New Zealand is not workable despite the ASBVd testing capacity. With extensive effort required to facilitate a workable protocol, a conservative estimate of 10% of the eventual trade outcome is assumed on account of the ASBVd testing capacity.
Counterfactual attribution	80% (±25%)	It is unlikely that the industry could have initiated an equivalent program resulting in the development of a revised ASBVd testing methodology and widescale nursery testing. Therefore, a high counterfactual (80%) attribution is assumed.
Duration of residual benefits	10 years (±5 years)	The duration of benefits attributable to AV18007 are assumed to apply for a 10 year period, before a straightline annual attribution decline of 10% is assumed, reflecting the increased likelihood of changes to trading partner expectations impacting the ongoing application of the AV18007 research. The sensitivity of the duration of residual benefits were tested over a shorter (5 year) and longer (15 year) time period.

Results

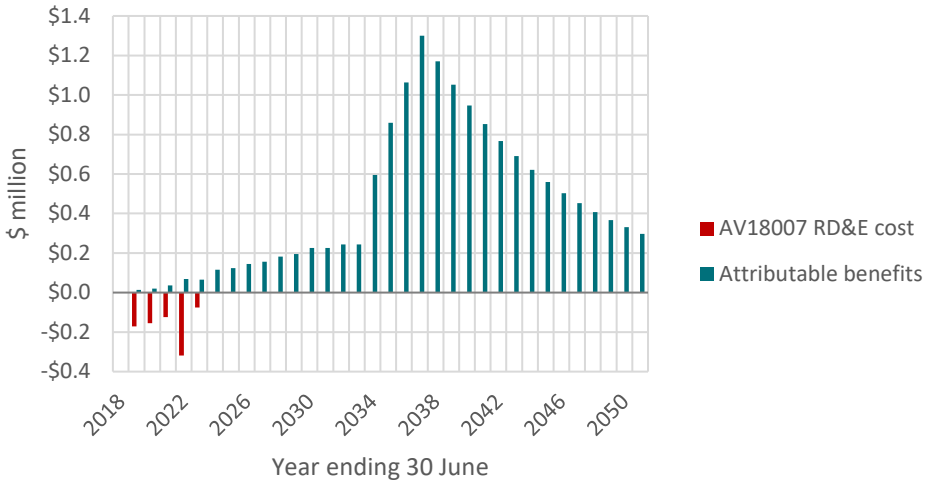
The analysis identified PV costs (PVC) of $0.97 million (2023-24 PV) between 2018-19 and 2022-23, and estimated PV benefits (PVB) of $7.61 million (2022-23 PV) accruing between 2019 and 2054 (Table 5). When combined, these costs and benefits generate a net present value (NV) of $6.64 million, an estimated benefit-cost ratio (BCR) of 7.82 to 1, an internal rate of return (IRR) of 23% and a modified internal rate of return (MIRR) of 12%.

Table 5. Impact metrics for the total investment in project CT17008

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	0.97	0.97	0.97	0.97	0.97	0.97	0.97
PVB ($m)	0	1	2	4	6	7	7.61
NPV ($m)	-1	0	1	3	5	6	6.64
BCR	0.23	0.90	1.72	4.54	6.49	7.40	7.82
IRR	Negative	2%	14%	22%	23%	23%	23%
MIRR	Negative	4%	10%	14%	14%	13%	12%

Figure 2 shows the annual undiscounted benefit and cost cash flows for AV18007.

Figure 2. Annual cash flow of undiscounted total benefits and total investment costs

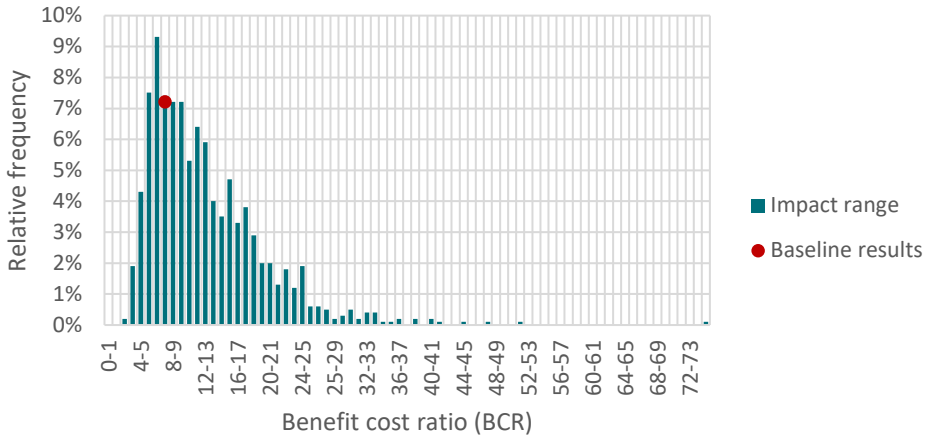


Sensitivity analysis

Given the risk and uncertainty associated with a number of underlying modelling variables, the potential model variation was estimated and drivers of variation identified. The sensitivity testing used @Risk stochastic modelling to incorporate the combined effect of changing all variables across their full ranges over 1000 simulations. This process showed:

Impact variation (Figure 3). Compared to the baseline BCR of 7.82:1, the 1000 simulation showed a potential BCR range of between 2.58:1 and 74.88:1, with 90% of results falling between 4.70:1 and 24.94:1 (i.e. excluding the low probability tails), and a simulation average of 9.08:1 (below the baseline results). Of the 1000 simulations, all had a BCR greater than 1:1 (benefits greater than RD&E costs), giving a high level of confidence that the investment will generate a positive impact.

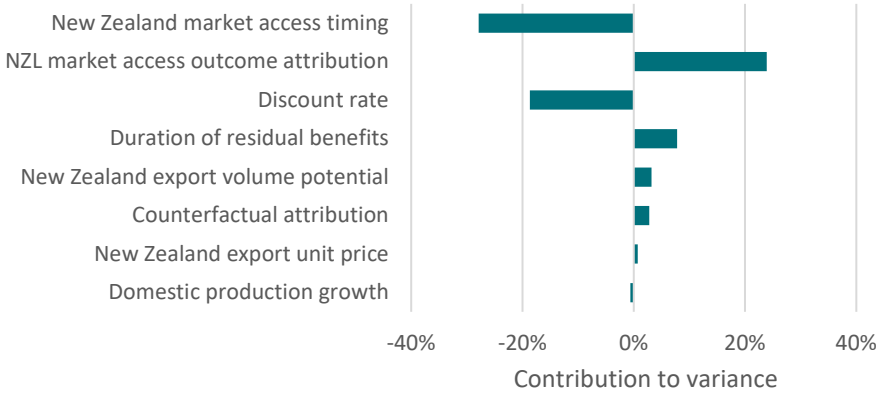
Figure 3. Impact variation over 1000 simulations



Contribution to variance (Figure 4). Contribution to variance is a measure of how much a variable contributes to the total variance of an output. Contribution to variance also shows whether a variable is positively or negatively correlated with impact. A negative contribution to variance, with bar extending to the left, indicates that this input has a negative effect on BCR: increasing this input will decrease the impact.

- **The timing of New Zealand market access** showed the largest contribution to variance (28%) but with a negative correlation with investment impact, i.e. the later the market access is realised, the lower impact realised for the avocado industry.
- **Outcome attribution** considering the extent to which the ASBVd testing protocol is attributed to supporting overall market access outcomes for New Zealand showed the second highest contribution to variance (24%).
- **The discount rate** had the third highest contribution to variance (accounting for 19% of variation), but with a negative correlation with investment impact. The breakeven discount rate is reflected in the IRR (23%), or the MIRR (12%) if we assume that generated cashflows are reinvested at the risk-free discount rate.

Figure 4. Contribution to variance



Implications and learnings

The analysis identified a clear pathway to impact for AV18007. The project delivered a cost-effective testing and sampling methodology to demonstrate orchard level freedom from ASBVd and improved knowledge of the distribution of ASBVd in Australia. These outcomes have contributed to market access improvements for avocado growers directly through the granting of plant health certificates for North Queensland growers to New Caledonia and the availability of a sampling and testing protocol that is now sufficient to meet one of the export protocol conditions for the New Zealand market. These market access improvements have and will continue to contribute to increased export volumes over time supporting increased industry revenue. AV18007 also confirmed the very low prevalence of ASBVd amongst existing orchards,

supporting grower confidence regarding the integrity and ongoing production capacity. Finally, the low cost, high-throughput testing protocols established through AV18007 have also contributed to a renewed participation in the ANVAS scheme by production nurseries. This will ensure that new industry plantings having the capacity to demonstrate establishment from clean planting material free from ASBVd, which will in-turn support the capacity to establish eventual 'free from' status for ASBVd within Australia (Geering 2018).

The novel research component that explored the potential role of pollinator honey bees for detecting ASBVd has not been directly progressed beyond AV18007, however stakeholders commented that the 'proof of concept' practice holds strong potential that may be progressed for other plant disease biomonitoring efforts over time. In the case of AV18007, the inclusion of a novel research element represented an opportunistic utilisation of resources and expertise to establish the foundations for a potentially valuable surveillance monitoring method even through no impact can be directly attributed at the time of analysis.

The modelling results showed a baseline economic impact (BCR) of 7.82:1, realised through increased export revenues achieved through contributions of AV18007 to accessing new markets. The baseline impact is likely an underestimate of the true industry impact from the investment given that several identified impacts such as the reduced risk of ASBVd being imported into Australia through enforcement of international best practice biosecurity protocol were not reflected in the analysis as a result of data limitations.

Sensitivity testing showed a potential impact range of between 2.58:1 and 74.88:1, with 90% of results falling between 4.70:1 and 24.94:1 giving a high level of confidence that the investment will generate a positive impact. The variation was driven primarily by the expected year by which a workable protocol to New Zealand will be realised, given that the potential export volumes to New Zealand are the major driver of industry impact supported through AV18007. Refining these estimates as part of future research would provide a more accurate estimate of investment impact.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Greg Chandler, Hort Innovation Head of Biosecurity R&D	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Dr Andrew Geering, University of Queensland, Principal Research Fellow	RD&E practitioner	✓	✓	✓	✓	✓		✓
John McDonald, Greenlife Australia, Biosecurity Manager	RD&E beneficiary	✓	✓	✓	✓	✓	✓	✓
Richard Magney, Avocados Australia Limited, Chief of Export – Market Access	RD&E beneficiary and industry representative				✓	✓	✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	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.
Direct Effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting and Present Values	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018) with results sensitivity tested at discount rates of 2.5% and 7.5%.
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Internal rate of return (IRR)	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 (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	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.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover Effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

ANVAS Avocado Nursery Voluntary Accreditation Scheme

ASBVd Avocado sunblotch viroid

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

NIASA Nursery Industry Accreditation Scheme Australia

RD&E Research, Development and Extension

SIP Strategic Investment Plan

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Ends.