Hort Innovation

Industry-specific impact assessment program: Almond

Impact assessment report for project *Advanced Processing of Almonds* (AL12003)

Impact analyst:

Michael Clarke

Delivery partner:

AgEconPlus and Agtrans Research

Project code:

MT19012

Date:

December 2020

Disclaimer:

Horticulture Innovation Australia Limited (Hort Innovation) makes no representations and expressly disclaims all warranties (to the extent permitted by law) about the accuracy, completeness, or currency of information in this Final Report.

Users of this Final Report should take independent action to confirm any information in this Final Report before relying on that information in any way.

Reliance on any information provided by Hort Innovation is entirely at your own risk. Hort Innovation is not responsible for, and will not be liable for, any loss, damage, claim, expense, cost (including legal costs) or other liability arising in any way (including from Hort Innovation or any other person's negligence or otherwise) from your use or non-use of the Final Report or from reliance on information contained in the Final Report or that Hort Innovation provides to you by any other means.

Funding statement:

This project has been funded by Hort Innovation, using the research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Publishing details:

Published and distributed by: Hort Innovation

Level 7

141 Walker Street

North Sydney NSW 2060

Telephone: (02) 8295 2300

www.horticulture.com.au

Contents

Tables

Figures

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 *VG12003: Advanced Processing of Almonds.* The project was funded by Hort Innovation over the period September 2012 to June 2019.

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 2019/20 dollar terms and were discounted to the year 2019/20 using a discount rate of 5% to estimate the investment criteria and a 5% reinvestment rate to estimate the modified internal rate of return (MIRR).

Results/key findings

The investment in AL12003 has delivered pioneering work showing earlier harvest decreases almond damage, and there is no loss of yield or quality with ‘shake and catch’ harvesting. The project created improved hulling equipment, demonstrated the use of moisture spears for stockpile management and developed a tool for yield mapping.

Investment Criteria

Total funding from all sources for the project was $2.84 million (present value terms). The investment produced estimated total expected benefits of $11.34 million (present value terms). This gave a net present value of $8.50 million, an estimated benefit-cost ratio of 3.99 to 1, an internal rate of return of 14.1% and a modified internal rate of return of 9.2%.

Conclusions

Investment in Project AL12003 has delivered important new knowledge for harvesting almonds under Australian conditions as well as technology for more efficient processing on-farm and in-factory. Five identified impacts were not valued as they were considered uncertain and difficult to value with credible assumptions. Hence, investment criteria provided by the valuation may be underestimates of the actual performance of the investment.

Keywords

Impact assessment, cost-benefit analysis, almond, processing.

Introduction

All research, development, and extension (RD&E) and marketing levy investments undertaken by Horticulture Innovation Australia Limited (Hort Innovation) are guided and aligned to specific investment outcomes, defined through a Strategic Investment Plan (SIP). The SIP guides investment of the levy to achieve each industry's vision. The current industry SIPs apply for the financial years 2016/17 – 2020/21.

In accordance with the Organisational Evaluation Framework, Hort innovation has the obligation to evaluate the performance of its investment undertaken on behalf of industry.

This impact assessment program addresses this requirement through conducting a series of industry-specific ex-post independent impact assessments of the almond (AL), banana (BA), citrus (CT) and onion (VN) RD&E investment funds.

Twenty-nine RD&E investments (projects) were selected through a stratified, random sampling process. The industry samples were as follows:

- Nine AL projects were chosen worth $5.84 million (nominal Hort Innovation investment) from an overall population of 21 projects worth an estimated $10.78 million,
- Eight BA projects worth $3.02 million (nominal Hort Innovation investment) from an overall population of 22 projects worth approximately $16.72 million,
- Eight CT projects worth $5.4 million (nominal Hort Innovation investment) from a total population of 35 projects worth $15.78 million, and
- Four VN projects worth $2.4 million (nominal Hort Innovation investment) from an overall population of 8 projects worth $3.89 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2014 to 30 June 2019.

The projects for each industry sample were chosen such that the investments represented (1) at least 10% of the total Hort Innovation RD&E investment expenditure for each industry, and (2) the SIP outcomes (proportionally) for each industry.

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 almond industry is a significant horticultural sector with a five-year average production area of 36,206 ha, a production volume of 85,909 tonnes (kernel weight equivalent), and a Farmgate Value of $665.6 million – Table 1.

Table 1: Almond Industry Performance 2015-2019

Year Ended 30 June	Area of Production (ha)	Production (t)	Gross Value of Production ($m)	Farmgate Value ($m)
2015	29,437	82,509	707.5	672.1
2016	30,981	82,333	854.1	811.4
2017	35,866	80,800	553.6	525.9
2018	39,662	79,901	553.1	525.4
2019	45,089	104,000	835.1	793.3
Average	36,206	85,909	700.7	665.6

Source: Australian Horticulture Statistics Handbook and Almond Insights, various years. Tonnes is kernel weight equivalent.

The industry is comprised of a value chain that spans investors, almond growers through to end retail consumers and export markets. A number of the larger Australian growers have become vertically integrated and encompass processing, packing, domestic and export marketing (Hort Innovation, 2017).

Almond research and development (R&D) activity is guided by the Almond industry's Strategic Investment Plan (SIP). The activities are funded by levies payable on almonds produced in Australia; and the R&D levy funds are managed by Hort Innovation.

The current SIP has been developed with levy payers and addresses the Australian Almond 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. Pest and disease damage to almonds has been reduced through enhanced integrated pest management and integrated disease management.
2. A major productivity gain in almond pollination by 2022 through a 25% reduction in honey bee stocking rate with no loss in pollination efficiency (nut set).
3. Improvements in the crop production system have lifted average industry kernel yield from 3 to 4 t/ha, 4ML of irrigation water generates a tonne of almond kernel yield and proven 'shake and catch' harvesting / processing technology is in place.
4. Australian almonds are an informed industry that adopts R&D outcomes and has the capacity to support current and future industry needs.
5. Increased domestic almond consumption up from 16,000 t in 2016 to 27,500 t in 2022. Increased export sales up from 61,000 t in 2016 to 110,000 t in 2022.

Australian almond harvest and processing systems are based on those used in California, the world's largest almond industry with a true 'Mediterranean-style' dry summer. Almonds are shaken from the tree and remain on the orchard floor for a week to dry. On the orchard floor in Australia, almonds are vulnerable to summer rain, mould, and the development of poisonous aflatoxins. After a week, the whole almond, consisting of hull, shell, and edible kernel, is gathered, and stored on-farm in bulk silos, bunkers, and sheds. Under current production systems, almonds are not de-hulled on farm. An on-farm de-hulling system would reduce the cost of transport to a processing facility and provide valuable nutrient by-product for use in the orchard.

To deliver a ready to eat kernel, almonds must pass through shear rollers and over belts at the processing facility to remove the hull and the shell. This cracking process takes between 5 and 11 passes per tonne of almonds processed. Cracking causes damage to the almond including breaks, chips, and scratches.

Rationale

In 2011, the University of South Australia (UniSA) undertook a review of the Australian almond processing industry which highlighted a number of areas that could be improved from harvest through to cracking and packing.

Subsequent to this review, undergraduate student projects at UniSA have confirmed that the main source of physical damage to almond kernels (broken, chipped, and scratched) is the cracking process. Work was also undertaken at the UniSA modelling the failure of the almond shell under compressive and shear loads and examining the mechanism of damage to the kernel during shelling using high speed video of the shelling process.

Consequently, a project was designed to be delivered by a PhD student (over 4 years) and a post-doctorate student (over 2.75 years) that would address effective aeration and dehydration of bulk almonds in solos/bunkers/sheds to prevent mould, effective on-farm hulling, and improved cracking. Final year mechanical engineering student projects would also investigate improved equipment for cleaning almonds, better devices for picking almonds up off the orchard floor, and best practice layout of the almond processing factory.

Project Details

Summary

Project Code: AL12003
Title: Advanced Processing of Almonds
Research Organisation: University of South Australia
Project Leader: John Fielke
Period of Funding: September 2012 to June 2019

Objectives

The objectives of this study were to investigate:

1. *Effective aeration and dehydration of bulk almonds in silos/bunkers/sheds*. This work aimed to provide models of airflow and moisture movement through stockpiled almonds that may be in-hull, in-shell, or kernels. Using airflow to effectively aerate the almonds, storage conditions will be improved and earlier storage of almonds with higher moisture content will be feasible. Potentially, this change will allow growers to avoid destructive rains during harvest and orchard floor drying.
2. *Improved cracking of almonds*. This work aimed to provide new processes that reduce the damage done to kernels and increase recovery of undamaged kernels, reduce losses, improve the appearance of shelled almonds, and permit better machine vision sorting for defects such as insect and pest damage.
3. *Effective hulling of almonds in-field and during processing*. This work aimed to provide designs and operating parameters for equipment to be used both on-farm and in-factory to condition and remove hulls from almonds. As hulls make up 50% of the almond mass and contain many nutrients, hulling at the farm prior to stockpiling would provide a nutrient-rich by-product that could be used to reduce the cost of orchard fertiliser.

Logical Framework

Table 2 provides a detailed description of the project in a logical framework.

Table 2: Logical Framework for Project AL12003

Activities	Task 1 Effective aeration and dehydration of bulk almonds in solos, bunkers, and sheds: • Review and define parameters for moisture and heat transfer in-hull, in-shell, and kernel and how they affect colour, shelf-like, product freshness/rancidity. • Development of a method for modelling air flow through a bulk stack of almonds. • Evaluate bunker bases (bare earth, road base, concrete) so as to avoid contamination. • Development of a method to predict the performance of bulk stored aerated almonds. • Provide recommendations and design specifications for optimising aerated bulk storage. • Construct a best practice, bulk storage to demonstrate recommendations. Use the demonstration facility to extend and communicate recommendations to industry. • Deliver presentations to industry at industry events, publications prepared and accepted by relevant scientific journals, and completion of a PhD. Task 2 Improved cracking of almonds included: • Investigation of technologies that may be applicable to the shelling of almonds. • Completion of a technology performance assessment inside a range of shelling facilities.

	• Completion of trials using existing equipment and new processes to evaluate the potential for improved almond shelling. Tests examined variety, maturity, moisture content, conditioning (temperature, and moisture), and time since harvest. • Recommendations based on a compact and efficient machine that eliminates the need for intermediate cleaning of kernels between shear roller and over belt cycles. • Demonstration of performance at UniSA facility Mawson Lakes and progress toward installing prototype equipment in an industry processing facility. Task 3 Effective hulling of almonds in-field and during processing: • Review current threshing methods in a range of nut and other processing industries (e.g. grain) that may be applicable to the hulling of almonds. • Review methods for conditioning nuts and grains prior to their processing. • Completion of trials to measure the effectiveness of existing almond hulling equipment. • Evaluate a range of concepts for machinery and conditioning for improved hulling. • Develop concepts for dehulling for use on-farm (at pick-up and/or at bunker). • Provide industry with recommendations for best methods and processes for hulling. Project management, communication and extension activities included: • Engagement with the ABA Processing and Marketing Committees which include all of the industry's processing facilities, packers, and marketers. • Provision of milestone, draft, and final reports to Hort Innovation. • Contribution to a mid-term review that recommended a focus on nonpareil, use of funds to support stockpile management with breathable tarpaulins, ensure in-field huller can manage the volume of waste/contaminants, and focus on solutions industry can adopt. • Presentation of project findings to relevant conferences and dissemination of project information in relevant industry forums and publications.
Outputs	The important outputs from Task 1 (aeration/dehydration of bulk almonds) were: • A definition of requirements for drying almonds in-hull, in-shell and just kernels. • Knowledge of how heat/moisture effects almond quality (colour, shelf life, freshness). • Specification of conditions for effective aeration that minimise the growth of mould. • A comparison of differences in storage requirements with/without hulls. • Computer simulation of air flow and drying rates for bulk almonds. • A design for building an aerated storage facility for almonds. • An aeration and dehydration facility constructed on a cooperating almond orchard. The important outputs from Task 2 (improved cracking) were: • A detailed analysis of damage caused to kernels by each stage of existing shellers. • A specification detailing operating parameters for an improved shelling machine. • Reports/demonstrations showing the performance of alternative equipment. • Samples of almonds shelled under a range of conditions. • Technical assistance provided to processors interested in upgrading their equipment. The important outputs from Task 3 (effective hulling) were: • A report on the hulling efficiency of current equipment. • A report on the efficiency of pre-conditioning of almonds prior to hulling. • A report on the effect of time/moisture content between hull spilt and processing on hulling efficiency. • A design and operating parameters for improved hulling of almonds. • Demonstration of improved hulling equipment to industry using prototype equipment. In summary AL12003 has: • Shown earlier harvesting avoids damage, improves yield/quality, makes hulling easier. • A movement to 'shake and catch' harvesting will not decrease yield or quality and has advantages when combined with in-field hulling. • Delivered designs for improved hulling equipment that can be used in factory or field. • Delivered moisture spears for use through the value chain but especially in grower stockpiles. The spears have proved popular with growers.

	• Prototyped a yield mapping system that may be able to be retrofitted to harvesters.
Outcomes (potential)	The outcomes delivered by the project included: • A reduction in yield loss caused by almond exposure to rain and poor storage conditions. • A reduction in health risks from almonds exposed to rain that develop aflatoxins. • A trained PhD student with new knowledge of almond bulk storage. • More efficient shelling with a reduction in the downgrade of almonds due to breakage, chipping, and scratching. Also, less re-work/cost when sorting out other defects (AL12003 targeted an 80% reduction in damage to less than 5% of throughput). • Almond hulling on farm with a reduction in the cost of harvesting, the cost of on-farm storage, the cost of transporting almonds in-hull to processors and the opportunity to use almond hulls to part replace purchased fertiliser.
Impacts (potential)	• Economic – increase in grower revenue associated with avoided yield loss caused by exposure to rain and poor storage conditions as well as a reduction in broken, chipped, and scratched kernels. • Economic – a reduction in almond production costs with savings in processing, storage, transport, and fertiliser expenses as a result of on-farm hulling. • Economic – increase in processor profit associated with saved processing costs. • Environmental – reduced risk of fertiliser runoff with the substitution of some chemical fertiliser with almond hulls. • Capacity – almond growers, processors, and researchers with additional knowledge on best practice almond storage and processing. • Capacity - a PhD awarded to Michael Coates for research on almond bulk storage. • Social – further reduction in the already small risk of illness caused by consumption of almonds exposed to rain that have developed aflatoxins. • Social - contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project AL12003 by Hort Innovation. The University of South Australia (UniSA) contributed a similar amount of in-kind funding. The project also received voluntary contributions from the Almond Board of Australia (ABA) for assistance in funding the construction of a demonstration and research aeration/dehydration facility on a grower's property.

Table 3: Annual Investment in Project AL12003 (nominal $)

Year ended 30 June	Hort Innovation ($)	UniSA ($)	ABA ($)	TOTAL ($)
2013	33,000	32,316	70,000	135,316
2014	170,000	166,474	70,000	406,474
2015	170,000	166,474	0	336,474
2016	310,000	303,570	0	613,570
2017	75,000	73,444	0	148,444
2018	75,000	73,444	0	148,444
2019	83,000	81,278	0	164,278
Total	**916,000**	**897,000**	**140,000**	**1,953,000**

Source: AL12003 Revised Schedule

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, Further Development and Extension Costs

For purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). Impacts described in Table 2 Logical Framework will require further investment to deliver commercially viable machines. No additional extension costs are envisaged.

Impacts

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

Table 4: Triple Bottom Line Categories of Principal Impacts from Project AL12003

Economic	• Increase in almond grower profit associated with reduced yield and quality loss and saved production costs (net of capital costs to achieve the profit increase). • Increase in almond processor profit associated with a reduction in processing costs (net of capital costs to achieve the profit increase).
Environmental	• Reduced risk of fertiliser runoff with the substitution of some chemical fertiliser with almond hulls.
Social	• Almond growers, processors, and researchers with additional knowledge on best practice almond storage and processing. • A PhD awarded for research on almond bulk storage. • Further reduction in the already small risk of illness caused by consumption of almonds exposed to rain that have developed aflatoxins. • Contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

Public versus Private Impacts

The impacts identified from the investment are predominantly private impacts accruing to almond growers and processors i.e. additional profit with reduced yield and quality loss and saved production costs. However, some public benefits have also been produced including capacity building, a reduction in health risk from almond consumption and spill-over benefits to regional communities.

Distribution of Private Impacts

The private impacts (additional profit) will be distributed between growers, processors, and the balance of the supply chain. The share of impact realised by each link in the supply chain will depend on both short- and long-term supply and demand elasticities in the almond market.

Impacts on Other Australian Industries

Some of the technologies developed (e.g. stockpile management, moisture spears, yield mapping systems) may be relevant to other nut industries. However, it is noted that almonds are somewhat unique in their approach to harvesting and stockpile management.

Impacts Overseas

Technologies developed will have relevance to almond industries in other countries and it is noted that some of the research was completed in partnership with the Almond Board of California and the University of California, Davis.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project outcomes and related impacts will contribute to Rural DR&E Priority 1 and Science and Research Priority 1, 3 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 Almond Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the almond industry are outlined in the Almond Industry's Strategic Investment Plan 2017-2021[1] (Hort Innovation, 2017). Project AL12003 addressed Outcome 3, (improved yields, 'shake and catch' harvesting/processing technology in place), Strategy 9 ('Develop improved harvesting techniques') and Strategy 10 ('Develop improved postharvest handling techniques').

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.

Two impacts were valued:

- Increase in almond grower profit associated with reduced yield and quality loss and saved production costs (net of capital costs to achieve the profit increase).
- Increase in almond processor profit associated with saved processing costs (net of capital costs to achieve the profit increase).

The project funding agreement notes that based on experience in other industries adoption will be slow but new technologies will be included as capital is replaced.

Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. Those not valued included:

- Reduced risk of fertiliser runoff with the substitution of some chemical fertiliser with almond hulls.
- Almond growers, processors, and researchers with additional knowledge on best practice almond storage and processing.
- A PhD awarded for research on almond bulk storage.
- Further reduction in the already small risk of illness caused by consumption of almonds exposed to rain that have developed aflatoxins.
- Contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

These impacts were not valued due to lack of data to support credible assumptions.

Valuation of Impact 1: Increase in almond grower profit

The AL12003 investment will contribute to improvements in grower revenue through the reduction in yield and

[1] For further information, see: https://www.horticulture.com.au/hort-innovation/funding-consultation-and-investing/investment-documents/strategic-investment-plans/

quality loss associated with exposure of nuts on the orchard floor to rain and improvement in storage conditions. In addition, on-farm hulling will reduce grower costs associated with harvest, storage, transport, and fertiliser. A 1% improvement in grower profit has been assumed and this increase is net of costs associated with the purchase and deployment of new capital equipment.

Valuation of Impact 2: Increase in almond processor profit

The AL12003 investment will also contribute to improved almond processor profit via saved processing costs. Almond processing costs $30/tonne and a 1% saving in cost, including an allowance for purchase and deployment of new capital equipment, is assumed.

Attribution

AL12003 included pioneering work showing earlier harvest decreases almond damage, and there is no loss of yield or quality with 'shake and catch' harvesting. The project created improved hulling equipment, demonstrated the use of moisture spears for stockpile management and developed a tool for yield mapping. Work contributing to these outputs was limited to pre-project scoping studies and the application of technologies developed for other purposes. For these reasons, a high 90% attribution estimate for AL12003 has been assumed.

Counterfactual

If project AL12003 had not been funded by Hort Innovation, it is assumed that the project would have proceeded with ABA and UniSA funding which constituted half of the AL12003 budget. Consequently a 50% counterfactual has been applied.

Summary of Assumptions

A summary of the key assumptions is provided in Table 6.

Table 6: Summary of Assumptions for Impact Valuation

Variable	Assumption	Source/Comment
Impact 1: Increase in almond grower profit		
Area of Australian almond production.	45,089 ha	2019 area of production sourced from Hort Innovation 2020.
Increase in grower net profit due to increased yield, reduced quality loss, decreased production costs and an allowance for the cost of new capital.	1%	Analyst assumption to be tested using sensitivity analysis.
Profit on almond production – without AL12003.	$11,360/ha	Gross receipts of $25,000/ha (Australian Nut Industry Council, undated) less production costs of $13,640 (adapted from Waycott, 2011).
Impact 2: Increase in almond processor profit		
Australian almond production.	85,909 tonnes	Five-year average production 2015 to 2019 sourced from Hort Innovation 2018 and 2020.
Reduction in almond processing cost as a result of AL12003 generated technologies including an allowance for the cost of new capital.	1%	United States data presented in the Hort Innovation *ex-ante* benefit cost analysis of AL12003.
Cost of almond processing – without AL12003.	$30/tonne	United States data presented in the Hort Innovation *ex-ante* benefit cost analysis of AL12003.
Assumptions common to quantification of both impacts		
Year of first impact.	2023/24	Five years after AL12003 completion and consistent with the project funding agreement that notes 'adoption will be slow but new technologies will be included as capital is replaced'.

Year of maximum impact.	2026/27	Three years after initial adoption.
Year of final impact.	2046/47	Capital equipment incorporating AL12003 innovations is replaced after 20 years.
Level of first adoption.	15%	Analyst assumption – one large industry player adopts in the first year.
Level of maximum adoption.	75%	Analyst assumption – the project has delivered worthwhile products for the Australian almond industry. The almond growing, and processing sectors are characterised by a limited number of large and well informed 'corporate' businesses. ABA Directors control 85% of the industry's production, 95% of processing and 99% of marketing. A 75% adoption rate potentially errs on the conservative.
Probability of outputs.	100%	Analyst assumption – outputs are already available.
Probability of outcomes.	80%	Analyst assumption – there is some risk that outputs will not translate into commercial outcomes.
Probability of impact.	80%	Analyst assumption – there is some risk that growers and processors will not adopt.
Attribution	90%	See above.
Counterfactual.	50%	See above.

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 (2018/19) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

Tables 7 and 8 show the investment criteria estimated for different periods of benefit for the total investment and Hort Innovation investment, respectively. The present value of benefits (PVB) attributable to Hort Innovation investment only, shown in Table 8, has been estimated by multiplying the total PVB by the Hort Innovation proportion of real investment (51%).

Table 7: Investment Criteria for Total Investment in Project AL12003

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.00	0.18	3.46	6.56	8.99	10.90	11.34
Present Value of Costs ($m)	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Net Present Value ($m)	-2.84	-2.66	0.62	3.72	6.15	8.05	8.50
Benefit-Cost Ratio	0.00	0.06	1.22	2.31	3.16	3.83	3.99
Internal Rate of Return (%)	negative	negative	5.8	11.5	13.3	14.0	14.1
MIRR (%)	negative	negative	5.7	9.5	10.0	9.9	9.2

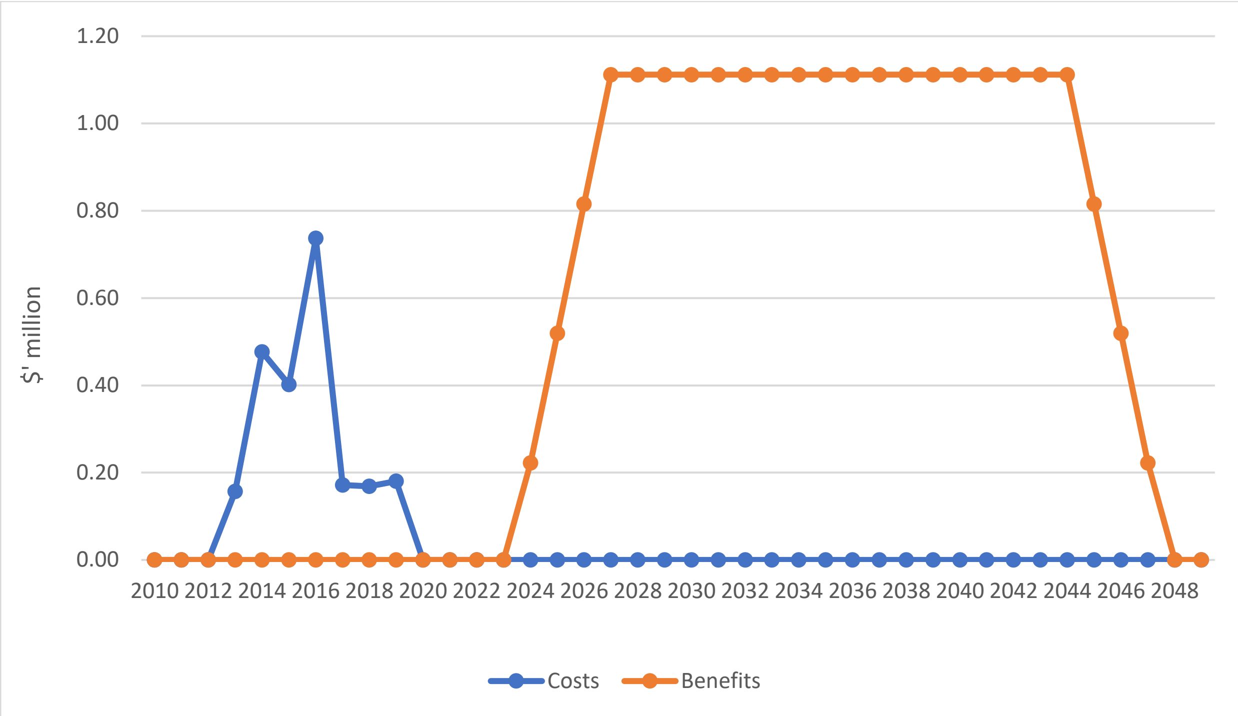
Table 8: Investment Criteria for Hort Innovation in Project AL12003

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.00	0.09	1.75	3.32	4.55	5.51	5.74

Present Value of Costs ($m)	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Net Present Value ($m)	-1.43	-1.33	0.32	1.89	3.12	4.09	4.31
Benefit-Cost Ratio	0.00	0.06	1.23	2.33	3.19	3.86	4.02
Internal Rate of Return (%)	negative	negative	5.9	11.6	13.4	14.1	14.2
MIRR (%)	negative	negative	5.8	9.6	10.1	9.9	9.3

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the AL12003 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



Source of Benefits

Estimates of the relative contribution of each benefit valued, given the assumptions made, are shown in Table 9.

Table 9: Contribution to Total Benefits from Each Source

	Contribution to PVB ($m)	**Share of benefits (%)**
Increase in almond grower profit – reduced yield/quality loss and saved production costs.	11.29	99.5
Increase in almond processor profit – reduction in processing costs.	0.06	0.05
Total	11.34	100.0

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 10 presents the results. The results are sensitivity to the discount rate and this is due to the lag between project and the realisation of project impacts.

Table 10: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**

Present Value of Benefits ($m)	23.13	11.34	6.22
Present Value of Costs ($m)	2.29	2.84	3.51
Net Present Value ($m)	20.84	8.50	2.71
Benefit-cost ratio	10.09	3.99	1.77

A sensitivity analysis was then undertaken on the assumed contribution of project AL12003 to increased grower profit. Results are provided in Table 11. Even when the assumed increase in grower profit is reduced from 1% to 0.5%, the project continues to show a favourable return on investment.

Table 11: Sensitivity to Contribution of AL12003 to Increase in Almond Grower Profit
(Total investment, 30 years)

Investment Criteria	**AL12003 Increase in Profit**		
	0.5%	**1% (base)**	**2%**
Present Value of Benefits ($m)	5.70	11.34	22.63
Present Value of Costs ($m)	2.84	2.84	2.84
Net Present Value ($m)	2.86	8.50	19.79
Benefit-cost ratio	2.01	3.99	7.96

A final sensitivity test examined the attribution of benefits to AL12003 (Table 12). The assumed attribution factor would need to fall from 90% to 23% before the project would be reduced to 'breakeven'.

Table 12: Sensitivity to Assumed Attribution Factor
(Total investment, 30 years)

Investment Criteria	**AL12003 Attribution Factor**		
	23% (breakeven)	**45%**	**90% (base)**
Present Value of Benefits ($m)	2.90	5.67	11.34
Present Value of Costs ($m)	2.84	2.84	2.84
Net Present Value ($m)	0.06	2.83	8.50
Benefit-cost ratio	1.02	2.00	3.99

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 13). 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 13: Confidence in Analysis of Project

Coverage of Benefits	**Confidence in Assumptions**
High	Medium-Low

Coverage of benefits valued was assessed as High – the two major benefits were valued. Confidence in assumptions was rated as Medium-Low, a number of key assumptions were made by the analyst.

Conclusion

The investment in AL12003 has delivered pioneering work showing earlier harvest decreases almond damage, and there is no loss of yield or quality with 'shake and catch' harvesting. The project created improved hulling equipment, demonstrated the use of moisture spears for stockpile management and developed a tool for yield mapping.

Total funding from all sources for the project was $2.84 million (present value terms). The investment produced estimated total expected benefits of $11.34 million (present value terms). This gave a net present value of $8.50 million, an estimated benefit-cost ratio of 3.99 to 1, an internal rate of return of 14.1% and a modified internal rate of return of 9.2%.

As five of the identified impacts were not valued, the investment criteria estimated by the evaluation may be underestimates 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.

Reference List

Almond Board of Australia (ABA) (2019) Almond Insights various editions https://industry.australianalmonds.com.au/almond-board/almond-insights/

Australian Bureau of Statistics. (2020, March 4). *5206.0 – Australian National Accounts: National Income, Expenditure and Product, Dec 2019*. Table 5. Expenditure on Gross Domestic Product (GDP), Implicit price deflators. Retrieved from Australian Bureau of Statistics: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Dec%202019?OpenDocument

Australian Nut Industry Council (undated) Growing Tree Nuts in Australia. Retrieved at https://nutindustry.org.au/growing-tree-nuts-in-australia/

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 (DAWR). (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) Almond 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 (2019) Horticulture Statistics Handbook 2017/18.

Hort Innovation (2020) Horticulture Statistics Handbook 2018/19. 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 (OCS). (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

Waycott, R (2011) The Economics of Growing Almonds. Retrieved at ttps://www.almonds.com/sites/default/files/content/attachments/economics_of_growing_almonds_revised.pdf

Acknowledgements

AgEconPlus and Agtrans Research would like to thank all the project and program personnel associated with Horticulture Innovation Australia Limited that were involved in the evaluation process. Their cooperation and feedback throughout the evaluation process contributed significantly to this report.

Specific acknowledgements:
John Fielke, Industry Professor of Mechanical Engineering, UniSA
Brendan O'Keeffe, Analyst, Hort Innovation
Ross Skinner, Chief Executive Officer, Almond Board of Australia

Abbreviations

ABA	Almond Board of Australia
AL	Almond
BA	Banana
CRRDC	Council of Research and Development Corporations
CT	Citrus
DAWR	Department of Agriculture and Water Resources (Australian Government)
EOI	Expression of Interest
FTE	Full Time Equivalent
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
RD&E	Research, Development and Extension
RIRDC	Rural Industries Research and Development Corporation (now AgriFutures Australia)
UniSA	University of South Australia
VN	Onion