Final Report

Project title:

Horticulture Impact Assessment Program:

Appendix 14: Pathogen Persistence from Paddock to Plate (VG16042 Impact Assessment)

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Delivery partner:

AgEconPlus and Agtrans Research

Project code:

MT18011

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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 *VG16042: Pathogen Persistence from Paddock to Plate.* The project was funded by Hort Innovation over the period September 2017 and March 2020.

Methodology

The investment was analysed qualitatively within a logical framework that included activities and outputs, outcomes, and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts identified were then considered for valuation. Past and future cash flows were expressed in 2019/20 dollar terms and were discounted to the year 2019/20 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

Findings from VG16042 have been communicated to growers, food safety trainers, auditors, and the industry food safety scheme Freshcare. Extension of findings to vegetable industry stakeholders reduces the risk of a pathogen such as *E. coli*, *Salmonella* or *Listeria* being detected on Australian fresh vegetables with a resultant loss of consumer confidence, consumption, and prices received by growers. Additional economic, environmental, and social impacts are also anticipated.

Investment Criteria

Total funding from all sources for the project was $1.0 million (present value terms). The investment produced estimated total expected benefits of $1.8 million (present value terms). This gave a net present value of $0.9 million, an estimated benefit-cost ratio of 1.9 to 1, an internal rate of return of 10.8% and a modified internal rate of return of 6.9%.

Conclusions

Five economic, environmental, and social impacts were not valued. When inability to value all impacts is combined with conservative assumptions for the principal economic impacts valued, it is reasonable to conclude that the valuation may be an underestimate of the actual performance of the investment.

Keywords

Impact assessment; cost-benefit analysis; VG16042; food safety; vegetable; *E. coli; Salmonella; Listeria*; irrigation water; manure; pathogen.

Introduction

Horticulture Innovation Australia Limited (Hort Innovation) required a series of impact assessments to be carried out annually on a number of investments in the Hort Innovation research, development, and extension (RD&E) portfolio. The assessments were required to meet the following Hort Innovation evaluation reporting requirements:

- Reporting against the Hort Innovation's current Strategic Plan and the Evaluation Framework associated with Hort Innovation's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to Hort Innovation stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

Under the impact assessment program (Project MT18011), three series of impact assessments were conducted in calendar 2019, 2020 and 2021. Each included 15 randomly selected Hort Innovation RD&E investments (projects). The third series of impact assessments (current series) was randomly selected from an overall population of 56 Hort Innovation investments worth an estimated $38.9 million (nominal Hort Innovation investment) where a final deliverable had been submitted in the 2019/20 financial year.

The 15 investments were selected through a stratified, random sampling process such that investments chosen represented at least 10% of the total Hort Innovation RD&E investment in the overall population (in nominal terms) and was representative of the Hort Innovation investment across six, pre-defined project size classes.

Project *VG16042: Pathogen Persistence from Paddock to Plate* was randomly selected as one of the 15 investments under MT18011 and was analysed in this report.

General Method

The impact assessment follows 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 includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and impacts. The principal economic, environmental, and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then 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 & Rationale

Background

The Australian vegetable industry is one of Australia's largest horticultural industries with a five-year estimated annual production value for levied vegetables of $2.9 billion and a production volume of 1.7 million tonnes – Table 1.

Table 1: Australian Vegetable Production and Value 2015/16 to 2019/20

Year Ended 30 June	Production (tonnes)	Gross Value of Production ($m)	Farmgate Value of Production ($m)
2016	1,627,149	2,462.1	2,339.0
2017	1,638,539	2,762.5	2,624.4
2018	1,709,198	2,792.2	2,652.6
2019	1,752,690	3,092.5	2,937.9
2020	1,749,935	3,330.9	3,164.4
Average	1,695,502	2,888.0	2,743.6

Source: Horticulture Statistics Handbook 2018/19 and 2019/20 total vegetable production less estimates for potato, tomato, onion, mushroom, asparagus, sweetpotato, garlic, and ginger. Farmgate value estimated by AgEconPlus.

Australian vegetable growers grow more than 130 different vegetable crops. Most growers are located in New South Wales, followed by Queensland and Victoria. The top three states by value of production are Queensland, Victoria, and South Australia.

The vegetable industry has a research and development (R&D) levy that is used for vegetable RD&E activities across a range of disciplines targeting both on-farm and supply chain sectors in accordance with industry priorities. The levy is collected on most vegetable commodities, with exceptions of particular note being potato, onion, and tomato, and is matched by Hort Innovation with funding from the Australian Government. Some 1,676 growers pay the vegetable levy each year (Hort Innovation, 2017).

Vegetable R&D levy investment is guided by the Vegetable industry's Strategic Investment Plan (SIP). The current SIP has been driven by levy payers and addresses the Australian vegetable industry's needs from 2017 to 2021. Strategies and priorities in the Plan have been driven by a set of five desired outcomes (Hort Innovation, 2017):

1. Growth in the domestic market
2. Growth in export markets
3. Improved farm productivity
4. Increased levels of post-farmgate integration
5. Improved industry capabilities for adoption and innovation.

Vegetable consumers naturally expect that the food they eat will not make them sick. Maintaining a high standard of food safety is critically important for products that are eaten uncooked, such as leafy salad greens.

Rationale

In 2015, the Fresh Produce Safety Centre commissioned the project "Understanding the Gaps", to summarise current fresh produce food safety knowledge and identify research gaps. The project addressed priorities that were initially identified by industry, food safety trainers and auditors in the 2013 Freshcare Forum and that were further explored and refined by industry at the 2014 Fresh Produce Safety Centre, Food Safety Conference. The final output of this work was a set of key research questions:

- What is the background level of microbial contamination of fresh produce in Australia?
- What is the potential for pathogen transfer from agricultural water to produce surfaces? How well can pathogens survive and grow on fresh produce in different environments (pre-harvest and post-harvest) and what factors increase or decrease pathogen survival?
- What is the potential for pathogen survival in different types of manure or other untreated materials of animal origin placed on, or incorporated into, soil? How is this affected by soil type and what is the subsequent survival on harvested parts of fresh produce?

The risk of contamination of fresh produce with human pathogens from irrigation water and soil amendments is usually managed through setting withholding periods that define the time between application and harvest.

The Guidelines for Fresh Produce Food Safety (2019) stipulate a withholding period of 48 hours between pre-harvest water use and harvest if water contacts the harvestable part of products that may be eaten uncooked (e.g., overhead irrigation or spray application to leafy salad greens).

The Guidelines also propose a minimum 90 day exclusion period between application of untreated soil amendments and harvest if the harvestable part is grown in or close to the soil and may be eaten uncooked (e.g., carrots, leafy greens) and a 45 day exclusion period for lower risk products (e.g., potatoes).

These exclusion periods are based on published data. However, most research has been conducted in the USA or Europe, where temperatures, UV radiation and soil types are very different to Australian conditions. Moreover, studies often use initial concentrations of pathogens higher than would be expected to occur through normal commercial practices.

The issue of soil amendments has become particularly significant as some food safety standards have moved to mandate 365 day withholding periods on use of all materials of animal origin (unless treated and certified as meeting AS4454). This would effectively make these products unworkable for vegetable farmers.

At the same time, recent outbreaks of food-borne pathogens (e.g., *Listeria monocytogenes* on melons) has sharpened interest in understanding and mitigating sources of risk.

Project Details

Summary

Project Code: VG16042 Title: *Pathogen Persistence from Paddock to Plate* Research Organisation: Fresh Produce Safety Centre – Australia & New Zealand (FPSC-ANZ) Principal Leader: Emma Walters, Jessica Purbrick and Richard Bennett Period of Funding: September 2017 to March 2020

Objectives

The objective of this project was to examine the population dynamics of human pathogens in manure amended soils and carried in contaminated irrigation water. As with all microbial studies, the response of populations will vary based on individual climatic variables and production practices, however this may provide valuable evidence as to the appropriateness of current recommendations on withholding periods in Australia as part of a holistic approach to managing food safety.

Logical Framework

Table 2 provides a description of VG16042 in a logical framework.

Table 2: Logical Framework for Project VG16042

Activities	• Develop relevant linkages and refine the project plan including engagement with the Fresh Produce Safety Centre (FPSC) technical committee, development of a project reference group and collaborate with the Australian Research Council, Industrial Transformation Training Centre for Food Safety in the Fresh Produce Industry. • Determine existing levels of food safety pathogens on Australian vegetables via desktop review of existing literature and data sets. A total of 5,533 individual data sets were examined from fresh levy-paying vegetables. • Survey of grower practices. Freshcare staff emailed 1,191 grower surveys requesting information on use of composts and manures, 41 responses were received of which 14 indicated that they did not use any of these products. The remaining 27 growers were contacted for follow-up phone interviews. • Determine background levels of human pathogens in manure via literature review and sampling of manure from vegetable farms. In total, 41 samples were collected and submitted to Symbio laboratory for testing. Each sample was tested for *E. coli*, *Salmonella* spp. and *Listeria* spp. • Determine background levels of human pathogens in irrigation water via collation of over 4,000 water test records, unfortunately 3,800 were from a single laboratory in WA. The analysis was augmented with data collected from the Hawkesbury-Nepean by a PhD candidate but could not be considered representative of the industry.

	• Determine pathogen survival times in different types of manure amended soil. Trials were completed across spring, summer, and autumn at the University of Sydney field site at Cobbitty. Trials tested unamended soils, and soils with poultry and cow manure added and soils with poultry litter, *E. coli* and *Salmonella*, and soils with cow manure, *E. coli* and *Listeria* added. • Determine potential for pathogens to transfer from irrigation water to product surfaces and factors affecting survival. Trials were completed examining die off rates of *E. coli* and *Salmonella spp*. on the surfaces of leafy vegetables including cos lettuce, baby spinach, parsley, kale, and silver beet. The plants were damaged or left intact before irrigation to runoff with contaminated water. • Project reporting and communication including milestone reports, a final project report, various articles in industry magazines (Vegetables Australia, WA Grower, Freshcare Newsletter), posting on the FPSC website, direct mail to the Freshcare stakeholder network (growers, trainers, auditors, etc.) and presentations to industry events (annual Freshcare Forum, presentations to Coles, Woolworths, Aldi, Costco, Metcash, and McDonalds).
Outputs	• Knowledge that human pathogens are rarely found in Australian fresh vegetables. Pathogenic bacteria were found in <1% of 5,533 samples, with most positive tests showing levels unlikely to cause human illness. • Bacteria were also uncommon in samples of manure/compost used on farms and in irrigation water. • *E. coli* in poultry litter incorporated into soils fell >99% after 20 days. *E. coli* in cattle manure incorporated into soils declined rapidly in spring and summer but was more likely to persisted in autumn. *E. coli* generally reduced to below detectable levels after 50 days, while in some cases *Salmonella* could persist in soils for up to 60 days. • Trials showed that *E. coli* and *Salmonella* in contaminated irrigation water were undetectable after 2 days on intact vegetables but could survive at least 6 days on damaged vegetables. • Withholding periods between application of irrigation water and manure and harvest provide one method of reducing the risk of food borne illness. • Scientific papers prepared "Differences in persistence of *Salmonella hofit* and *Escherichia coli* on cos lettuce compared to baby leaf spinach" and "Persistence of human pathogens in manure amended Australian soils used for production of leafy vegetables[1]" (published). • Industry articles and presentations – "How Safe are my Soils", "Pathogens on Leafy Greens", "Managing the risk of microbes on leafy greens", "Horticultural Water and Food Safety", "Guidelines for Fresh Produce Food Safety" and "Managing the Risks from Microbes on Leafy Greens".

[1] Ekman, J.; Goldwater, A.; Bradbury, M.; Matthews, J.; Rogers, G. Persistence of Human Pathogens in Manure-Amended Australian Soils Used for Production of Leafy Vegetables. ***Agriculture*** 2021, 11, 14

	• Project summaries and fact sheets were prepared and made available through the Fresh Produce Safety Centre and Freshcare.
Outcomes	• Growers informed by science and guidelines that minimise food safety risks. • Ongoing beneficial reuse of animal waste in vegetable production that might otherwise be an environmental hazard. • Avoided need to sterilise irrigation water before application to vegetables. • Ongoing consumer confidence in Australian vegetables.
Impacts	• [Economic] Potential cost savings for growers with ongoing use of cost-effective manures / composts and cost savings associated with the sterilisation of irrigation water. • [Environmental] Avoided environmental impacts associated with the accumulation of animal waste no longer required by the vegetable industry. • [Social] Reduced risk of a food safety scare (e.g., *Listeria* detection) on vegetables reducing consumer confidence, consumption and prices received by growers. • [Social] Improved food safety systems with the possibility of improved health outcomes for Australian vegetable consumers. • [Social] Additional grower food safety capacity and researcher food safety capacity. • [Social] Increased income in vegetable growing areas associated with a more profitable and sustainable industry (spillover impact).

Project Investment

Nominal Investment

Table 3 shows the annual investment (cash and in-kind) in project VG16042. Hort Innovation was the only investors in the project.

Table 3: Annual Investment in the Project VG16042 (nominal $)

Year ended 30 June	Hort Innovation ($)	Other ($)	Total ($)
2018	290,930	0	290,930
2019	249,369	0	249,369
2020	290,930	0	290,930
Totals	**831,229**	**0**	**831,229**

Program Management Costs

For the Hort Innovation investment the cost of managing the Hort Innovation funding was added to the Hort Innovation contribution for the project via a management cost multiplier (1.162). This multiplier was estimated based on the share of 'payments to suppliers and employees' in total Hort Innovation expenditure (3-year average) reported in the Hort Innovation's Statement of Cash Flows (Hort Innovation Annual Report, various years). This multiplier was then applied to the nominal investment by Hort Innovation shown in Table 3.

Real Investment and Extension Costs

For the purposes of the investment analysis, investment costs of all parties were expressed in 2019/20 dollar terms using the GDP deflator index. No additional costs of extension were included; the project included communication of research findings to industry, food safety trainers and auditors (an extension activity).

Impacts

Table 4 provides a summary of the principal types of impacts delivered by the project. Impacts have been categorised into economic, environmental, and social impacts.

Table 4: Triple Bottom Line Categories of Principal Impacts from Project VG16042

Economic	• Potential cost savings for growers with ongoing use of cost-effective manures / composts and cost savings associated with the sterilisation of irrigation water.
Environmental	• Avoided environmental impacts associated with the accumulation of animal waste no longer required by the vegetable industry.
Social	• Reduced risk of a food safety scare (e.g., *Listeria* detection) on vegetables reducing consumer confidence, consumption and prices received by growers. • Improved food safety systems with the possibility of improved health outcomes for Australian vegetable consumers. • Additional grower food safety capacity and researcher food safety capacity. • Increased income in vegetable growing areas associated with a more profitable and sustainable industry (spillover impact).

Public versus Private Impacts

Private benefits will be realised by vegetable growers who are more likely to avoid a food safety incident that will reduce demand and prices received. There is also potential for production cost savings with ongoing use of cost-effective manures/composts and cost savings associated with the unnecessary sterilisation of irrigation water. Public benefits will be realised through improved vegetable industry food safety systems with the possibility of improved health outcomes for Australian vegetable consumers. Other public benefits include improved environmental outcomes from ongoing beneficial use of animal manures, increased capacity (industry and research) as well as increased income in vegetable growing areas associated with a more profitable and sustainable industry.

Distribution of Private Impacts

The impacts on the vegetable industry from investment in this project will be shared along the vegetable supply chain with manure and compost suppliers, growers, transporters, wholesalers, exporters, and retailers all capturing a share of the impact. The share of total impact retained by each link in the supply chain will be dependent on a combination of both short and long-term supply and demand elasticities.

Impacts on Other Australian Industries

Impacts on other Australian industries may include potential gains via future spillovers from the increase in researcher food safety capacity.

Impacts Overseas

The review of the food safety literature and published scientific papers will be relevant to vegetable industries and food safety professionals in other countries.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project findings and related impacts will contribute primarily to Science and Research Priority 1 and 8.

Table 5: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
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

Sources: (DAWR, 2015) and (OCS, 2015)

Alignment with the Vegetable Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the Vegetable industry are outlined in the Vegetable Industry's SIP 2017-2021 (Hort Innovation 2017). Project VG16042 addressed Outcome 1 ('Growth in the domestic market') and Outcome 5 ('Improved industry capabilities for adoption and innovation').

Valuation of Impacts

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, 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.

A single impact was valued – reduced risk of a vegetable industry food safety scare.

Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. The extent of possible cost savings from use of manures/composts and unsterilised irrigation water was unknown as was the environmental benefit associated with ongoing beneficial use of manure. The social impacts were hard to value due to lack of evidence/data, difficulty in quantifying the causal relationship and pathway between VG16042 and the impact and the complexity of assigning monetary values to the impact.

The impacts identified but not valued were:

- Potential cost savings for growers with ongoing use of cost-effective manures/composts and cost savings associated with the sterilisation of irrigation water.
- Avoided environmental impacts associated with the accumulation of animal waste no longer required by the vegetable industry.
- Improved food safety systems with the possibility of improved health outcomes for Australian vegetable consumers.
- Additional grower food safety capacity and researcher food safety capacity.
- Increased income in vegetable growing areas associated with a more profitable and sustainable industry (spillover impact).

Valuation of Impact: Reduced risk of a vegetable industry food safety scare

Findings from this study have been communicated to growers, food safety trainers, auditors, and the industry food safety scheme Freshcare. Extension of findings to vegetable industry stakeholders reduces the risk of a pathogen such as *E. coli*, *Salmonella* and *Listeria* being detected on Australian fresh vegetables with a resultant loss of consumer confidence, consumption and prices received by growers.

Attribution

A 40% attribution factor has been assumed for VG16042's contribution to a reduced risk of a food safety scare. The attribution factor allows for previous research on which study findings are based and the ongoing cost of food safety communication and practice change.

Counterfactual

The scenario assumed if the investment had not been made is that it is 50% likely that some other project would have addressed vegetable industry food safety (e.g., large corporate supply chain partners and/or Australian supermarkets).

Summary of Assumptions

A summary of the key assumptions made for valuation of the impacts is shown in Table 6.

Table 6: Summary of Assumptions

Variable	Assumption	Source/Comment
Impact: Reduced risk of a vegetable industry food safety scare		
Cost of food safety scare involving Listeria on fresh Australian produce.	$60 million.	In 2018 a food safety event involving detection of Listeria on rockmelons in the Griffith area of NSW cost growers $60 million. This cost included lost domestic and export sales (ABC Rural, March 2018 and Good Food & Vegetables, July 2018).
Probability of a food safety scare involving Listeria on vegetables in the absence of food safety research.	2% (one event every 50 years).	Analyst estimate noting that there has not been a Listeria food safety event in fresh Australian vegetables but noting that an incident occurred in relation to Listeria on frozen imported vegetables in 2018 (NSW Country Hour, July 2018).
Probability of a food safety scare involving Listeria on vegetables with food safety research completed and communicated to industry.	1% (one event every 100 years).	
Year of first impact.	2020/21.	One year after project completion in 2019/20.
Year of last impact.	2049/50.	Benefits are sustained throughout the analysis period.
Attribution of impacts to VG16042.	40%	See above text.
Counterfactual.	50%	See above text.
Probability of valuable outputs.	100%	Valuable outputs have been created.
Probability of valuable outcome.	100%	Analyst assumption.
Probability of valuable impact.	100%	Analyst assumption.

Results

All costs and benefits were discounted to 2019/20 using a 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 (2019/20) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

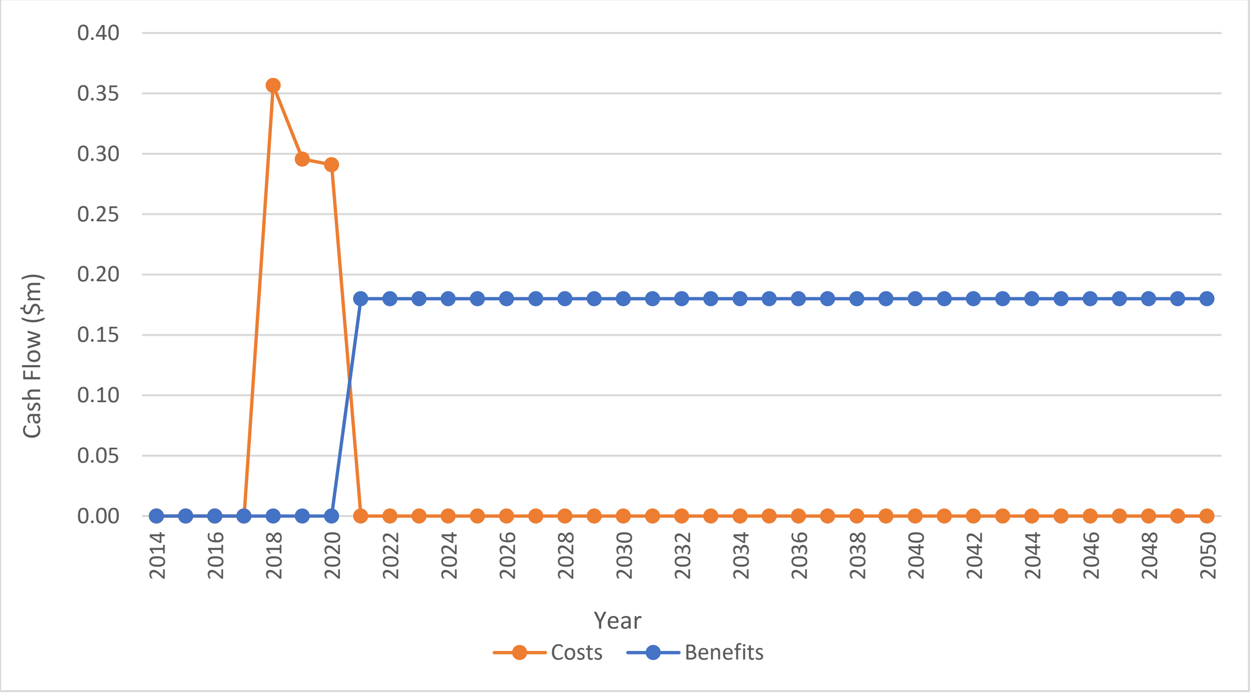
Tables 7 shows the investment criteria estimated for different periods of benefit for the total investment. Hort Innovation was the only investor in VG16042.

Table 7: Investment Criteria for Total Investment in Project VG16042

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.00	0.52	0.93	1.25	1.50	1.69	1.84
Present Value of Costs ($m)	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Net Present Value ($m)	-0.99	-0.47	-0.07	0.25	0.50	0.70	0.85
Benefit-Cost Ratio	0.00	0.52	0.93	1.25	1.50	1.70	1.86
Internal Rate of Return (%)	Negative	Negative	3.8	8.0	9.7	10.5	10.8
MIRR (%)	Negative	Negative	4.5	6.3	6.8	6.9	6.9

The annual undiscounted benefit and cost cash flows for the total investment for the duration of VG16042 investment plus 30 years from the last year of investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 8 present the results. The results are moderately sensitive to the discount rate and benefits continue to exceed costs at a discount rate of 10%.

Table 8: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	**5%**	**10%**
Present Value of Benefits ($m)	3.60	1.84	1.13
Present Value of Costs ($m)	0.94	0.99	1.05
Net Present Value ($m)	2.66	0.85	0.08
Benefit-cost ratio	3.82	1.86	1.08

A sensitivity analysis was then undertaken for the assumed reduction in probability of a food safety event in the vegetable industry. Results are provided in Table 9. At half the assumed probability, the investment fails to break even.

Table 9: Sensitivity to Avoided Food Safety Scare
(Total investment, 30 years)

Investment Criteria	Net Probability of a Food Safety Scare		
	0.5%	**1% (base)**	**2%**
Present Value of Benefits ($m)	0.92	1.84	3.69
Present Value of Costs ($m)	0.99	0.99	0.99
Net Present Value ($m)	-0.07	0.85	2.69
Benefit-cost ratio	0.93	1.86	3.71

A final sensitivity test examined the assumed attribution of benefits to VG16042. At half the assumed probability, the investment failed to breakeven- Table 10.

Table 10: Sensitivity to the Attribution of Benefits to VG16042
(Total investment, 30 years)

Investment Criteria	Attribution of Benefits to VG16042		
	20%	**40% (base)**	**60%**
Present Value of Benefits ($m)	0.92	1.84	2.77
Present Value of Costs ($m)	0.99	0.99	0.99
Net Present Value ($m)	-0.07	0.85	1.77
Benefit-cost ratio	0.93	1.86	2.78

Confidence Rating

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 11). The rating categories used are High, Medium, and Low, where:

High:	denotes a good coverage of benefits or reasonable confidence in the assumptions made
Medium:	denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
Low:	denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 11: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium-high	Medium-Low

Coverage of benefits was assessed as medium-high – the key economic benefit was valued. Confidence in assumptions was rated as Medium-Low – a number of key assumptions were made by the analyst.

Conclusion

Findings from VG16042 have been communicated to growers, food safety trainers, auditors, and the industry food safety scheme Freshcare. Extension of findings to vegetable industry stakeholders reduces the risk of a pathogen such as *E. coli*, *Salmonella* or *Listeria* being detected on Australian fresh vegetables with a resultant loss of consumer confidence, consumption, and prices received by growers. Additional economic, environmental, and social impacts are also anticipated. When unquantified impacts and conservative assumptions for the valued economic impact are considered, it is reasonable to conclude that the valuation may be an underestimate of the actual performance of the investment.

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.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
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.

References

Council of Rural Research and Development Corporations. (2018). Cross-RDC Impact Assessment Program: Guidelines. Canberra: Council of Rural Research and Development Corporations. Retrieved from http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA-Guidelines-V.2.pdf

Department of Agriculture and Water Resources. (2015). Agricultural Competitiveness White Paper. Canberra: Commonwealth of Australia. Retrieved from http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf

Hort Innovation (2017) Vegetable Industry Strategic Investment Plan 2017-2021. Retrieved from https://www.horticulture.com.au/hort-innovation/funding-consultation-and-investing/investment-documents/strategic-investment-plans/

Hort Innovation (2020) Australian Horticulture Statistics Handbook, 2019/20. Retrieved from https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/australian-horticulture-statistics-handbook/.

Office of the Chief Scientist. (2015). Strategic Science and Research Priorities. Canberra: Commonwealth of Australia. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/STRATEGIC-SCIENCE-AND-RESEARCH-PRIORITIES_181214web.pdf

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Abbreviations

CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
FPSC-ANZ	Fresh Produce Safety Centre – Australia & New Zealand
GDP	Gross Domestic Product
GVP	Gross Value of Production
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
OCS	Office of Chief Scientist Queensland
PVB	Present Value of Benefits
R&D	Research and Development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan