Horticulture Impact Assessment Program:

Appendix 1: Profitable Pears: Maximising productivity and quality of new pear varieties (AP12002 Impact Assessment)

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AgEconPlus and Agtrans Research

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Contents

Contents 3
Tables 3
Figures 3
Executive Summary 4
Keywords 4
Introduction 5
General Method 6
Background & Rationale 6
Project Details 7
Project Investment 14
Impacts 15
Valuation of Impacts 17
Results 23
Conclusion 26
Glossary of Economic Terms 27
Reference List 28
Acknowledgements 29
Abbreviations 29

Tables

Table 1: Logical Framework for Project AP12002 8
Table 2: Annual Investment in the Project AP12002 (nominal $) 14
Table 3: Triple Bottom Line Categories of Principal Impacts from Project AP12002 15
Table 4: Australian Government Research Priorities 16
Table 5: Australian Pear Production Statistics 18
Table 6: Summary of Assumptions 20
Table 7: Investment Criteria for Total Investment in Project AP12002 23
Table 8: Investment Criteria for Hort Innovation Investment in Project AP12002 23
Table 9: Contribution of Benefits 24
Table 10: Sensitivity to Discount Rate 24
Table 11: Sensitivity to Attribution of Benefits to AP12002 25
Table 12: Confidence in Analysis of Project 25

Figures

Figure 1: Australian Pear Production and Area (2008/09 to 2017/18) 18
Figure 2: Australian Pear Value and Yields (2008/09 to 2017/18) 19
Figure 3: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs 24

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 *AP12002: Profitable Pears: Maximising productivity and quality of new pear varieties.* The project was funded by Hort Innovation over the period July 2012 to May 2018.

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 2017/18 dollar terms and were discounted to the year 2018/19 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 AP12002 has improved orchard management practices for Australian pears and contributed to improved identification and prioritisation of key areas for future pear RD&E. Consequently, AP12002 is likely to have contributed to improved productivity and profitability for the Australian pear industry as well as to increased efficiency of resource allocation for both public and private funds invested in pear RD&E.

Investment Criteria

Total funding from all sources for the project was $3.56 million (present value terms). The investment produced estimated total expected benefits of $6.22 million (present value terms). This gave a net present value of $2.66 million, an estimated benefit-cost ratio of 1.8 to 1, an internal rate of return of 8.0% and a MIRR of 5.3%.

Conclusions

Several environmental and social impacts were also identified but not valued as part of the current assessment. Combined with conservative assumptions made for the principal economic impacts valued, it is reasonable to conclude that the investment criteria reported may be an underestimate of the actual performance of the AP12002 investment.

Keywords

Impact assessment, cost-benefit analysis, AP12002, pear, orchard management, profitability

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 impact assessment program MT18011, the first series of impact assessments included 15 randomly selected Hort Innovation RD&E investments (projects) worth a total of approximately $9.31 million (nominal Hort Innovation investment). The investments were selected from an overall population of 85 Hort Innovation investments worth an estimated $50.38 million (nominal Hort Innovation investment) where a final deliverable had been submitted in the 2017/18 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.

Under a separate impact assessment program (MT18009), a second series of impact assessments addressed a requirement for industry-specific ex-post independent impact assessments of the apple & pear (AP), avocado (AV), mushroom (MU) and table grape (TG) RD&E investment funds.

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

- Nine AP projects were chosen worth $15.46 million (nominal Hort Innovation investment) from an overall population of 19 projects worth an estimated $33.31 million,
- Seven AV projects worth $1.91 million (nominal Hort Innovation investment) from an overall population of 27 projects worth approximately $9.97 million,
- Five MU projects worth $1.75 million (nominal Hort Innovation investment) from a total population of 20 projects worth $7.94 million, and
- Six TG projects worth $2.84 million (nominal Hort Innovation investment) from an overall population of 11 projects worth $5.0 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2013 to 30 June 2018.

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 Strategic Investment Priorities (SIP) outcomes (proportionally) for each industry.

Five projects included in the MT18009 industry specific samples were also randomly selected and evaluated as part of a separate, whole of Hort Innovation impact assessment program (MT18011). Such overlapping projects were evaluated such that the impact assessment reporting would meet Hort Innovation's requirements under both MT18011 and MT18009.

Project *AP12002: Profitable Pears: Maximising productivity and quality of new pear varieties* was randomly selected as one of the 15 investments under MT18011, and also as one of the investments under MT18009, 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 actual and/or potential 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 used 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

Apples and pears are two of the main horticulture crops produced in Australia. Combined, the apple and pear industries produce more fresh fruit than any other fruit industry in Australia (APAL, 2019). The main production of apples and pears occurs in Victoria (at 45% and 88% of national production respectively), with major apple producers also located in all other states. Most Australian apples and pears are for fresh supply, but both also have significant production sent for processing (for juices and other value-added products).

In 2017/18, Australian apples had a farm gate value (FGV) of $490.8 million and production of 268,355 tonnes, while pears (including Nashi) had an FGV of $91.4 million and production of 103,748 tonnes (ABS, 2019a). Domestic apple consumption has remained relatively stable over time, but per capita consumption has been. Fresh pear (excluding Nashi) per capita consumption has remained stable since 2002/03 (Hort Innovation, 2017).

Exports, while relatively small compared to domestic consumption, represent an important growth area for apples and pears. A total of 2,134 tonnes (or 1% of fresh production) of apples was exported in 2014/15 (Hort Innovation, 2017) with major markets being Papua New Guinea, United Kingdom, Sri Lanka, and Hong Kong S.A.R.

For pears, a total of 7,647 tonnes (7% of fresh production) was exported the same year (Hort Innovation, 2017), with major export markets being New Zealand, Indonesia, Canada, Singapore, and more recently India. Australia does allow imports of both apples and pears, but quantities are relatively small compared to domestic production.

There are both opportunities and challenges for the Australian apple and pear industry to improve in areas such as biosecurity, inconsistency of eating quality, export competition and market access, and an oversupply leading to lower prices (Hort Innovation, 2017).

The collective goal of the two industries is to increase the growth in domestic consumption of apples and pears, and to see growth in exports. The apple and pear industries have funded a number of projects, through Hort Innovation and industry RD&E investments, around improving access to the Asian export market, improved marketing of apples and pears, and improving industry productivity and quality (APAL, 2013).

Statutory levies are in place for both industries for Emergency Plant Pest Response, National Residue Testing, Plant Health Australia, Marketing and Research and Development (R&D). Marketing and R&D levies are managed by Hort Innovation. Apple and Pear Australia Ltd (APAL) is the apple and pear industries' representative body and non-profit membership organisation.

Rationale

Total Australian pear production has steadily declined over the past decade. This decline has largely been driven by a decrease in pear exports because of global pricing pressures (APAL, 2009) and a period of industry consolidation whereby a number of small producers exited the industry and larger, viable growers consolidated their positions and upgraded their production systems (Xia, 2014).

The Hort Innovation Apple and Pear Strategic Investment Plan 2017-2021 (2017) identified a number of major challenges for the industry including relatively low and viariable yields, inconsistent fruit quality, and a lack of export competitiveness and capability. The Australian National Pear Breeding Program (ANPBP) was developing new varieties with the potential to recapture markets for fresh pears (both domestic and international) through improved yields and fruit quality. Project AP12002 (*Profitable Pears: Maximising productivity and quality of new pear varieties*) was funded to support the ANPBP by developing orchard management systems to maximise productivity and sustain high yields of consistent quality fruit for the pear industry.

Project Details

Summary

Project Code: AP12002

Title: *Profitable Pears: Maximising productivity and quality of new pear varieties*

Research Organisation: Victorian Department of Primary Industries (VIC DPI[1])

Principal Investigator: Ian Goodwin

Period of Funding: July 2012 to May 2018

Objectives

The objectives of the investment were to:

1. Establish and operate the Pear Field Laboratory at DPI Tatura.
2. Investigate the mechanisms and effects of training system, planting density and rootstock on tree growth, precocity, fruitfulness, yield and fruit quality.
3. Investigate the mechanisms and effects of irrigation systems and management on tree growth and precocity.
4. Explore the relationships between fruit bud type and fruit quality, and investigate the principles of bud extinction of new pear varieties.

In 2015 the scope of the project was broadened to include more work on irrigation and nutrients. The objectives of this extra work were to:

5. Analyse and review the effects of nitrogen on the colour and quality attributes of red blush pears,
6. Investigate the effects of irrigation method and irrigation frequency on nitrogen leaching,
7. Collect pear relevant information on the canopy chorophyll content index, and
8. Collect data on the nitrogen flux to validate modelling (SPASMO) specifically for pears.

Logical Framework

Project AP12002 utilised a pear field laboratory to investigate irrigation, root pruning, tree training, planting density, rootstock and plant growth regulator options to optimize young tree production of new blush pear cultivars ‘ANP-0131’ (marketed as Deliza®), ‘ANP-0118’ (marketed as Lanya®) and ‘ANP-0534’. Table 1 provides a description of AP12002 in a logical framework.

[1] Now known as the Department of Jobs, Precincts and Regions (DJPR). Also formerly known as the Department of Economic Development, Jobs, Transport and Resources (DEDJTR). See http://agriculture.vic.gov.au/agriculture for further information.

Table 1: Logical Framework for Project AP12002

Activities	• A field laboratory, known as the 'Pear Field Laboratory' (PFL), was established at the DJPR Tatura facility in the Goulburn Valley region of Victoria. • The PFL project activity was initially divided into three experiments to investigate the mechanisms and effects of rootstock, training system, planting density, irrigation method and root pruning on tree growth, precocity, fruitfulness, yield and fruit quality. *Experiment 1: Rootstock, training system and planting density* • A comparison of three training systems (Open Tatura, Vertical Leader, and Conventional), three rootstocks (D6, BP1 and Quince A (QA)/Buerre Hardy (BH)) and four tree planting densities (741 – 4444 trees per hectare) was made on the cultivar 'ANP-0131' over a five-year period in a split-plot randomised complete block design with three replicates of each treatment. • Tree planting density of 4444 (Ultra-High), 2222 (High), 1482 (Moderate) and 1111 (Low) trees per hectare were compared in the Open Tatura training system. • Tree planting density of 4444 (Ultra-High), 2222 (High), 1111 (Moderate) and 741 (Low) trees per hectare were compared in the Vertical Leader and Conventional training systems. • All trees were drip irrigated and over the experimental period measurements were taken for tree growth, canopy light interception, flowering and fruiting behaviour, yield and fruit quality. *Experiment 2: Rootstock and cultivar* • A comparison of seven rootstocks (D6, D6+virus, D6-Nijisseiki+virus, BP1, D6-BM2000, Quince A-Beurre Hardy and Quince C-Beurre Hardy) and three cultivars ('ANP-0131', 'ANP-0118' and 'ANP-0534') were made over a five-year period in a randomised complete block design with four replicates. • All trees were trained as Open Tatura at a tree planting density of 2222 trees per hectare and drip irrigated. • During the five-year experiment, measurements were taken for tree growth, canopy light interception, flowering and fruiting behaviour, yield and fruit quality. *Experiment 3: Irrigation system and root pruning* • This experiment was conducted from 2012/13 to 2015/16 to observe the effects of irrigation method and root pruning on vegetative growth, precocity, yield and fruit quality of young trees from planting to the start of cropping. • A comparison of four irrigation treatments (Drip and Microjet applied as Pulse or Standard interval, imposed from planting) with and without Root Pruning was made on the cultivar 'ANP-0118' on BP1 rootstock in a randomised complete block design with four replicates. • All trees were trained as Open Tatura at a tree planting density of 2222 trees per hectare. Measurements taken during the course of the experiment included tree water status, soil water profiles, tree growth, canopy light interception, root growth, flowering and fruiting behaviour, yield and fruit quality. • The same irrigation experiment block also was used to parameterize and validate a model (SPASMO[2], Plant & Food Research New Zealand) to estimate nitrogen (N) flux and requirements. • Drainage flux meters were installed within plots and in the interrows to measure drainage volume and N concentrations.

[2] SPASMO: Soil and Plant Atmosphere System Model. SPASMO models the transport of water, microbes and solutes through soils integrating variables such as climate, soil, water uptake by plants in relation to farm and orchard practices, and any other factors affecting environmental process and plant production. For more information see: http://tools.envirolink.govt.nz/dsss/soil-plant-atmosphere-system-model/

- Leaf, wood and fruit N concentrations, trunk diameters, fruit size and fruit number at harvest were then measured.

Experiment 4: The use of multi-spectral cameras to measure pear canopy nitrogen status

- Mature trees of 'ANP-0131' on BP1 rootstock from an adjoining the pear repository at DJPR at Tatura were used to acquire remote sensing imagery and corresponding N concentrations to determine the feasibility of remote sensing to characterize N status of pear orchards.
- Canopy reflectance measurements were made using a six-band multispectral camera flown on a multirotor unmanned aerial vehicle (UAV).
- Ground-based and leaf-level measures of reflectance were also made.
- Several indices were evaluated to determine the most appropriate index for estimation of orchard N status.
- Research also was undertaken to evaluate lab-based leaf reflectance measurements using a portable spectrometer.

Other activities

<u>Economic analysis of expected initial returns from growing new pear cultivars</u>

- An ex-ante cost-benefit analysis (CBA) of the project investment was undertaken in May 2012.
- The economic analysis was undertaken using a participatory case study method.
- The economic and financial assessment focused on trees grafted to QA/BH rootstock and trained on Open Tatura trellis at densities of 1481, 2222 and 4444 trees per hectare.
- Results were compared to those for a traditional low-density (343 trees/ha) planting of Packham's Triumph.
- Business risk was accommodated in the analysis through changes in farm-gate prices, yields, pack-outs and prices paid for water during each year over the planning horizon.
- Financial performance was determined from the cumulative (nominal) net cash flows using the payback period; that is, the time required for the investment in additional capital to break even.

<u>Bearing habits of new cultivars</u>

- Bearing habits and influence of bud type on fruit quality were investigated using trees of 'ANP-0131' and 'ANP-0118' in their sixth leaf within the pear breeding repository at DJPR Tatura.
- Observations of the bearing habits of 'ANP-0534' were later made in the pear field laboratory.

<u>Effects of plant growth regulators</u>

- The effects of plant growth regulators on the promotion of shoots on young trees and fruit set were investigated using guard trees within the PFL and mature 'ANP-0131' trees beside the pear breeding repository.
- Applications of cytokinin (6-benzyladenine, BA) and gibberellin with cytokinin (GA4+7+BA) were applied on three dates (25 September, 10 October and 31 October) both with and without notching.
- The treatments were then compared to notching alone and a control treatment using 'ANP-0131' trees on D6 rootstock in 2014.
- The treatments were assessed eight weeks after each application for shoot development and the following season for flower density.
- Fruit set was assessed following applications of gibberellin (GA3) applied to 'ANP-0131' on BP1 at full bloom in 2014; GA3 and GA4+7+BA, applied to 'ANP-0131' on BP1 and 'ANP-0118' on BP1 at full bloom in 2015; and GA4+7+BA (at full bloom) and paclobutrazol (post-bloom) applied to 'ANP-0131' on D6 and QA/BH in 2017.

<u>Preliminary studies</u>

- A number of preliminary studies were completed by visiting scientists, Masters students and project staff using buffer trees in the PFL.

	• Professor Luca Corelli-Grappadelli (University of Bologna, a visiting scientist funded by 'veski sustainable agricultural fellowships') studied physiological responses of pear trees to irrigation, in particular the flux of water and assimilate to pears. • The effects of N status, reflective mulch, netting and training system on colour development of 'ANP-0131', and the seasonal pattern of colour development in 'ANP-0534' were investigated by Iris Visscher (Masters student, Wageningen University). • Preliminary studies on the effects of thinning on yield and fruit size in 'ANP-0118' were undertaken on buffer rows by project staff. <u>Communication</u> • Communication with growers and farm consultants was achieved through a range of project extension activities and media including: industry articles, seminars and orchard walks, updating of the Intensive Pears website (http://apal.org.au/industry-info/intensive-pear-production/), production of new materials for 'Blush Pear Research' on the Horticulture Industry Network (HIN) web site (http://www.hin.com.au/networks/blush-pear-research (funded by DJPR project 'Premium Fruit to Asia'), HIN newsletters (provided to growers by the DJPR project 'Premium Fruit to Asia'), grower and consultant visits to the site and the Speed Updating forum at APAL-AUSVEG conferences. • Annual meetings with the industry liaison committee also provided opportunity for both communication of experimental results to key growers in Victoria and input from growers regarding orchard management and future research directions. • Communication of project results to the scientific community occurred in the form of conference presentations and peer-reviewed papers. • More broadly, the project featured in a number of newspaper articles, radio interviews and TV news stories.
Outputs	*Cultivars* • 'ANP-0131' was the most vigorous and productive of the three grafts and yielded over 80 t/ha in fifth-leaf (2017/18, dependent on rootstock). • 'ANP-0118' and 'ANP-0534' had lower yield potentials and produced a maximum of 49 t/ha in their fifth-leaf (dependent on rootstock). • Average red colour coverage of individual fruit was typically 30, 40 and 50% for 'ANP-0118', 'ANP-0534' and 'ANP-0131', respectively. • All cultivars were observed to return bloom and return set (a proportion of buds that flowered in season 2016/17 that flowered and set fruit in the following season). • 'ANP-0534' had a return bloom (proportion of buds that set fruit in 2016 and flowered in 2017) of 24 % and a return set (proportion of buds that set fruit in 2016 and set fruit in 2017) of 19 %. • Return bloom and return set exceeded 67 and 51 %, respectively, for 'ANP-0131' and 'ANP-0118'. *Rootstocks* • QA/BH rootstocks produced fruit earlier and set fruit well but the high crop loads increased the likelihood of needing thinning intervention to ensure adequate fruit size. • Conversely, in years with low fruit set, trees with D6 rootstock may lose pack-out yield due to oversizing of fruit. At this stage, D6 could be recommended as a preferred rootstock for use with 'ANP-0131' due to high pack-out yields (yield of fruit 150 – 280g) of fifth-leaf trees. • QA/BH and QC/BH were preferred rootstocks for 'ANP-0118' on the basis of yields of young trees. However, crop load management appeared necessary to size fruit with these rootstocks and long-term production may be improved by use of D6. • 'ANP-0534' performed similarly well on QA/BH, QC/BH and D6 rootstocks. • Use of BP1 rootstock was not recommended with any of the cultivars due to lower yield potential. *Planting Densities*

	• The project found that growers seeking to maximize yield should consider high density (~ 2200 trees/ha) plantings on D6 or QA/BH rootstocks. • Further, there was no yield benefit from increasing tree density from 'High' to 'Ultra-High' (~4400 trees/ha), consistent with predictions from economic modelling. • For growers wishing to remain with moderate planting densities (~1100 – 1400 trees/ha), D6 was found to be the most attractive rootstock option with moderate crop loads and good fruit size resulting in maximum total yields and pack-out as trees approach maturity. • By contrast, in low density planting systems (~700 – 1100 trees/ha), crop load and fruit size of trees on QA rootstocks in fifth-leaf was sufficient to maximize total yield and pack-out yield while avoiding oversizing of fruit. *Training systems* • Yield tended to be highest in the 'High' and 'Ultra-High' density Open Tatura trellis (on D6 and QA rootstocks) this was attributed to fruit size. • It was noted that more intensive tree management may be required to ensure adequate colour development in Open Tatura systems. *Economic analysis* • The ex-ante economic analysis results indicated that there was an advantage of growing high-density plantings of the new red-blushed pears over the traditional low-density planting of Packham's Triumph. • The analysis estimated an average net present value (NPV) for a high-density planting of 'ANP-0131' of $15,835/ha p.a. • The net cash flow for the low-density (343 trees/ha) planting of Packhams was estimated to be $4,595/ha p.a., and there was approximately a 20 per cent chance that such plantings would lose money in any one year. • Through Monte Carlo simulations (10,000 simulations) it was found that growers could invest in the new pear plantings with confidence. • The most profitable planting was found to be 2,222 trees/ha, where the NPV was estimated at $258,471/ha over 30 years using a discount rate of 4.5%. • The payback period ranged from 7 to 11 years from best to worst case scenarios. *Irrigation and root pruning* • The project found that drip irrigation was able to meet pear crop water requirements and provide substantial improvement in water use efficiency in young trees. • Water savings of approximately 35% were achieved over the first four years after planting when compared with microjet irrigation. • Further, drip irrigation was found to increase early yields by 167%. • Based on the project's findings, pulse irrigation with microjets was not advised for pear trees in their first-leaf because of increased water losses via evapotranspiration, which decreases soil water availability and increases the risk of water stress. • Once trees beared fruit (cropped), pulse irrigation improved fruit size. • Combined with a trend for increased fruit number, the increased fruit size contributed to a 23% increase in yield for Pulse irrigation over standard irrigation treatments in the sixth-leaf. • Root pruning of young pear trees did not affect tree vigour or increase precocity. *Nitrogen sensing and modelling* • Project results supported the use of a UAV based assessment for field canopy N concentration using the new 'M3CI_710nm' index. • Further, results also indicated that reflectance indices (NDVI and NDRE_720nm) measured at the leaf level, with a controlled light source and calibration could be used to estimate leaf N concentration. • Over the six years of monitoring in the irrigation experiment during project AP12002, results showed total drainage recharge was 180 mm (cf. the total irrigation volume of 2200 mm) and the total drainage flux of nitrate-nitrogen was 35 kg-N ha-1 (cf. the total nitrogen application of 287 kg-N ha-1) under drip irrigation.

	• Model parameters for SPASMO were refined based on these observations of N applications and flux combined with tree and fruit N content and soil mineralization to simulate realistic yield and nitrogen uptake by blush pears. *Plant growth regulators* • Treatments of BA with notching and GA_{4+7}+BA with notching in early October (slight leaf emergence) were found to be the most effective in promoting development of long shoots. • Effectiveness of notching alone did not differ from that of plant growth regulators alone. • Later application of treatments (31 October, full leaf emergence) encouraged the development of spurs. • Fruit set responses to applications of plant growth regulators varied between seasons and cultivars and were affected by application rates. • It is likely that plant growth regulators have no or little effect when environmental conditions are conducive to pollination and set. *Pollination compatibility* • 'ANP-0131' was compatible with all tested cultivars ('Corella', 'Ya Li', 'Tanzhiya' and 'ANP-0118'). • 'ANP-0118' was compatible with all tested cultivars ('Corella', 'Hosui', 'Howell' and 'ANP-0131'). • 'ANP-0534' was compatible with all tested cultivars ('Hosui', 'Howell', 'ANP-0131' and 'ANP-0118') and appeared to be self-compatible. • Attempts to collect pollen from 'ANP-0534' were unsuccessful. • 'Packham's Triumph' was thought to be compatible with the cultivars but flowering was not synchronous in the last two seasons. • All pollinisers tested in this study were synchronous with the respective cultivars in 2017. <u>Summary of Key Findings</u> • Yield in the first three bearing years increased with increases from 'Low' to 'High' (2222 trees/ha) tree density. Increasing density to 'Ultra-High' (4444 trees/ha) provided no further yield benefit. • QA rootstocks with BH interstems increased precocity and total yield in the first three years of bearing. Trees on D6 provided better fruit size and, consequently, similar yield and improved pack-out in the fifth-leaf. Use of BP1 rootstock was detrimental to yield. • High density planting systems (2222 trees/ha) were predicted to be most profitable with payback periods of 7 to 11 years dependent on pack-outs, prices and yield. • Drip irrigation optimized yield, fruit size and water use efficiency outcomes in comparison to microjet treatments. • Results support the use of a multispectral camera mounted on a UAV to assess field canopy N concentration using the new M3CI_710nm index. • Modelling of N use and movement indicated that 'ANP-0118' bearing trees allocated approximately 60% of applied nitrogen to fruit and 13% of applied N was lost by leaching under drip irrigation.
Outcomes	• The refined SPASMO model now can be used to develop irrigation and fertilizer schedules for a range of different soil types and climates. • As a result of the project findings, some pear producers already have begun to adopt higher-density planting systems with new cultivar x rootstock combinations to improve fruit yield and quality. • Similarly, some growers are implementing improved drip/pulse irrigation systems and management and also are adopting improved methods to monitor and manage N concentration.

	• Research funding organisations (such as Hort Innovation and various Victorian government departments) are utilising the pear RD&E framework to guide and prioritise new pear research investments. • A framework for future RD&E titled "Smarter pear orchards for high quality and labour efficient production systems" evolved as a result of project AP12002. Recommended future research themes in the framework include orchard design for automation; maximising colour development and expression; sensing techniques and platforms for orchard decision making; and crop load management. • At the time the final report for AP12002 was submitted, assessments of rootstock performance had focused on total annual and cumulative yield in the first three years of production. The project team noted that cultivar x rootstock combinations that set moderate crop loads with minimal interventions once trees reach full production may be more profitable than trees with a tendency to crop heavily and undersize fruit. Therefore, further investigations of long-term trends in flower density and fruit set, and desirable crop loads for each cultivar x rootstock were recommended to ensure maximum pack-out.
Impacts	• Increased productivity and profitability for Australian pear producers through adoption of optimal orchard management systems and practices that increase average yield and fruit quality. This impact likely will be driven by: i) Adoption of optimal, high-density planting, ii) Selection of appropriate cultivar x rootstock combinations, and iii) Implementation of new/improved irrigation and monitoring systems to improve water and chemical use efficiency. • Increased area of pear trees planted because of potentially improved market access (through increased average quality) and crop profitability. • Potentially, increased capital and operating costs for Australian pear producers adopting new management systems (e.g. drip irrigation, high-density planting, UAV monitoring, etc.), likely offset by improved productivity and profitability of pear orchards. • Increased efficiency of pear RD&E resource allocation because of improved identification and prioritisation of future research areas. • Potentially, improved environmental outcomes as a result of increased water use efficiency and reduced export of chemicals off-farm. • Increased industry capacity to maximise orchard potential through implementation of new management systems and practices, and new cultivar x rootstock combinations. • Increased knowledge and scientific capacity. • Potentially, improved regional community well-being from spill-over benefits from more productive and profitable Australian pear producers.

Project Investment

Nominal Investment

Table 2 shows the annual investment (cash and in-kind) in project AP12002 by Hort Innovation and DJPR. There were no other investors in this project.

Table 2: Annual Investment in the Project AP12002 (nominal $)

Year ended 30 June	Hort Innovation ($)	DJPR ($)	Total ($)
2013	100,000	213,794	313,794
2014	200,000	213,794	413,794
2015	238,000	213,794	451,794
2016	281,750	213,794	495,544
2017	218,635	213,794	432,428
2018	377,877	213,794	591,671
Totals	1,416,262	1,282,762	2,699,024

Source: AP12002 Project Agreement and Variation documents supplied by Hort Innovation 2019

Program Management Costs

For the Hort Innovation investment the cost of managing and administrating 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, various years). This multiplier was then applied to the nominal investment by Hort Innovation shown in Table 2.

For the DJPR investment, it was assumed that the management and administration costs were already included in the nominal values reported in Table 2.

Real Investment and Extension Costs

For the purposes of the investment analysis, investment costs of all parties were expressed in 2017/18 dollar terms using the Gross Domestic Product deflator index (ABS, 2018). No additional costs associated with project extension were incorporated as the project included a high level of industry participation and a number of extension activities. Results were communicated to Apple and Pear Australia Limited and pear growers as part of the project.

Impacts

Table 3 provides a summary of the principal types of impacts delivered by the project. Impacts have been categorised into economic, environmental and social impacts.

Table 3: Triple Bottom Line Categories of Principal Impacts from Project AP12002

Economic	• Increased productivity and profitability for Australian pear producers through adoption of optimal orchard management systems and practices that increase average yield and fruit quality. This impact likely will be driven by: i) Adoption of optimal, high-density planting, ii) Selection of appropriate cultivar x rootstock combinations, and iii) Implementation of new/improved irrigation and monitoring systems to improve water and chemical use efficiency. • Increased area of pear trees planted because of potentially improved market access (through increased average quality) and crop profitability. • Potentially, increased capital and operating costs for Australian pear producers adopting new management systems (e.g. drip irrigation, high-density planting, UAV monitoring, etc.), likely offset by improved productivity and profitability of pear orchards. • Increased efficiency of pear RD&E resource allocation because of improved identification and prioritisation of future research areas. • Increased industry capacity to maximise orchard potential through implementation of new management systems and practices, and new cultivar x rootstock combinations
Environmental	• Potentially, improved environmental outcomes as a result of increased water use efficiency and reduced export of chemicals off-farm.
Social	• Increased knowledge and scientific capacity. • Potentially, improved regional community well-being from spill-over benefits from more productive and profitable Australian pear producers.

Public versus Private Impacts

Impacts identified in this evaluation are predominantly private in nature. Private benefits are likely to be realised by Australian pear producers through a net increase farm profits from adopting new and improved orchard management systems. Some public benefits may occur and include improved environmental outcomes (through increased water use efficiency and reduced chemical use), increased scientific capacity as well as increased income in pear growing communities/regions associated with a more profitable industry.

Distribution of Private Impacts

The impacts on the Australian pear industry from investment in project AP12002 will be shared along the pear supply chain with input suppliers, growers, processors, transporters, wholesalers, retailers and consumers all sharing impacts produced by the project. 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 pear market.

Impacts on Other Australian Industries

Impacts on industries other than the Australian pear industry may include potential gains to other fruit tree industries (e.g. apples) via potential future spill-overs from the increase in knowledge and scientific capacity.

Impacts Overseas

No significant or direct overseas impacts were identified. However, the knowledge created by the project and shared through international scientific and industry networks may results in some positive impacts for pear industries overseas where similar orchard management systems may be relevant.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 4. The project findings and related impacts will contribute to Rural RD&E Priority 3, with some contribution to Priority 1, and to Science and Research Priority 1 and 2.

Table 4: 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 6. Resources 7. Advanced Manufacturing 8. Environmental Change 9. Health

Sources: (Commonwealth of Australia, 2015) and (Australian Government, 2015)

Alignment with the Apple and Pear Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the pear industry are outlined in the Apple & Pear Strategic Investment Plan 2017-2021[3] (Hort Innovation, 2017). Project AP12002 primarily addressed Outcome 3 (Strategy 3.1) with some contribution to Outcome 1 (through Strategy 1.1) and Outcome 2 (Strategy 2.5).

[3] 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.

Three impacts were valued. The first was the net increase in profitability for Australian pear growers because of adoption of improved orchard management systems. The second impact valued was an increase in the total area of pear trees planted. The third impact valued was improved resource allocation efficiency for future pear RD&E.

Impacts Not Valued

Not all of the impacts identified in Table 3 could be valued in the assessment. Specifically, within the scope of the current Hort Innovation impact assessment program, environmental and social impacts were hard to value due to lack of evidence/data on which to base credible assumptions, difficulty in quantifying the causal relationship and pathway between AP12002 and the impact and the complexity of assigning magnitudes and monetary values to the impact.

The economic impacts identified but not valued were:

- Increased industry capacity to maximise orchard potential through implementation of new management systems and practices, and new cultivar x rootstock combinations.

The environmental impacts identified but not valued were:

- Potentially, improved environmental outcomes as a result of increased water use efficiency and reduced export of chemicals off-farm.

The social impacts identified but not valued were:

- Increased knowledge and scientific capacity.
- Potentially, improved regional community well-being from spill-over benefits from more productive and profitable Australian pear producers.

Valuation of Impact 1: Increased Net Profits for Australian Pear Growers

Through the Hort Innovation Apple and Pear Strategic Investment Plan (SIP) 2017 – 2021, the Australian pear industry aspires to create a more profitable industry by driving value growth, reducing costs and equipping industry to re-enter Asia's growing export markets.

Table 5 shows the national, Australian production statistics for the pear industry for the 10-year period from 2008/09 to 2017/18.

Figure 1 and Figure 2 show that total Australian pear production and area has declined over the last ten years. Gross value of production (GVP) also has declined, and pear yields have remained relatively flat.

The investment in AP12002 is likely to have resulted in the adoption of improved orchard management systems and practices, such as optimal high-density planting, cultivar x rootstock combinations, and water and chemical management, that are likely to increase average yields and fruit quality.

Although implementation of new and improved orchard management systems may have a higher average operating cost per hectare, it was assumed that the capital and additional operational costs of adoption would be more than offset by the increased profits generated by the increase in productivity resulting in a net increase in farm profits for Australian pear growers.

Table 5: Australian Pear Production Statistics

Year ended 30 June	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	10-year Average
Area (ha)	5,058	4,273	4,780	4,657	4,523	4,306	4,336	4,256	4,368	n/a	4,506
No of Trees (Total)	1,904,683	1,688,430	1,843,086	1,987,557	1,786,130	1,640,646	1,737,764	1,573,887	1,582,692	1,536,405	1,728,128
No. of Trees (Bearing Age)	1,643,076	1,427,490	1,624,968	1,668,898	1,638,224	1,529,042	1,620,640	1,441,294	1,464,515	1,353,696	1,541,184
Production (tonnes)	120,376	95,111	123,267	119,274	109,206	98,035	105,243	104,928	96,741	103,748	107,593
Yield (kg/tree)	73.3	67.0	76.0	71.5	66.7	64.0	64.9	72.8	66.1	76.6	69.9
GVP ($m)	123.8	74.4	174.9	102.3	114.9	106.8	125.2	90.9	120.6	91.4	112.5

n/a: data not available

Source: ABS (Agricultural Commodities Statistics and Value of Agricultural Commodities Statistics, various years)

Figure 1: Australian Pear Production and Area (2008/09 to 2017/18)

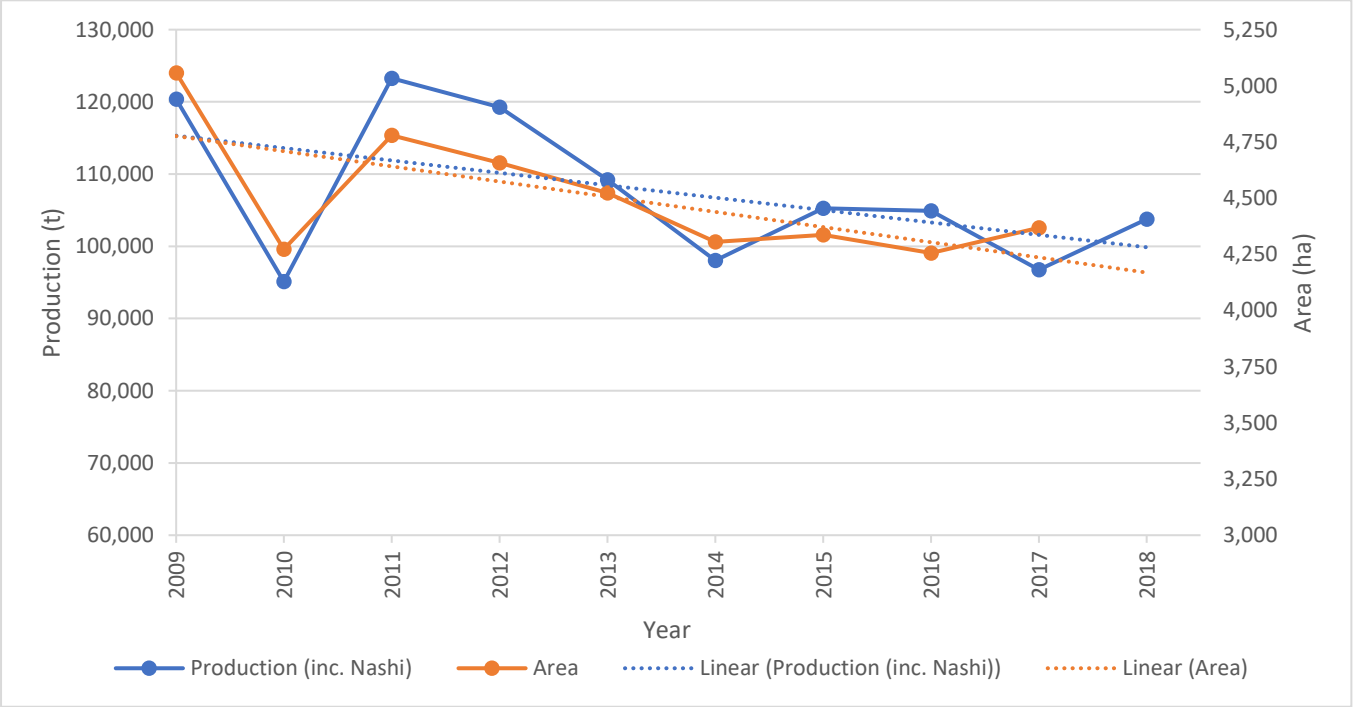
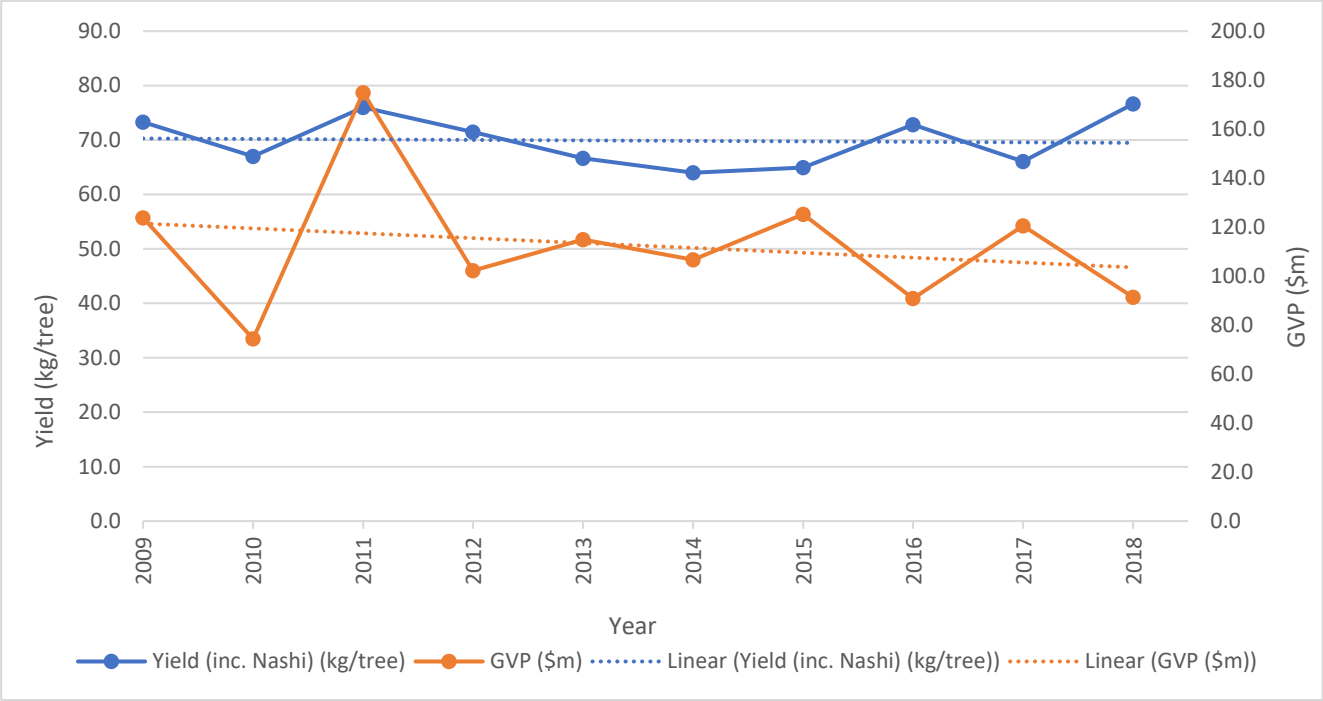


Figure 2: Australian Pear Value and Yields (2008/09 to 2017/18)



Attribution

The expected, potential future net increase in pear profitability will ultimately be realised through a range of RD&E investment, including other investments in the ANPBP and the DJPR 'Premium Fruit to Asia' investment. It is important to recognise that the investment in AP12002 was intended to provide support to the overall ANPBP by developing orchard management systems to maximise productivity and sustain high yields of consistent quality fruit for the pear industry (Adam Briggs, pers. comm., 2019). Therefore, an attribution factor of 30% was applied to the benefits estimated, this attribution was consistent with the attribution assumed in the 2012 ex-ante CBA for the project.

Counterfactual

It was assumed that, in the absence of Hort Innovation investment in AP12002, some alternative investments in orchard management and variety selection would have occurred (e.g. through DPJR and other co-investors such as CSIRO), however it is likely that the level of investment would have been less and the RD&E would have less efficient and/or effective. For this reason, 70% of the impacts were considered driven by to the AP12002 investment.

Valuation of Impact 2: Increased Area of Pears Grown

As noted in Figure 1, total production and the total area of land used to grow Australian pears has been declining since 2008/09. Improved productivity and profitability for pear crops attributable to the investment in AP12002 is likely to contribute to an increase in the area of pear trees planted, trending back toward the 2008/09 peak of approximately 5,000 hectares. It was assumed that the new area of pears would generally replace pasture in terms of land use and that orchards would be planted at the recommended tree density.

Attribution

As for Impact 1, it was considered likely that any area increase, driven by improved productivity and profitability of Australian pears, will have been due to AP12002 as well as a number of other pear orchard management and other related RD&E investments. Consequently, only part of Impact 2 is attributable to AP12002, and for the purposes of this assessment, a 30% attribution factor was assumed.

Counterfactual

Also similar to Impact 1, it was assumed that, in the absence of Hort Innovation investment in AP12002, some alternative RD&E investments in orchard management and variety selection would have occurred, however it is

likely that the level of investment would have been less and the RD&E would have less efficient and/or effective. For this reason, 70% of the impacts were considered driven by the AP12002 investment.

Valuation of Impact 3: Efficiency Gains in Australian Pear RD&E Resource Allocation

Each year, approximately $3.9 million is spent on apple and pear RD&E through Hort Innovation and its funding partners (based on a three-year average) (Hort Innovation, 2018). It was assumed that, based on pear production as a proportion of total apple and pear production, approximately 30% of the annual RD&E investment or approximately $1.16 million p.a. is spent on pear specific RD&E.

AP12002 has contributed to the identification and prioritisation of future pear RD&E investments. Therefore, it was assumed that pear RD&E investment, guided by the framework developed as a result of AP12002, will be made in a more efficient manner than it would have been without the project being funded. It was assumed that there will be an efficiency dividend equivalent to 5% of RD&E spending over a 10-year period. That is, the same outcomes and impact will be achieved with a 5% reduction in the RD&E spending that would have occurred without project AP12002.

Attribution

As for Impacts 1 and 2, it was considered likely that, any the efficiency gain in RD&E resource allocation will likely be due to AP12002 as well as a number of other pear orchard management and other pear RD&E investments. However, the "Smarter pear orchards for high quality and labour efficient production systems" RD&E framework that evolved as a result of project AP12002 was considered a key factor contributing to future resource allocation efficiency. For the purposes of this assessment, an 80% attribution factor to AP12002 was assumed.

Counterfactual

It was assumed that, in the absence of the AP12002 investment, some alternative analysis of pear RD&E requirements, particularly with respect to the ANPBP, would have been completed. For this reason, it was assumed that 70% of the impacts relating to the efficiency dividend were driven by the AP12002 investment.

Summary of Assumptions

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

Table 6: Summary of Assumptions

Variable	Assumption	Source/Comment
Baseline Data		
Average no. of pear trees in the ground (total)	1.7 million	10-year average (see Table 5)
Proportion of trees of bearing age	90%	Derived from ABS statistics (see Table 5)
Average yield (2008/09 to 2017/18)	70 kg/tree	10-year average (see Table 5)
Average GVP of fruit (2008/09 to 2017/18)	$1.05/kg	Derived from ABS statistics (see Table 5)
Farm profit as a proportion of GVP	15%	Conservative analyst assumption. Based on average net orchard profits (before tax) of $0.20 per gross kg of production. 0.20/1.05 = ~19.0% reduced for tax (AgFirst, 2017)
Average yield for new varieties planted post-2018/19	+15%	Driven by the overall pear breeding program (improved new varieties) including improvements attributable to orchard management practice
Average 'price' (value – GVP/kg) of fruit for new	+15%	

varieties post-2018/19 driven by improved average fruit quality		change. AP12002 project documentation
Optimal planting density post-2018/19	2,200 trees/ha	
Time to bearing age (commercial yield) for new varieties post-2018/19	5 years	
Impact 1: Increased net profits for Australia pear growers (replacement area)		
Valuation Assumptions		
Rate of replanting (no. of trees replaced annually)	34,000 (2% of total no. of trees) – new varieties planted utilising new orchard management practices	Analyst assumption
Period of adoption (that is, period over which new plantings utilising new varieties and practices will occur)	15 years	
First year of planting under new varieties/orchard management practices	2019/20	Consistent with publication of final AP12002 outputs in 2018/19
Year maximum new plantings achieved	2033/34	15 years after first year of impact
Risk Factors and Other Variables		
Attribution of increased pear area to AP12002	30%	See above
Counterfactual – proportion of benefits relevant to AP12002	70%	See above
Probability of Output	100%	Analyst assumption – based on successful completion of AP12002
Probability of Outcome	90%	Analyst assumption – accommodates the risk of non-adoption/dis-adoption of project findings in relevant pear growing regions
Probability of Impact	90%	Analyst assumption – accommodates the risk that exogenous factors may prevent the predicted impact from being achieved
Impact 2: Increased area of pears grown		
Valuation Assumptions: with AP12002		
New area of pear tree plantings	700 ha over 10 years	Analyst assumption – based on current area of approximately 4,300 ha trending back to a peak of 5,000 ha.
Pear orchard establishment cost (high-density)	$175,000/ha	Analyst assumption after consultation with industry – assumes other existing infrastructure (e.g. storage, packing facilities, transport etc.) can accommodate additional production
Average total GVP for Australian pears	$112.5 million p.a.	ABS Statistics, Value of Agricultural Commodities Produced (ABS, 2019b)
Equivalent GVP per ha	$26,000/ha	Derived from ABS statistics (approximately $112.5m / 4,300 ha)
Land use replaced	Pasture	Analyst assumption after consultation with industry

Average GVP per ha for pasture	$670/ha	Derived from ABS Statistics, Value of Agricultural Commodities Produced
Net increase in farm GVP per ha	$25,330/ha	$26,000 - $670
First year of planting under new varieties/orchard management practices	2019/20	Consistent with publication of final AP12002 outputs in 2018/19
Year maximum new plantings achieved	2028/29	10 years after first year of impact
Risk Factors and Other Variables		
Attribution of increased pear area to AP12002	30%	See above
Counterfactual – proportion of benefits relevant to AP12002	70%	See above
Probability of Output	100%	Analyst assumption – based on successful completion of AP12002
Probability of Outcome	90%	Analyst assumption – accommodates the risk of non-adoption/dis-adoption of project findings in relevant pear growing regions
Probability of Impact	90%	Analyst assumption – accommodates the risk that exogenous factors may prevent the predicted impact from being achieved
Impact 3: Efficiency Gains in Australian Pear RD&E Resource Allocation		
Valuation Assumptions: with AP12002		
Total average annual expenditure on apple and pear RD&E by Hort Innovation and other funding partners	$3.86 million p.a. (3-year average)	Hort Innovation annual report (2016-2018)
Total annual expenditure on pear RD&E	$1.16 million p.a.	30% of total apple and pear RD&E expenditure, based on Australian pear production as a proportion of total apple and pear production
Efficiency dividend	5%	Analyst assumption.
RD&E saving	$58,000 p.a.	5% x $1.16 million
Year of first impact.	2019/20	Consistent with publication of final AP12002 outputs in 2018/19
Last year of impact	2028/29	10-years after first year of impact – assumes diminishing relevance of RD&E priorities identified from the outputs of AP12002 over time
Risk Factors and Other Variables		
Attribution of efficiency dividend to AP12002	80%	Analyst assumption.
Counterfactual – proportion of benefits relevant to AP12002	70%	Analyst assumption.
Probability of impact	90%	Analyst assumption – accommodates the risk that exogenous factors may prevent the predicted impact from being achieved

Results

All costs and benefits were discounted to 2017/18 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

Table 7 shows the investment criteria estimated for different periods of benefit for the total investment. Table 8 shows the investment criteria estimated for different periods for the Hort Innovation only. The present value of benefits (PVB) for Hort Innovation was estimated by multiplying the total PVB by the proportion of Hort Innovation investment in project AP12002 (56.1%).

Table 7: Investment Criteria for Total Investment in Project AP12002

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.09	0.86	2.32	3.89	5.20	6.22
Present Value of Costs ($m)	3.56	3.56	3.56	3.56	3.56	3.56	3.56
Net Present Value ($m)	-3.56	-3.47	-2.70	-1.24	0.33	1.64	2.66
Benefit-Cost Ratio	0.00	0.03	0.24	0.65	1.09	1.46	1.75
Internal Rate of Return (%)	negative	negative	negative	1.8	5.6	7.2	8.0
MIRR (%)	negative	negative	negative	0.9	4.2	5.1	5.3

Table 8: Investment Criteria for Hort Innovation Investment in Project AP12002

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.05	0.48	1.30	2.18	2.91	3.49
Present Value of Costs ($m)	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Net Present Value ($m)	-1.97	-1.92	-1.49	-0.67	0.21	0.94	1.51
Benefit-Cost Ratio	0.00	0.03	0.24	0.66	1.11	1.48	1.77
Internal Rate of Return (%)	negative	negative	negative	1.8	5.7	7.3	8.1
MIRR (%)	negative	negative	negative	1.0	4.3	5.2	5.3

The annual undiscounted benefit and cost cash flows for the total investment for the duration of AP12002 investment plus 30 years from the last year of investment are shown in Figure 3.

Figure 3: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs

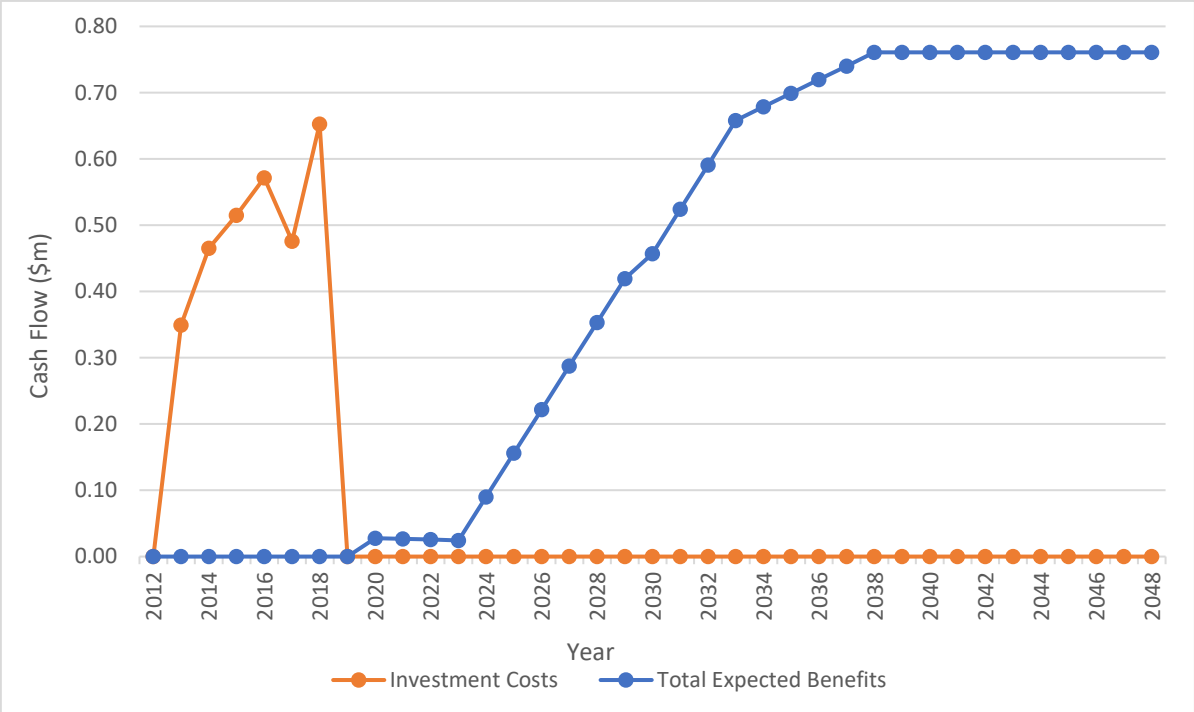


Table 9 shows the contribution of each impact to the total PVB.

Table 9: Contribution of Benefits

Impact	PVB ($m)	% of Total PVB
Impact 1: Net increase in farm profits for Australian pear growers	2.19	35.2%
Impact 2: Increased area of pears grown	3.80	61.2%
Impact 3: Efficiency gains in pear RD&E resource allocation	0.23	3.6%
Total	6.22	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 present the results. The results were moderately sensitive to the discount rate. This is largely due to the benefit cash flows from the planting and fruit bearing of new pear trees occurring in the future and therefore being subjected to more significant discounting.

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

Investment Criteria	Discount rate		
	0%	5%	10%
Present Value of Benefits ($m)	15.07	6.22	2.94
Present Value of Costs ($m)	3.03	3.56	4.18
Net Present Value ($m)	12.04	2.66	-1.24
Benefit-cost ratio	4.97	1.75	0.70

A sensitivity analysis was then undertaken for the assumed attribution of the benefits to the investment in AP12002. Benefits attributable to AP12002 were assumed to be 30% for impacts 1 and 2, and 80% for impact 3. The results are presented in Table 11 and show a moderate sensitivity to the assumed level of attribution.

Table 11: Sensitivity to Attribution of Benefits to AP12002
(Total investment, 30 years)

Investment Criteria	Benefits Attributable to AP12002		
	10%, 10%, 25%	30%, 30%, 80% (base)	50%, 50%, 100%
Present Value of Benefits ($m)	2.07	6.22	10.27
Present Value of Costs ($m)	3.56	3.56	3.56
Net Present Value ($m)	-1.49	2.66	6.71
Benefit-cost ratio	0.58	1.75	2.88

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 12). 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 12: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
High	Medium

Coverage of benefits was assessed as High – the three major benefits identified were quantified.

Confidence in assumptions was rated as Medium. Data used in the analysis were mostly drawn from published and/or credible sources such as Hort Innovation, APAL and the ABS. However, the attribution and counterfactual estimates assumed were analyst derived and were major drivers of the investment criteria reported.

Conclusion

The investment in AP12002 has improved orchard management practices for Australian pears and contributed to improved identification and prioritisation of key areas for future pear RD&E. Consequently, AP12002 is likely to have contributed to improved productivity and profitability for the Australian pear industry as well as to increased efficiency of resource allocation for both public and private funds invested in pear RD&E.

Total funding from all sources for the project was $3.56 million (present value terms). The investment produced estimated total expected benefits of $6.22 million (present value terms). This gave a net present value of $2.66 million, an estimated benefit-cost ratio of 1.8 to 1, an internal rate of return of 8.0% and a modified internal rate of return of 5.3%.

Several environmental and social impacts were also identified but not valued as part of the current assessment. Given the impacts not valued, combined with conservative assumptions made for the principal economic impacts valued, it is reasonable to conclude that the investment criteria reported may be an underestimate of the actual performance of the AP12002 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

ABS	Australian Bureau of Statistics
ANPBP	Australian National Pear Breeding Program
AP	Apple and Pear
APAL	Apple and Pear Australia Limited
AV	Avocado
BH	Buerre Hardy
CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DEDJTR	Department of Economic Development, Jobs, Transport and Resources (Victoria)
DJPR[(a)]	Department of Jobs, Precincts and Regions (Victoria)
FGV	Farm Gate Value
GVP	Gross Value of Production
HIN	Horticulture Industry Networks
Hort Innovation	Horticulture Innovation Australia Limited
MIRR	Modified Internal Rate of Return
MU	Mushroom
N	Nitrogen
NPV	Net Present Value
PFL	Pear Field Laboratory
PVB	Present Value of Benefits
QA	Quince A
R&D	Research and Development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan
TG	Table Grape
UAV	Unmanned Aerial Vehicle
VIC DPI	Department of Primary Industries (Victoria)

(a) Formerly known as DEDJTR and VIC DPI.