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

Annex 14: Impact assessment of *Field and landscape management to support beneficial arthropods for IPM on vegetable farms* (VG16062)

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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 *Field and landscape management to support beneficial arthropods for IPM on vegetable farms (VG16062)*. The project was funded by Hort Innovation over the period August 2017 to August 2020.

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 real (inflation-adjusted), risk free, pre-tax 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

Hort Innovation project VG16062 produced practical IPM strategies focused around farm vegetation. The project included the vegetable crops; brassicas, sweetcorn, carrot, lettuce and French beans. It focused on plants that could be rapidly established as nectar strips in-field to support beneficial insects. The trials found that pest numbers and damaged crop plants were reduced for up to 20m into the crop. The project conducted internal economic analysis which identified that the economic benefits of these habitat management strategies varied depending on the placement of the flowering plants. In scenarios where the habitat manipulation plants were placed in the borders of crops or uncultivated areas such as sprinkler rows (so not taking land out of production) the farm level investment benefit cost ratio (BCR) ranged from 4.65:1 to 7.91:1.

The impacts valued for VG16062 were:

- [Economic] Better decisions relating to vegetation management and suppression of targeted vegetable pests, resulting in improved farm productivity through reduced pest damage, and increased marketable yield.

Not all of the identified impacts could be valued in the assessment, particularly where there was a lack of credible data. These additional economic, social and environmental impacts have the potential to provide additional industry impact above what has been identified.

Investment criteria

Total funding from all sources for the project was $1.8 million (2021 equivalent value). The investment produced estimated total expected benefits of $8.5 million (2021 equivalent value). This gave a net present value of $6.7 million, an estimated benefit-cost ratio of 4.74 to 1, an internal rate of return of 26% and a modified internal rate of return of 10%.

Conclusions

VG16062 conducted a range of activities that generated clear findings and outcomes with industry wide impact. Consistent with the projects cost benefit analysis (CBA), this analysis focused on the impact to the brassica vegetables. However it is highly probable that the grower recommendations for the brassicas could also be applied across other vegetable or horticultural crops both domestically and internationally with the resulting impact of increased marketable yield. Credible estimates for the inputs were developed based on the findings of VG16062, industry data resources, and discussions with industry stakeholders.

Sensitivity testing was also undertaken to account for uncertainty in some of the variables, showing a BCR ranging from 1.90 to 9.49. The results were particularly sensitive to the impact multiplier (the extent that this project would directly impact other vegetable industries).

Keywords

Impact assessment, cost-benefit analysis, vegetable, integrated pest management, IPM, landscape management.

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 *Field and landscape management to support beneficial arthropods for IPM on vegetable farms (VG16062)* 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 vegetable industry has approximately 1700 growers across Australia (Hort Innovation 2022a), with a 5-year average (to 2021) production value of $4.7 billion growing at a trend 3.7% per annum (Hort Innovation 2022b). Brassica vegetables, sweetcorn, carrot, lettuce and French bean (which were the focus crops of VG16062) had a 5-year average value of $1.1 billion, growing at a trend 5.7% per annum. Across the five focus vegetables in 2020-21, approximately 76% of production was supplied to the domestic fresh market, 14% to the fresh export market, and 10% to the processing market. Across the five focus vegetables in 2020-21, 29% production occurred in Queensland, 27% in Victoria, 20% in Western Australia, 9% in South Australia, 8% in Tasmania, and 7% in New South Wales (Hort Innovation 2022b).

Producers in the vegetable industry pay levies to the Department of Agriculture, Fisheries and Forestry (DAFF), which is responsible for the collection, administration and disbursement of levies and charges on behalf of Australian agricultural industries. Levy is payable on vegetables 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 vegetable levy funds which are directed to R&D investments.

Rationale

The vegetable industry's levy investments are guided by a Strategic Investment Plan (SIP). The Vegetable SIP 2017-21 (under which VG16062 was delivered) identified "environmental, pest and disease factors" as major challenges for Australia's vegetable industry, and also highlighted the growing consumer concerns about environmental impact, and preferences for vegetable products grown with reduced pesticides and herbicides inputs. The industry also recognized that the use of insecticides was increasingly constrained by regulations and pest resistance (Hort Innovation 2017).

Prior to VG16062, advances in applied ecology had already been translated into habitat management strategies in other crop types. This had clearly demonstrated outcomes that support beneficial insects to such an extent that pests pressure was reduced, grower use of insecticide was reduced, and yields and profits were increased. In line with this, VG16062 aimed to investigate the use of landscape management in key vegetable crops to support improved pest and productivity outcomes.

Alignment with the Vegetable Strategic Investment Plan 2017-2021

VG16062 was closely aligned to the Outcome 3: Productivity – Increased farm productivity and decreased production costs through better utilisation of resources, adaptation to climate, reduced impact of pests and diseases and better utilisation of advanced technologies on the farm.

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 Priorities 2, 3, and 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	VG16062
Title	*Field and landscape management to support beneficial arthropods for IPM on vegetable farms*
Research organization	Charles Sturt University (CSU)
Project leader	Geoff M Gurr
Funding period	August 2017 to August 2020

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	• A survey of 491 fields of brassica vegetables, sweetcorn, carrot, lettuce, French bean and lettuce to understand how pest and beneficial insects are affected by the immediately adjacent land use. • Research new planting options for growers, based on plants that can be rapidly establish within fields. Three annual plants (alyssum, buckwheat and cornflower) were selected based on a review of the international literature and an analysis of the potential benefits and risks of plant species. These were trialed on brassica vegetable and sweetcorn farms as nectar sources to support beneficial insects. One biennial plant (yellow rocket) was tested in additional trials as a trap crop that would reduce egg laying by diamondback moth on brassica vegetable crops. • Cost benefit analysis quantifying the farm level project outcomes. • A research master student (funded by the Commonwealth Government) was recruited to the project team to undertake an additional component of the study.

	• Regular communication with the vegetable industry across a range of channels to promote the promote awareness and adoption of the research findings and recommendations. • Broader community communication was undertaken through ABC Landline, which filmed a segment at the Victorian field sites as well as interviewing team members and growers.
Outputs	• Practical, evidence -based recommendations for growers that guide crop placement in relation to other land uses were developed for brassica vegetables, sweetcorn, carrot, lettuce, French bean, and lettuce. • Field survey report (from nearly 500 fields across NSW, VIC, QLD, SA, TAS, WA). • Grower interview report (on pest management practices of 75 vegetable growers and potential for incorporating habitat management). • Cost benefit report on the farm-level project findings. • Communication outputs including industry–focused magazine and TV features, factsheets, workshop and farm walk activities.
Outcomes	• Advancements in industry knowledge about how beneficial and pest insects can be managed through crop placement in relation to existing land uses and in-crop plantings. With key research findings including: o Woody vegetation such as shelterbelts, riparian areas and roadside vegetation appeared to be a robust, widely applicable management technique that (in addition to widely recognised benefits for shelter, on-farm biodiversity conservation and hydrology) promote beneficials and provide pest suppression in adjacent vegetable crops. o The use of nectar plants to protect brassica vegetable crops supported pest suppression through a significantly higher number of beneficial arthropods including ladybeetles, lacewings, parasitic wasps and damsel bugs. This in turn was found to significantly reduced pest numbers. Effects on arthropods were evident up to 15 -20 meters from the flowering plants into the crop. The economic benefits of these habitat management strategies varied depending on the placement of the flowering plants. In scenarios where the habitat manipulation plants were placed in the borders of crops or uncultivated areas such as sprinkler rows so not taking land out of production, the investment BCR ranged from 4.65:1 to 7.91:1. • Increase in the willingness for Australian vegetable growers to adopt vegetation management to support beneficial insects and suppress pests. • Expressed intent by participating Australian growers to continue to develop the strategies identified during the study and field trials, potentially applying them to additional crop types. • Increase in awareness about the vegetable sectors among the wider public as a result of extensive mainstream media coverage.
Impacts	• [Economic] By making better decisions based on vegetation managements and suppression of targeted vegetable pests, growers will: o Improve farm productivity through reduced pest damage, and increased marketable yield. o Reduce pest management costs. • [Economic] Reduced risk of widespread pests outbreak. • [Economic] Increased appeal of Australian vegetables in domestic and export markets as a result of an enhanced clean and green image, supporting increased vegetable demand. • [Social] Increased social license from broader community awareness of and perceptions of industry moving to a more clean and green production methods. • [Social] A more sustainable and affordable supply of Australian vegetables, supporting increased vegetable consumption with associated health and wellbeing effects. • [Social] A more resilient vegetable industry will continue to provide an important source of employment and economic stimulant to local communities. • [Environmental] Increased farm biodiversity as a result of the maintenance and increase in farm vegetation and reduced chemical use.

Project costs

Nominal investment

Table 4. Project nominal investment

Year end 30 June	Hort Innovation ($)	Other^ ($)	Total ($)
2018	265,982	151,737	417,716
2019	268,569	153,213	421,782
2020	192,480	109,806	302,286
2021	181,111	103,320	284,431
Total	908,142	518,076	1,426,218

^see In-kind costs below

In-kind costs

In kind costs were contributed by CSU, the University of Queensland, IPM Technologies, and the New South Wales Department of Primary Industries. These in kind costs were provided as a single whole-of-project figure, and were apportioned on a yearly basis in line with 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 16.1% for the VG16062 funding period (2018-2021). 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

Communication and extension was conducted as part of VG16062 including industry–focused magazine and TV features, factsheets, workshop and farm walk activities. No additional extension costs have been included in this analysis.

Project impacts

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.

Impacts valued

The impact(s) valued were:

- [Economic] By making better decisions based on vegetation management and suppression of targeted vegetable pests, growers will achieve improved farm productivity through reduced pest damage, and increased marketable yield.

Impacts not valued

Not all of the impacts identified in Table 3 could be valued in the assessment, particularly where there was a lack of data to quantify the identified impact.

The impacts identified but not value were:

- [Economic] By making better decisions based on vegetation managements and suppression of targeted vegetable pests, growers will be able to:
  - Reduce pest management costs, including through a net reduction in pesticide use.
- [Economic] Reduced risk of widespread pests outbreak.
- [Economic] Increased appeal of Australian vegetables in domestic and export markets as a result of an enhanced clean and green image, supporting increased vegetable demand.
- [Social] Increased social license from broader community awareness of and perceptions of industry moving to a more clean and green production methods.
- [Social] A more sustainable and affordable supply of Australian vegetables supporting increased vegetable consumption with associated health and wellbeing effects.
- [Social] A more resilient vegetable industry will continue to provide an important source of employment and economic stimulant to local communities.
- [Environmental] Increased farm biodiversity as a result of the maintenance and increase in farm vegetation and reduced chemical use.

Public versus private impacts

The impacts identified from the investment are predominantly private impacts accruing to vegetable growers and supply chain participants. However, some public benefits have been produced in the form of increased industry capacity, spillovers to regional communities from enhanced grower (marketable) yield and income, and increased sustainability and affordability of vegetables to incorporate into a healthy diet.

Distribution of private impacts

This analysis quantified private benefits accruing to vegetable growers. Additional spillover private impacts would be generated in the wider economy. Changes in farm costs from increased marketable yield would result in spillover changes in income for businesses providing those goods and services. The total private impacts will have been further redistributed between growers, processor/packers, wholesalers, exporters, and retailers depending on both short- and long-term supply and demand elasticities.

Impacts on other Australian industries

Findings from the project are broadly relevant to growers of other horticultural crops outside of the five focus crops of the project. The specific IPM strategies may be applied where the beneficial and pest insects are the same, or the broad strategy could be adjusted for wider application.

Impacts overseas

Findings from this project are broadly relevant to horticultural industries internationally.

Method for impact evaluation

The impact was quantified by calculating the farm level value of increased marketable yield, less variable post-harvest costs, and less adoption costs. This was scaled up to an industry net benefit by applying an adoption curve (see Appendix A). An attribution timeframe was considered. In-line with the project CBA the analysis focused on brassica crops (cabbage, cauliflower, Chinese cabbage). An impact multiplier was applied in consideration of the relevance and identified impact for all five of the vegetable crops involved in the project (brassica vegetables, sweetcorn, carrot, lettuce and French bean).

Data and assumptions

A summary of the key assumptions made in the assessment is provided in Table 5.

Table 5. Summary of assumptions for impact valuation

Variable	Assumption	Source / comment
Discount rate	5% (± 50%)	CRRDC Guidelines (2018)
Impact start	2021 season	Analysts assumption, growers were engaged early in the project, but recommendations were developed towards the end.
Annual production (t) cabbage	72,453 (± 11%)	Australian Horticulture Statistics Handbook, 5 year average 2017-2021 (Hort Innovation 2022b).
Annual production (t) cauliflower	75,452 (± 8%)	
Annual production (t) Chinese cabbage	11,345 (± 5%)	
Time to max adoption	11 years	ADOPT model output (see Appendix A).
Max adoption (% of industry annual production)	50% (± 30%)	ADOPT framework (Appendix A) showed a likely industry adoption of between 43% and 65% depending on whether benefits were restricted to the year of adoption (i.e. using annual plantings or included for future years (i.e perennial plantings, permanent plantings on field boarders). Based on this and stakeholder consultation, max adoption was tested at 35%, 50% (base), and 65%.
Baseline industry yield (t/ha) Cauliflower	21.1 (± 10%)	ABS Ag Commodities (2018-2022) 5yr av and stdev. Consistent with QDAF (2004) and NSW DPI (2005)
Additional income (% applied to additional yield)	63% (± 20%)	Additional yield has been assumed to be a reduction in damaged (non saleable) product which would incur post harvest yield based costs (i.e octabins, cooling, freight, levies, agents commissions). These costs are assumed at 37% of additional income (NSW DPI 2009), therefore 63% of additional income is applied as a benefit.
Yield increase % Cabbage	4.7% (± 35%)	VG16062 final report / CBA
Yield increase % Cauliflower	6.7% (± 27%)	
Yield increase % Chinese cabbage	6.9% (± 25%)	
Impact multiplier (application to other crops)	2.5 (- 60%, + 100%)	CBA analysis within VG16062 was only conducted for Cabbage, Cauliflower and Chinese Cabbage, although was funded by and extended to other vegetable crops. An upper bounds of 5 x impacts was considered as the brassicas included within the CBA are approximately 20% of production of the five vegetables involved in the project (brassica vegetables, sweetcorn, carrot, lettuce and French bean). A conservative lower bound of 1 x impacts quantifies the impact to the brassica crops only.
R&D counterfactual	50% (± 30%)	IPM habitat management is gaining momentum among cropping industries and some similar research had been completed suggesting that this research may have been done eventually without levy investment. Additionally, this project attracted outside funds (36% of total), suggesting broader willingness to invest in this type of research.
Attribution period	15 years	Full attribution was applied for a period of 10 years, followed by a straight-line decrease to zero by 15 years reflecting the likelihood that further research will provide updated knowledge and resources relating to landscape management for beneficial arthropods, as well as the potential for other production and industry changes that reduce the relevance of VG16062 findings.

Results

All costs and benefits were discounted to 2020-21 using a real, risk-free 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

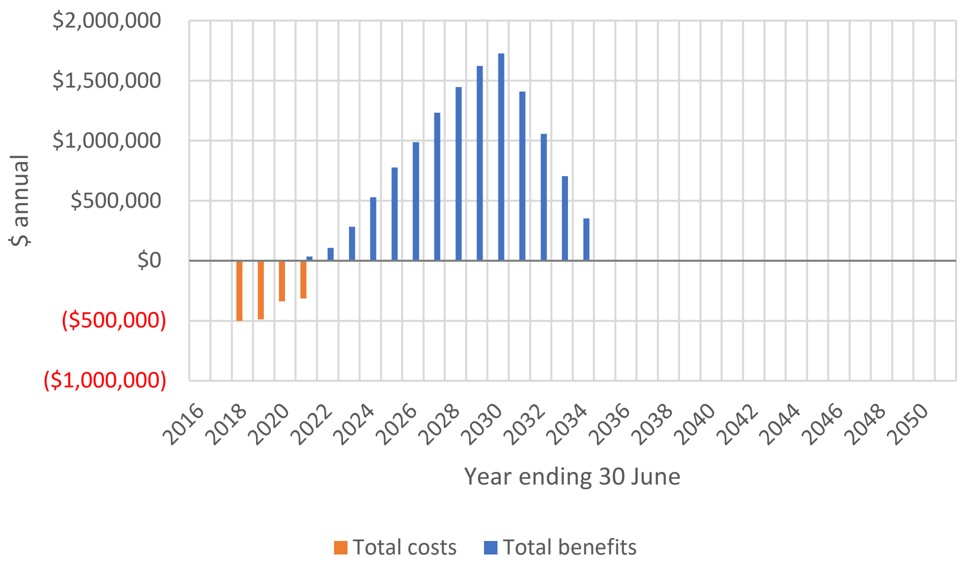
Table 6 shows the impact metrics estimated for different periods of benefit for the total investment. Hort Innovation was the only investor in VG16062.

Table 6. Impact metrics for the total investment in project VG16062

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC	1.79	1.79	1.79	1.79	1.79	1.79	1.79
PVB	0.04	2.26	7.28	8.48	8.48	8.48	8.48
NPV	-1.75	0.47	5.50	6.69	6.69	6.69	6.69
BCR	0.02	1.26	4.07	4.74	4.74	4.74	4.74
IRR	Negative	10%	25%	26%	26%	26%	26%
MIRR	Negative	8%	17%	15%	12%	11%	10%

Figure 1 shows the annual undiscounted benefit and cost cash flows for the total investment in VG16062. Cash flows are shown for the duration of the investment plus 30 years from the last year of investment.

Figure 1. 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 (Table 7). Data ranges and sources are described in Table 5.

Table 7. Impact BCR sensitivity to changes in key underlying variables

Variable		Low	Baseline	High
Discount rate	Variable range	2.5%	5%	7.5%
	BCR range	5.93	4.74	3.83
Baseline industry production (t) Cabbage	Variable range	64,483	72,453	80,423
	BCR range	4.58	4.74	4.91
Baseline industry production (t) Cauliflower	Variable range	69,416	75,452	81,488
	BCR range	4.53	4.74	4.98
Baseline industry production (t) Chinese Cabbage	Variable range	10,778	11,345	11,912
	BCR range	4.72	4.74	4.77
Baseline industry yield (t/ha) Cauliflower	Variable range	19.0	21.1	23.2
	BCR range	4.59	4.74	4.87
Additional income (% applied to additional yield)	Variable range	51%	63%	76%
	BCR range	3.34	4.74	6.15
Max adoption (% of industry annual production)	Variable range	35%	50%	65%
	BCR range	3.32	4.74	6.17
Yield Increase (%) Cabbage	Variable range	3.1%	4.7%	6.4%
	BCR range	3.95	4.74	5.59
Yield Increase (%) Cauliflower	Variable range	4.9%	6.7%	8.5%
	BCR range	3.63	4.74	5.90
Yield Increase (%) Chinese cabbage	Variable range	5.2%	6.9%	8.7%
	BCR range	4.61	4.74	4.88
Impact multiplier (Application to other crops)	Variable range	1	2.5	5
	BCR range	1.90	4.74	9.49
Counterfactual attribution	Variable range	35%	50%	65%
	BCR range	3.32	4.74	6.17

Discussion and conclusions

The analysis showed that the investment in VG16062 has generated benefits greater than four times that of the project cost, with a BCR of 4.74:1.

The impact pathway presented in Table 3 identified a number of potential impacts from the project. The key impact valued was:

- [Economic] By making better decisions based on vegetation management and the suppression of targeted vegetable pests, growers will achieve improved farm productivity through reduced pest damage, and increased marketable yield.

This impact was quantified by calculating the industry wide value of the increased marketable yield (less variable post-harvest costs) less adoption costs. Maximum adoption levels of 50% were considered and the timeframe of 10 years for full attribution. An impact multiplier was also applied in consideration of the relevance and potential impact the projects outputs may have on other horticultural industries both domestically and internationally.

All efforts were made to provide credible estimates for the inputs. The projects internal cost benefit analysis was confirmed and updated through discussions with industry stakeholders providing a higher level of uncertainty compared to a typical impact assessment of a single innovation’s RD&E.

To account for the uncertainty in some of the variables, sensitivity testing was conducted that showed a BCR ranging from 1.90 to 9.49. The results were most sensitive to the tested ranges of three inputs:

- Impact multiplier. The extent to which this project will impact other vegetable or horticultural crops both domestically and internationally is unknown. While the project's cost benefit analysis applied only to brassicas, it was noted that the research could be broadly applied, particularly to the other funding industries. As such, an impact multiplier was applied to consider this additional impact, and was sensitivity tested at 1 (no impact valued outside three vegetables modelled), 2.5 (base case), 5 (brasiccas included within the CBA are <20% of production of the five vegetables the project covered).
- Additional industry income. When marketable yield increases (as a result of IPM practices implemented from VG16062), not all additional income can be attributed as an industry benefit. Firstly, yield based post-harvest costs (such as octabins, cooling, freight, levies, and agents commissions) need to be removed. Using the NSW DPI 2009, *Cabbage Gross Margin* as a guide, these costs were calculated as 37% of additional income (63% of additional income is applied as a benefit). While not included in the industry benefit calculated as part of this analysis, these costs would result in corresponding spillover increases in income for upstream and downstream businesses providing those goods and services.
- R&D counterfactual. The extent to which VG16062 would have been delivered without Hort Innovation levy investment. As 36% of this project was funded outside Hort Innovation and there is a general growing momentum of landscape IPM, there was an assumption that this research may have been conducted by without levy funding but at a later date or with a reduced scope.
- Adoption level. The maximum adoption and time to maximum adoption was calculated through the CSIRO ADOPT framework (Appendix A).

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 vegetable industry.

The CRRDC Guidelines focus on first round impacts, which calculate shifts in the supply and demand curves with no price effect. When considering these second-round price effects RD&E that focusses on increased productivity would support increased industry supply, and thereby put downward pressure on prices, effectively shifting some of the benefit from producers to consumers. The extent to which this would occur would depend on the slope of the short and long-term 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

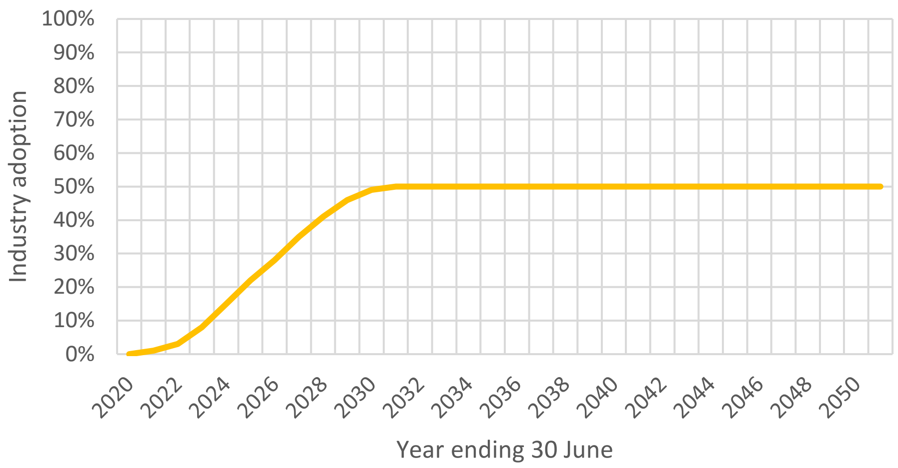
RD&E Research, Development and Extension

SIP Strategic Investment Plan

Appendix A. ADOPT questions and answers for VG16062 impact assessment

Appendix A includes the data inputs for the ADOPT model (Kuehne et al 2017) used in this analysis. The inputs were developed through a review of VG16062 outputs and in consultation with project stakeholders. The resulting adoption curve applied in the model is shown in Figure 2.

Figure 2. Anticipated adoption curve and timeline of benefits assessed for VG16062.



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?
Almost all 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?
Moderately trialable

8. Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?
Moderately 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?
Moderately observable

10. What proportion growers use paid advisors capable of providing advice relevant to the project?
A minority use a relevant advisor (natural IPM / area wide management skills)

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

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 this innovation in their district?

A minority would be aware of the use or trialling of this 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?
Minor initial investment

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

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?
Small profit advantage in years that it is used

17 To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?
No profit advantage or disadvantage in the future – generally annual plantings

18 How long after the innovation is first adopted would it take for effects on future profitability to be realised?
Immediately

19. To what extent would the use of the innovation have net environmental benefits or costs?
Moderate environmental advantage

20. How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?
Immediately

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