Final Report

Project title:

Horticulture Impact Assessment Program:

Appendix 1: Almond Productivity, Tree Architecture and Development of New Growing Systems (AL14007 Impact Assessment)

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Project code:

MT18011

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What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in *AL14007: Almond Productivity, Tree Architecture and Development of New Growing Systems.* The project was funded by Hort Innovation over the period August 2014 to November 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

Investment in this research project has delivered further refinements to current, Horizon 1 growing systems and progress toward Horizon 2 production. A Horizon 2 production system is based on increased tree density with higher yields earlier in the orchards life. New knowledge on tree architecture has been generated to inform increased orchard density and almond breeding priorities. The research impact quantified was progress toward higher yielding and more profitable almond orchards.

Investment Criteria

Total funding from all sources for the project was $1.53 million (present value terms). The investment produced estimated total expected benefits of $4.8 million (present value terms). This gave a net present value of $3.27 million, an estimated benefit-cost ratio of 3.13 to 1, an internal rate of return of 10.6% and a MIRR of 8.5%.

Conclusions

The Hort Innovation investment in Project AL14007 has delivered further refinements to Horizon 1 growing systems and progress toward Horizon 2 production. A novel, low cost pruning system was developed for 2-year-old trees that will improve light interception, encourage orchard intensification, and facilitate ‘shake and catch’ harvesting. Yield improvement is attributable to this refined growing system. Three social impacts identified were not valued as the impacts 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 productivity; tree architecture; breeding, cultivars, rootstocks, pruning systems; central leader trees; high density plantings; propagation; trunk girdling; reflective ground covers; light interception

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 *AL14007: Almond Productivity, Tree Architecture and Development of New Growing Systems* 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 almond industry is a significant horticultural sector with a five-year average production area of 40,922 ha, a production volume of 91,627 tonnes (kernel weight equivalent), and a Farmgate Value of $712.5 million – Table 1.

Table 1: Almond Industry Performance 2016-2020

Year Ended 30 June	Area of Production (ha)	Production (t)	Gross Value of Production ($m)	Farmgate Value ($m)
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
2020	53,014	111,100	954.0	906.3
Average	40,922	91,627	750.0	712.5

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

Almonds are grown in the south of Australia, with the majority of production occurring along the Murray River. Key production areas include the North Adelaide Plains (South Australia), Riverland (South Australia), Sunraysia (Victoria) and the Riverina (NSW). Together these four areas account for 97% of production.

Australia's almond growing season commences with the almond blossom in July to September each year. Harvest takes place from February to April, with produce ready for the market in April and May. Newly planted almond trees take three years to bear a crop and seven years to reach mature production levels.

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 driven by levy payers and addresses the Australian Almond industry's needs from 2017 to 2021. The SIP reflects industry's long-term thinking in relation to orchard planning:

- Horizon 1 – improving current orchard production systems based on standard distances and orchard machinery that dominates existing plantings. These current production systems are based on Californian varieties and technologies.
- Horizon 2 – development of production systems with standard row widths and orchard machinery but with increased planting density along rows that offers the potential for higher returns earlier in an orchard's life. Horizon 2 will make use of existing and new cultivars and rootstocks.
- Horizon 3 – development of production systems best suited to Australian growing conditions that improves yields and input efficiency whilst reducing risks. Horizon 3 will make use of new cultivar and rootstock combinations planted at high density with closer row and tree spacing that will require development of new orchard machinery for harvesting and general orchard maintenance operations.

The SIP targeted improvements in the plant growing system that would lift average industry kernel yield from 3 to 4 t/ha.

Rationale

The rapidly increasing cost of water for irrigation has put pressure on orchard profits and the industry has recognised, at a strategic level, that substantial changes are required in terms of orchard design and management to maintain and increase orchard profit.

Current Australian almond orchards are characterised by trees of up to 10 years old displaying 60-80% light interception, dominated by the major Californian cropping variety 'Nonpareil', and the Californian pollinators 'Carmel', 'Monterey' and 'Price'. Current orchards are established with multiple limbs and canopies wider at the top than at the base (an inverted pyramid). Fruit bud development and ongoing health is reliant on good exposure to sunlight and shading results in the gradual movement of fruiting zones from the lower to upper canopy zones as the tree ages. Almond growers are well aware that current tree architecture is not optimal in terms of light interception and its conversion to kernel yield.

Smaller trees with narrow canopies, planted closer together, as successfully adopted by other tree crop industries, are likely to lead to large improvements in orchard productivity and grower profits. This project was to improve almond productivity through improved tree architecture (light interception) and development of new growing systems (denser plantings, new cultivar/rootstock combinations). The project was designed in partnership with leading Californian almond industry researchers at the University of California, Davis (US Davis) and involved collaboration with almond breeders in Australia, California and Spain.

Project Details

Summary

Project Code: AL14007
Title: *Almond Productivity, Tree Architecture and Development of New Growing Systems*
Research Organisation: Plant and Food Research Australia Pty Ltd
Project Leader: Grant Thorp
Period of Funding: August 2014 to November 2019

Objectives

The objective of the project was to provide industry with a range of options and strategies to maximise profitability from both well-established orchards (trees up to 10 years old), younger orchards (less than 5 years old) and future orchards (new growing systems). Put simply, the project was to 'double yields without increasing production costs'.

The objective was delivered through the study of the natural growth habit of a range of almond varieties and rootstocks combinations, pruning and training using basic plant physiology principles, and better understanding of light management through the use of reflective groundcover mulches. The planned output was progress toward development of a new almond growing system using new cultivars with architectural features better suited to more intensive growing systems.

Logical Framework

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

Table 2: Logical Framework for Project AL14007

Activities	Horizon 1 and 2 research: • The project included assessment of pruning, reflective groundcovers, and trunk girdling on trees up to 5 years old in fully replicated scientific trials. • Treatments were established in year one using existing trees on commercial orchards and then continued for up to four cropping seasons. • Data were collected on fresh fruit weight per tree, the canopy light environment, flowering and kernel yield and quality. Horizon 2 and 3 orchard and new cultivar research: • Horizon 2 and 3 research addressed development of intensive, high density planting systems suitable for the fast track establishment of new orchards planted with either existing cultivars or new cultivar/rootstock combinations. • Growing systems were explored using basic architectural data on branching patterns collected in the nursery and in the field from pruned and unpruned trees. • Assessments were completed on both major commercial varieties bred in California (Nonpareil, Carmel, Monterey, and Price) and new scion selections from the Australian almond breeding program. • Projects were established to examine the effect of rootstocks on precocity, tree growth habit and vigour on both commercial and new scion varieties. The aim being to identify rootstocks with a range of vigour suitable for intensive plantings.

	• Preliminary treatments were used to evaluate the plant growth regulator Cytolin (a blend of gibberellins and cytokinins) applied to the nursery to increase branching frequency and improve early tree structure. • Following the early testing of novel training and pruning techniques in commercial blocks with rows 6 to 7 m wide and trees spaced from 3 to 4.25 m along the rows a fully replicated scientific study was planted at the almond industry experimental orchard with trees planted in rows 4.5 or 6.5 m wide and trees at 2.0 or 3.0 m distance along the rows. Semi-commercial trials were also established on private orchards with narrow rows from 4.5 to 5.7 m wide and trees planted at 2 or 3 m spacing along the rows. • Data were collected on tree size, fresh fruit weight per tree and kernel yield. L-systems architectural modelling: • With assistance from The University of Queensland and UC Davis, data from architectural studies were analysed and simulation models developed using the L-systems programming language. • The modelling was used to aid understanding of tree architecture in one-year-old trees in the nursery and the growth habit of mature fruiting trees and in time to assist the development of new varieties and production systems. Seasonal patterns in light utilisation: • Combinations of fixed sensor arrays and spot measurements were used to quantify light interception and distribution within the modified and unmodified tree canopies. • Measurements were made in July (pre-blossom), September (post-blossom), November, January (floral initiation, pre-harvest), and March (immediate post-harvest). • The project examined changes in light interception as fruiting limbs moved under the weight of developing fruit. Cooperation with the Californian almond industry: • Similar projects to AL14007 were established with funding from the Almond Board of California in collaboration with UC Davis, California State University and Burchell Nursery in order to deliver two seasons of research findings each year of the project. • Australian and Californian trial results were compared for consistency and differences attributable to local conditions.
Outputs	The important outputs of the project were: • Demonstration that insufficient light transmission was occurring in Horizon 1 orchards to promote cropping in the lower canopy zones. While the use of selective limb removal pruning and reflective ground covers increased light transmission to the lower canopy of trees, and as a consequence increased the amount of crop produced in the lower canopy, the additional crop was very late maturing and not suitable for harvesting with the main crop. Average yield in years 7-9 was 5 t/ha for trees planted at 6 x 3 m spacing. • Demonstration that poor light transmission could be addressed using a novel, low cost narrow-pruning system applied to two year old trees. It was predicted that trees treated this way, and grown in more intensive orchards planted at 5 x 3 m would deliver a yield of 5.4 t/ha at 6-years of age. • Narrow pruning was also evaluated for new, high yielding, self-fertile cultivars 'Carina' and BA2 (Shasta®). The project revealed high yields will

	need to be managed on young trees to avoid canopy collapse with the weight of fruit causing branches to bend and break. • Investigations into the use of central leader trees and narrow pruning with a combination of dormant and in-season pruning revealed benefits from the use of 'unpruned' central leader trees when planting new orchards. Although the central leader structure was difficult to maintain in future years, planting 'unpruned central leader trees provided resilience to wind damage and ease of establishing and maintaining a tall, narrow canopy suitable for high density plantings. • Trunk girdling to promote precocity and increase yield on young trees was not successful. However, it did produce smaller trees which may be a ready alternative to the use of dwarfing rootstock. • Overall there were few existing almond cultivars identified that were compatible with orchard intensification and advice was provided to breeders in Australia, California, and Spain regarding the identification and selection of desirable architectural traits in new varieties. • Technology transfer occurred through presentations to the annual industry conferences in Australia and California, the Australian R&D forum, field days held at trial sites, written contributions to industry publications, Hort Innovation reports and planning discussions with industry representatives and growers who participated in project trials. Knowledge was transferred to the broader scientific community through published papers and direct engagement with colleagues in Australia, California and Spain.
Outcomes	The outcomes driven by the project included: • Progress toward the long-term goal of matching architectural features of cultivars and rootstocks to high density growing systems to deliver more precocious, productive, and profitable almond orchards. The eventual movement from Horizon 1 to Horizon 2 and 3 orchards has been forecast to deliver productivity improvements of up to 50%. • In the interim, the project has delivered further refinements to Horizon 1 growing systems and progress toward Horizon 2 production. A novel, low cost pruning system was developed for 2-year-old trees that will improve light interception, encourage orchard intensification, and facilitate 'shake and catch' harvesting. Yield improvement is attributable to this refined growing system. • Knowledge shared with almond breeders on architectural traits required for future Horizon 2 and 3 orchards. • Stronger international collaboration among almond researchers in Australia, California and Spain.
Impacts (potential)	• [Economic] Progress toward higher yielding and more profitable almond orchards. • [Social] Additional researcher skills in the assessment of tree architecture and almond growing systems. • [Social] More informed almond breeders with knowledge on architectural traits required for future intensive growing systems. • [Social] Contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yields and grower income.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project AL14007 by Hort Innovation. There were no other investors in the project, however, supplementary investments were made by the Almond Board of California for project related activities in California.

Table 3: Annual Investment in Project AL14007 (nominal $)

Year ended 30 June	HORT INNOVATION ($)	TOTAL ($)
2015	111,956	111,956
2016	170,361	170,361
2017	144,852	144,852
2018	177,253	177,253
2019	248,093	248,093
2020	322,833	322,833
Total	**1,175,348**	**1,175,348**

Source: AL14007 Executed Research Agreement

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, the investment costs of all parties were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). Plant Food and Research Australia completed a comprehensive program of industry communication and technological transfer as part of the project and no additional extension costs were incurred.

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 AL14007

Economic	• Progress toward higher yielding and more profitable almond orchards.
Environmental	• Nil.
Social	• Additional researcher skills in the assessment of tree architecture and almond growing systems. • More informed almond breeders with knowledge on architectural traits required for future intensive growing systems. • Contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yields and grower income.

Public versus Private Impacts

The impacts identified from the investment are predominantly private impacts accruing to almond growers (progress toward more productive and profitable orchards delivering additional kernel yield). However, public benefits also have been produced and these include the development of capacity (research skills and breeder knowledge) and potential spill-overs to regional communities from enhanced grower income.

Distribution of Private Impacts

Private impacts will be distributed between tree nurseries, growers, processors, packers, wholesalers, exporters, and retailers depending on both short- and long-term supply and demand elasticities in the almond market.

Impacts on Other Australian Industries

No impacts on other Australian industries were identified.

Impacts Overseas

Almond architecture and growing system knowledge, developed in partnership with the Californian almond industry, and to a lesser extent with the Spanish almond industry, will be directly relevant to North American, European, and North African growers.

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 RD&E Priority 1, and to Science and Research Priorities 1 and 2.

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 AL14007 addressed outcome three ('improvements in the crop production system that lift average industry kernel yield from 3 to 4t/ha using 4ML of irrigation water to generate a tonne of almond kernel yield and proven 'shake and catch' harvesting/processing technology).

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

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.

The impact that was valued was progress toward higher yielding and more profitable almond orchards.

Impacts Not Valued

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

- Additional researcher skills in the assessment of tree architecture and almond growing systems.
- More informed almond breeders with knowledge on architectural traits required for future intensive growing systems.
- Contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yields and grower income.

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

Summary of Assumptions

A summary of the key assumptions made for valuation of progress toward higher yielding and more profitable almond orchards is provided in Table 6.

Table 6: Summary of Assumptions for Impact Valuation

Variable	Assumption	Source/Comment
Annual almond area planted (includes replant of existing orchards).	4,746 ha/year	Based on 5-year average to 2019 (ABA, 2020).
Share of new planting adopting project findings.	80%	Industry is dominated by corporate growers who worked closely with project principal investigator Dr Grant Thorp.
Profit on almond production.	$11,360/ha	Gross receipts of $25,000/ha (Australian Nut Industry Council, undated) less production costs of $13,640 (adapted from Waycott, 2011).
Increase in profit attributable to project findings.	12%	AgEconPlus assumption that allows for the additional capital costs associated with more intensive orchards, year two pruning costs plus a yield increase from 3 to 4 t/ha of almond kernel.
Year of first impact.	2029/30	Allows for establishment of first orchards incorporating project findings in 2023/24, pruning in 2025/26 and mature yields 6 years after first planting.
Attribution of impacts to this project.	50%	Impacts are also attributable to ABA's extension and adoption programs.

Probability of the project generating useful outputs.	100%	Outputs have been delivered through research and communicated to industry.
Probability of valuable outcomes.	75%	There is some risk that year two pruning, and closer planting will not be adopted.
Probability of impact (assuming successful outcome)	75%	Increased yields are yet to be realised under commercial conditions.
Counterfactual.	50%	In the absence of AL14007 research, it is 50% likely that results would have been generated by a UC Davis research project, completed without Hort Innovation investment.

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

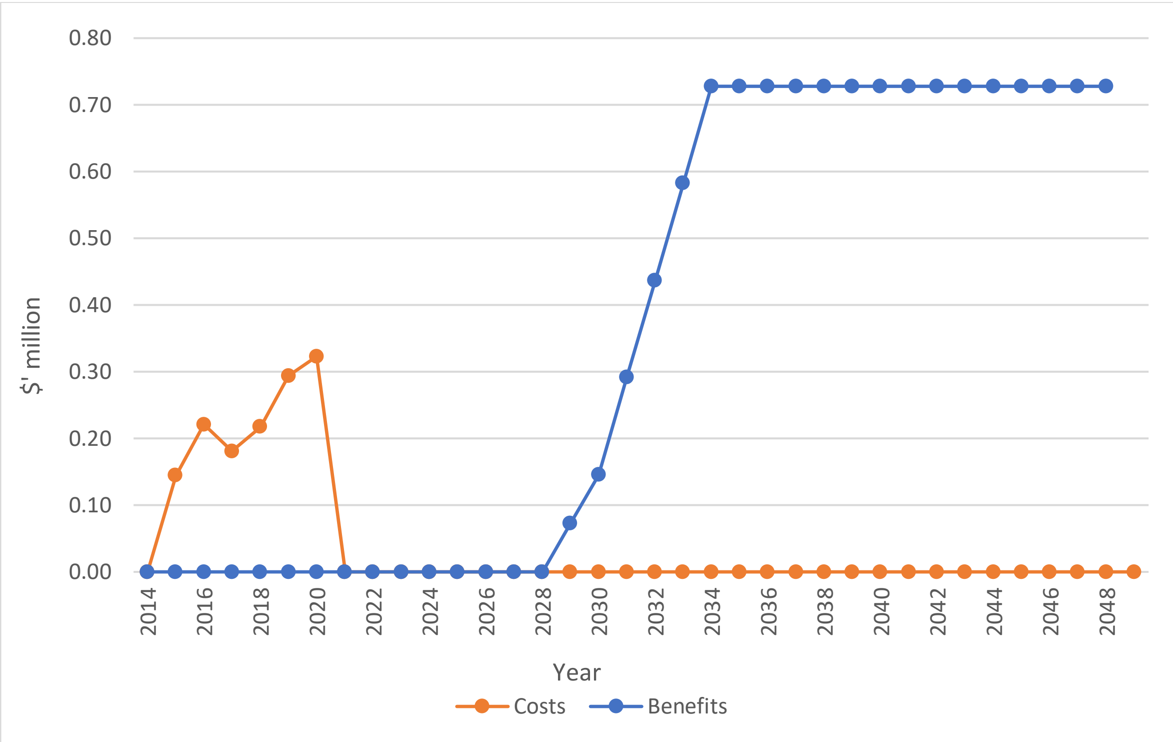
Table 7 shows the investment criteria estimated for different periods of benefits for the total investment. Hort Innovation was the only investor in the project.

Table 7: Investment Criteria for Total/Hort Innovation Investment in Project AL14007

Investment Criteria	Years after Last Year of Investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.00	0.04	1.17	2.68	3.87	4.80
Present Value of Costs ($m)	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Net Present Value ($m)	-1.53	-1.53	-1.49	-0.37	1.15	2.34	3.27
Benefit-Cost Ratio	0.00	0.00	0.03	0.76	1.75	2.53	3.13
Internal Rate of Return (%)	negative	negative	negative	3.0	8.2	9.9	10.6
MIRR (%)	negative	negative	negative	3.4	7.4	8.3	8.5

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the AL16004 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 presents the results. The results are sensitive to the discount rate. This is due to the long lag assumed between project investment and subsequent yield increase in more intensive almond orchards.

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

Investment Criteria	Discount rate		
	0%	**5% (base)**	**10%**
Present Value of Benefits ($m)	13.17	4.80	1.95
Present Value of Costs ($m)	1.38	1.53	1.71
Net Present Value ($m)	11.79	3.27	0.25
Benefit-cost ratio	9.55	3.13	1.14

A sensitivity analysis was then undertaken for the increase in profit that might be associated with adoption of project findings. Results are provided in Table 9. When assumed increase in profit is 6%, and all other factors remain unchanged, project benefits continue to exceed project costs.

Table 9: Sensitivity to Increase in Profit Associated with Project
(Total investment, 30 years)

Investment Criteria	Increase in Profit with 2 Year Pruning and Closer Planting		
	6%	**12% (base)**	**24%**
Present Value of Benefits ($m)	2.40	4.80	9.60
Present Value of Costs ($m)	1.53	1.53	1.53
Net Present Value ($m)	0.87	3.27	8.07
Benefit-cost ratio	1.57	3.13	6.27

A final sensitivity analysis tested the annual area grown using project recommendations. The results (Table 10) show that assumed adoption would need to fall to 1,500 ha/year before project investment failed to breakeven.

Table 10: Sensitivity to Area Planted Using Project Recommendations
(Total investment, 30 years)

Investment Criteria	Area Grown of Closer Plantings		
	1,500 ha/year	**2,373 ha/year**	**4,746 ha/year (base)**
Present Value of Benefits ($m)	1.52	2.40	4.80
Present Value of Costs ($m)	1.53	1.53	1.53
Net Present Value ($m)	-0.02	0.87	3.27
Benefit-cost ratio	0.99	1.57	3.13

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
High	Medium-Low

Coverage of benefits valued was assessed as High as the key impact, progress toward higher yielding and more profitable almond orchards, was valued. Confidence in assumptions was rated as Medium-Low, key data was estimated by the analyst.

Conclusion

The investment in AL14007 has led to further refinement of Horizon 1 production systems and progress toward Horizon 2 production. A novel low cost pruning system was developed for 2-year-old trees that will improve light interception, encourage orchard intensification, and facilitate 'shake and catch' harvesting.

Total funding from all sources for the project was $1.53 million (present value terms). The investment produced estimated total expected benefits of $4.8 million (present value terms). This gave a net present value of $3.27 million, an estimated benefit-cost ratio of 3.13 to 1, an internal rate of return of 10.6% and a modified internal rate of return of 8.5%.

As three social impacts identified 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.

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Abbreviations

ABA	Almond Board of Australia
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
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
SIP	Strategic Investment Plan