ECONOMIC ANALYSIS OF SIX RESEARCH, DEVELOPMENT AND EXTENSION INVESTMENTS BY THE DEPARTMENT OF AGRICULTURE AND FISHERIES (QLD)

[FINAL]

Summary Report

to

The Department of Agriculture and Fisheries Queensland

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by

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Acknowledgments

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Acronyms & Abbreviations

BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CRC	Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries (Queensland)
GDP	Gross Domestic Product
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
NPV	Net Present Value
PVB	Present Value of Benefits
PVC	Present Value of Costs
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation

Glossary of Economic Terms

Cost-benefit analysis (CBA)	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) to Australia, regardless of to whom they accrue.
Investment criteria	Measures of the economic worth of an investment such as Net Present Value, Benefit Cost Ratio, and Internal Rate of Return.
Present Value of Costs (PVC)	The discounted value of RD&E investment costs.
Present Value of Benefits (PVB)	The discounted value of benefits.
Net Present Value (NPV)	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. PVB - PVC.
Benefit-Cost Ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Internal Rate of Return (IRR)	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits is equal to present value of costs.
Modified Internal Rate of Return (MIRR)	The MIRR is a modified IRR estimated so that any cash inflows from an investment are assumed re-invested at the rate of the cost of capital (a designated re-investment rate).

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Executive Summary

This report presents the results of a series of cost-benefit analyses (CBA) of completed research, development and extension (RD&E) investments made by the Department of Agriculture and Fisheries, Queensland (DAF).

DAF required an analysis of six project and project cluster investments. The project and project cluster investments were:

- Investment 1: Avocado Cluster (Project Investments AV14000 and AV17005)
- Investment 2: Engineered Wood Products (Project Investment PNB 407-1516: Increasing the value of under-utilised forest resources through the development of advanced engineered wood products)
- Investment 3: Food Cluster (ten food-oriented RD&E project investments spanning the period 2016/17 to 2020/21)
- Investment 4: FutureBeef (Project Investments E.INV.1412 and L.GBF.1802)
- Investment 5: Supply Chain Model – Asian Markets (Project Investment AM15002: Serviced supply chains: Monitoring and modelling to improve the quality of Australian fresh produce into Asian markets)
- Investment 6: Wambiana (a long-term, ongoing investment comprised of nine discrete investments funded over the period 1995/96 to 2020/21)

The analyses were carried out to demonstrate accountability and the value of the Queensland Government's contribution to RD&E investment across a range of industries and disciplines. The six investments were all supported by DAF resources, as well as by Research and Development Corporations (RDCs) including Horticulture Innovation Australia, Forest and Wood Products Australia, and Meat and Livestock Australia. Other funding external to DAF included contributions by the Australian Government Innovation Connections grants program, the University of the Sunshine Coast, other state government departments (e.g. the Department of Jobs, Precincts and Regions Victoria), various leading industry bodies (e.g. Avocados Australia) and individual partner businesses (e.g. Manbulloo), and other research funding partners/ organisations.

As each of the six investments was partly funded by DAF, this report addresses the individual return to:

- The total investment in each project including funding by DAF, other funding agencies, and any investment provided by researchers and other parties, and
- The specific resource investment provided by DAF only.

Available documentation was assembled for each project or project cluster, with assistance from DAF personnel and others involved with the investments and associated industries. Documentation included the original project proposals, project agreements, milestone reports, final reports where available, budget information for each investment (including variations), and other relevant reports.

Each of the six analyses provides a description of the individual project or cluster of projects including objectives, RD&E input costs (cash and in-kind) by contributor and by financial year, activities, outputs, outcomes, and potential and/or actual impacts. Impacts are first described qualitatively according to their contribution to the triple bottom line categories of economic, environmental, and social impacts. Some of the identified impacts were then valued in monetary terms.

The economic analyses were carried out using the current guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018). Impacts were estimated for up to 30 years from the year of last investment in each project/project cluster. The DAF contribution to the total investment made in each of the six projects/clusters varied from 22.2% to 59.6% (present value terms). A degree of conservatism was used when finalising assumptions. Sensitivity analyses were undertaken for several assumptions that had the greatest degree of uncertainty or for those variables that were seen to be key drivers of the investment criteria.

Some identified impacts were not quantified, this was mainly due to:

- A suspected weak or uncertain scientific or causal relationship between the research investment and the actual research and development (R&D) outcomes and associated impacts.
- The magnitude of the value of the impact was considered to be only minor relative to the impacts valued.
- A lack of credible evidence/data on which to base assumptions.

Once each of the six individual analyses were completed, the undiscounted cash flows (benefits and costs) from each analysis were combined to generate a set of aggregate investment criteria across all six investments. The tables below present the investment criteria for the total investment and the DAF investment in each of the six investments respectively.

The investments were evaluated using a 5% discount rate, with benefits valued over 30 years from the last year of investment. All costs and benefits were expressed in 2019/20 real dollar terms and discounted to 2019/20. In addition, the bottom row in each table shows the investment criteria for the aggregate investment in all six individual projects/project clusters (investment areas).

Investment Criteria for the Total Investment by Project/Project Cluster

Investment Area	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**BCR**	**IRR (%)**	**MIRR (%)**
Avocado Cluster (Project Investments AV14000 and AV17005)	37.77	4.16	33.61	9.09	38.88	15.33
Engineered Wood Products (Project Investment PNB 407-1516)	6.93	1.27	5.66	5.47	19.50	10.40
Food Cluster (ten food-oriented RD&E project investments spanning the period 2016/17 to 2020/21)	4.58	1.27	3.31	3.60	15.30	9.10
FutureBeef (Project Investments E.INV.1412 and L.GBF.1802)	20.61	3.64	16.97	5.66	66.45	17.66
Supply Chain Model – Asian Markets (Project Investment AM15002)	45.08	19.16	25.93	2.35	12.04	8.07
Wambiana (a long-term, ongoing investment comprised of nine discrete investments funded over the period 1995/96 to 2020/21)	132.88	12.06	120.82	11.02	25.86	35.65
Aggregate investment criteria	**247.85**	**41.56**	**206.29**	**5.96**	**25.54**	**17.46**

Investment Criteria for the DAF Investment by Project/Project Cluster

Investment Area	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**BCR**	**IRR (%)**	**MIRR (%)**
Avocado Cluster (Project Investments AV14000 and AV17005)	12.90	1.50	11.40	8.58	31.79	13.75
Engineered Wood Products (Project Investment PNB 407-1516)	2.58	0.47	2.11	5.49	19.70	10.40
Food Cluster (ten food-oriented RD&E project investments spanning the period 2016/17 to 2020/21)	2.70	0.75	1.95	3.60	15.20	9.10
FutureBeef (Project Investments E.INV.1412 and L.GBF.1802)	12.69	2.17	10.51	5.83	133.71	24.34
Supply Chain Model – Asian Markets (Project Investment AM15002)	10.09	4.26	5.83	2.37	12.18	8.12
Wambiana (a long-term, ongoing investment comprised of nine discrete investments funded over the period 1995/96 to 2020/21)	58.47	5.22	53.25	11.20	27.46	46.58
Aggregate investment criteria	**99.43**	**14.37**	**85.06**	**6.92**	**27.44**	**17.60**

1. Introduction

This report presents the results of cost-benefit analyses (CBA) of a discrete set of research, development and extension (RD&E) investments made by the Department of Agriculture and Fisheries, Queensland (DAF) and its predecessors, with support from other research funding bodies.

Ascertaining the extent of impacts that have accrued as a result of these investments can demonstrate to other stakeholders that RD&E investments made by DAF are delivering real, positive impacts. In addition, it can inform DAF RD&E management about performance from past investments as well as provide possible guidance for future allocation of RD&E resources.

The investments were made across a range of Queensland (QLD) primary industries including livestock production/grazing (two investments), horticulture (two investments), wood products (one investment), and supply chains (one investment). The investments were:

- Investment 1: A cluster of two avocado RD&E investments (Project AV14000 and AV17005)
- Investment 2: A single engineered wood products investment (Project PNB 407-1516: Increasing the value of under-utilised forest resources through development of advanced engineered wood products)
- Investment 3: A cluster of ten food RD&E investments supported by DAF and the Australian Government Innovation Grants Program spanning the period 2016/17 to 2020/21
- Investment 4: Investment in FutureBeef across two projects (E.INV.1412 and L.GBF.1802) funded from 2013/14 to 2021/22
- Investment 5: A single supply chain research project (AM15002: Serviced supply chains: Monitoring and modelling to improve the quality of Australian fresh produce into Asian markets)
- Investment 6: A long-term grazing trial RD&E investment at Wambiana (QLD) comprised of nine discrete investments funded over the period 1995/96 to 2020/21

A summary of methods used in the analysis is provided in Section 2, including the steps involved in the evaluation of each individual investment. Section 3 reports the investment criteria for each of the six investments as well as investment criteria for the aggregate investment. A brief conclusion is provided in Section 4. Appendices A to F provide the detailed impact assessments and analyses for each of the six investments.

2. Method

The evaluation approach used in this analysis followed guidelines that are now well accepted within the Australian primary industry research sector including Rural Research and Development Corporations (RDCs), Cooperative Research Centres (CRCs) and some universities. The evaluation includes both qualitative and quantitative approaches with the latter using CBA as a primary tool. The evaluation was conducted in accord with the current guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

Each investment was evaluated through the following steps:

1. Information from any original project documentation, including proposals and schedules, progress reports, and other relevant reports, was assembled with assistance from DAF personnel.
2. An initial description of the relevant background, objectives, RD&E costs, activities, outputs, and expected outcomes and impacts was drafted for each of the six investments. Additional information needs were then identified.
3. The actual and/or potential impacts from each investment were identified and described in a triple bottom line context. Some of these impacts were then valued as part of the CBA.
4. Telephone and/or email contact was made with relevant project personnel (i.e. Principal Investigators) and the initial draft project description sent to them for perusal and comment, together with specific information requests.
5. Further information was assembled where appropriate from publications and consultation with other project stakeholders (e.g. industry and other DAF researchers).
6. Some analyses proceeded through several drafts, both internally within the evaluation team as well as externally via Principal Investigators and other reviewers.
7. Draft reports for each investment were provided to DAF management for comment.
8. Comments on each of the draft reports were addressed and incorporated into a final report that was provided to DAF management.

In general, the factors that drive the investment criteria for research and development (R&D) include:

- The cost of the RD&E.
- The magnitude of the net benefit per unit of production affected; this net benefit per unit also takes into account any additional costs of implementation/usage.
- The quantity of production affected by the RD&E, in turn a function of the size of the target audience and/or applicable area, and the level of initial and maximum adoption ultimately expected, the expected commencement year of adoption and the level of adoption in the intervening years.
- The discount rate.
- An attribution factor that can apply when the specific project or investment being considered is only one of several pieces of research or activity that have contributed to the impact being valued.
- The assumptions associated with the ‘without RD&E’ scenario, referred to as the ‘counterfactual’.

CBAs were conducted individually on all six investments to generate investment criteria for each project or project cluster. The Present Value of Benefits (PVB) and Present Value of Investment Costs (PVC) were used to estimate investment criteria of Net Present Value (NPV) and Benefit-Cost Ratio (BCR) at a discount rate of 5%. The Internal Rate of Return

(IRR) was estimated from the annual net cash flows. The Modified Internal Rate of Return (MIRR) for each investment also was estimated. The MIRR is a modified IRR estimated so that any positive cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate). For these analyses, the re-investment rate was set at 5% as required by the CRRDC. These terms are defined in the Glossary of Economic Terms at the beginning of this report.

All costs and benefits were expressed in 2019/20 real dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) and discounted to 2019/20. A 30-year benefit time frame was used in all analyses, with benefits estimated for up to 30 years from the year of last investment in each project or project cluster. Total investment costs for each project included the expenditure on the project by DAF and the industry RDC (where applicable), as well as any other resources contributed by third parties. Investment criteria were estimated and reported for the total investment as well as for the investment by DAF.

A degree of conservatism was used when making specific assumptions. Sensitivity analyses were undertaken for several assumptions that had the greatest degree of uncertainty or for those that were seen to be key drivers of the investment criteria.

Some identified impacts were not quantified mainly due to factors such as:

- A suspected weak or uncertain scientific or causal relationship between the research investment and the associated outputs, outcomes and impacts.
- The magnitude of the value of the impact was thought to be only minor relative to the impacts valued.
- A lack of evidence/ data on which to base credible assumptions for valuation.

Once each of the six individual analyses was finalised, the undiscounted cash flows (benefits and costs) from each analysis were combined to provide the basis for the estimation of aggregate investment criteria, generated for the total investment and for the DAF investment separately, across all six investments combined.

3. Summary of Results

Aggregate investment criteria estimated for both the total investment and the DAF investment alone and summarised in Table 1 (Total) and Table 2 (DAF) for each of the six investments analysed at a 5% discount rate and 30 years after the last year of investment. The investment criteria first are presented by project and then with the cash flows for the six investments aggregated.

Further details on each of the investments analysed and the associated results are provided in the six individual evaluation reports presented in Appendices A to F.

Table 1: Investment Criteria for the Total Investment by Investment Area (discount rate 5%, 30 years from last year of investment)

Investment Area	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**BCR**	**IRR (%)**	**MIRR (%)**
Avocado Cluster (Project Investments AV14000 and AV17005)	37.77	4.16	33.61	9.09	38.88	15.33
Engineered Wood Products (Project Investment PNB 407-1516)	6.93	1.27	5.66	5.47	19.50	10.40
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Wambiana (a long-term, ongoing investment comprised of nine discrete investments funded over the period 1995/96 to 2020/21)	132.88	12.06	120.82	11.02	25.86	35.65
Aggregate investment criteria	**247.85**	**41.56**	**206.29**	**5.96**	**25.54**	**17.46**

Table 2: Investment Criteria for the DAF Investment by Investment Area
(discount rate 5%, 30 years from last year of investment)

Investment Area	PVB[(a)] ($m)	PVC ($m)	NPV ($m)	BCR	IRR (%)	MIRR (%)
Avocado Cluster (Project Investments AV14000 and AV17005)	12.90	1.50	11.40	8.58	31.79	13.75
Engineered Wood Products (Project Investment PNB 407-1516)	2.58	0.47	2.11	5.49	19.70	10.40
Food Cluster (ten food-oriented RD&E project investments spanning the period 2016/17 to 2020/21)	2.70	0.75	1.95	3.60	15.20	9.10
FutureBeef (Project Investments E.INV.1412 and L.GBF.1802)	12.69	2.17	10.51	5.83	133.71	24.34
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Wambiana (a long-term, ongoing investment comprised of nine discrete investments funded over the period 1995/96 to 2020/21)	58.47	5.22	53.25	11.20	27.46	46.58
Aggregate investment criteria	**99.43**	**14.37**	**85.06**	**6.92**	**27.44**	**17.60**

(a) The DAF PVB in each individual evaluation was estimated by multiplying the total PVB by the proportion of real DAF investment in the particular project/program evaluated.

The PVCs in Table 2 (DAF investment only) compared to those in Table 1 (Total investment) demonstrate the importance of DAF funding in all of the six investments. As a proportion of total funding in each of the six investments, DAF funding varied from approximately 22.2% to 59.6% with a weighted average of 34.6% across all six investments (present value terms).

The DAF PVB for each investment was estimated by multiplying the total benefit cash flow by the DAF proportion of real investment (undiscounted). The DAF BCR of 6.92 is notably higher than the total investment BCR of 5.96. This likely reflects the relative contribution and timing of the DAF investment costs.

4. Conclusions

All six of the investments analysed provided positive NPVs at a 5% discount rate. The BCRs ranged from 2.35 to 11.02 to 1 for the total investment analysis for the 30-year period from the year of last investment. The highest BCR was provided by the long-term grazing trial RD&E investment at Wambiana QLD.

Any comparisons between the results for the individual investments should be made with some caution due to the uncertainties involved in some assumptions and the differing industries, types of research, and valuation frameworks used across the six individual evaluations.

Across the six investments the aggregate BCR for the total aggregate investment was estimated at 5.96 to 1, the aggregate IRR was 25.5%, and the aggregate MIRR 17.5%.

References

CRRDC (2018), *Cross-RDC Impact Assessment Program: Guidelines*, Updated April 2018 – Version 2, April 2018, CRRDC, Canberra. Retrieved from: http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA-Guidelines-V.2.pdf

Appendices

The following table lists the titles of the individual impact assessment reports that form the appendices to the 2021 DAF Aggregate Summary Report (six evaluations).

Table 3: Individual Impact Assessment Report Titles: Assessment of DAF Investment in Six RD&E Projects/ Programs 2021

Appendix Reference	**Report Title**
Appendix A	An Impact Assessment of DAF Investment a Cluster of Two Avocado RD&E Projects (AV14000 and AV17005)
Appendix B	An Impact Assessment of DAF Investment in Project PNB 407-1516: Increasing the value of under-utilised forest resources through the development of advanced engineered wood products
Appendix C	An Impact Assessment of DAF Investment in a Cluster of Ten Food RD&E Projects
Appendix D	An Impact Assessment of Investment in FutureBeef (Project codes E.INV.1412 and L.GBF.1802)
Appendix E	An Impact Assessment of Investment in Serviced Supply Chains: Monitoring and Modelling to Improve the Quality of Australian Fresh Produce into Asian Markets (Horticulture Innovation Australia Frontiers Asian Markets Fund Project: AM15002)
Appendix F	An Impact Assessment of DAF Investment into the Long-Term Grazing Trial at Wambiana QLD 1998-2022

Appendix A: An Impact Assessment of DAF Investment a Cluster of Two Avocado RD&E Projects (AV14000 and AV17005)

Acknowledgments

Lynda Bull, Executive Support Officer, Agri-Science Queensland, Department of Agriculture and Fisheries

Wayne Hall, Executive Director, Agri-Science Queensland, Department of Agriculture and Fisheries

David Innes, Director, Subtropical Fruit and Genetic Improvement in Horticulture and Forestry Sciences, Department of Agriculture and Fisheries, Queensland

Simon Newett, Principal Extension Horticulturist, Department of Agriculture and Fisheries, Queensland

Abbreviations

AAL	Avocados Australia Limited
CBA	Cost Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries – Queensland
Hort Innovation	Horticulture Innovation Australia Limited
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
RDC	Research and Development Corporation
RFID	Radio-Frequency Identification
SIP	Strategic Investment Plan
USQ	University of Southern Queensland

Executive Summary

This report presents the results of an impact assessment of a Queensland Department of Agriculture and Fisheries (DAF) investment in a cluster of two projects associated with avocado quality and productivity. The projects were predominantly funded by DAF and Horticulture Innovation Australia Limited (Hort Innovation). The projects were undertaken by DAF over the years ending June 2015 to June 2022.

Each project is first described qualitatively using a logical framework that included project objectives, activities and outputs, outcomes and impacts. Impacts were then categorised into a triple bottom line framework. Principal impacts were then valued.

The cost-benefit analysis was conducted according to the current Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018). Benefits were estimated for a range of time frames up to 30 years from the last year of investment (2021/22). Past and future cash flows in 2019/20 dollars were discounted to the year 1999/20 using a discount rate of 5% to estimate the investment criteria.

The large investment in this cluster of two projects, and their outputs and outcomes to date, have been important in driving increased productivity and profitability of the Australian avocado industry. The pathway to these impacts has been through an increase in yield and quality for some growers, as well as a reduction in costs along the value chain.

Total funding from all sources over the project duration was approximately $4.16 million (present value terms). The value of total potential benefits due to the project are estimated at $37.8 million (present value terms). This result generated an estimated net present value of $33.6 million, a benefit-cost ratio of 9.09 to 1, an internal rate of return of 38.9% and a modified internal rate of return of 15.3%.

As there were several potential impacts identified that were not valued in monetary terms, it is likely that the investment criteria reported may have undervalued the full value of benefits delivered by the investment.

1. Evaluation Methods

The evaluation approach follows general evaluation guidelines that now are well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses cost-benefit analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, and potential and actual 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. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the limited time and resources available for undertaking the evaluation. However, the impacts valued are deemed to represent the principal benefits delivered by the project.

2. Background and Rationale

Industry Background
The Australian avocado industry is one of Australia's 'growth' horticultural industries as illustrated in Table A1 below.

Table A1: Avocado Industry Performance (years ended June 2014-2020)

Year ended June	Production (tonnes)	Farmgate value ($m)	Export value ($m)
2014	48,715	297	5.6
2015	57,595	331	6.4
2016	66,716	412	9.2
2017	65,992	374	12.5
2018	77,032	543	11.6
2019	85,545	444	19.7
2020	87,546	450	25.0

Sources: Facts at a Glance for the Australian avocado industry-2017/18 (Avocados Australia, 2018) and Hort Innovation (2019/20).

While avocados are grown in all Australian states and the Northern Territory, production is dominated by Queensland followed by Western Australia; together these two states produced 95% of avocados in 2019/20. Due to the broad range of climatic conditions and locations where avocados are grown, they are produced nearly all year round. Two varieties of avocados dominate the industry: Hass (78%) and Shepard (19%) (Hort Innovation, 2020).

Australian consumption of avocados, as well as exports, have increased in line with the production increase. Based on new plantings, production of Australian avocados is expected to increase significantly in the next few years. Avocado exports were small at 2.3% of production in 2017/18, but the proportion of production that is exported has increased to nearly 5% of production in 2020.

The marketing and research and development (R&D) activities of the avocado industry are guided by the avocado Strategic Investment Plan (SIP). The activities are funded by levies payable on avocados produced in Australia; the marketing and R&D levy funds are managed by Hort Innovation.

The previous avocado Industry Strategic Plan expired in 2015 and placed emphasis on development of the domestic market, increased production for year-round supply, and the maintenance of demand and price via marketing programs and supply of consistent quality avocados. The current SIP has been driven by levy payers and addresses the Australian avocado industry's needs from 2017 to 2021. Strategies and priorities in the Plan have been driven by a set of four desired outcomes (Hort Innovation, 2017):

1. By 2021, domestic demand for Australian avocados has increased by at least 20%.
2. By 2021, over 90 per cent of avocados received by consumers will meet or exceed their expectations of quality.
3. By 2021, over 10 per cent of production will be exported to markets where customers have a willingness and capacity to pay a premium for Australian avocados.
4. By 2021, productivity (marketable yield per hectare) has improved by 15 per cent on average, without increased production costs per kilogram.

Rationale for the Investment

Inconsistent supply of high-quality avocados was identified as an important issue limiting profitability and development of the Australian avocado industry. One of the important issues leading to inconsistent supply was the occurrence of irregular bearing. While reducing the incidence of irregular bearing was central to improving the consistency of supply, such reductions in irregular bearing needed to be managed carefully, as combined with increasing yields, alternate bearing issues could then develop.

Inconsistent supply of avocados from year to year created year to year negative impacts along the avocado supply chain. These included additional costs and other management impacts due to disrupted planning including preparations for staffing and cash flows.

Various issues had been identified as contributing to irregular bearing including climatic conditions (particularly during flowering), various factors affecting fruit shedding such as the management of disease and nutrition, canopy management and irrigation, and issues associated with pollination. Project AV14000 was developed by DAF to provide knowledge and management guidelines to assist growers take steps to improve yields and quality of avocados, as well as minimise the incidence of irregular and alternate bearing.

In addition to addressing irregular bearing, in 2019, there was perceived to be a continuing need to improve avocado quality and reduce cost of production to expand the domestic market, increase exports and compete with growing avocado imports into Australia.

Following AV14000, an Australia-wide extension project, was then developed to enhance and continue to extend existing and new best management practices to both existing and new avocado growers, advisers and businesses along the supply chain including wholesalers. This industry extension project was developed by DAF and the industry association Avocados Australia Limited (AAL); the project involved also the state agricultural agency in Western Australia (Department of Primary industries and Regional Development (DPIRD)).

3. Investment Details

Summary of Projects Assessed
The investment in the two projects assessed was, and is being made, in the years ending June 2015 to June 2022. DAF was the lead research agency and Hort Innovation the principal external funding organisation. The project codes, title, key research personnel, and funding periods for each investment are summarised in Table A2. Logical Frameworks for each project are provided separately in Table A3.

Table A2: Summary of Avocado Projects Included in the Avocado Cluster

Project Code	Title	Key Personnel	Funding Period
AV14000	Achieving More Consistent Yields of Quality Fruit in the Australian Avocado Industry	Simon Newett, Project Leader and Principal Extension Horticulturist, Department of Agriculture and Fisheries, Queensland	Years ending 30 June 2015 to 30 June 2018
AV17005	Avocado Industry Development and Extension	Simon Newett, Project Leader and Principal Extension Horticulturist, Department of Agriculture and Fisheries, Queensland John Tyas, Chief Executive Officer, Avocados Australia	Years ending 30 June 2019 to September 2022

Table A3: Logical Frameworks for the Two Avocado RD&E Projects

Project AV14000: Achieving more consistent yields of quality fruit in the Australian avocado industry	
Objectives and Specific Strategies	The overall aim of the project was to provide Australian avocado growers with the knowledge required to implement practices that will lead to more consistent high yields of good quality fruit. Specific strategies within this overall aim were: 1. Engage commercial avocado growers in a series of regional farm workshops where they will develop a better understanding of avocado phenology and how to implement practices that will result in more consistent yields of high-quality fruit. There will be an emphasis on strategies to minimise the occurrence and development of irregular bearing. 2. Encourage growers to become more observant in their orchards particularly at flowering time so that they can make appropriate management decisions to improve and maintain fruit set. This may include instructing growers on how to carry out their own small scale trials to test changes in management practices. 3. Encourage growers to make use of the 'Growing' section of the industry's electronic 'Best Practice Resource' (BPR) to get the most up-to date information on growing avocados. This will be achieved by promoting the BPR whenever possible and keeping it current with engaging and 'grower friendly' information. The information will be presented in a way that helps develop a basic understanding of the topics as well as covering more advanced management practices.

	4. Review the best practice guidelines for avocado nutrition, update where necessary and extend them to growers.
Activities	The principal project activities included: • The project assembled the latest information associated with flowering, fruit-set and fruit retention that related to irregular bearing. • A series of grower workshops was held throughout eight major avocado growing regions of Australia, ranging from North Queensland to Western Australia. The workshops were designed to provide growers with knowledge to encourage management practices that would deliver more consistent yields of high-quality avocados. • Growers were encouraged to monitor trees during flowering, fruit-set and fruit shedding periods and to react with appropriate management practices to optimise fruit-set and fruit retention. • The project team and growers were involved in monitoring of flowering and fruit-set across 28 orchards, in conjunction with the use of data loggers for monitoring temperature and humidity. • The existing BPR was updated and knowledge of its importance was extended to growers. • A focused study and update of good avocado nutritional practices was carried out; this included a workshop for nutrition experts. The previous guidelines were based on a previously popular avocado variety (Fuerte) and were inappropriate for the newer popular Hass variety. Therefore, good avocado nutritional practices required an updated version. • The project supported the project leader to attend the 9th World Avocado Congress in 2015 in Peru and a four-day pre-congress tour of four new Peruvian exporting orchards. The project leader co-organised a grower study tour of cutting edge orchards in Chile for 12 Australian participants immediately following the Congress in Peru (Simon Newett, pers. comm., March,2021).
Outputs	• Information on the latest management information relevant to irregular bearing and alternate bearing was assembled. • A total of 42 grower workshops were held in eight avocado growing regions across five states; some of these workshops were organised by the project and some by Avocados Australia. • Total attendance at the workshops was 2,613, with coverage estimated to be greater than 60% of the estimated 682 avocado growers in Australia. • The data from the tree monitoring activity in relation to fruitset and irregular bearing were analysed and results presented at the workshops mentioned above; outputs from these analyses were made available on the BPR. • The review and updating of the BPR was achieved and the material and its availability was further communicated to growers. • Three new YouTube videos on management practices were produced, shown at the grower workshops, and made available via the BPR. • Customised ‘Avo Alert’ lists were produced for each of the eight main production regions for each month of the year; these were designed to alert growers to the orchard practices due. • The applicable findings from the South American activities (last dot point activity above) were extended to the Australian avocado industry, presented at workshops and made available on the BPR.
Outcomes	• Management practice changes by some growers that will deliver higher and more consistent yield of good quality fruit, increase fruit size,

	reduce irregular bearing, and reduce the likelihood of development and severity of alternate bearing. • The management practice changes were expected to be delivered by the knowledge imparted by the workshops on irregular bearing, the increased use of the BPR, and the additional nutritional management guidelines available and their promotion. • Some reduction in year to year variability of the quantity and quality of avocados that flow along the supply chain to market. • While grower practice change and smoothing along the supply chain is expected, evidence of these expected changes is not available and has not been sought (Simon Newett, pers. comm., July 2019). • While further information has not been formally sought, there is definitely a greater awareness and understanding of the issue amongst growers as evidenced by the following (Simon Newett, pers comm., March 2021): o the greater importance placed on introducing pollinators (mainly honey bees) at flowering, o keen interest in the research into alternative pollinators (e.g. project PH16002), o the inclusion of pollinising varieties in new plantings in at-risk regions, o closer monitoring of environmental conditions at flowering (e.g. installation of automatic weather stations), o greater interest in being able to measure carbohydrate levels in trees (commissioning of project AV19006), o passionate grower support for the continuation of the work commenced by project AV16005 ('Maximising yield and reducing seasonal variation'), o attempts to increase humidity at flowering through irrigation and the use of overhead sprinklers, o more interest in canopy management for optimising light penetration for better flowering, and o a greater effort to optimise tree health through irrigation and nutrition in the current season to ensure a productive canopy for generating the carbohydrate levels required for the next season's flowering and fruitset.
Impacts	• Potential increases in avocado yields and quality for a number of Australian growers. • Reduced costs along the supply chain due to more consistent year to year throughputs allowing improved planning for resources required. • A potential increase in positive regional spillover impacts from future gains in productivity by avocado growers and their supply chains.
Project AV17005: Avocado Industry Development and Extension	
Objectives	The overall objective of the project is to improve Australian avocado orchard productivity fruit quality and profitability through the promotion of best practice. This is to be achieved by delivering a range of events and resources to assist the avocado industry access, understand, and complement best practice information. While the project is promoting and supporting uptake of best practice, the research to develop the best practice has been undertaken through a number of Avocado Research and Development (R&D) Fund investments.

	The combined investments contribute to improved productivity, fruit quality and associated profitability.

Activities	<u>Management</u>
	• A Project Reference Group (PRG) was formed to oversee the project; the PRG included growers, consultants, project team members (DAF and AAL) and representatives from DPIRD and Hort Innovation.
	• Annual work plans were developed in consultation with the PRG.
	• A Monitoring and Evaluation (M&E) plan was developed that specified the expected outputs from the project and both intermediate and end point outcomes.
	• Also, a Communication Strategy was developed as well as a Stakeholder Management Plan and a Risk Management Plan.
	
	Project activities that followed included:
	• Attendance of some members at World Avocado Congress.
	• Monthly Avo Alerts were produced and distributed by the PRG.
	
	<u>Regional Forums</u>
	• DAF and AAL worked together to plan and deliver a series of Regional Forums.
	• The one-day Regional Forums targeted avocado growers and included corporate producers, consultants and re-sellers due to their perceived influence on growers.
	• The primary aim of the Regional Forums was to provide information and learning opportunities to growers on best management practice that lead to high productivity and quality.
	• A number of forums were held across a range of avocado growing regions in the various states; due to COVID-19 restrictions, five of the eight Forums in 2020 were held as online webinars engaging keynote speakers from Australia, Spain, Chile and California. Growers have requested that more of these webinars be conducted in addition to the scheduled Regional Forums (Simon Newett, pers. comm., March 2021).
	• Separate sessions during the webinars were held at each forum and included:
	  ○ An industry update: this included industry trends and the future outlook, the R&D and marketing programs, and key industry issues; as well, the session elicited feedback from growers on key issues for potential R&D investment.
	  ○ A best practice session: this session aimed to increase knowledge and adoption and further promote the Best Practice Resource (BPR) Library.
	  ○ A farm walk session was planned: this session aimed to demonstrate key principles in the best practice session; this session did not take place.
	  ○ Consideration was given to the farm walk session taking place via video technology; however, it was ruled out based on travel restrictions, the lack of interesting material close to the home base and the considerable production time required to do a good enough job to make it interesting (Simon Newett, pers. comm., March 2021).

	Foundation Workshops • DAF personnel planned and prepared resources for these workshops with promotional assistance from AAL. • The aim of the Foundation Workshops was to provide information on best management practices including nutrition, irrigation and root rot control. • The Foundation Workshops were to target new avocado growers, re-sellers and emerging consultants; it was argued that re-sellers and new consultants often have more direct contact with growers than the contact possible from the handful of extension staff available. • The workshops were to include information presentations, field visits and interaction with successful farm managers. • However, the Foundation Workshops did not take place as scheduled. The interaction and practical needs of the curriculum also ruled them out from being delivered by webinars. The workshops were postponed and are one of the reasons for seeking an extension for the project to September 2022 (Simon Newett, pers. comm., March 2021). Advanced Management Workshops • Three Advanced Management Workshops were planned and are being held. Each of the three is a review of a key management topic. • The first is irrigation involving a comprehensive literature search, a survey of current avocado irrigation practices across all eight production regions of Australia, and a survey of avocado irrigation trends in five other countries. A final face-to-face 'summit' over two days is to be held with leading Australian growers and consultants and an international speaker where the above information will be discussed and recommendations made to update the current irrigation recommendations, identify opportunities and identify research gaps (Simon Newett, pers. comm., March 2021). • The 'summit' has been postponed several times but is due to be held in May of 2021 this year (another reason for the project extension). • Comprehensive reports from each of the three reviews will be made available to growers on the Best Practice Resource (BPR) where all other information generated by the project is posted. It is likely that key outcomes will also be presented at future activities (Simon Newett, pers. comm., 2021). Other Communication Activities • A number of other communication activities were planned and carried out.
Outputs	Management • The PRG provided added purposeful direction to the project activities and outputs. • Annual work plans were produced to aid in project management. • A M&E plan was developed that specified the expected outputs from the project and both intermediate and end-point outcomes to be pursued.

	• The Communication Strategy, Stakeholder Management Plan and a Risk Management Plan all gave purposeful direction to the project and raised the awareness of issues that needed to be addressed in project execution. <u>Regional Forums</u> • Outputs included the presentation and discussion of best practice management and opportunities for attendees to update/learn new skills that might be appropriate for their specific situations. • Copies of presentations and key points from the forums were produced and made available to attendees following the event via the BPR Library. <u>Foundation Workshops</u> • Potential outputs include the presentation and discussion of best practice management and opportunities for new growers and other industry personnel likely to be able to influence new growers; the workshops are being held at a range of locations across avocado growing regions. • Workshop material will be made available for later reference via the BPR Library. <u>Advanced Management Workshops</u> Outputs from the first of the three management workshops will include information on current irrigation practices by region, irrigation trends in other countries, and discussions held leading to potential updating of current irrigation recommendations and future priorities for research investment (Simon Newett, pers. comm., 2021). <u>Other Communication Outputs</u> • Project team members held meetings with wholesalers in capital cities. • Other communication products were developed including you-tube videos and posters. • Quarterly summaries of research abstracts were prepared and reported in the Industry Magazine 'Talking Avocados'.
Outcomes	• Increased awareness and knowledge by growers and others of best management practices for producing avocados. • Potentially, future higher levels of uptake of best production practice by avocado growers as well as informed advice from their advisors and other participants in the value chain. • Potentially, higher grower productivity and improved fruit quality achieved by some growers due to the project activities, their associated outputs, and the various communication products delivered by the project. • Growers have been asked to complete an evaluation after each Regional Forum (including webinars) and Foundation Workshop, renamed AvoSkills. Summaries are included in the minutes generated after each Regional Forum and webinar (minutes are uploaded to the BPR) (Simon Newett, pers. comm., March 2021). • Key data from the evaluation of the Regional Forums include answers to the question addressing intentions of making management changes as a result of attending the Forums that addressed soil health, canopy management, irrigation and nutrition, and plant growth regulators.

	• Of 1,294 attendees at all five Forums, 59-88% answered that they would be making changes (average across the five Forums was 71%). • Of the 100 attendees at the first AvoSkills event, 97% of participants reported that they found the course either very useful or extremely useful, 82% said that the course improved their knowledge either significantly or very significantly and 68% intended to make changes to their practices as a result of participating in the course. To help assist in monitoring adoption and practice change, a pre-course survey was conducted before the workshop to gauge the group's current level of avocado agronomy. These participants will be surveyed again at the end of the project to assess whether involvement in the workshop and participation in the project events has led to an increase in their knowledge and changes to their practices (Simon Newett, pers. comm., 2021). • The project team was overwhelmed by expressions of interest for the AvoSkills WA course and raised the intended limit of 40 students to 60; these were selected from 89 applicants. Participants included a cross section of industry members including new growers, farm supervisors, general farm staff, agronomists, resellers (five) and an agricultural college teacher. Evaluation revealed that 98% of participants found the course either useful, very useful or extremely useful, 78% said that the course improved their knowledge either significantly or very significantly and 93% intended to make changes to their practices as a result of participating in the course (Simon Newett, pers. comm., 2021).
Impacts	• Potentially future increases in avocado productivity and quality leading to an increase in grower profitability. • A potential increase in positive regional spillover impacts from future gains in productivity by avocado growers and their supply chains. • Increased capability and capacity by other 'grower influencers' external to traditional extension personnel.

4. Project Investment

Nominal Investment
Table A4 shows the nominal, annual investment (cash and in-kind) for each of the two projects in the cluster.

Table A4: Annual Investment by Project and Source of Funds (nominal $)

Project	**Year ending 30 June**	**DAF**	**Hort Innovation**	**AAL**	**Total**
AV14000[(a)]	2015	63,982	35,500	0	99,482
	2016	342,336	189,942	0	532,278
	2017	256,861	142,517	0	399,378
	2018	165,795	91,990	0	257,785
Subtotal	**AV14000**	**828,974**	**459,949**	0	**1,288,923**
AV17005[(b)]	2019	52,590	133,339	81,991	267,840
	2020	153,535	389,279	239,138	781,952
	2021	139,302	353,193	216,969	709,464
	2022[(c)]	103,450	262,291	161,128	526,869
Subtotal	**AV17005**	**448,877**	**1,138,102**	**699,146**	**2,286,125**
Total (AV14000 + AV17005)		**1,277,851**	**1,598,051**	**699,146**	**3,575,048**

(a) Source: Signed Research Agreement between Hort Innovation and DAF 23rd March 2015
(b) Source: Signed Research Agreement between Hort Innovation and DAF 10th April 2019
(c) Note: An extension was approved to allow time to conduct events that had to be postponed due to Covid (Simon Newett, pers, comm., March 2021)

Program Management Costs
For the Hort Innovation investment the cost of managing and administration of funding was added to the Hort Innovation contribution for the project via a management cost multiplier (x1.162). 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 A4.

For the DAF and the AAL investment the management and administration costs for the project are assumed already built into the nominal dollar amounts appearing in Table A4.

Real Investment and Extension Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 $ terms using the Implicit Gross Domestic Product (GDP) Deflator index (ABS, 2020). No additional costs of extension were included as the project already involved a high level of industry participation through growers and Avocado Australia Limited.

5. Impacts

Impact on Industry Productivity and Profitability
The combined investment in the two projects in this cluster commenced in the year ended Jun 2015 and will be completed by September 2022.

Both projects will have contributed to industry productivity and profitability gains to Australian avocado growers via:

- Increased yields and quality of avocado fruit for a proportion of Australian growers influenced by the investments, and
- A reduction in supply chain costs (largely due to the improvement in yields and quality).

Any increase in productivity and profitability that benefits avocado growers are likely to be shared along the supply chain including input suppliers, transport and storage operators, wholesalers, retailers, exporters and consumers.

Social Impact
Positive spillover impacts will be experienced by regional communities connected with avocado growing. Such impacts will be driven by increased grower incomes and their associated supply chain businesses.

Maintained or increased applied science and extension capability and capacity will be delivered, particularly in DAF and in DPIRD.

Summary of Impacts
An overview of impacts in a triple bottom line categorisation is shown in Table A5.

Table A5: Categories of Impacts from the Investment in Projects AV14000 and AV17005

Economic	Environmental	Social
Increased productivity and profitability for a proportion of Australian avocado growers, including yield and quality improvements. Reduced costs along the supply chain due to more consistent year to year throughputs allowing improved planning for resources required. Associated productivity and profitability gains will be shared along the input and product supply chains with businesses, transporters, exporters, wholesalers, exporters and consumers.	Potential for reduced wastage of avocados by growers and their supply chains with an associated reduction in environmental costs of disposal.	Increased spillovers to regional communities from increased incomes for avocado growers and their associated supply chain businesses. Maintained or increased applied science and extension capability and capacity in public sector agencies (DAF and DPIRD).

Distribution of Benefits along the Supply Chains
Some of the potential benefits from the increased productivity and profitability due the project investments will be shared along the supply chain including growers, supply chain businesses including agents, wholesalers, retailers, exporters and consumers. according to relevant supply and demand elasticities that exist along the supply chains.

Public versus Private Impacts
The impacts identified from the investment are predominantly private, namely accruing to growers and private sector supply chains. Some public benefits will be produced including spillovers to regional communities from enhanced grower and supply chain member incomes, as well as a maintained/increased applied science and extension capability and capacity in some public sector agencies.

Impacts Overseas
It is likely that there will be some positive quality impacts in countries importing Australian avocados

Match with National and State Priorities
The Australian Government's Science and Research Priorities and Rural RD&E Priorities are reproduced in Table A6. The investment is mostly relevant to Rural RD&E Priority 4 and to Science and Research Priority 1.

Table A6: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities[a] (est. 2015)	**Science and Research Priorities[b] (est. 2016)**
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

(a) Source: Commonwealth of Australia (2015)
(b) Source: Office of the Chief Scientist (2016)

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision-making around future investment are reproduced in Table A7.

The investment primarily addresses QLD Science and Research Priority 1. In terms of the guides to investment, the investment is likely to have a real future impact through increased horticultural exports. The project was well supported and funded by others external to the QLD Government (e.g. Hort innovation) and had a distinctive angle as QLD growers dominate the production of Australian avocados.

Table A7: Revised QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally-enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Chief Scientist Queensland (2015)

6. Valuation of Impacts

Impacts Valued
The impact valued in the quantitative analysis is the expected contribution to an increase in avocado productivity and profitability by some Australian avocado growers. This valuation is supported via assumptions regarding:

- the number of avocado growers influenced by the cluster investment to change practices,
- the yield and price increase gained by the growers influenced, and
- a cost reduction along the product supply chain largely attributed to quality improvements

Avocado Producers Influenced to Change Practices
Based on information from the Regional Forums, a proportion of avocado growers are assumed to have changed their practices as a result of the two avocado extension investments. This proportion is assumed to apply to both yield and quality increases, although the two types of improvements may not necessarily apply to the same growers. For purposes of valuation, the first year of any improvement is assumed to be in the year ended June 2019 and the maximum influence is assumed to be in 2023. Specific assumptions are provided in Table A8.

The Yield and Quality Improvements
The assumptions for the yield and quality increases have had to be made conservatively as survey data of growers to assess the value of practice changes was not available. Specific assumptions used for valuing the yield and quality improvements are provided in Table A8.

Cost Reduction along the Product Supply Chain
The costs along the supply chain are assumed to have been reduced by a reduction in year to year variability of avocados flowing along the chain, allowing more efficient planning for application of resources. This cost reduction is assumed to have been influenced in the main by the impact of Project AV14000.

A summary of all assumptions for valuing impacts from the cluster investment is provided in Table A8.

Table A8: Summary of Assumptions for Valuing Impacts

Variable	Assumption	Source
Extent and Timing of Avocado Producers Influenced		
Maximum percentage of all avocado growers influenced	20%	Analyst assumption, based conservatively on information from Regional Forums (see outcomes section in Logical Framework
Year of initial influence	Year ended June 2019	Year after Project AV14000 completed and first year of Project AV17005
Year of maximum influence	Year ended June 2023	Year AV17005 completed
Progression of influence	Linear over 5 years from initial influence to maximum influence	Analyst assumption

Yield Improvements		
Average farm gate value of avocado production in Australia	$450 m per annum	Avocados Australia (2020)
Extent of average yield improvement by those influenced	4%	Analyst assumption
Maximum potential value of increased yield	$3.6 m per annum	$450 m x 20% x 4%
Additional costs to secure yield gain	20% of value gain	Analyst assumption
Maximum potential net value increase	$2.88 m per annum	$3.6 m x (1-20%)
Quality Improvements		
Average farm gate value of avocado production in Australia	$450 m per annum	Avocados Australia (2020)
Extent of average quality/price improvement by those influenced	2%	Analyst assumption
Maximum value of increased quality	$1.8 m per annum	$450m x 20% x 2%
Additional costs to secure price gain	10% of value gain	Analyst assumption
Maximum net value increase	$1.62 per annum	$450,000 x (1-10%)
Cost Reduction along the Product Supply Chain		
Value added along the supply chain from grower to retail	$23 m per annum	Avocados Australia (2018)
Proportion of added value contributed by supply chain costs	90%	Agtrans Research
Supply chain costs	$20.7 m per annum	$23m x 90%
Proportion of added value costs influenced by reduced supply chain variability	20%	Agtrans Research
Reduction in supply chain costs due to reduced variability in production	5%	Agtrans Research
Reduction in supply chain costs	$207,000 per annum	$20.7m x 20% x 5%
Attribution and Risk Factors		
Probability of output	100%	Analyst assumptions
Probability of outcomes occurring	75%	
Probability of impact given successful outcome	75%	
Attribution to project investment	90%	

Impacts not Valued

The impacts identified but not valued included:

- The potential for any positive environmental impacts was not valued, that is, the reduced wastage and disposal of fruit due to efficiencies gained along the supply chain.
- The increased spillovers to regional communities from increased profitability of avocado production in Australia. This impact was not valued as any increased economic activity and employment along the product supply chain would be difficult to value, given the number and geographic spread of avocado production systems in Australia.
- The impact of Increased applied science and extension capability and capacity in public sector agencies (DAF and DPIRD) was not valued. This impact was not valued due to insufficient resources/time and the difficulty in assembling appropriate data. Moreover, this impact was already valued in part via its contribution to the outcomes that were valued.

Counterfactual

It is unlikely that the resources required or the expertise brought together in the two projects would have been available other than through the investments. However, it is likely that a small proportion of some of the impacts attributed to the project may have occurred through the traditional extension services. Hence, an attribution factor of 90% was applied to the value of the impacts.

7. 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 investment period plus 30 years from the last year of investment (2021/22) to the final year of benefits assumed.

Investment Criteria
Tables A9 and A10 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table A10, has been estimated by multiplying the total PVB by the DAF proportion of real total investment (34.2%)

Table A9: Investment Criteria for Total Investment in the Avocado Cluster

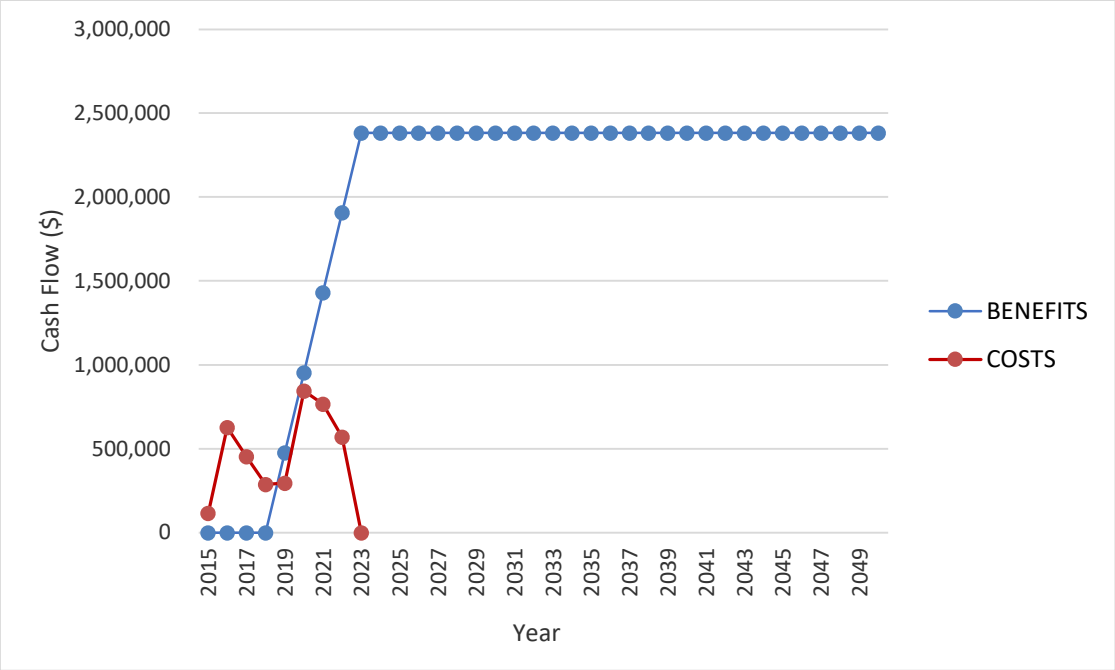
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	4.54	13.90	21.23	26.98	31.48	35.01	37.77
Present value of costs ($m)	4.16	4.16	4.16	4.16	4.16	4.16	4.16
Net present value ($m)	0.39	9.75	17.08	22.82	27.32	30.85	33.61
Benefit-cost ratio	1.09	3.34	5.11	6.49	7.57	8.42	9.09
Internal rate of return (%)	negative	36.05	38.40	38.79	38.86	38.87	38.88
MIRR (%)	no solution	37.35	27.96	22.64	19.29	17.00	15.33

Table A10: Investment Criteria for DAF Investment in the Avocado Cluster

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	1.55	4.75	7.25	9.22	10.75	11.96	12.90
Present value of costs ($m)	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Net present value ($m)	0.05	3.25	5.75	7.71	9.25	10.45	11.40
Benefit-cost ratio	1.03	3.16	4.83	6.13	7.15	7.95	8.58
Internal rate of return (%)	negative	28.39	31.07	31.63	31.76	31.79	31.79
MIRR (%)	no solution	29.79	23.54	19.56	16.95	15.11	13.75

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure A1.

Figure A1: Cash Flow of Undiscounted Total Net Benefits and Total Investment Costs



Conservatism of Impact Valuation

It should be noted that the investment criteria reported above should be considered conservative for the following reasons:

- The impacts have been valued with 2019/20 production of avocados as a base (about 87,000 tonnes). However, Avocados Australia forecasts production by 2025 to be at least 115,000 tonnes (Avocados Australia, 2020). As new growers were specifically targeted in AV17005, it is likely that the increase in production would be quite relevant to the current analysis.
- The reduction in negative environmental impacts from a reduction in disposal costs of damaged fruit was not valued.
- The increased spillovers to regional communities from improved grower and supply chain impacts were not valued
- The impact of increased applied science and extension capability and capacity in public sector agencies was not valued.

Sources of Benefits

There were three sources of benefits valued in the analysis. Table A11 shows estimates of the relative contribution from each source.

Table A11: Contribution of Source of Benefits to Present Value of Benefits (PVB) (Total investment, 30 years)

Source of Benefit	PVB ($m)	Proportion of Total PVB (%)
Yield improvements	23.11	61.18
Quality improvements	13.00	34.42
Supply chain cost reduction	1.66	4.40
Total	**37,77**	**100.00**

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 A12 presents the results that showed a moderate sensitivity to the discount rate, due to the relatively long period of benefits assumed

Table A12: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	76.25	37.77	22.92
Present value of costs ($m)	3.96	4.16	4.40
Net present value ($m)	72.29	33.61	18.52
Benefit-cost ratio	19.24	9.09	5.21

A sensitivity analysis also was carried out on the assumption of the proportion of 2020 avocado production that will be influenced by the two investments via increases in yield and quality. Results are reported in Table A13. The proportion could fall to 1.4% before the yield and quality benefits are outweighed by the investment costs.

Table A13: Sensitivity to Proportion of Production Influenced via Yield and Quality
(Total Investment, 30 years, 5% discount rate)

Investment Criteria	**Proportion of Production Influenced**		
	5%	**20% (Base)**	**30%**
Present value of benefits ($m)	10.69	37.77	55.82
Present value of costs ($m)	4.16	4.16	4.16
Net present value ($m)	6.53	33.61	51.67
Benefit-cost ratio	2.57	9.09	13.43

Confidence Ratings

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 for the benefits valued, including the linkage between the research and the assumed outcomes and impacts.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table A14). 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 A14: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium-High. While there were several benefits identified but not valued, the principal economic impacts from the project were valued.

Confidence in assumptions for the valuation was rated as Medium-Low as some of the assumptions associated with the improved avocado industry performance were not well supported by strong evidence of industry changes that are likely to have occurred due to the two investments.

8. Conclusion

The foregoing assessment presents the results of an analysis of investment in a cluster of two projects associated with quality and productivity in the Australian avocado industry. The projects were jointly funded by DAF, Horticulture Innovation Australia Limited (Hort Innovation), and Avocados Australia Limited (AAL) over the years ending June 2015 to June 2022.

The assessment describes each of the two projects in a logical framework that included project objectives, activities and outputs, outcomes and impacts. Impacts were then were categorised into a triple bottom line framework. Principal impacts were then identified and valued.

The investment in this cluster of two extension projects, and their outputs and outcomes to date, have been important in driving increased productivity and profitability of the Australian avocado industry. The pathway to these impacts has been through an increase in yield and quality for some growers, as well as a reduction in costs along the value chain.

The total investment in the two projects of $4.16 million (present value terms) has been estimated to produce total gross benefits of $37.8 million (present value terms) providing a net present value of $33.6 million, a benefit-cost ratio of 9.09 to 1 (using a 5% discount rate), an internal rate of return of 38.9% and a modified internal rate of return of 15.3%.

The investment criteria reported are likely to have somewhat undervalued the full set of impacts delivered by the investment. The non-valued impacts included spillover regional benefits and some capability and capacity impacts that were only partly valued.

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Appendix B: An Impact Assessment of DAF Investment in Project PNB 407-1516: Increasing the value of under-utilised forest resources through the development of advanced engineered wood products

Acknowledgments

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Abbreviations

ABS	Australian Bureau of Statistics
CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries (Queensland)
EWPs	Engineered Wood Products
FWPA	Forest and Wood Products Australia
GDP	Gross Domestic Product
QLD	Queensland
LVL	Laminated Veneer Lumber
MIRR	Modified Internal Rate of Return
R&D	Research and Development
RD&E	Research, Development and Extension

Executive Summary

The Engineered Wood Products project considered in this evaluation was delivered by the Queensland (QLD) Department of Agriculture and Fisheries (DAF) between June 2016 and October 2019. The research project examined ways to increase the value of under-utilised forest resources through the development of advanced Engineered Wood Products (EWP).

The project has delivered a commercial outcome for the Australian forestry industry. Laminated veneer lumber (LVL) beams are in production and finding ready sales. There is also potential for production of LVL crossarms.

The total investment in the EWP project by all contributors of $1.27 million (present value terms) has been estimated to produce total gross benefits of $6.93 million (present value terms) providing a net present value of $5.66 million, a benefit-cost ratio of 5.5 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 19.5% and a modified internal rate of return of 10.4%.

1. Evaluation Methods

The evaluation approach follows general evaluation guidelines that now are well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses cost-benefit analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, and actual and potential 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. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the likely low relative significance of the impact compared to those that were valued. The impacts valued therefore are deemed to represent the principal benefits delivered by the project.

2. Background and Rationale

The forest industry in Australia is predominantly based on traditional sawing production systems and traditional products. In the hardwood sector, forest growers are experiencing a decline in traditional market sectors and failing to implement best practice forest management due to a lack of viable processing options for lower grade resource.

Worldwide the demand for wood is increasing. This is due to various reasons including the relatively new and growing demand from the mid-rise sector – residential apartments and commercial construction of up to ten stories in height. This new interest is also occurring in Australia due to favourable changes to the National Construction Code, 2016.

Two major drivers of the increased interest in wood are the desire from architects, designers and building owners to use environmentally friendly products such as wood and the increasing interest in using high performance EWPs.

EWPs are high-value construction and appearance grade products manufactured from a range of feedstocks including but not limited to low-value forest residues and sub-optimum quality logs. EWPs exhibit uniform and predictable mechanical properties that are analogous to steel and concrete. EWPs include plywood, laminated veneer lumber (LVL), multi-laminar wood, glulam, cross laminated timber, I-beams, oriented strand board, engineered strand lumber, and parallel strand lumber. One of the major benefits of EWPs is that lower grade materials can be used to produce high performing structural and appearance products. EWPs provide opportunities to improve the utilisation of existing forest resources.

At present, forest residues and low-grade logs in Australia have limited use in value-added products due to technical and economic constraints. As a result, they return minimal value to forest growers. Consequently, this project was to address technical and economic constraints and identify innovative EWPs. The work built upon preliminary findings (e.g., Hague 2013, McGavin *et al*. 2014a, 2014b, 2015, Forestry Tasmania 2015) that show that low-grade plantation hardwood logs and resource blending can be used to create high-value, high-performing products that meet contemporary building needs.

The project addressed the Forest and Wood Products Australia (FWPA) investment plan for *Maximising Product Yields and Values from Current Forest Resources – Recommendation 3 (d) optimising the value of low performing plantations and native forests*. The project was delivered by the Queensland (QLD) Department of Agriculture and Fisheries (DAF), Agri-Sciences QLD.

3. Investment Details

The EWP project is described in a logical framework in Table B1.

Table B1: Project Description in a Logical Framework

PNB 407-1516: Increasing the value of under-utilised forest resources through the development of advanced engineered wood products.	
Project Details	Organisation: DAF, Agri-Sciences. Period: June 2016 to October 2019. Project Leader(s): Dr Rob McGavin
Project Description	The project was to assess technologies suitable for turning low-value by-product into high-value EWPs.
Objectives	• To deliver and validate technologies to transform low-value forest resources into viable, high-value engineered wood construction and appearance grade products suitable for Australian and international markets.
Activities and Outputs	• Identification and appointment of an industry-led project steering committee. The steering committee included forest growers, sawmill and veneer/EWP processors, product end-users, peak industry body representatives and researchers. Industry members were co-investors in the project. • Completion of a scoping study to identify market trends, alternative processing methods, potential EWP opportunities and technical innovations. • Description of the quantities, characteristics, qualities, and locations of available forest resources suitable for new EWP development. This task included a desktop national analysis of QLD resources, drew on existing literature and the completion of field-based case studies. The project identified an ample resource including spotted gum and cypress pine, small diameter logs. • Processing trials were performed on sub-optimal quality native hardwood and cypress pine forest resources to validate qualities and processing characteristics. Most emphasis was placed on spindleless veneering methods which offered higher recovery rates than traditional processing techniques. • Potential 'best bet' products and processes were selected following processing trials and in consultation with the project steering committee. The most prospective EWPs were from the LVL product group. Six LVL products were tested for fire retardation, termites, structural properties, and an assessment of market size was completed. • Economic analyses were completed that outlined the feasibility of using new technologies and protocols to produce EWPs from various forest types. The economic assessments confirmed that the cost of producing veneer from sub-optimum logs is higher than plantation softwood veneer, however high performing products are able to absorb the additional costs. Two-stage LVL products were projected to be highly profitable. • Blending high quality native hardwood veneer and plantation softwood veneer was demonstrated as being advantageous. • Outputs from the research included recommendations in relation to commercial scale EWPs, an understanding of a range of processing methods, 'best bet' products and processes along with user guides detailing optimised EWP designs and manufacturing specifications. Two PhD candidates were trained during the project.

	• Industry engagement and technological transfer activities encouraged the adoption of project outputs. Extension included direct engagement with industry through the project steering committee, broader industry meetings, presentations, seminars, field days, fact sheets, distribution of product samples, website updates, use of FWPA communication channels, reports, and journal papers.
Outcomes	• A more viable market for forest residues and low-grade resources. • Utilisation of small diameter logs to assist with improved silviculture management of both native forests and plantations. • Improved profitability of forest enterprises with a viable market for under-utilised forest resources. • Growth in the forest processing sector through simple processing systems that use low-cost infrastructure to produce high-value saleable products. • Increased forest value and increased market share of locally produced construction and appearance products. • Enhanced profitability and greater efficiency in resource conversion. • Increased returns for forest growers and processors. • Greater investment in the industry through the value chain. • As a result of the project veneer-based bridge beams, rounded bollards and posts are now being commercially manufactured and marketed. Opportunities also exist for electricity network crossarms and large diameter posts and beams suitable for mid-rise buildings. • Veneer-based bridge beams are lighter, stronger, and more durable than difficult-to-source hardwood girders. In the first year after project completion Big River Group, an industry partner in the project, had sold and installed 150 new veneer beams valued at $600,000.
Impacts	• More profitable sawmilling operations via the production of new EWPs e.g., veneer-based bridge beams. • Reduced forestry waste and reduced harvest pressure on the higher grade native hardwood resource. • Additional capacity with researchers and industry gaining forest product value-adding skills and knowledge. Two PhD candidates trained during the project. • Social – increased industry social licence to operate with reduced waste, more responsible use of resources. • Social – a contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD and Australian forest growing and processing industry.

4. Project Investment

Nominal Investment

Table B2 shows annual investment (cash and in-kind) in project PNB 407-1516. DAF funding was supported with contributions from FWPA, researchers, and industry. Researcher contributions were received from the University of the Sunshine Coast (USC). Industry contributions were received from leading sawmill and veneer/EWP processors and industry bodies including the EWP Association of Australia, Parkside, Hurfords, Austral, HQP, Timber Queensland, Big River Group, and TPC Solutions.

Table B2: Annual Total Investment in PNB 407-1516 Engineered Wood Products for Years Ending June 2016 to June 2020 (nominal $)

Year ended 30 June	DAF ($)	FPWA ($)	Industry ($)	Total ($)
2016	0	70,000	0	70,000
2017	173,008	60,000	169,351	402,359
2018	117,642	40,000	115,155	272,797
2019	103,376	40,000	101,191	244,567
2020	5,974	35,000	5,848	46,822
Totals	**400,000**	**245,000**	**391,545**	**1,036,545**

Source: FWPA research agreement

Program Management Costs

For the DAF investment, the management and administration costs for the project are assumed already built into the nominal dollar amounts appearing in Table B2. The salary multiplier used by DAF was 2.85 (Wayne Hall, pers. comm., July 2017). For the FWPA investment a multiplier of 1.15 was added to account for the organisation's management and administration costs and was based on the share of 'payments to suppliers and employees' in total expenditure sourced from FWPA's Statement of Cash Flows (FWPA Annual Report, various years). This multiplier was then applied to FWPA contributions shown in Table B2. It was further assumed that industry contributions already included an allowance for project management and administration costs and no further multiplier was required.

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 GDP Deflator index (ABS, 2020). The project was delivered in partnership with a steering committee that included leading sawmill and veneer/EWP processors who contributed their own resources to the research and who were enthusiastic about adoption of project outputs. The project also delivered broad industry engagement and made use of FWPA's extension networks. No additional, post-project extension costs were expended.

5. Impacts

Impacts across the Triple Bottom Line
An overview of potential project impacts in a triple bottom line categorisation is shown in Table B3.

Table B3: Categories of Impacts from the Investment

Economic	Environmental	Social
More profitable sawmilling operations via the production of new EWPs e.g., veneer-based bridge beams.	Reduced forestry waste and reduced harvest pressure on higher grade native hardwood resource.	Additional capacity with researchers and industry gaining forest product value-adding skills and knowledge. Two PhD candidates trained during the project. Increased industry social licence to operate with reduced waste, more responsible use of resources. A contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD and Australian forest growing and processing industry.

Public versus Private Impacts
The EWP project will generate both private and public benefits. The principal private impact is more profitable sawmilling operations via the production of new EWPs. Public impacts may include superior environmental outcomes and social impacts such as increased capacity, increased social licence for the forestry industry and spillover benefits for regional communities.

Impacts Accruing to other Primary Industries
Value-adding capacity developed by DAF researchers may also be relevant to the further development of other QLD primary industries.

Distribution of Benefits along the Supply Chain
Private benefits from the EWP project will accrue to plantation managers, native forest managers, logistics operations, forest product processors and manufacturers (sawmills). The share of benefits realised by each link in the supply chain will depend on both short- and long-term supply and demand elasticities.

Impacts Overseas
Value-added forestry products produced using spindleless veneer technology from a combination of softwood and eucalyptus hardwood may also be relevant to overseas countries which grow Australian hardwoods. It is understood that South America and the Iberian Peninsula (Spain and Portugal) both have large eucalyptus-based plantation industries.

Match with National and State Priorities

The Australian Government's Science and Research Priorities and Rural Research, Development and Extension (RD&E) Priorities are reproduced in Table B4. The investment in the EWP project is relevant to Rural RD&E Priority 1 and 4, and to Science and Research Priority 6, with some potential contribution to Priority 5.

Table B4: Australian Government Research Priorities

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

(a) Source: Commonwealth of Australia (2015)
(b) Source: Office of the Chief Scientist (2015)

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision making around future investment are reproduced in Table B5.

Table B5: QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Chief Scientist Queensland (2015)

The investment addressed QLD Science and Research Priority 1, with some contribution to Priority 6. In terms of the guides to investment, the investment is likely to have a real future impact on forest industries and, through FWPA and industry participation, was well supported by others external to the QLD Government.

6. Valuation of Impacts

Impacts Valued
Analyses were undertaken for total impacts that included future expected impacts. 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 investment criteria.

A single EWP project impact was valued in monetary terms:

- Profit from production of new EWPs.

Impacts not Valued
Not all impacts identified in Table B3 could be valued in the assessment. Some environmental and social impacts are difficult to value and may involve the application of non-market valuation techniques that were beyond the scope of the current assessment. Impacts were not valued due to:

- A lack of evidence and/or data on which to base credible assumptions,
- The complexity of assigning monetary values to the impact (e.g., capacity built),
- Uncertainty regarding the pathways to impact, and
- The relative importance of the impact compared to the primary impacts valued.

The following impacts were not valued in the current analysis:

- Reduced forestry waste and reduced harvest pressure on higher grade native hardwood resource.
- Additional capacity with researchers and industry gaining forest product value-adding skills and knowledge. Two PhD candidates trained during the project.
- Increased industry social licence to operate with reduced waste, more responsible use of resources.
- A contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD and Australian forest growing and processing industry.

Valued Impact 1: Profit from production of new EWPs
The project concluded that significant volumes of sub-optimal logs were available and suitable for processing using spindleless veneer technology before manufacture into LVL beams and crossarms. Comprehensive financial analysis completed as part of the project showed that LVL beams and crossarms were highly profitable and one year after project completion Big River Group was manufacturing and selling veneer beams produced using project recommendations. This study assumes that there is sufficient resource and commercial interest to support two medium, sized LVL plants each producing 15,000 cubic metres of veneer beam and crossarm.

Attribution of Impacts to the Project
The project builds on a strong pre-existing knowledge base developed by the Principal Investigator and others. This knowledge base included the potential for spindleless veneer technology to make better use of small, sub-optimal sawlogs. Consequently a 50% attribution factor has been assumed.

Counterfactual
In the absence of this project with expertise and funding provided by DAF, it is assumed that it is 50% likely that project benefits would have been generated through a FWPA and industry funded investment.

Summary of Assumptions
A summary of assumptions and data sources is provided in Table B6.

Table B6: Summary of Assumptions

Variable	Assumption	Source
Profit from production of new EWPs		
Annual production of LVL beams and crossarms from sub-optimal logs as a result of the project.	30,000m^3	Two medium sized production plants each producing 15,000m^3 of beams and crossarms per year. Size estimate derived from capital cost description provided in the project final report (McGavin *et al*. 2019).
Profit on LVL beam and crossarm production.	\$100/m^3	Analyst assumption after considering capital and operating costs of both veneer and LVL manufacture and next best use of sub-optimal logs.
Year of first benefit.	2020/21	One year after project completion in 2019/20, Big River Group was already making and selling LVL beams.
Year of maximum benefit.	2025/26	Analyst assumption that it takes five years of production to reach maximum capacity and sales potential.
Probability of output.	100%	Valuable outputs have been delivered.
Probability of outcome	85%	While commercial LVL production is underway, sales might not reach volumes assumed.
Probability of impact	85%	Commercial LVL production may not sustain ongoing profitability as assumed.
Attribution of impact to the project.	50%	See above text.
Counterfactual	50%	See above text.

7. Results

All past costs were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2020). 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 investment period plus 30 years from the last year of investment (2019/20) to the final year of benefits assumed.

Investment Criteria
Table B7 and B8 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment, respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table B8, was estimated by multiplying the total PVB by the DAF proportion of real investment (37.2%).

Table B7: Investment Criteria for Total RD&E Investment in the EWP Project

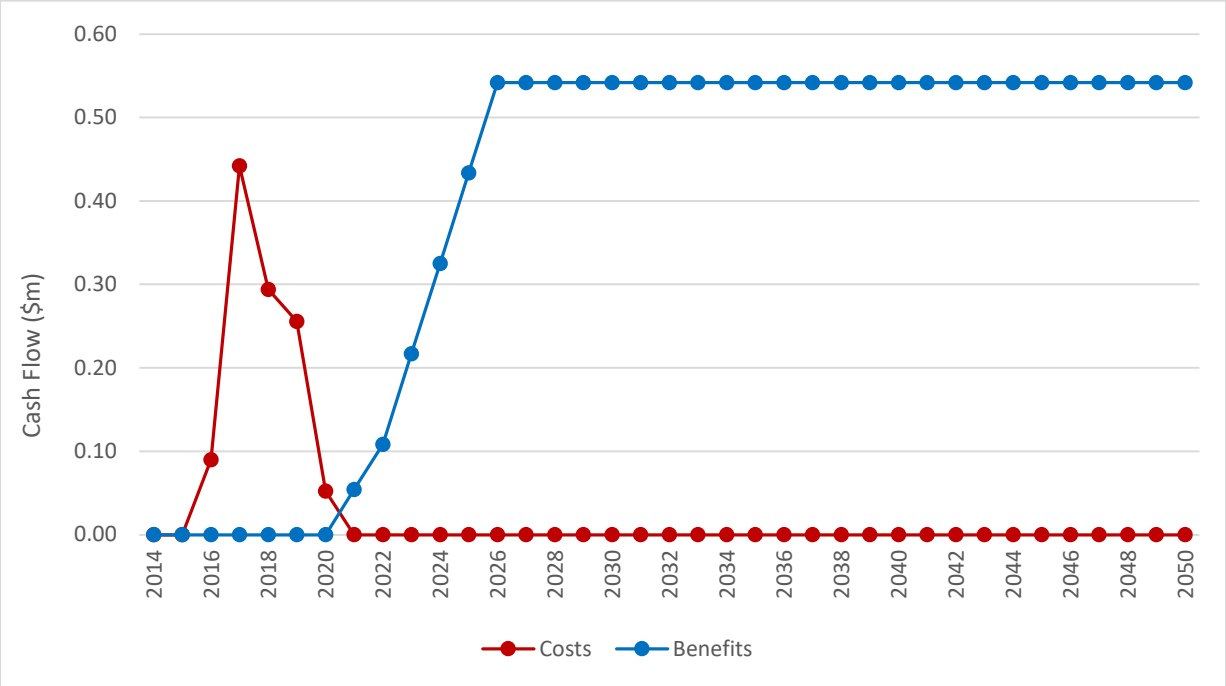
Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.94	2.78	4.22	5.35	6.24	6.93
Present value of costs ($m)	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Net present value ($m)	-1.27	-0.32	1.52	2.96	4.09	4.97	5.66
Benefit-cost ratio (BCR)	0.00	0.75	2.20	3.34	4.23	4.93	5.47
Internal rate of return (IRR) (%)	Negative	0.1	15.1	18.1	19.0	19.4	19.5
Modified IRR (%)	Negative	1.6	11.1	11.9	11.5	10.9	10.4

Table B8: Investment Criteria for DAF RD&E Investment in the EWP Project

Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.35	1.03	1.57	1.99	2.32	2.58
Present value of costs ($m)	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Net present value ($m)	-0.47	-0.12	0.57	1.10	1.52	1.85	2.11
Benefit-cost ratio	0.00	0.75	2.21	3.35	4.24	4.95	5.49
Internal rate of return (IRR) (%)	Negative	0.1	15.3	18.3	19.2	19.6	19.7
Modified IRR (%)	Negative	1.7	11.1	11.9	11.5	11.0	10.4

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the investment period plus 30 years from the last year of investment are shown in Figure B1.

Figure B1: Annual Cash Flow of Undiscounted Total Net 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. Results are reported in Table B9. The results show that the investment criteria are sensitive to the discount rate.

Table B9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	14.68	6.93	3.85
Present value of costs ($m)	1.13	1.27	1.41
Net present value ($m)	13.55	5.66	2.44
Benefit-cost ratio	12.95	5.47	2.73

A sensitivity analysis was then completed on the assumed profit on LVL products after allowing for capital costs, operating costs and next best sawlog uses (Table B10). Results show that profit would need to fall to approximately $18m^3 before the project would fail to break even i.e., project costs exceed project benefits.

Table B10: Sensitivity to Profit on LVL Beams and Crossarms
(Total investment, 30 years, 5% discount rate)

Investment Criteria	Profit on LVL Products		
	$18/m^3	$50/m^3	$100/m^3 (base)
Present value of benefits ($m)	1.25	3.46	6.93
Present value of costs ($m)	1.27	1.27	1.27
Net present value ($m)	-0.02	2.20	5.66
Benefit-cost ratio	0.99	2.74	5.47

Confidence Ratings and other Findings

The investment analysis results 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 B11). 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 B11: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
High	Medium-Low

Coverage of benefits was assessed as High. The principal benefit, profit from production of new engineered wood products was quantified.

Confidence in assumptions was rated as Medium-Low. Though key data and assumptions were drawn from credible sources (e.g., comprehensive financial analysis of LVL production provided in McGavin *et al.* 2019), there were a number of potential drivers of the impacts where values were estimated by the analyst.

8. Conclusion

The investment in increasing the value of under-utilised forest resources through the development of advanced EWPs has delivered a commercial outcome for the Australian forestry industry. Big River Group sales of LVL beans are brisk and there is potential for production of LVL crossarms.

The total investment in the EWP project by all contributors of $1.27 million (present value terms) has been estimated to produce total gross benefits of $6.93 million (present value terms) providing a net present value of $5.66 million, a benefit-cost ratio of 5.5 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 19.5% and a modified internal rate of return of 10.4%.

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Appendix C: An Impact Assessment of DAF Investment in a Cluster of Ten Food RD&E Projects

Acknowledgments

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Abbreviations

AFDS	Agri-Food Data Sciences (of DAF)
CBA	Cost-Benefit Analysis
CRC	Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries (Queensland)
DPI	(NSW) Department of Primary Industries
FRDC	Fisheries Research and Development Corporation
GE	gene-edited
GM	genetically modified
GVP	Gross Value of Production
HPP	High Pressure Processed
IQF	Individual Quick Frozen
NSW	New South Wales
QLD	Queensland

Executive Summary

The Food Cluster considered in this evaluation was delivered by the Queensland (QLD) Department of Agriculture and Fisheries (DAF) between June 2017 and June 2021 and consisted of ten projects. Research projects addressed value-added mango and mandarin products, post-harvest seafood quality, as well as consumer intelligence on frozen seafood, new mango varieties, and gene edited crops.

All projects in the Food Cluster had a strong focus on improving the profitability and sustainability of farming and fishing enterprises. Research was undertaken by DAF and was supported in some projects by the Australian Government Innovative Grants program. Matching contributions were made by farming and fishing enterprises.

Investment in the Food Cluster produced a number of potential impacts; potential impacts valued included facilitation of new value-added mango products, development of new mandarin quick frozen segments, insight on the fresh equivalent eating quality of snap frozen seafood and techniques to reduce post-harvest crustacean loss.

The total investment in the Food Cluster by all contributors of $1.27 million (present value terms) has been estimated to produce total gross benefits of $4.58 million (present value terms) providing a net present value of $3.31 million, a benefit-cost ratio of 3.6 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 15.3% and a modified internal rate of return of 9.1%.

1. Evaluation Methods

The evaluation approach follows general evaluation guidelines that now are well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses cost-benefit analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

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

Some, but not all, of the impacts identified for the cluster were then valued in monetary terms. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the likely low relative significance of the impact compared to those that were valued. The impacts valued therefore are deemed to represent the principal benefits delivered by the cluster. However, as not all impacts were valued, the investment criteria reported represent an underestimate of the performance of the cluster.

2. Background and Rationale

The Queensland (QLD) Department of Agriculture and Fisheries Queensland (DAF) shortlisted ten Food Cluster projects for impact assessment. The impact assessment was to provide insight on how specific Agri-Food Data Sciences (AFDS) capabilities add-value to businesses and how this value could be amplified when projects are combined.

Projects in the cluster addressed:

- Value-adding through product development - these projects have drawn on AFDS product research and development capability to support QLD farmers and food production and processing businesses to create new products or modify existing products that will offer new or additional benefits to the consumer.
- Post-harvest quality - this group of projects draws on AFDS's Post-Harvest Quality (Seafood) capability to work with aquaculture and fisheries industries to maintain quality, protect food safety and reduce losses between harvest and consumption. The research undertaken with this team encompasses all points within supply chains from live/fresh through to processed and packaged products, providing practical tools for adding value to QLD primary production and food processing industries.
- Consumer intelligence - these projects have drawn on AFDS consumer intelligence research and development capability to build deeper and more effective knowledge of key target markets and understanding of consumer behaviour and motivations. These insights are intended to allow QLD businesses to develop, maintain and increase their market share by satisfying consumer demand.

3. Investment Details

The ten projects in the Food Cluster were delivered by DAF and many were supported by the Australian Government Innovative Grants program. Projects span the period 2016/17 to 2020/21. The ten projects were:

1. CF10586: QLD Mandarin Individual Quick Frozen (IQF) Processing Study – Stage 1
2. CF10717: Improving the Survival and Quality of Crabs and Lobsters in Transportation from First Point of Sale to Market
3. CF10767: Manbulloo Frozen Mango Products
4. CF10793: Sensory Benchmarking of 6 Mango Varieties, Compositional Analysis and Export Market Acceptability Testing (Asia)
5. CF10924: QLD Mandarin IQF Food Processing Study – Stage 2
6. CF10939: Stage 2 – Pilot Plant Research into Bottled Mango Nectar (High Pressure Processed (HPP) versus Pasteurised)
7. CF10941: Mango Road – Development of 'Fresh Cut' Mango Products Suitable for Retail
8. CF10961: Sensory Testing of Seafood – Fresh versus Frozen – and Development of Frozen Seafood Recipes: Sensory and Technical Component
9. CF11094: Mango Road Stage 2 – Research on Value-added Mango Products Suitable for Retail
10. HF11568: Consumer Acceptance of Gene Edited Crops

Each of the ten projects is described in a logical framework in Table C1 through to Table C10.

Table C1: CF10586 Mandarin IQF Stage 1 Logical Framework

CF10586: QLD Mandarin Individual Quick Frozen (IQF) Processing Study – Stage 1	
Project Details	Organisation: DAF. Period: April 2017 to June 2018. Project Leader(s): Toni Ferguson and Colin Leung Client: Barcross Investments Pty Ltd.
Background	QLD Imperial Mandarins have a short shelf-life from April through to July. Both the Australian and export markets have high demand for fresh fruit all year round. New approaches to utilising second grade fruit were required. IQF is an opportunity to extend product shelf-life. IQF technology has shown considerable growth in Australian supermarkets and successful products include vegetables and seafood.
Project Description	The project focussed on stage one research, exploring the possibility of peeling three mandarin varieties for IQF segments, utilisation of fruit glaze dip and blast freezing technology to provide a minimally processed frozen product that will maintain shelf-life quality over a 12-month period.
Objectives	• To research and develop initial protocols, processes, and shelf-life for an IQF mandarin product. • To do sensory research profiling for three QLD mandarin varieties.
Activities and Outputs	• Investigate processing optimisation for peeling, freezing, glazing, refreezing, and packaging.

	• Investigate formal processes for shelf-life evaluation of samples as well as sensory panel profiling for three different varieties for suitability for the Chinese/Asian markets. • Self-life assessment over 12 months using analytical chemistry, micro and consumer testing for acceptability. Stage 1 research showed IQF Imperials had an acceptable storage life of up to 9 months, Low Seed Murcott 7 months, and Satsuma 13+ months. • The project delivered stage 1 of IQF mandarin retail pack, stage 1 commercialisation of IQF mandarin bulk pack, and sensory panel profiling results to be used in future commercial and marketing development.
Outcomes (potential)	• Reduced second grade mandarin wastage. • Increased value of first grade mandarins by reducing total market volume. • Increased business revenue through the sale of IQF mandarins. • Increased business portfolio in processed product. • Opportunities for business to export into international markets.
Impacts (potential)	• Economic – profit from development of a new market for second grade mandarin. • Environmental – reduced waste and disposal of second grade fruit. • Capacity – researchers and industry with enhanced fruit processing skills. • Social – a contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD mandarin industry.

Table C2: CF10717 Crab and Lobster Survivability Logical Framework

CF10717: Improving the Survival and Quality of Crabs and Lobsters in Transportation from First Point of Sale to Market	
Project Details	Organisation: DAF. Period: September 2017 to July 2020. Project Leader(s): Sue Poole Client: Fisheries Research and Development Corporation (FRDC).
Background	Rock lobsters, mud crabs and spanner crabs generate $20 million in revenue in NSW. Industry stakeholders have noted that crustaceans suffer quality deterioration from point of capture along the distribution chains, resulting in product downgrading at sale point (Sydney Fish Markets). Downgrade, including death, is caused by stress. It was suggested that both transport vibration and duration are the most likely factors imposing stress to the animal resulting in quality loss and higher mortality rates.
Project Description	It is known that quality loss in crustaceans is often caused by stress imposed along the supply chain. To reduce the likelihood of downgrading of product, there was a need to undertake an examination of the handling and transport issues pertinent to various landing ports, distribution chains and market sales points. Identification of specific stress factors and where they occur would enable development of specific mitigation measures for Industry implementation.
Objectives	• Document current handling practices and transport pathways within the three crustacean industries and identify the factors contributing most to animal stress. • Develop adapted handling and transport protocols that minimise critical stress factors. • Trial amended protocols within commercial operations. • Evaluate success by change in number of downgrades and market price achieved for live product.

	• Extend knowledge to industry sectors and encourage adoption by demonstration of protocols at local port meetings.
Activities and Outputs	• The project delivered an improved understanding of current transport pathways and the factors delivering greatest stress on live crustaceans. The project noted recent, pre-project, improvements in lobster transport protocols to the point where mortality was no longer an issue. • Best practice protocols specific to the two crab species and distance from market. • Direct local Industry interaction for knowledge transfer and protocol demonstration. • Practical concise information precis readily accessible to industry.
Outcomes (potential)	• Improved quality of live crustaceans (crabs) at market, with fewer downgrades. The project targeted a 20% increase in industry revenue. • Greater buyer satisfaction creating increased demand for product. • Effective resource use with avoided waste. • Improved social licence for coastal fishery operators.
Impacts (potential)	• Economic – increased profitability from reduced post-harvest crustacean (crab) loss. • Economic – increased social licence to operate for fishers in NSW coastal waters. • Environmental – reduced waste and disposal of valuable lobsters and crabs. • Capacity – researchers and industry with enhanced seafood management skills. • Social - contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable NSW fishing industry.

Table C3: CF10767 Frozen Mango Products Logical Framework

CF10767: Manbulloo Frozen Mango Products	
Project Details	Organisation: DAF. Period: December 2017 to June 2018. Project Leader(s): Toni Ferguson, Philippa Tyler, and Colin Leung. Client: Manbulloo Limited.
Background	Manbulloo is Australia's largest grower of the Kensington Pride mango variety. Its farms are located in both QLD and the Northern Territory. As part of its long-term plans to expand the business, Manbulloo was looking to develop value-added mango products.
Project Description	Formulate frozen Kensington Pride mango products and test them with Australian consumers.
Objectives	• Product development in laboratory and processing studies. • Map the demographic population of the study, determining purchase and consumption preferences. • Evaluate consumer liking for six frozen mango products: taking into consideration overall liking, appearance, aroma, flavour, and texture. • Capture specific likes and dislikes of the six frozen mango products in order to ascertain any stand-alone positive and/or negative traits. • Determine whether any statistically significant differences exist between the six frozen mango products, and if so, which sample is preferred and why. • Evaluate consumer liking and acceptance of the proposed packaging; including graphics, serving format and price point.

Activities and Outputs	• Laboratory evaluation of recipes for frozen mango cheeks on a stick (two types), frozen mango popsicles, chocolate couverture, frozen mango tubes with and without yoghurt. • Consumer evaluation of value-added products – 120 consumers from a range of relevant demographics. • Mango popsicles (+5% sugar) and pure mango tube were the best performing samples and consumers expressed a willingness to pay $5 per 75-gram pack. • Project reporting including interim and final project reports.
Outcomes	• Progress toward development of a value-added frozen mango product that makes use of second grade Kensington Pride fruit.
Impacts (potential)	• Economic – profit from development of a new market for second grade mango. • Environmental – reduced waste of second grade fruit. • Capacity – researchers and industry with enhanced fruit processing skills. • Social - some contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD and Northern Territory mango industry.

Table C4: CF10793 Mango Variety Sensory Testing Logical Framework

CF10793: Sensory Benchmarking of 6 Mango Varieties, Compositional Analysis and Export Market Acceptability Testing (Asia)	
Project Details	Organisation: DAF. Period: July 2018 to June 2019. Project Leader(s): Philippa Tyler and Colin Leung. Client: Seven Fields Operations.
Background	Seven Fields is an Australian company that grows, packs, and markets premium fresh produce. Seven Fields had two new commercial mango lines (Lady Jane™ and Lady Grace™) which they wished to have evaluated to identify optimal harvest time. A third new variety, Mango 1243, was also subject to sensory testing.
Project Description	Evaluation of early, mid, and late season mango (two cultivars by ten repetitions) photographed to capture blush cover, brix, and titratable acidity, along with sensory panel testing at each time point. The two new mango varieties plus Mango 1243 were compared with established varieties including Kensington Pride, Calypso™, and R2E2 for their acceptance to Chinese consumers.
Objectives	• Document blush coverage on both mango cultivars via photographs taken early, mid, and late season. • Conduct brix and titratable acidity tests on both mango cultivars early, mid, and late season. • Identify changes in organoleptic profile of both mango cultivars at the three time points using a trained sensory panel.
Activities and Outputs	• Trained laboratory technicians conducted replicate assessments of blush coverage (via photographs), brix and titratable acidity for both mango cultivars at three points in time (early, mid, and late season). • A trained sensory panel conducted flesh profiling of both mango cultivars at three points in time (early, mid, and late season). • Both mango varieties exhibited different organoleptic profiles across the tested harvest time points. Notably, the balance between acidic and sweet flavour attributes as well as the fibrousness (of Lady Jane™) imparted the greatest differences. Brix and titratable acidity showed correlation with the

	sensory profiles and blush coverage photos reflected an increase in blush coverage and darkening of blush colour from the various harvest points. • Chinese consumers found the new variety Lady Grace™ to be the most preferred of all six varieties. They also gave a high rating to Lady Jane™ and Mango 1243. • As well as delivering photographs, brix, and titratable acid results, the project reported findings and recommendations from the sensory panel.
Outcomes	• Identification of optimal harvest times to maximise consumer acceptance of the two new mango varieties. • Confidence that the three new varieties are highly acceptable to the Chinese palate.
Impacts (potential)	• Economic – additional profit from sale of three new mango varieties, especially in Asian export markets, when these fruits are harvested at their optimal times. • Capacity – researchers and industry with enhanced mango assessment skills. • Social – a contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD mango industry.

Table C5: CF10586 Mandarin IQF Stage 2 Logical Framework

CF10924: QLD Mandarin IQF Food Processing Study – Stage 2	
Project Details	Organisation: DAF. Period: November 2018 to October 2019. Project Leader(s): Toni Ferguson and Colin Leung. Client: Barcross Investments Pty Ltd.
Background	Following successful completion of IQF processing of QLD mandarins in May 2018, Barcross wished to pursue stage 2 - commercialisation of the opportunity.
Project Description	DAF assisted Barcross in utilising stage 1 pilot plant mandarin IQF processing procedures and in moving the technology to commercialisation.
Objectives	• To commercialise stage 1 IQF research and produce a quick frozen, minimally processed QLD mandarin product.
Activities and Outputs	• Assessment of IQF equipment processing options, partnering with a commercial contract packer to produce frozen mandarin segments. • Contract packer was Farm Fresh Fine Foods Ltd, Bundaberg. • Confidentiality agreement signed between Barcross and contract packer. • Packaging suitability assessment – review of dimensions and materials. IQF mandarins can be manufactured at Farm Fresh Fine Foods through a manual peeling process and a commercial spiral freezer. • Label development including logo, graphics and a digital packet mock up. Retail packs of 700-grams proposed. • Commercial trial with contract packer using enzyme-based methodology developed during stage 1 research. • Contract packer provided Barcross with commercial trial samples for promotion and marketing purposes. • Evaluation of commercial trial including chemistry quality specification, sensory quality specification descriptors, enzyme processing reformation, processing loss with cost analysis, and finished product microbiological testing. • Preparation of waste skin for value-adding opportunities was identified using existing facility equipment (roaster) for further processing.

	• Sensory analysis of defrosted segments indicated that a time frame of between 30 and 40 minutes was when segments were at their peak. • Initial stages of commercialisation would now involve manual peel and bulk packaging prior to further investment in manufacturing automation. • Next steps include a market and business feasibility study. • The project delivered a final written report and IQF mandarin samples from the commercial trial.
Outcomes (potential)	• Reduced second grade mandarin wastage. • Increased value of first grade mandarins by reducing total market volume. • Increased business revenue through the sale of IQF mandarins. • Increased business portfolio in processed product. • Opportunities for business to export into the international market.
Impacts (potential)	• Economic – profit from development of a new market for second grade mandarin. • Environmental – reduced waste and disposal of second grade fruit. • Capacity – researchers and industry with enhanced fruit processing skills. • Social – a contribution to increased regional community wellbeing through spillover benefits from a more productive and profitable QLD mandarin industry.

Table C6: CF10939 Bottled Mango Nectar Logical Framework

CF10939: Stage 2 – Pilot Plant Research into Bottled Mango Nectar (High Pressure Processed (HPP) versus Pasteurised)	
Project Details	Organisation: DAF. Period: October 2018 to May 2019. Project Leader(s): Toni Ferguson, Philippa Tyler, and Colin Leung. Client: Manbulloo Limited.
Background	Manbulloo is a large Australian mango grower whose farms span QLD and the Northern Territory. As part of its long-term plans to expand the business, Manbulloo was looking to develop value-added mango products. Subsequently, DAF designed a development project with Manbulloo and CSIRO using second and third grade Kensington Pride and R2E2 mango varieties.
Project Description	Assist Manbulloo by providing technical expertise to use second and third grade mango to develop new nectar type products for commercialisation.
Objectives	• Investigate the feasibility and most suitable processing option for mango nectar.
Activities and Outputs	• Complete a food processing feasibility study and liaise with HPP food researcher CSIRO on equipment options and suitable nectar products. • Negotiate a confidentiality agreement between Manbulloo and CSIRO. • Complete a research trial comparing a pasteurised nectar product prepared by DAF to a HPP product prepared by CSIRO. HPP is a form of cold pasteurisation which uses water pressure to inactivate bacteria, virus, yeasts, moulds, and parasites. • Undertake consumer research to compare preferences for pasteurised and HPP product. Research showed that consumers could not separate the two nectar products. • Evaluate commercial trial samples for shelf-life and provide Manbulloo with recommendations that address product chemistry, sensory attributes, and results from testing the finished product's microbiology. • Preliminary shelf-life evaluation of samples showed satisfactory results across both food safety and product quality.

	• The project recommended a larger trial to validate results, extended yeast and mould microbiological analysis, continued evaluation of shelf life beyond 5 months, consideration of packaging options, and further discussions with a contract packer to manage the evaluation of next year's production. • The project delivered interim and final written reports.
Outcomes (potential)	• Progress toward development of a value-added mango nectar product that makes use of second and third grade Manbulloo fruit. • Progress toward increased value of first grade fruit by reducing the total volume of mango available on the domestic market. • Progress toward increased business revenue through sales of new value-added products. • Progress toward export of a new value-added Australian mango product. • Progress toward reduction in the waste and disposal of lower grade mango.
Impacts (potential)	• Economic – profit from development of a new market for second grade mango. • Environmental – reduced waste of second and third grade fruit. • Capacity – researchers and industry with enhanced fruit processing skills. • Social - some contribution to increased regional community wellbeing through spillover benefits from a more productive and profitable QLD and Northern Territory mango industry.

Table C7: CF10941 Fresh Cut Mango Product Logical Framework

CF10941: Mango Road – Development of 'Fresh Cut' Mango Product Suitable for Retail	
Project Details	Organisation: DAF. Period: October 2018 to May 2019. Project Leader(s): Toni Ferguson, Philippa Tyler, and Colin Leung. Client: Manbulloo, Mango Road Pty Ltd.
Background	Manbulloo is a large Australian mango grower whose farms span QLD and the Northern Territory. Mango Road Pty Ltd is the mango export arm of Manbulloo. As part of its long-term plans to expand the business and reduce fresh product waste, Manbulloo was looking to develop value-added mango products.
Project Description	Make progress toward the development of a chilled 'fresh cut' mango product with acceptable eating quality and optimal shelf life for retail.
Objectives	• Identify a suitable treatment solution for 'fresh cut' mango. • Evaluation of both Kensington Pride and R2E2 raw materials. • Optimisation of a pilot packaging plant. • Shelf-life evaluation. • Consumer evaluation.
Activities and Outputs	• Development of treatment solutions that deliver appropriate texture, acidification (pH), and flavour optimisation. • Development of suitable portion sizing and processing techniques. • Pilot plant scale packaging optimisation using modified atmosphere gas and barrier film. • Produce samples for shelf-life and consumer evaluation. • Complete shelf-life trials that extend until product failure. • Research and report pH, texture, drip loss, brix, titratable acid, and colour. • Complete sensory testing and report appearance, flavour, aroma, texture, and aftertaste.

	• Complete a food safety assessment and report on total plate count, key food pathogens, yeast, and mould. • Undertake consumer evaluation across demographics, purchase / consumption habits, price point analysis, and packaging preferences. • Both Kensington Pride and R2E2 were found to be suitable for processing into 'fresh cut' products acceptable to consumers. • The project delivered chilled, 'fresh cut' mango product insights with a suitable treatment solution and packaging type, a shelf-life study report, and a report on consumer acceptability and preference.
Outcomes (potential)	• Progress toward development of a chilled 'fresh cut' mango product with acceptable eating quality and optimal shelf life for retail. • Progress toward increased value of first grade fruit by reducing the total volume of mango available on the domestic market. • Progress toward increased business revenue through sales of new value-added products. • Progress toward export of a new value-added Australian mango product. • Progress toward reduction in the waste and disposal of lower grade mango.
Impacts (potential)	• Economic – profit from development of a new market for second grade mango. • Environmental – reduced waste of second and third grade fruit. • Capacity – researchers and industry with enhanced fruit processing skills. • Social - some contribution to increased regional community wellbeing through spillover benefits from a more productive and profitable QLD and Northern Territory mango industry.

Table C8: CF10961 Sensory Test Frozen Seafood Logical Framework

CF10961: Sensory Testing of Seafood – Fresh versus Frozen – and Development of Frozen Seafood Recipes: Sensory and Technical Component	
Project Details	Organisation: DAF. Period: September 2018 to September 2019. Project Leader(s): Sue Poole Client: FRDC.
Background	Frozen product offers innumerable advantages including a long shelf life and user convenience. Perceived and real differences in fresh versus frozen eating quality need to be addressed for the benefit of fishers and the seafood supply chain.
Project Description	Test differences in the eating quality of fresh and frozen Goldband snapper, Wild barramundi, Spanish mackerel, and Yellowtail kingfish.
Objectives	• To establish the eating qualities of frozen fish product compared to its counterpart held chilled.
Activities and Outputs	• Chilled fish supplied by species fisher, fillets frozen by DAF to -18^{o}C or - 30^{o}C using best practice. • Frozen fillet to be thawed and drip loss to be determined using standard time and temperature protocols. • Sensory assessment completed on seafood by DAF seafood panel. • A triangle test sensory evaluation completed to determine differences between chilled and thawed product for the four project species. • Raw fillets of both chilled and frozen product were evaluated using a directional comparison methodology and individual attributes assessed.

	• A range of cooking methods were applied to both chilled and thawed fillets and a comparative assessment completed. Methods included pan-fry, sous vide steam bake, and tempura-style. • A chefs' forum was convened to assess fresh and frozen products. • Assessments addressed physical attributes including colour, drip loss, texture analysis, slicing capability, sensory eating quality – bite and chew texture, and after mouth feel. • Interim and final reports were prepared and distributed by DAF.
Outcomes (potential)	• Identification of quality differences between chilled and frozen fish product showed that there are no discernible differences between chilled and frozen product. The finding held true for up to a six-month frozen storage period. • Raised awareness of the eating qualities of frozen fish within the high-end hospitality sector.
Impacts (potential)	• Economic – increased profitability in the Australian fishing industry with greater acceptance of frozen product providing opportunities for fishers to improve catch management and marketing. • Environmental – reduction in wastage associated with an unnecessary reliance on quick to spoil chilled fish fillets. • Capacity – researchers and industry with an enhanced understanding of seafood management. • Social - contribution to increased regional community wellbeing through spillover benefits from a more productive and profitable Australian fishing industry.

Table C9: CF11094 Manbulloo 'Fresh Cut' and Nectar Stage 2 Logical Framework

CF11094: Mango Road Stage 2 – Research on Value-added Mango Products Suitable for Retail	
Project Details	Organisation: DAF. Period: October 2019 to September 2020. Project Leader(s): Colin Leung, Toni Ferguson. Client: Manbulloo, Mango Road Pty Ltd.
Background	Manbulloo is a large Australian mango grower whose farms span QLD and the Northern Territory. Manbulloo is actively pursuing processing opportunities for lower grade mango.
Project Description	Following stage 1 trials Manbulloo wished to proceed to HPP commercialisation with contract processor Valley Harvest, Shepparton. Two products were under consideration – mango nectar and 'fresh cut' cheeks. HPP is a form of cold pasteurisation which uses water pressure to inactivate bacteria, virus, yeasts, moulds, and parasites.
Objectives	• To assess and provide technical expertise in mango nectar HPP parameters in a commercial factory. Commissioning of equipment and production line to be carried out by processor Valley Harvest. • Shelf-life evaluation of manufactured mango nectar product (retail temperature and simulated supply chain study). • Packaging feasibility study on a chilled 'fresh cut' mango product utilising HPP technology.
Activities and Outputs	• Liaise with contract processor Valley Harvest, review stage 1 findings, arrange bulk freezing of mango product, provide technical expertise on processing parameters, complete a processing line survey, and provide recommendations on quality parameters.

	• Develop and deliver a shelf-life trial that simulates retail scenarios and continues until product failure. • Complete a preliminary trial to assess the feasibility of bulk freezing mango puree and processing the puree during the mango off season. • Complete chemistry and sensory testing and report pH, colour, texture, titratable acidity, and product organoleptic properties. • Complete microbiological testing for key food pathogens, total plate count, yeast, and mould. • The output from this project was an assessment of product quality, supply chain and shelf-life of a chilled mango nectar product. The study showed that both food quality and food safety aspects were maintained up to two months at 4ºC storage. • The project also delivered a positive preliminary evaluation of the HPP processed chilled 'fresh cut' mango product.
Outcomes (potential)	• The study provided valuable information for Manbulloo to transition into manufacturing at Yeppoon in the 2020/2021 financial year. • Further progress toward development of a HPP chilled mango nectar. • Progress toward development of a HPP chilled 'fresh cut' mango product. • Progress toward increased value of first grade fruit by reducing the total volume of mango available on the domestic market. • Progress toward increased business revenue through sales of new value-added products. • Progress toward export of a new value-added Australian mango product. • Progress toward reduction in the waste and disposal of lower grade mango.
Impacts (potential)	• Economic – profit from development of a new market for second grade mango. • Environmental – reduced waste of second grade fruit. • Capacity – researchers and industry with an enhanced fruit processing skills. • Social - some contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD and Northern Territory mango industry.

Table C10: HF11568 Consumer Acceptance Gene Editing Logical Framework

HF11568: Consumer Acceptance of Gene Edited Crops	
Project Details	Organisation: DAF. Period: April 2019 to July 2020. Project Leader(s): Philippa Lyons, Simone Moller
Background	The benefits of genetically modified (GM) and gene-edited (GE) crops are well published however, previous research indicates that consumers are exhibiting fearful behaviour when it comes to weighing up the pros and cons of the two biotechnologies, ultimately influencing their purchase behaviour.
Project Description	The project set out to determine whether consumer acceptance of GE crops is an issue preventing increased market consumption within Australia and whether or not key methods of communication can be targeted to ensure greater understanding and assurance in this evolving area of science.
Objectives	• Review current literature to understand consumer attitudes towards GM and GE crops in Australia and other countries. • Determine whether consumer acceptance of GE crops is an issue preventing increased market consumption.

	• Determine whether there is confusion in the public around GE versus GM crops. • Identify the key communication messages that should be included in a public awareness/educational campaign. • Identify advertising/social media opportunities for these messages to be distributed.
Activities and Outputs	• Consumer surveys were completed in Brisbane, Sydney, and Melbourne. • The study found that consumers are confused as to what GM and GE biotechnologies are and conflicted in their opinions regarding the use of GM and GE biotechnologies in crop development. • Older generations are more fearful and less likely to adapt their behaviours than younger generations. • Overall, consumers perceive the benefits of GE technology outweigh the negatives and with the correct information provision in the most suitable format, consumer opinion can be positively influenced. • It is, however, essential to consider demographic characteristics of a population when creating the message to be conveyed to consumers, as both age and education have been shown to strongly influence not only consumer trust in the source of information but also the way in which they would like it demonstrated.
Outcomes	• Approaches that can be used to reduce consumer concerns in relation to GM and GE crops. • Scope to increase the uptake of GM and GE crops in Australia with additional gains in farm profitability, human health, and environmental performance.
Impacts (potential)	• Economic – long term profit for Australian crop growers from additional adoption of GM and GE crops than would otherwise have occurred without consumer support. • Environmental – gains for the Australian cropping environment with the potential adoption of GM and GE crops that require fewer chemicals for their production. • Capacity – researchers and the Australian community with an enhanced understanding of gene technology and its implications. • Social – reduced community anxiety associated with GM and GE crops and potentially, improved human health outcomes from their adoption e.g., crops fortified with vitamins and minerals.

4. Project Investment

Nominal Investment

Table C11 shows the annual investment (cash and in-kind) for each project by DAF. DAF funding was supported with contributions from the Australian Government Innovative Connections grants program. Table C12 shows funding provided by food producers supported by the program.

Table C11: Annual Investment by DAF in Food Cluster Projects for Years Ending June 2017 to June 2021 (nominal $)

Project	2017	2018	2019	2020	2021	Total
CF10586: IQF mandarins – stage 1	72,492	55,581				128,073
CF10717: Crab/lobster market survival		61,550	131,756	14,164		207,470
CF10767: Manbulloo frozen mango		37,800				37,800
CF10793: Mango variety sensory testing			48,000			48,000
CF10924: IQF mandarins – stage 2			25,000	25,000		50,000
CF10939: Manbulloo mango nectar			49,673			49,673
CF10941: Manbulloo 'fresh cut' mango			44,196			44,196
CF10961: Sensory test frozen seafood			40,000	4,000		44,000
CF11094: Manbulloo 'fresh cut' & nectar				39,735	8,934	48,669
HF11568: Consumers & gene edit crops				20,046	7,798	27,844
Total	**72,492**	**154,931**	**338,625**	**102,945**	**16,732**	**685,725**

Source: DAF project documents

Table C12: Annual Investment by Others in Food Cluster Projects for Years Ending June 2017 to June 2021 (nominal $)

Project	2017	2018	2019	2020	2021	Total
CF10586: IQF mandarins – stage 1	25,000	25,000				50,000
CF10717: Crab/lobster market survival		42,394	107,538	8,527		158,459
CF10767: Manbulloo frozen mango		37,800				37,800
CF10793: Mango variety sensory testing			10,000			10,000
CF10924: IQF mandarins – stage 2			25,000	25,000		50,000
CF10939: Manbulloo mango nectar			49,673			49,673
CF10941: Manbulloo 'fresh cut' mango			44,196			44,196
CF10961: Sensory test frozen seafood			26,000	2,000		28,000
CF11094: Manbulloo 'fresh cut' & nectar				39,735	8,934	48,669
HF11568: Consumers & gene edit crops				0	0	0
Total	**25,000**	**105,194**	**262,407**	**75,262**	**8,934**	**476,797**

Source: DAF project documents

Table C13: Annual Total Investment in Food Cluster Projects for Years Ending June 2017 to June 2021 (nominal $)

Year (ended 30 June)	DAF ($)	Others ($)	Total ($)
2017	72,492	25,000	97,492
2018	154,931	105,194	260,125
2019	338,625	262,407	601,032
2020	102,945	75,262	178,207
2021	16,732	8,934	25,666
Totals	**685,725**	**476,797**	**1,162,522**

Program Management Costs
For the DAF investment, the management and administration costs for the project are assumed already built into the nominal dollar amounts appearing in Table C11. The salary multiplier used by DAF was 2.85 (Wayne Hall, pers. comm., July 2017).

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 GDP Deflator index (ABS, 2021). The investment was almost entirely delivered in partnership with farming and fishing enterprises who identified the projects as priorities, contributed financially to the research and who were enthusiastic about adoption. No additional extension costs were included.

5. Impacts

Summary of Impacts

Table C14 summarises the contributions of the principal impacts delivered by each of the projects. Projects are identified as contributing to one or several of the impact categories and the future anticipated impact is represented as follows:

Significant Impact: ✓✓✓
Moderate Impact: ✓✓
Minor or Undetermined Impact: ✓

Table C14: Summary of Potential Impacts from Individual Food Cluster Projects

Project code	Value adding, product development – mango, and mandarin	Post-harvest quality – snap frozen seafood	Consumer intelligence	Improved environmental outcome (e.g., reduction in crop, seafood waste)	Other – increased capacity, social licence, or regional spillover
CF10586: IQF mandarins – stage 1	✓✓✓		✓✓	✓	✓
CF10717: Crab/lobster market survival		✓✓✓		✓	✓
CF10767: Manbulloo frozen mango	✓✓✓		✓✓	✓	✓
CF10793: Mango variety sensory testing	✓		✓✓✓		✓
CF10924: IQF mandarins – stage 2	✓✓✓			✓	✓
CF10939: Manbulloo mango nectar	✓✓✓		✓✓	✓	✓
CF10941: Manbulloo ‘fresh cut’ mango	✓✓✓		✓✓	✓	✓
CF10961: Sensory test frozen seafood		✓✓✓	✓✓✓	✓	✓
CF11094: Manbulloo ‘fresh cut’ & nectar	✓✓✓		✓✓	✓	✓
HF11568: Consumers & gene edit crops			✓✓	✓	✓

Impacts across the Triple Bottom Line
An overview of potential impacts in a triple bottom line categorisation is shown in Table C15.

Table C15: Categories of Impacts from the Investment

Economic	Environmental	Social
Profit from development of a new market for second grade mango. Profit from development of a new market for second grade mandarin. Profit from improved marketing of three new mango varieties. Profit from catch management with greater acceptance of snap frozen seafood. Profit from reduced post-harvest crustacean loss. Long term profit for crop growers with improved appreciation and understanding by consumers of GM and GE technologies.	Reduced waste and disposal of second grade fruit and spoilt seafood.	Increased research and industry capability. Increased industry social licence to operate with reduced waste, more responsible use of resources. Regional community wellbeing through spillover benefits of more productive and profitable farming and fishing industries.

Public versus Private Impacts
The primary impacts identified from the Food Cluster investment are mostly private in nature. Private impacts are likely to accrue to growers (mango and mandarin) and fishers (frozen fish and live crustacean producers) in the form of increased profitability. Public impacts may include spillover benefits associated with reduced waste in the environment, increased research and industry capacity, and regional spillover benefits from more productive and profitable primary industries.

Impacts Accruing to other Primary Industries
While the information and activities provided by the Food Cluster investment were specifically targeted, general principles such as the value-adding of second grade fruit, will be relevant to multiple horticultural crops.

Distribution of Benefits along the Supply Chain
Private benefits from the Food Cluster investments will accrue, in the first instance, directly to fruit and seafood producers. However, over time, benefits to producers will be shared across industry supply chains according to the relevant elasticities of supply and demand.

Impacts Overseas
Overseas impacts may include benefits to consumers in export markets who purchase value-added and higher quality Australian fruit and seafood.

Match with National and State Priorities

The Australian Government's Science and Research Priorities and Rural Research, Development and Extension (RD&E) Priorities are reproduced in Table C16. The investment in the Food Cluster is relevant to Rural RD&E Priority 1 and 4, and to Science and Research Priority 1, with some potential contribution to Priority 6.

Table C16: Australian Government Research Priorities

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

(a) Source: Commonwealth of Australia (2015)
(b) Source: Office of the Chief Scientist (2015)

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision making around future investment are reproduced in Table C17.

Table C17: QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Chief Scientist Queensland (2015)

The investment addressed QLD Science and Research Priority 1, with some contribution to Priority 6 via resilience. In terms of the guides to investment, the investment is likely to have a real future impact on both the fruit and seafood industries and, through the Australian Government and participating businesses, was well supported by others external to the QLD Government.

6. Valuation of Impacts

Impacts Valued
Analyses were undertaken for total impacts that included future expected impacts. 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 investment criteria.

Four Food Cluster impacts were valued in monetary terms:

- Profit from development of a new market for second grade mango.
- Profit from development of a new market for second grade mandarin.
- Profit from catch management with greater acceptance of snap frozen seafood.
- Profit from reduced post-harvest crustacean loss.

Impacts not Valued
Not all impacts identified in Table C15 could be valued in the assessment. Some economic, environmental, and social impacts are difficult to value and may involve the application of non-market valuation techniques that were beyond the scope of the current assessment. Impacts were not valued due to:

- A lack of evidence and/or data on which to base credible assumptions,
- The complexity of assigning monetary values to the impact,
- Uncertainty regarding the pathways to impact, and
- The relative importance of the impact compared to the primary impacts valued.

The following impacts were not valued in the current analysis:

- Profit from improved marketing of three new mango varieties.
- Long term profit for crop growers with additional adoption of GM and GE technologies.
- Increased research and industry capability.
- Increased industry social licence to operate with reduced waste, more responsible use of resources.
- Regional community wellbeing through spillover benefits of more productive and profitable farming and fishing industries.

Valued Impact 1: Profit from development of a new market for second grade mango
The Food Cluster supported four projects with Manbulloo Limited/Mango Road Pty Ltd aimed at turning low value second grade mango into profitable value-added products. Manbulloo and DAF explored three product options (frozen mango, ‘fresh cut’ mango and mango nectar) before Manbulloo concluded that the mango nectar product was the most prospective. When this product comes into production, approximately three years after final Food Cluster project completion, it is estimated to add $150/tonne to the value of second grade mango used in processing and consume up to 10% of the Australian mango crop.

Valued Impact 2: Profit from development of a new market for second grade mandarin
The Food Cluster supported two projects with Barcross Investments Pty Ltd working on behalf of the Gayndah & District Fruitgrowers Association which also aimed at turning low value second grade fruit into profitable value-added products. In this instance, efforts were focussed on individual quick frozen mandarin segments. Commercialisation of this product is much less advanced than mango nectar. Consequently, it is assumed that quick frozen mandarin production is not commercialised for five years after final project completion and growers receive an additional $200/tonne for second grade mandarins when commercialisation occurs. When mature, quick frozen mandarin segment production may consume 4,000 tonnes/year of second grade fruit from the Australian mandarin crop.

Valued Impact 3: Profit from catch management with greater acceptance of snap frozen seafood

The Food Cluster project CF10961: '*Sensory Testing of Seafood – Fresh versus Frozen – and Development of Frozen Seafood Recipes: Sensory and Technical Component*' showed that there is no discernible difference in quality between chilled and frozen finfish and communicated this finding to opinion leading Australian chefs. With greater acceptance of frozen seafood, fishers will be better able to manage their catch, releasing frozen product onto the market without incurring a price discount from buyers who previously supposed that there was a quality loss. A price increase for fishers of 20% for snap frozen finfish carried over to periods of low supply has been assumed for this analysis.

Valued Impact 4: Profit from reduced post-harvest crustacean loss

The Food Cluster project CF10717: '*Improving the Survival and Quality of Crabs and Lobsters in Transportation from First Point of Sale to Market*' identified practical solutions to improve the survivability of wild-caught mud and spanner crabs. Solutions for rock lobster had already been implemented prior to project commencement. The wild-caught crab industry has a GVP of $53 million, and a 10% improvement in industry revenue has been assumed (NB: a too ambitious 20% targeted was set by project researchers). Impacts are realised immediately following project completion.

Summary of Assumptions

A summary of assumptions and data sources is provided in Table C18.

Table C18: Summary of Assumptions

Variable	Assumption	Source
Impact 1: Profit from development of a new market for second grade mango		
Annual production of Australian mango.	76,752 tonnes	Australian Horticulture Statistics Handbook, 3-year average to 2019/20.
Share of Australian production that might be directed toward a Manbulloo processing plant.	10%	Analyst assumption.
Increase in farmgate price for second grade mango due to development of Manbulloo processing facility.	$150/tonne	Analyst assumption.
Attribution of impact to Food Cluster investment.	20%	Non-Food Cluster investment will be dominated by expenditure on mango processing plant and its subsequent operation.
Year of first impact.	2023/24	Analyst assumption.
Impact 2: Profit from development of a new market for second grade mandarin		
Annual quick frozen mandarin production potential.	4,000 tonnes	Judy Shepard, Gayndah & District Fruitgrowers Association, pers. comm., March 2021.
Increase in farmgate price for second grade mandarin due to development of	$200/tonne	Judy Shepard, Gayndah & District Fruitgrowers Association, pers. comm., March 2021.

processing capacity.		
Attribution of impact to Food Cluster investment.	20%	Non-Food Cluster investment will be dominated by expenditure on mandarin processing plant and equipment.
Year of first impact.	2024/25	Analyst assumption.
Impact 3: Profit from catch management with greater acceptance of snap frozen seafood		
Value of wild-caught finfish.	$95.1 million/year.	Data sourced from ABARES 2018 and includes major wild caught finfish species such as barramundi, bream, coral trout, flathead, Spanish mackerel, and whiting.
Share of catch frozen and retained for catch management purposes.	10%	Analyst assumption.
Price increase realised by fishers on retained product.	20%	Analyst assumption.
Attribution of impact to Food Cluster investment.	50%	Accounts for costs incurred to implement project findings.
Year of first impact.	2021/22	Analyst assumption.
Impact 4: Profit from reduced post-harvest crustacean loss		
GVP of the Australian wild-caught crab.	$53 million/year.	ABARES 2018.
Increase in revenue associated with implementation of project recommendations.	10%	Analyst assumption after consideration of 20% revenue gain targeted by project researchers to be too ambitious.
Share of fishers who are able to garner supply chain support for adoption of project recommendations.	50%	Analyst's assumption noting that control of transport company and other links in the supply chain may be beyond fisher and therefore beneficiary control.
Attribution of impact to Food Cluster investment.	30%	Accounts for costs incurred to implement project findings.
Year of first impact.	2020/21	Analyst assumption.
Other factors		
Probability of output.	90%	Anticipated outputs have mostly been delivered.
Probability of outcome	70%	Outcomes will depend on investment that is yet to be made and is somewhat uncertain.
Probability of impact	70%	Impact is mostly reliant on market acceptability e.g., mango nectar, IQF mandarin, frozen is as good as fresh finfish. Market acceptability has been tested but remains unproven.
Counterfactual	40%	It was assumed that, in the absence of the Food Cluster investment, it is 60% likely that the benefits estimated would have been realised via other initiatives.

7. Results

All past costs were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2020). 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 investment period plus 30 years from the last year of investment (2020/21) to the final year of benefits assumed.

Investment Criteria
Table C19 and C20 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment, respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table C20, was estimated by multiplying the total PVB by the DAF proportion of real investment (59.1%).

Table C19: Investment Criteria for Total RD&E Investment in the Food Cluster

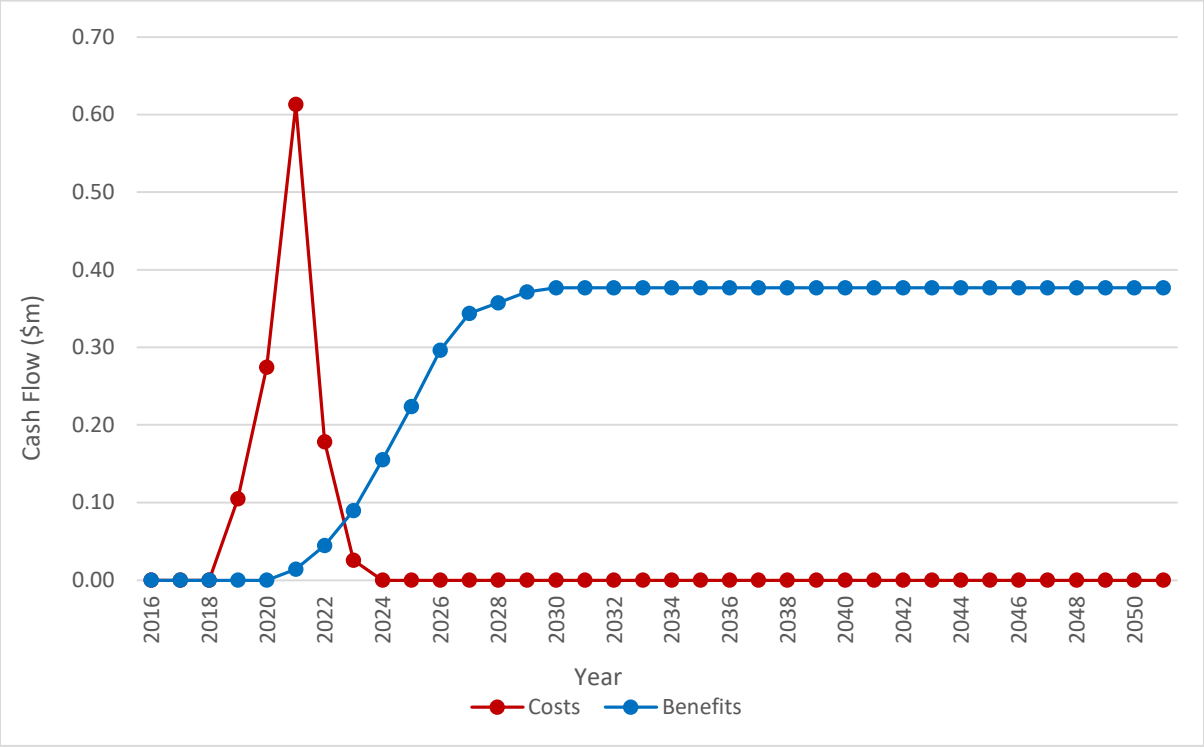
Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.01	0.66	1.83	2.79	3.53	4.12	4.58
Present value of costs ($m)	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Net present value ($m)	-1.26	-0.61	0.56	1.52	2.26	2.85	3.31
Benefit-cost ratio (BCR)	0.01	0.52	1.44	2.19	2.78	3.24	3.60
Internal rate of return (IRR) (%)	Negative	Negative	9.6	13.3	14.5	15.0	15.3
Modified IRR (%)	Negative	Negative	7.8	9.5	9.6	9.4	9.1

Table C20: Investment Criteria for DAF RD&E Investment in the Food Cluster

Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.01	0.39	1.08	1.65	2.09	2.43	2.70
Present value of costs ($m)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Net present value ($m)	-0.74	-0.36	0.33	0.89	1.34	1.68	1.95
Benefit-cost ratio	0.01	0.52	1.44	2.19	2.78	3.24	3.60
Internal rate of return (IRR) (%)	Negative	Negative	9.5	13.2	14.4	15.0	15.2
Modified IRR (%)	Negative	Negative	7.8	9.5	9.6	9.4	9.1

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the investment period plus 30 years from the last year of investment are shown in Figure C1.

Figure C1: Annual Cash Flow of Undiscounted Total Net Benefits and Total Investment Costs



Source of Benefits
Estimates of the relative contribution of each benefit valued, given assumptions made, are shown in Table C21.

Table C21: Contribution to Total Benefits from Each Source

Impact Valued	**Contribution to PVB ($m)**	**Share of Benefits (%)**
Profit from Development of a New Market for Second Grade Mango	0.43	9.4
Profit from Development of a New Market for Second Grade Mandarin	0.28	6.1
Profit from catch management with greater acceptance of frozen seafood	2.04	44.6
Profit from reduced post-harvest crustacean loss	1.82	39.8
Total	**4.58**	**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. Results are reported in Table C22. The results show that the investment criteria had a moderate sensitivity to the discount rate.

Table C22: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	10.19	4.58	2.43
Present value of costs ($m)	1.20	1.27	1.35
Net present value ($m)	8.99	3.31	1.08
Benefit-cost ratio	8.52	3.60	1.80

A sensitivity analysis was then completed on the assumed counterfactual – it is 60% likely that the benefits estimated would have been realised via other initiatives (Table C23). Results show that the likelihood of investment being completed without the DAF Food Cluster would need to increase to 90% before Food Cluster costs exceed Food Cluster benefits.

Table C23: Sensitivity to Counterfactual
(Total investment, 30 years, 5% discount rate)

Investment Criteria	Counterfactual		
	30%	60% (base)	90%
Present value of benefits ($m)	8.01	4.58	1.14
Present value of costs ($m)	1.27	1.27	1.27
Net present value ($m)	6.74	3.31	-0.13
Benefit-cost ratio	6.31	3.60	0.90

Confidence Ratings and other Findings

The investment analysis results 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 C24). 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 C24: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium	Medium-Low

Coverage of benefits was assessed as Medium. While a number of principal economic benefits was quantified (profit from processing mango and mandarin, profit from finfish catch management, profit from reduced post-harvest crustacean loss), a number of economic impacts identified (profit from improved marketing of three new mango varieties, long term profit from adoption of GM and GE crops) and social impacts were not valued.

Confidence in assumptions was rated as Medium-Low. Though some key data and assumptions were drawn from credible sources (including ABARES), there were less well-supported assumptions required for a number of potential drivers of the impacts valued and thus the assumed magnitude of the impacts was somewhat uncertain.

8. Conclusion

The investment in ten Food Cluster projects has produced a number of potential impacts of value to fruit and seafood producers and the Australian community. Four of these impacts have been valued: facilitation of new value-added mango products, development of new mandarin quick frozen segments, insight on the fresh equivalent eating quality of snap frozen seafood and techniques to reduce post-harvest crustacean loss.

The total investment in the Food Cluster by all contributors of $1.27 million (present value terms) has been estimated to produce total gross benefits of $4.58 million (present value terms) providing a net present value of $3.31 million, a benefit-cost ratio of 3.6 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 15.3% and a modified internal rate of return of 9.1%.

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Appendix D: An Impact Assessment of Investment in FutureBeef (Project codes E.INV.1412 and L.GBF.1802)

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Abbreviations

CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries – Queensland
DPIRD	Department of Primary Industries and Regional Development, Western Australia
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
MLA	Meat and Livestock Australia
NT	Northern Territory
NTDITT	Northern Territory Department of Industry, Tourism and Trade
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
WA	Western Australia
WADPIRD	Western Australia Department of Primary Industries and Regional Development

Executive Summary

This report presents the results of an impact assessment of a Queensland Department of Agriculture and Fisheries (DAF) investment in two projects associated with FutureBeef. The two projects are:

- the delivery of the FutureBeef website and webinars, and
- the delivery of FutureBeef industry engagement

The projects were jointly funded by Meat and Livestock Australia (MLA), DAF, the Western Australia Department of Primary Industries and Regional Development (WADPIRD), and the Northern Territory Department of Industry, Tourism and Trade (NTDITT).

The two projects were undertaken by DAF and its state agency partners over two funding periods (years ending June 2014 to June 2017, and then the years ending June 2018 to June 2022).

Each project is first described qualitatively using a logical framework that included project objectives, activities and outputs, outcomes and impacts. Impacts from each project then were categorised into a triple bottom line framework. Impacts from the two projects were then combined and some of the principal impacts from the projects were then valued.

The cost-benefit analysis was conducted according to the current Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018). Benefits were estimated for a range of time frames up to 30 years from the last year of investment in the two projects. Past and future cash flows in 2019/20 dollars were discounted to the year 2019/2020 using a discount rate of 5% to estimate the investment criteria.

The investment by the two projects in FutureBeef and its associated outputs and outcomes have been important for the productivity and profitability of the northern Australia beef industry. The avenue for such impacts has been through the more effective and efficient extension of information used in improving the management of beef herds across northern Australia.

Specifically, the principal impacts valued emanating from the investments were associated with the increased profitability of Australian beef production in northern Australia by some producers in Queensland, the Northern Territory and the north-west of Western Australia.

The combined investment in the two projects E.INV.1412 and L.GBF.1802 represented an investment of $3.23 million dollars in nominal terms. The total investment in the project of $3.64 million (present value terms) has been estimated to produce total gross benefits of $20.61 million (present value terms) providing a net present value of $16.97 million, a benefit-cost ratio of 5.7 to 1 (using a 5% discount rate), an internal rate of return of 66.5% and a modified internal rate of return of 17.7%.

There were several potential impacts identified that were not valued in monetary terms. The investment criteria reported therefore are likely to have undervalued the full value of benefits delivered by the investment.

1. Evaluation Methods

The evaluation approach follows general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses cost-benefit analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, and potential and actual 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. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the limited time and resources available for undertaking the evaluation. However, the impacts valued are deemed to represent the principal benefits delivered by the project.

2. Background and Rationale

FutureBeef is a northern Australian beef program that supports joint extension services to beef producers. It is a joint program supported by Meat and Livestock Australia (MLA), and the three State/Territory Governments of Queensland, Western Australia and the Northern Territory. The rationale for the joint program is that it provides a coherent and unified set of information to assist northern beef producers, minimising duplication of effort and making it easier for producers and extension personnel to more directly access relevant information that supports their livelihood and sustainability.

The first project (E.INV.1412) in this cluster of two projects was to further develop the FutureBeef website and produce a series of webinars and other communication material that would enhance the communication channels for the benefit of producers and extension personnel. It also included a monthly e-Bulletin, social media (Facebook and Twitter), YouTube channel, videos and newspaper features. This three-year project was completed in 2017.

A second project (L.GBF.1802) in the cluster was funded following a review and evaluation of E.INV.1412. The second project addressed many of the recommendations of the review/evaluation of the first project. This involved further developing the website and producing more webinars and continuing the communication effort through the e-Bulletin, social media (Facebook and Twitter), YouTube channel, videos and newspaper features, plus two new channels (LinkedIn and podcasts).

3. Investment Details

Investors in both projects included: Meat and Livestock Australia, the Department of Agriculture and Fisheries Queensland (DAF), the Western Australia Department of Primary Industries and Regional Development (WADPIRD), and the Northern Territory Department of Industry, Tourism and Trade (NTDITT).

The investment in the first project (E.INV.1412) was made in the years ending June 2014 to June 2017. DAF was the lead research agency and MLA the major external funding organisation, contributing about 22% of the total budget. DAF contributed about 37% of total funding and the other two state agencies (WADPIRD and NTDITT) jointly contributed about 40% of total funding. All of MLA's funding was cash, while the three state/territory departments contributed salary and salary on-costs as in-kind.

The second project investment (Project L.GBF.1802) was made in the years ending June 2018 to June 2022 and is currently nearing completion. Funding partners for the second project were the same as those in the first project. Again, all of MLA's funding was cash, while the three state/territory departments contributed salary and salary on-costs as in-kind.

The project codes, titles, key DAF research personnel, and funding period for the two-project investment are summarised below in Table D1. Specific funding contributions by year and for each contributor are provided later in Tables D4 and D5.

Table D1: Summary Details for the Investment

Project Code and Title	Key Personnel	Funding Period
E.INV.1412 Delivery of FutureBeef Website and Webinars	John James, FutureBeef Project Manager Department of Agriculture and Fisheries, Queensland Felicity McIntosh, Extension Officer, Department of Agriculture and Fisheries, Queensland Rebecca Farrell, Extension Officer, Department of Agriculture and Fisheries, Queensland Greg Bath, Extension Officer, Department of Agriculture and Fisheries, Queensland Jodie Ward, FutureBeef Extension Officer, Northern Territory Department of Primary Industry and Fisheries	Years ending June 2014 to June 2017
L.GBF.1802 Delivery of FutureBeef Industry Engagement	John James, Felicity McIntosh and Rebecca Farrell were still working on the FutureBeef project until about October 2018 Nicole Sallur, FutureBeef Project Manager, Department of Agriculture and Fisheries, Queensland (since October 2018) Greg Bath, Extension Officer, Department of Agriculture and Fisheries, Queensland	Years ending June 2018 to June 2022

	Jodie Ward, Extension Officer, Department of Agriculture and Fisheries, Queensland (since October 2018) Kate Brown, Extension Officer, Department of Agriculture and Fisheries, Queensland	

Tables D2 and D3 provide a description of each of the two projects in a logical framework format.

Table D2: Logical Framework for Project E.INV.1412

Specific Objectives	1. To further develop, populate, maintain and evaluate a public website (www.futurebeef.com.au) for the collaborative FutureBeef Program by providing timely, relevant and accurate information to the northern Australia beef industry. 2. To further develop, populate, maintain and evaluate a private staff intranet for the collaborative FutureBeef Program, to allow staff to find and share relevant information. This was to include a news section, a repository of technical information, a source of current promotional items, the latest versions of relevant document templates, and information on the different tools available to staff. Also, to deliver a Forum where staff can discuss relevant topics, and a Wiki to store and collaboratively work on various documents. 3. To further develop, deliver and evaluate a webinar series for the FutureBeef Program to enable improved staff engagement with stakeholders and the delivery of Research, Development and Extension information in a cost-effective manner for both presenters and attendees (e.g. reduced travel requirements). Also, to explore further partnerships to broaden the potential audience. 4. To develop a series of ten short videos to promote best management practices for the northern beef industry. 5. To rebuild the FutureBeef website to improve the user experience, information architecture, site speed and reliability.
Activities and Outputs	• Further development and upgrading of the existing FutureBeef website took place. This resulted in an upgraded FutureBeef website providing an increase in useful, relevant and up-to-date information to the northern Australia beef industry including to both producers and extension personnel (James and McIntosh, 2017). • By June 2017 there were over 500 pages on the FutureBeef website with most related to information such as contacts, tools, services and publications; in 2016-17 the site received nearly 182,000 visits from 129,742 unique visitors (Sallur and Ward, 2020). • The private staff intranet and a discussion forum were developed to facilitate internal staff communication. Outputs included relevant news, technical information, document templates, items to be promoted and their sources, and a set of available tools; there were 85 registered users of the staff intranet from the four partner agencies (DAF, WAPIRD, NTDITT, and MLA) (Sallur and Ward, 2020).

	• A series of webinars was developed as an additional resource to enhance engagement and communication between agency staff and stakeholders. The webinar series promoted information exchange between extension personnel and between extension personnel and producers. • A number of webinars were conducted during the project and were attended by a large number of participants (Sallur and Ward, 2020); the webinar series included BeefConnect webinars, Enabling change and innovation webinars, and FutureBeef fusion webinars. • A series of education videos (ten) promoting best management practices for beef producers was developed and delivered; the videos encouraged and enabled more profitable and sustainable beef production businesses. • The ten videos were uploaded to the FutureBeef You Tube channel and website for public viewing (Sallur and Ward, 2020). • Various social media communication avenues were running when the project commenced as FutureBeef had commenced initially as a Queensland only project. These communication channels were further developed in the project including Facebook, Twitter, e-Bulletin, as well as newspaper features. • A monthly FutureBeef e-Bulletin was produced and covered a range of information (e.g. useful tools, new publications, project updates and upcoming events); by June 2017, 58 editions had been distributed and 3,216 people has subscribed to receive it (Sallur and Ward, 2020). • Newspaper features (e.g. BeefTalk, CQ BEEF and Northern Muster) were published in the Queensland Country Life and North Queensland Register four times per year.
Outcomes	• An external evaluation of the investment in Project E.INV.1412 was undertaken by JR Coutts in 2016 (Coutts,2016a, 2016b, 2016c). • The evaluation targeted 150 randomly selected personnel including producer members, industry representatives and government extension providers. • Overall, the respondents reported that the information on the website was a valuable resource; there was a high level of satisfaction with usefulness, delivery and extension of information. • In addition, the evaluation found that there were indications that the information delivered via FutureBeef positively impacted knowledge and understanding as well as on-farm productivity (Sallur and Ward, 2020). • A series of recommendations for improvement to the project was made by Coutts in the evaluation; project activities addressed by the recommendations included: o Website o e-Bulletin o Social media o Webinars o Newspaper features A number of these recommendations were addressed in the following project L.GBF.1802.
Impacts	• An increasing number of northern beef producers changing to more profitable and sustainable practices due to enhanced availability of

	information directly from the web, via webinars and videos, and more complete extension advice delivered from both state agencies and private sector extension personnel. • Improvements in land condition via reduced soil loss and nutrient export due to enhanced grazing management practices. • Increased efficiency and effectiveness of beef management extension via a reduction in potential duplication of effort associated with information assembly. • Cost savings in staff time (including travel time) from the use of webinars instead of face-to-face meetings for both internal meetings and events with producer stakeholders. For example, over two years DAF estimated a saving of $2.1 million (Sallur and Ward, 2020). • Increased capacity and effectiveness of beef management extension personnel, both state agency and private, due to improved information availability. • An increase in spillover impacts to regional communities associated with beef production in northern Australia, driven by increased producer incomes and their associated supply chain businesses.

Table D3: Logical Framework for Project L.GBF.1802

Specific Objectives	1. To continue to support the website and increase its annual usage, pageviews, time spent per visit plus an overall increase in user satisfaction by the end of the project. 2. To continue to deliver up to 10 webinars with an annual increase in registrations and attendance, plus an overall increase in user satisfaction by the end of the project. 3. To extend messages via social media with an annual increase in number of followers, plus an overall increase in user satisfaction by the end of the project. 4. To continue to distribute up to 12 e-Bulletins with an annual increase in subscribers and an overall increase in user satisfaction by the end of the project. 5. To produce up to 15 short videos and up to 10 webinar recordings, an increase YouTube views, and an overall increase in user satisfaction by the end of the project. 6. A number of newspaper features in the Queensland Country Life and North Queensland Register, with at least one item from WA or NT.
Activities and Outputs	• Further development and upgrading of the existing FutureBeef website took place; this delivered a more effective website with regard to increased usage and effectiveness of the website. • More webinars were delivered; this further enhanced engagement and communication between agency staff and stakeholders, including producers and others extending advice. All webinar recordings are published on the website and YouTube channel. • The social media channels (Facebook and Twitter) addressing information dissemination and communication between agency staff, advisers and producers was further developed; this opened up an additional channel (LinkedIn) of communication in turn developing contact with an increased number of stakeholders. • Further e-Bulletins also were produced and distributed to an increased number of recipients.

	• A total of 15 videos have been filmed and are currently undergoing editing and approvals (Nicole Sallur, pers. comm., 2021). • Newspaper features continue to be published in the Queensland Country Life and North Queensland Register with an increased frequency of six times per year (Nicole Sallur, pers. comm., 2021).
Outcomes	• Improved delivery of information through multiple pathways that is providing up to date, relevant and accurate information to the northern Australia beef industry. • Increased industry engagement with northern Australia beef producers, RD&E staff of the FutureBeef project partners, and northern Australia beef industry service providers through the delivery of an increasing range of effective and useful online activities. • The 2018-2022 project has delivered, and is delivering, information to an increased number of northern Australia beef producers, compared to the earlier project. This is supported by an increasing trend in numbers of people visiting the website, subscribing to the e-Bulletin, participating in webinars and the number of followers on social media (Nicole Sallur, pers. comm., 2021). • Surveys of producers and extension agents were undertaken in a review of communication tools and impacts on practice change (Folder et al, 2021). • The review included an on-line survey that elicited 202 responses including 184 from northern beef jurisdictions; a second component of the review involved one-on-one interviews with 19 FutureBeef stakeholders who indicated they had undertaken a practice change partly attributable to FutureBeef (Folder et al, 2021). • The review reported that satisfaction levels of communication tools were high and that the FutureBeef investment has been successful in influencing practice change by northern Australia beef producers. • Nearly half of all survey respondents indicated the communication tools had contributed to a practice change on their property or their client's property. • It is likely that there will be a continuation of the FutureBeef investment after August 2021/ February 2022 and a new proposal is currently being developed.
Impacts	• A further increase in numbers of northern Australian beef producers changing to more profitable and sustainable practices due to enhanced availability of information from the web, webinars, social media channels, e-Bulletins, videos and newspaper features, and more complete extension advice from both state agencies and private sector extension personnel. • Further improvements in land condition via reduced soil loss and nutrient export due to enhanced grazing management practices. • Increased efficiency and effectiveness of beef management extension via a reduction in potential duplication of effort and reduced costs associated with information assembly, travel time, salaries etc. • Increased capacity and effectiveness of beef management extension personnel, both state agency and private, due to improved information availability. • An increase in spillover impacts to regional communities associated with beef production in northern Australia, driven by increased producer incomes and their associated supply chain businesses.

4. Project Investment

Nominal Investment

Table D4 shows the annual investment in Project E.INV.1412 (cash and in-kind) by funding organisation and by year. Table D5 shows the annual investment in Project L.GBF.1802 (cash and in-kind) by funding organisation and by year.

Table D4: Annual Investment in Project E.INV.1412 by Funding Organisation

Year ended 30 June	2014	2015	2016	2017	Total
MLA (cash)	68,240	38,420	38,420	44,000	189,080
DAF (in kind, direct and indirect)	115,765	65,177	65,177	74,643	320,762
WADPIRD (in kind)	65,237	36,729	36,729	0	138,695
NTDITT (In kind)	97,855	55,094	55,094	0	208,043
Total Cash and In-kind	347,097	195,420	195,420	118,643	856,580

Source: Signed Research Agreement between MLA and DAF

Table D5: Annual Investment in Project L.GBF.1802 by Funding Organisation

Year ended 30 June	2018	2019	2020	2021[(a)]	Total
MLA (cash)	81,120	187,626	212,063	118,461	599,270
DAF (in kind, direct and indirect)	147,902	521,640	549,058	472,731	1,691,331
WADPIRD (cash and in kind)	6.500	15,250	15,500	6,500	43,750
NTDITT (cash and In kind)	6,500	15,250	15,500	6,500	43,750
Total Cash and In-kind	242,022	739,766	792,121	604,192	2,378,101

Source: Signed Research Agreement between MLA and DAF

(a) Note: The project has been extended to February 2022.

Program Management Costs

For both the DAF and the other investments, any management and administration costs for the project are assumed already built into the nominal $ amounts appearing in Tables D4 and D5.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 $ terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2021).

Because the two projects were focused on delivering information and were carried out by the three state agencies already involved in extension to livestock producers in the three jurisdictions, any additional extension and communication costs were not considered relevant. Furthermore, the funding of the two projects actually may have reduced total extension costs across the agencies and private extension by delivering efficiencies in collecting, assembling and disseminating data.

5. Impacts

Impact on Industry Profitability
Industries benefiting from both project investments are beef producers in the three jurisdictions of Queensland, the north of Western Australia, and the Northern Territory.

Environmental Impact
Key messages associated with increased productivity and profitability in northern Australia grazing management are often positively aligned with sustainability of land and vegetation resources and associated land condition. Hence, increased uptake of best management practices are likely to enhance land condition, including a reduction in soil loss and maintenance of biodiversity.

Social Impacts
Social impacts are likely to include:

- savings in extension delivery costs by state agencies.
- an increase in spillover impacts to regional communities associated with increased profitability of beef production and their supply chain businesses in northern Australia.
- a contribution to the maintenance of, and/or increases in, extension capability and capacity in public sector agencies in northern Australia.

Summary of Impacts
An overview of the combined impacts from both projects in a triple bottom line categorisation is shown in Table D6.

Table D6: Categories of Impacts from Investments in Projects E.INV.1412 and L.GBF.1802

Economic	Environmental	Social
Increased productivity and profitability of beef producers in northern Australia. Increased efficiency and effectiveness of northern beef management extension via a reduction in potential duplication of effort associated with information assembly by state agencies.	Contribution to improved land condition and biodiversity and a reduction in soil loss in northern Australian grazing lands.	Savings in extension delivery costs (e.g. travel and time costs due to webinars and online information availability). Increased spillovers to regional communities from increased incomes for northern beef producers and their associated supply chain businesses. Maintained or increased extension capability and capacity in public sector agencies in Queensland, the Northern Territory and in the north-west of Western Australia.

Distribution of Benefits along the Supply Chains
Any increase in productivity and profitability that benefits livestock producers in northern Australia are likely to be shared along the supply chain with input suppliers, transport operators and infrastructure, processors, wholesalers, exporters, retailers and consumers, according to the relevant supply and demand elasticities.

There will be savings by northern Australian extension agencies via the use of low-cost webinars replacing some face-to-face meetings, with savings in travel and staff time.

Public versus Private Impacts
The impacts identified from the investment are predominantly private, namely accruing to northern Australian private sector producers and their supply chains. Some public benefits will be produced including spillovers to regional communities from enhanced beef producer and supply chain member incomes, some environmental benefits, and a maintained/increased extension capacity in public sector agencies.

Impacts Overseas
It is unlikely that there will be any major significant impacts in countries external to Australia. However, there were people from overseas countries visiting the website, joining the webinars and subscribing to the e-Bulletin (Nicole Sallur, pers. comm., June 2021).

Match with National and State Priorities
The Australian Government's Science and Research Priorities and Rural RD&E Priorities are reproduced in Table D7. The investment is directly relevant to Rural RD&E Priorities 3 and 4. The investment addresses Science and Research Priorities 1 and 2.

Table D7: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities[(a)] (est. 2015)	**Science and Research Priorities[(b)] (est. 2016)**
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

(a) Source: Commonwealth of Australia (2015)
(b) Source: Office of the Chief Scientist (2016)

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision-making around future investment are reproduced in Table D8.

The investment addressed QLD Science and Research Priority 1, with some minor contributions to Priority 3, 6 and 9. In terms of the guides to investment, the investment is likely to have a real future impact through increased financial and environmental impacts in northern Australia. The project was well supported and funded by others external to the QLD Government including the relevant industry body (MLA) and two other government jurisdictions (WA and NT). Beef producers and their supply chains in Queensland, the Northern Territory and in northern Western Australia will be the major beneficiaries.

Table D8: Revised QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally-enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Queensland Chief Scientist (2015)

6. Valuation of Impacts

Impacts Valued

The impact valued in the following quantitative analysis is the contribution made by the two project investments in increasing adoption of improved management practice by northern Australian beef producers. The first impact valued is an increase in net annual profitability of some northern Australian beef producers due to an increase in adoption of improved management practices. This impact would be the principal impact; however, the proportion of all northern beef producers employing practice changes due to FutureBeef cannot be confidently estimated from information in the communication review. However, the review supported the case that the incidence of practice change due to FutureBeef would most likely be higher in Queensland compared to Western Australia and the Northern Territory.

The second impact valued is a reduction in extension costs due to the use of webinars and information provision through other online sources. The specific assumptions made for impact valuation are provided in Table D9.

Table D9: Summary of Assumptions for Valuing Impacts

Variable	Assumption	Source
Base industry data – number of beef producers in northern Australia		
Five year average of number of beef producers in Queensland	5,669	Years ending June 2015 to June 2019 (ABARES, 2019)
Five year average of number of beef producers in the Northern Territory	154	ABARES, 2019
Five year average of number of beef producers in northern Western Australia	196	Includes Kimberley (43) and Pilbara regions (153) (ABARES, 2019)
Base industry data – average annual beef producer farm business profit in northern Australia		
Five year annual average in Queensland (all regions)	$26,518	ABARES, 2019
Five year annual average in the Northern Territory	$1,092,118	
Five year annual average in northern Western Australia	$410,131	
Impact of FutureBeef on beef producers		
Estimate of proportion of producers increasing profitability due to FutureBeef	10% Queensland 5% Northern Territory 5% Western Australia	Analyst estimates
Impact on farm business profit	7.5%	
Year of first impact	2015	Analyst estimates
Year of maximum impact	2022 and continuing thereafter	
Cost savings due to webinars		
Estimate of savings in travel and staff time from reduced face-to face meetings	$2.1 million over two years	DAF estimate reported by Sallur and Ward (2020)
Attribution to two project investments	75%	Allows for some face-to-face potential benefits not delivered by webinars
Timing of impact	Annually 2015 to 2021	Analyst estimate

Counterfactual		
Proportion of both benefits that would have been delivered without the investment in FutureBeef	20%	Analyst estimate
Risk Factors		
Probability of output	100%	Analyst assumptions
Probability of outcomes (change in adoption) occurring	75%	
Probability of impact given adoption increase (a successful outcome)	75%	

Counterfactual
It is unlikely that the resources required or the expertise applied would have been made available other than through the two investments. Such investments are unlikely to have been attempted formally in the absence of the cooperation between the three jurisdictions and the industry partner. This is assumed to apply in the Northern Territory and Western Australia jurisdictions due to less online communication and lower staff numbers than in Queensland.

However, it is likely that in Queensland some online communication would still have occurred without the FutureBeef investment (Nicole Sallur, pers. comm., 2021). To recognise these differences, the counterfactual assumed that 20% of the estimated Queensland benefits (both increases in producer profitability and extension cost savings due to online communication) would have occurred anyway, that is without the FutureBeef investment.

Impacts not Valued
The impacts identified but not valued are listed in Table D10, together with the principal reason why they were not valued in monetary terms.

Table D10: Impacts Identified but Not Valued in Monetary Terms

Impact Identified	Reason for not Valuing in Monetary Terms
Increased extension efficiency and effectiveness via a reduction in potential duplication of effort associated with information assembly	Apart from the extension cost savings valued due to webinars replacing travel and time, other extension efficiency impacts would be too difficult to quantify without extensive surveying of participants in the three jurisdictions.
Contribution to improved land condition and biodiversity in northern Australian grazing lands	Environmental values such as biodiversity and export of soil/nutrients were considered difficult to value without further data. Also, the value of impact of improved land condition is partly included in the average profitability gains that were valued.
Increased spillovers to regional communities from increased incomes for northern beef producers and their associated supply chain businesses.	Any increase in spillovers from increased economic activity and employment along the product supply chains would be difficult to value, given the geographic spread and diversity of beef production systems in northern Australia.

Maintained or Increased extension capability and capacity in public sector agencies	The impacts of Increased capability and capacity for the three public sector agencies were not valued due to insufficient resources/time and the difficulty in assembling appropriate data. Moreover, this impact was already valued in part via its contribution to the impacts that were valued.

7. 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 base analyses ran for the length of the investment period plus 30 years from the last year of investment (2021/22) to the final year of benefits assumed.

Investment Criteria
Tables D11 and D12 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table D12, has been estimated by multiplying the total PVB by the DAF proportion of real investment (61.6%).

Table D11: Investment Criteria for Total Investment in the Two Projects

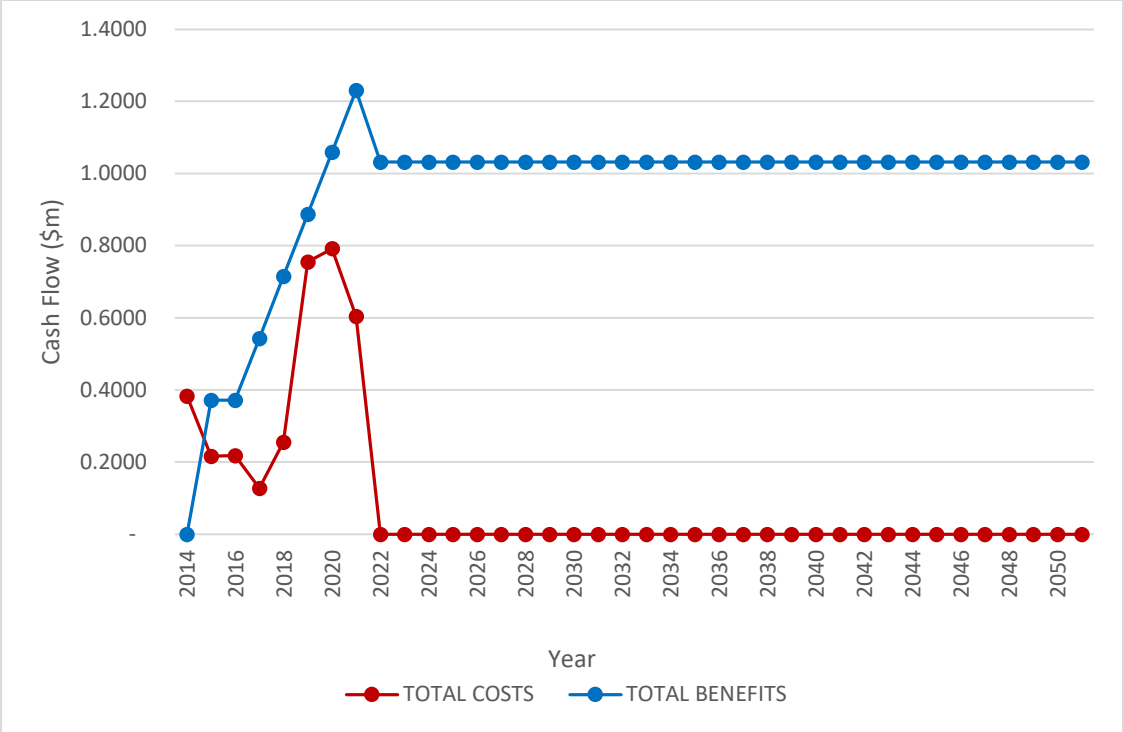
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	5.51	9.76	13.09	15.70	17.75	19.35	20.61
Present value of costs ($m)	3.64	3.64	3.64	3.64	3.64	3.64	3.64
Net present value ($m)	1.86	6.12	9.45	12.06	14.11	15.71	16.97
Benefit-cost ratio	1.51	2.68	3.59	4.31	4.87	5.31	5.66
Internal rate of return (%)	negative	66.03	66.42	66.45	66.45	66.45	66.45
MIRR (%)	385.88	60.84	37.50	28.24	23.15	19.92	17.66

Table D12: Investment Criteria for DAF Investment in the Two Projects

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	3.39	6.01	8.06	9.67	10.93	11.91	12.69
Present value of costs ($m)	2.17	2.17	2.17	2.17	2.17	2.17	2.17
Net present value ($m)	1.21	3.83	5.88	7.49	8.75	9.74	10.51
Benefit-cost ratio	1.56	2.76	3.71	4.45	5.02	5.48	5.83
Internal rate of return (%)	negative	133.70	133.71	133.71	133.71	133.71	133.71
MIRR (%)	1597.92	110.47	60.08	42.57	33.52	28.05	24.34

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure D1.

Figure D1: Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Sources of Benefits

There were two sources of benefits valued in the analysis. Table D13 shows estimates of the relative contribution from each source.

Table D13: Contribution of Source of Benefits to Present Value of Benefits (PVB) (Total investment, 30 years)

Source of Benefit	PVB ($m)	Proportion of Total PVB (%)
Increased farm business profit	17.73	86.0
Extension cost savings	2.88	14.0
Total	**20.61**	**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 D14 presents the results that show only a moderate sensitivity to the discount rate.

Table D14: Sensitivity to Discount Rate (Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	36.13	20.61	14.73
Present value of costs ($m)	3.35	3.64	4.00
Net present value ($m)	32.78	16.97	10.73
Benefit-cost ratio	10.78	5.66	3.69

A sensitivity analysis also was carried out on the assumption of the probability of each of the outcomes and impacts occurring, that is, that the project outputs will be used by, and provide impacts to, the northern Australia beef industry. Results are reported in Table D15. The outcome and impact probabilities could each fall to 31% for the project benefits to still cover the investment costs.

Table D15: Sensitivity to Probabilities of Outcomes and Impacts
(Total investment, 30 years, 5% discount rate)

Investment Criteria	**Probability of Each of Outcomes and Impacts Occurring**		
	50%	**75% (Base)**	**100%**
Present value of benefits ($m)	9.16	20.61	36.64
Present value of costs ($m)	3.64	3.64	3.64
Net present value ($m)	5.52	16.97	33.00
Benefit-cost ratio	2.51	5.66	10.06

Confidence Ratings

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 for the benefit valued, including the linkage between the research and the assumed outcomes and impacts.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table D16). 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 D16: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium-High. While there were several benefits identified but not valued, the principal economic outputs from the project were valued (profitability improvements for producers and cost savings in the extension effort).

Confidence in assumptions for the valuation was rated as Medium as some of the assumptions associated with the value of the principal impact were somewhat uncertain (e.g. the adoption levels and profitability gains attributed to FutureBeef.

8. Conclusion

The investment in the two projects associated with FutureBeef has been successful and is likely to provide positive impacts on northern Australia beef producers operating in the three jurisdictions. Further, there are likely to be significant savings to agencies supplying extension services to beef producers in northern Australia, i.e. MLA and the three State/Territory agencies.

The private sector benefits will accrue to northern beef producers as well as their supply chains operating across northern Australia. Some public benefits will be delivered via:

- community spillovers from increased beef producer/supply chain incomes.
- a contribution to improved land condition and biodiversity in northern Australian grazing lands.
- an Increased extension capability and capacity in public sector agencies.

The combined investment in the two projects E.INV.1412 and L.GBF.1802 represented an investment of $3.23 million dollars in nominal terms. The total investment in the project of $3.64 million (present value terms) has been estimated to produce total gross benefits of $20.61 million (present value terms) providing a net present value of $16.97 million, a benefit-cost ratio of 5.7 to 1 (using a 5% discount rate), an internal rate of return of 66.5% and a modified internal rate of return of 17.7%.

The investment criteria reported are likely to have undervalued the full set of impacts as defined in this assessment. This was because several potential benefits identified were not valued in monetary terms for various reasons as detailed in the assessment.

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Appendix E: An Impact Assessment of Investment in Serviced Supply Chains: Monitoring and Modelling to Improve the Quality of Australian Fresh Produce into Asian Markets (Horticulture Innovation Australia Frontiers Asian Markets Fund Project: AM15002)

Acknowledgments

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Abbreviations

CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries – Queensland
DEDJTR	Department of Economic Development, Jobs, Transport and Resources, Victoria
DJPR	Department of Jobs, Precincts and Regions, Victoria
GQFE	Growing Queensland's Food Exports
Hort Innovation	Horticulture Innovation Australia Limited
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
RDC	Research and Development Corporation
RFID	Radio-Frequency Identification
USQ	University of Southern Queensland

Executive Summary

This report presents the results of an impact assessment of a Queensland Department of Agriculture and Fisheries (DAF) investment in a project associated with improvements to supply chains for export of Australian fresh horticultural produce into Asian markets. The project was jointly funded by DAF, Horticulture Innovation Australia Limited (Hort Innovation), and others including the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR), the University of Southern Queensland (USQ), Manbulloo Limited, Montague Fresh and Glen Grove. The project was undertaken by DAF and its partners over the years ending June 2017 to June 2022.

The project is first described qualitatively using a logical framework that included project objectives, activities and outputs, outcomes and impacts. Impacts then were categorised into a triple bottom line framework. Principal impacts were then valued.

The cost-benefit analysis was conducted according to the current Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018). Benefits were estimated for a range of time frames up to 30 years from the last year of investment in the project (2021/22). Past and future cash flows in 2019/20 dollars were discounted to the year 2020/21 using a discount rate of 5% to estimate the investment criteria.

The large investment in AM15002, and its outputs and outcomes to date, have been important in the maintenance of profitability and further development of horticultural markets for Australian produce exported to a number of Asian countries. The avenue for these impacts has been through an increase in freshness and consistency, and increased trust and reputation in the marketplace.

Specifically, the principal impacts valued emanating from the project were associated with the increased profitability of Australian mango, summerfruit and lemon exports to China, South Korea and some other Asian countries.

Total funding from all sources over the project duration was approximately $19.2 million (present value terms). The value of total potential benefits due to the project are estimated at $45.1 million (present value terms). This result generated an estimated net present value of $25.9 million, a benefit-cost ratio of 2.35 to 1, and internal rate of return of 12.0% and a modified internal rate of return of 8.1%.

There were several potential impacts identified that were not valued in monetary terms. These included:

- Any increased profitability of Australian table grapes and some vegetables exported to some Asian countries.
- The increased spillovers to regional communities from sustained or increased productivity of relevant fruit production in Australia.
- The impact of increased or maintained scientific capability and capacity building for government agencies, as well as within some horticultural industries.
- The reduction in negative environmental impacts from a reduction in disposal costs of wasted or discarded produce on arrival in the importing country.

In addition, the success of the project has spawned a number of new projects that are based on the principles and learnings from AM15002.The investment criteria reported therefore are likely to have undervalued the full value of benefits delivered by the investment.

1. Evaluation Methods

The evaluation approach follows general evaluation guidelines that now are well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses cost-benefit analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, and potential and actual 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. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the limited time and resources available for undertaking the evaluation. However, the impacts valued are deemed to represent the principal benefits delivered by the project.

2. Background and Rationale

The investment in Project AM15002 was a very large investment funded by Hort Innovation, two state government departments and several commercial entities. The project aims to monitor conditions of supply chains to Asian markets in order to improve the quality of exported fresh Australian horticultural produce. The project initially focused on the following commodities: mango, summerfruit, citrus and table grapes. The project addresses how product is transported with the aim to minimise loss of quality and "freshness", reduce wastage and increase reliability.

Horticulture Innovation Australia Ltd (Hort Innovation) developed a Horticulture (Hort) Frontiers strategic partnership initiative to expand its funding model to better equip Australian horticulture for the future. The initiative facilitates collaborative cross-industry investments focused on longer-term, complex and traditionally underinvested themes identified as critical for the future of the horticulture industry.

The Hort Frontiers partnership assembles resources from a wide range of both private and public co-investors. Funded projects are required to benefit all of Australian horticulture to be considered suitable investments.

Currently, there are seven different strategic investment funds within Hort Frontiers: These funds include:

- Advanced Production Systems Fund
- Asian Markets Fund
- Fruit Fly Fund
- Green Cities Fund
- Health, Nutrition and Food Safety Fund
- Leadership Fund
- Pollination Fund

The current project being assessed was funded in part by Hort Innovation's Asian Markets Fund. The purpose of the fund is to build a globally competitive, unified, agile and profitable Australian horticulture industry through sustainable investment in high value and high growth Asian markets.

Completed projects include:

- *Australia Fresh Collaboration Market Development Program - Almonds (AM15007)*
- *Market and consumer insights to drive food value chain innovation and growth: horticulture sub-project (ST15018)*

Currently (as of 2021) ongoing projects include:

- *Developing a national systems approach for meeting biosecurity requirements to access key Asian markets (AM17001)*
- *Serviced supply chains: Monitoring and modelling to improve the quality of Australian fresh produce into Asian markets (AM15002)*
- *Study of airfreight capacity for Australian horticulture exports to Asia and the Middle East (AM16012)*
- *Taste Australia global trade shows and retail programs*

Other Funding for Project AM15002

DAF and the former DEDJTR (now the Department of Jobs, Precincts and Regions (DJPR)) were the other principal funders of the project being evaluated, contributing jointly about a third of the total funding (See Table 3 below). DAF was committed to the ongoing support for developing exports of Queensland's food products, particularly horticultural products. For

example, DAF has supported a number of past export development programs via its Growing Queensland's Food Exports programs.

A critical aspect of the current investment was the involvement of three commercial entities who successfully export fruit to Asian countries (Manbulloo Limited, Montague Fresh, and Glen Grove). Manbulloo, an exporter of mangoes, has been involved in a number of previous DAF export development programs. Manbulloo, as well as the Australian and Queensland mango industries, have benefited in the past from such DAF initiatives including technical and export infrastructure development, export market development in a range of countries, and leadership and coordination among exporters. Montague Fresh is a grower, wholesaler and exporter of a range of horticultural products including summerfruit. The company sources fruit from growers in Queensland, New South Wales and Victoria. Glen Grove is a lemon exporter based in central Queensland,

Some additional support for the project was also made available from USQ and by in-kind support from the University of Queensland and the Chinese Academy of Sciences.

3. Investment Details

Summary of Project Investment
The investment in the project assessed (AM15002) was, and is being made, in the years ending June 2017 to June 2022. DAF was the lead research agency and Hort Innovation the principal funding organisation via its Asian Markets Fund (contributing about 50% of the total budget in nominal $ terms). DAF and DJPR jointly contributed about one third of total funding. The project code, title, key research personnel, and funding period for the investment are summarised in Table E1.

Table E1: Summary Details for the Investment

Project Code	Title	Key Personnel	Funding Period
AM15002	Serviced supply chains: Monitoring and modelling to improve the quality of Australian fresh produce into Asian markets	Peter Hofman, Senior Principal Horticulturist (Postharvest), Department of Agriculture and Fisheries, Queensland Andrew Macnish, Senior Horticulturist and Team Leader Supply Chain Innovation, Department of Agriculture and Fisheries, Queensland	Years ending June 2017 to June 2022

Table E2 provides a description of the project in a logical framework format.

Table E2: Logical Framework for Project AM15002

Overall Objective	The overall objective of the project is to increase the value and profitability of Australian horticulture by improving the 'freshness', consistency and reputation of Australia's exports into Asia.
Specific Objectives	6. Using internationally best monitoring systems of storage and transport environments (e.g. temperatures, gases, volatiles) around products and monitoring of actual product condition, to identify improvement strategies to increasingly meet consumer demand for product quality. 7. To implement predictive models of product quality at outturn to allow rapid decision-making that will maximise marketing opportunities and minimise quality loss. 8. Based on the above, and using value chain principles and participatory learning, to develop and implement effective, targeted chain improvement strategies and systems based on postharvest environment and product monitoring and real time feedback and advice. 9. Initially working at depth with at least one chain in each of 3-4 commodity groups as case studies to confirm and demonstrate the benefit/cost of the above approaches. 10. To upskill established providers to offer the information and services to interested chains on a long-term commercial basis.
Activities	**Project management** • A Project Management Committee and a Project Reference Committee were established to assist with management and advise on project

	matters. The Management Committee met regularly throughout the project • A Project Reference Group was appointed and met twice per annum (once face to face and once by teleconference) • A Monitoring and Evaluation Plan was developed and implemented. **Selection of supply chains** • Initially, five horticulture supply chains were selected for study by the project; these were Manbulloo Ltd for mangoes (China and South Korea markets), Montague Fresh for summerfruit, Glen Grove (Queensland) for citrus, table grapes and vegetables. • As specific industry partners for table grapes and vegetables were not found, activities for these two supply chains were somewhat limited. **Description of existing monitoring systems and potential improvements** • An understanding of the existing system of supply chain monitoring was required before any improvements could be identified. • The existing monitoring methods of supply chains were addressed via equipment/logger costs, data retrieval and installation of receiver systems in the importing country. • For existing supply chains the quality of product before export and at arrival in the importing country was determined (quality at arrival and residual holding life). • An understanding was developed of the customer/consumer requirements in relation to any characteristics likely to be influenced by supply chain conditions. • Supply chain characteristics, performance and function and comparisons against known best practice were documented; and improvement opportunities were identified (e.g. time reductions, refinement of protocols). • Relevant sensors were identified (e.g. off-the shelf carbon dioxide and oxygen loggers, ethylene, chlorophyll fluorescence, green colour sensors). **Development of effective predictive tools to improve quality/handling conditions** • The information that the predictive tools would need to address was identified. • Laboratory trials were undertaken to determine the impact of transport time and condition on outturn quality. • The trials were refined based on the results of the monitoring activity to develop more accurate predictive tools. • The predictive tools were then used to estimate holding life on arrival and the associated monitored conditions during transport from farm to importer. • The accuracy of the predictive tools was then tested under commercial conditions. **R&D targeting some other improvements** • Other activities were identified where even current best practices may not guarantee acceptable holding life and quality (e.g. time to undertake heat disinfestation treatments); improvements in such practices were

	developed to improve the overall effectiveness of the relevant supply chains. **Development of sustainable solutions across the horticulture export industry** • While sustainable solutions were pursued to create step changes in the supply chains specifically involved in the project, solutions also were pursued to provide export chain improvement across the broader horticultural fresh export industry. • Targeted chain improvement strategies were developed (with the assistance of the mainstream industry supply chain partners) that addressed information products, monitoring services, participatory learning principles, and supply chain industry training. • Communication activities were held with other supply chains (non-mainstream project partners e.g. vegetables) to promote project activities and associated results. • The project worked closely with private providers (e.g. exporters, transporters, freight forwarders, assessors, and importers) to build capability and capacity within the various nodes in the supply chains. These activities were undertaken so that services would be available to an increased number of supply chains after project completion.
Outputs	• Identification of areas of potential improvement to address improved quality along identified export supply chains particularly for the mango, summerfruit and citrus chains. • Development of reliable predictive tools to estimate conditions during transport and holding life on arrival. • Use of the predictive tools to assess benefits of streamlining steps in the supply chain. Examples included steps from harvest to packing, and loading containers at the packhouse as opposed to the port. • Algorithms were developed to predict remaining shelf life of R2E2 mangoes as well as for summerfruit. • It was determined that quality predictions must be tailored to individual cultivars for both mango and summerfruit. • Low temperature simulation trials with summerfruit have defined storage life limits for several cultivars, and hence suitability for export via air versus sea freight. • Workshops and industry forums were held to promote to other horticultural supply chains the availability of services, information products and case studies. • Examples of rules of thumb for improvement of export supply chains for R2E2 mangoes included the following (DAF, 2020) o Monitor mango temperature throughout the supply chain and ask chain partners to correct any departures from best practice. Mangoes must be 12–13˚C when they leave the pack shed, freight forwarder and at importation. o Mangoes at 13˚C can handle a maximum of 9 days in a refrigerated sea container but up to 20 days when Controlled Atmosphere is used. • It was difficult to test summerfruit quality models via summerfruit shipped by Montague Fresh in 2020 due to interruptions to travel plans by Covid-19, as well as for other reasons.

	• However, storage experiments for summerfruit have confirmed that both cultivar and duration of low temperature storage are the key factors affecting end point quality in exporting. • Overall, the project team developed considerable understanding of new technology temperature monitoring systems, developed draft predictive decision aid tools, and circulated and publicised a number of fact sheets and technical notes, articles in industry magazines, press releases, roadshows, videos and conference/workshop presentations.
Outcomes	• During 2019/20 increased interest was shown by mango, summerfruit and some table grape exporters to deploy autonomous reporting data loggers into air and sea shipments and view consignment temperature and location data; this has assisted them to identify inefficiencies relating to fruit quality, as well as sharing of monitoring data with their supply chain partners. **Mango** • Manbulloo was the first Australian grower to export R2E2 mangoes directly to mainland China and South Korea. Part of their success is due to cultivating close, trusting relationships with supply chain partners. • The ability to retrieve temperature data from the cold chain and share that with supply chain partners has been key to building further trust. The temperature data are critical to making improvements in supply chain practices and delivering consistently high-quality product with longer shelf life. • Scott Ledger, Export Manager at Manbulloo, has stated that, with the help of the Serviced Supply Chain team, they started looking for alternatives to USB temperature loggers, mainly because the logger recovery rate was less than 25%. SIM-based loggers were just becoming affordable, but none had approval on airlines with regular flights from Australia. So, they evaluated a radio-frequency identification (RFID) temperature monitoring system about 4 years ago. RFID systems use electromagnetic fields to automatically identify and track tags attached to objects. The loggers do not require airline approval, and the autonomous upload of data using communication units overcomes the difficulties of retrieving data from USB devices. • Manbulloo has increased the number of export shipments monitored from 25% in the 2016/17 season to 70% in 2019/20 and 85% in 2020/21. • Average supply chain temperatures have decreased from 16.0 degrees C to 13.2 degrees C in 2019/20, providing an additional 2.4 days of shelf life in the Asian market. • Manbulloo adopted and optimised a consignment management dashboard built by DAF and a third party software developer to ensure they could efficiently interpret data in real-time from each shipment. • For two export shipments in 2020/21, Manbulloo reacted to a low temperature alert sent from the SIM loggers to notify the Korean importer who then successfully moved the consignment to a warmer location and averted quality and revenue loss (Andrew Macnish, pers. comm., 2021). • Four other mango exporters are evaluating logger technologies and monitoring data to improve handling and maintain quality (Andrew Macnish, pers. comm., 2021).

	• A mango algorithm, as well as a summerfruit algorithm, are currently being tested for potential future commercialisation purposes. Such algorithms can be used to predict remaining shelf life.
	
	Summerfruit
	• During the 2019/20 season Montague Fresh, with assistance from DJPR has deployed data loggers for both air and sea freight shipments of summerfruit to a range of Asian countries.
	• Specific outcomes for Montague Fresh include: (Andrew Macnish, pers. comm., 2021)
	  ○ (Montague has increased the number of export shipments monitored from 0% in 2016/17 to 30% in 2020/21 in a targeted manner according to the risk profile of particular supply chains.
	  ○ For one export shipment in 2020, Montague responded to a high temperature alert sent from the SIM loggers by warning the shipping line who then successfully lowered the container temperature which averted quality and revenue loss.
	  ○ A further five export shipments in 2020 were the subject of a quality dispute and Montague are challenging this with their insurer by presenting consignment temperature records from the loggers that documents where and who was responsible for the deviation in temperature management. Montague have relied on the decision aid tools program data to only export selected stonefruit cultivars by sea that have been shown to be suited to this relatively long supply chain.
	  ○ Montague have also expressed interest in changing practice towards step-wise cooling prior to export dispatch based on the results and recommendations from project trials that show this can reduce internal fruit disorders and extend shelf life
	• An increased number of enquiries have been received from other exporters and growers of summerfruit, particularly regarding interest in being included in monitoring trials regarding maturity measuring technology. One other grower commenced shipment monitoring in 2020/21 based on the project recommendations.
	
	Citrus
	• During the 2017 and 2018 citrus season, Glen Grove Orchard monitored lemon shipments to Indonesia and identified quality issues on arrival. These issues were traced back to inconsistent fruit degreening and pre-cooling practices. Glen Grove rectified this based on recommendations from parallel trials completed by the project team.
	• Five other central Queensland citrus exporters joined Glen Grove in a follow-on project to monitor 53 citrus (lemon, mandarin) shipments to Asia in 2019. The temperature monitoring has provided the growers with confidence to raise container set temperatures closer to the protocol limit to reduce the risk of fruit chilling injury; this allowed them to increase sales during Chinese festivals. All six exporters have continued to monitor export shipments for selected high risk supply chains (Andrew Macnish, pers. comm., 2021).
	
	Table grapes and vegetables

- Three table grape exporters have introduced data loggers into their shipments and this has assisted them to improve fruit quality at destination, with assistance from their chain partners.
- A pilot temperature trial on zucchinis freighted to Japan was carried out to demonstrate value to vegetable exporters.
- This pilot helped stimulate interest by two Qld vegetable exporters and the peak industry body AusVeg to co-invest in subsequent export monitoring and improvement projects (Andrew Macnish, pers. comm., 2021).

Stimulation of Additional Project Investment

- The project has had an important additional outcome in that it has stimulated the development of a range of additional supply chain projects being funded (Broadley, 2019).
- The following existing and planned projects are based on the principles and learnings from AM15002. They are expanding the impact and outcomes of AM15002 into other domestic and export horticulture chains and / or commodities that are not involved in AM15002. The projects have been developed by AM15002 team members, with ongoing involvement ranging from leading, active involvement to advisory only. New projects include (based on Andrew Macnish, pers. comm., 2021):

  <u>Commenced from August 2018:</u>
  - Sustainable export supply chains for 'Calypso' mango to China: Facilitating adoption of 'Calypso' mango best practice based on 12 years of HI-supported R&D by DAF. Also facilitating routine cold chain monitoring and outturn assessment of the Perfection Fresh export supply chain using methodologies refined in AM15002. Project leader A Edwards (Perfection Fresh), with P Hofman (DAF) as expert advisor. Funded by the CRC for Developing Northern Australia and Perfection Fresh. Value: $189,998.00 cash, $399,278.57 in-kind.
  - Development of a Calypso™ mango decision support system (DSS): To develop a DSS that will use supply chain (including cold chain) performance data to drive change and improve profitability in the 'Calypso' Perfection Fresh chain. AM15002 project team and exporter experience with existing off-the-shelf temperature data platforms will be considered in designing the DSS. Project leader L Bonney (UTas) with P Hofman as expert advisor. Funded by the ARC project Pathways to Market (UTas) and Perfection Fresh.
  - Cherry exports development: To improve the performance of Victorian cherry exports to Vietnam by cold chain monitoring and fruit quality outturn assessment. Project leader Glenn Hale (DJPR). Funded by DJPR Market Access, Agriculture Policy – Agriculture, Food & Fibre for one year.

  <u>Commenced from January 2019:</u>
  - Implementing best practice of avocado fruit management and handling practices from farm to ripening DC: The project will undertake surveys of about 40 supply chains a year, including cold chain monitoring and quality assessment. Project leader N Ainsworth (DAF). Funded by HI and avocado levies. Value: $394,289.45 cash, $436,798.54 in-kind.
  - Delivering high-quality sea freight vegetables to Asia: The project includes supply chain monitoring of trial shipments of several

	vegetables to Japan, and developing a basic decision aid tool for sea freight of one leafy vegetable based on AM15002 experience. Project leader K Versteeg (Qualipac) with D Joyce (DAF) as key researcher/advisor. Funded by the Growing Queensland Food Exports program and several vegetable chains. Value: $6,350.00 cash, $64,391.27 in-kind. o Perishable products supply chain agility-horticulture: A "Constellation" of projects to support horticulture supply chain improvement. It consists of a number of programs: o "Supply chain performance" to objectively identify key improvement and development opportunities. o "Postharvest sensor development". o "Preharvest sensor development" to develop sensors that monitor field conditions impacting on product quality at harvest. o "Predicting fruit and vegetable quality". Using the sensor data, this program will develop the predictive tools (algorithms) to predict quality from the sensor data and allow integration with digital platforms. o "Digital platforms and decision support" will develop digital platforms that use the sensor data and predictive tools to generate on-the-ground recommendations for relevant farm, pack house, exporter, importer and retailer supervisors / decision makers. The project will build on the learnings relating to end-user preferences identified in AM15002. o Constellation leaders Peter Hofman (DAF) and DJPR, and includes Queensland University of Technology and RMIT Melbourne. Funded by the Food Agility CRC, co-investing chains and service providers. <u>Commenced from March 2020:</u> o Reducing economic and physical waste by minimising loss of value of fresh banana from farm to consumer: Based on the three programs of AM15002, and originally submitted to Hort Innovation for funding within AM15002. It involves banana only, and will implement regular chain monitoring to identify improvements, and develop DAT tools for banana. Project leader A Macnish (DAF). Funded by the Fight Food Waste CRC and Pacific Coast Produce. Value: $429,217.39 cash, $565,303.18 in-kind. o Improving Avocado Exports (Costa). To improve the avocado export supply chain to deliver an Australian premium and reduce avocado export claims. Based on the three programs of AM15002, and including a platform (smartphone app) for the DAT. Project leader S Jones (Costa). DAF project leader Daryl Joyce. Includes QUT and funded by the Food Agility CRC. Value: $307,480.62 cash, $802, 615.88 in-kind. o Green Beans Prediction (Mulgowie). To provide consistent delivery of quality data to support decision making in fulfillment of fresh vegetable demand plans. Based on programs 3 and 4 of the Horticulture Constellation. Project leader M Spear (Mulgowie). DAF leader D Carey with support from Daryl Joyce. Includes QUT and funded by the Food Agility CRC. Value: $36.062.71 cash, $117,137.48 o Deploying systems for pre and post-harvest Summerfruit supply chain intelligence. Develop, test and validate pre-harvest sensor technologies to improve prediction of harvest time, and postharvest

	sensor technologies predict changing product quality and the development of storage disorders. Based on programs 2, 3, 4 and 5 of the Horticulture Constellation. Project leader Dr Ian Goodwin. Includes RMIT and funded by the Food Agility CRC. <u>Commenced from August 2020:</u> ○ Increasing the competitiveness of Australian vegetable exports. This pilot project aims to demonstrate a range of collaborative activities that will assist in building the export capability and competitiveness of the Australian vegetable industry through (1) understanding target market/s competitive environment and windows of supply opportunity, (2) analysing existing and new supply chains to recommend improvements and efficiencies, (3) conducting simulation experiments to enrich monitoring data and decision aid tool development and (4) facilitating improved knowledge and decision making along the supply chain. Project leader J Campbell (DAF). Funded by AusVeg through levies via Hort Innovation. Value: $99,999.51 cash, $101,993.68 in-kind. **Protection of Intellectual Property** • A Trade Secret strategy is being preferred to protect the algorithms developed and is currently being developed, along with a commercialisation strategy.
Impacts	• Increased capacity of some Australian fresh fruit and vegetable supply chains to deliver outturn quality and increase remaining shelf life, allowing more predictable and profitable horticultural export consignments to Asian markets. • For example, Manbulloo has maintained or increased exports of mangoes to China and South Korea, receiving higher prices but with some increased costs of monitoring. • Manbulloo has also reduced costs of disputes with importers due to the availability of additional information provided by monitoring. • In addition to mangoes, other Australian horticultural industries that are exporting to Asian countries are expected to benefit from the project findings; these industries include summerfruit and lemon producers and, potentially, table grapes and some vegetable. • As with mangoes, impacts of other products could include a reduced cost of trade disputes due to the availability of additional information from monitoring. • Increased trust of Australian product quality by importers and consumers in some Asian markets has been delivered, allowing maintenance of, or an increase in, Australian export volumes and prices, particularly in the years ahead. • Some positive environmental impacts could accrue to importing countries from reduced wastage of fruit and the associated environmental costs of disposal. • In addition, an increased applied science capability and capacity has been built and /or strengthened, particularly in some public sector agencies such as DAF, as well as in some horticultural industries. • This capacity is being further developed and applied in a number of new projects that that have evolved out of the initial funding and success of Project AM15002.

4. Project Investment

Nominal Investment

Table E3 shows the annual investment in the project (cash and in-kind) by funding organisation and by year. The largest cash contribution emanated from Hort Innovation. The two principal cash funding organisations were Hort Innovation and DAF.

Table E3: Annual Investment in Project AM15002 by Funding Organisation

Year ended 30 June	2017	2018	2019	2020	2021	2022	Total
Cash Contributions (nominal $)							
Hort Innovation	676,256	876,584	801,573	850,206	813,969	146,781	4,165,369
DAF	326,847	489,514	522,890	535,926	549,287	143,386	2,567,849
DEDJTR (now DJPR)	289,478	300,959	312,896	414,898	338,208	89,592	1,746,031
USQ	112,000	46,309	0	0	0	0	158,309
Manbulloo	295,059	297,502	318,534	348,663	354,475	0	1,614,233
Montague Fresh	50,000	50,000	50,000	50,000	50,000	0	250,000
Glen Grove	0	207,071	67,973	0	0	0	275,044
Total Cash	**1,749,640**	**2,267,939**	**2,073,866**	**2,199,693**	**2,105,939**	**379,759**	**10,776,836**
Cash (%)	16.2	21.4	19.2	20.4	19.5	3.5	100.0
In-kind Contributions							
In-kind Contributions	1,033,760	1,339,994	1,225,323	1,299,668	1,244,275	224,375	**6,367,395**
Total Cash and In-kind							
Total Cash and In-kind	2,783,400	3,607,933	3,299,189	3,499,361	3,350,214	604,134	**17,144,231**

Source: Signed Research Agreement between Hort Innovation and DAF 9th February 2017 supplemented by information made available by Andrew Macnish of DAF (2021)

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 E3. For the DAF and the other investments, any management and administration costs for the project are assumed already built into the nominal $ amounts appearing in Table E3.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 $ terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2021)

Because the project was carried out in close cooperation with companies in the private sector, most extension and communication costs were already covered in the existing budget.

5. Impacts

Impact on Industry Profitability
The project was first funded in year ended June 2017 and is not due to be completed until the year ended June 2022.

Industries and potential industries benefiting via increased demand in Asian markets and associated profitability, could include:

- mango, particularly Manbulloo
- citrus (in particular, lemon producers in Queensland)
- summerfruit (in particular, nectarines from Victoria), and potentially
  - table grapes from Victoria
  - zucchini and some other vegetables

Any increase in productivity and profitability that benefits fruit growers and exporters are likely to be shared along the supply chain including exporters, transport and storage operators, wholesalers, retailers and consumers. Further, positive spillover impacts will be experienced by regional communities connected with fruit producers and their supply chains.

Environmental Impact
Potentially reduced need to dispose of damaged fruit in importing countries with an associated reduction in environmental impacts.

Social Impact
Increased spillovers to regional communities in some fruit growing regions of Australia, driven by increased grower incomes and their associated supply chain businesses.

Maintained or increased applied science capability and capacity, particularly in DAF, and in some horticultural industries.

Summary of Impacts
An overview of impacts in a triple bottom line categorisation is shown in Table E4.

Table E4: Categories of Impacts from the Investment in Project AM15002

Economic	Environmental	Social
Increased productivity and profitability of a range of Australian fruit producers including mango, summerfruit and some lemon producers in Queensland, and potentially, for table grapes and some vegetables. Associated productivity and profitability gains will be shared along the supply chains with transporters, exporters, wholesaler and retailers.	Potential for reduced wastage of fruit and associated reduced environmental costs of disposal.	Increased spillovers to regional communities from increased incomes for growers and their associated supply chain businesses. Maintained or Increased applied science capability and capacity in public sector agencies (DAF and DEDJTR) and in some horticultural industries.

Distribution of Benefits along the Supply Chains
Some of the potential benefits from the maintained/increased quality and avoided costs of disputes of fruit exports to Asian countries will be shared along the supply chain with growers, exporters and consumers according to relevant supply and demand elasticities.

Public versus Private Impacts
The impacts identified from the investment are predominantly private, namely accruing to private sector supply chains. Some public benefits will be produced including spillovers to regional communities from enhanced farm and supply chain member incomes, as well as a maintained/increased scientific capability and capacity in public sector agencies.

Impacts Overseas
It is likely that there will be some significant positive impacts in Asian countries importing fresh and higher quality fruit and some vegetable products from Australia, especially mangoes, summerfruit, and citrus.

Match with National and State Priorities
The Australian Government's Science and Research Priorities and Rural RD&E Priorities are reproduced in Table E5. The investment is relevant to Rural RD&E Priorities 1 and 4 and to Science and Research Priority 1.

Table E5: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities[(a)] (est. 2015)	**Science and Research Priorities[(b)] (est. 2016)**
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

(a) Source: Commonwealth of Australia (2015)
(b) Source: Office of the Chief Scientist (2016)

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision-making around future investment are reproduced in Table E6.

The investment addressed QLD Science and Research Priorities 1 and 2. In terms of the guides to investment, the investment is likely to have a real future impact through increased horticultural exports. The project was well supported and funded by others external to the QLD Government (e.g. Hort innovation and the Victorian Government) and had a distinctive angle as QLD horticultural producers and exporters will be a major beneficiary.

Table E6: Revised QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally-enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Chief Scientist Queensland (2015)

6. Valuation of Impacts

Impacts Valued

The impact valued in the quantitative analysis is the contribution made by the investment in developing opportunities for enhanced delivery of higher quality Australian fruit and vegetable products via more effective supply chains that service Asian markets. Valuation of such impacts is difficult as there is a range of industries that probably have benefitted to date (e.g. mango, citrus, and summerfruit), with prospects for table grapes and vegetables) and the extent of associated impacts have varied. As a result, the associated impacts for mangoes, summerfruit and lemons were valued in monetary terms but any impacts for table grapes and vegetables were not valued due to insufficient evidence available to date.

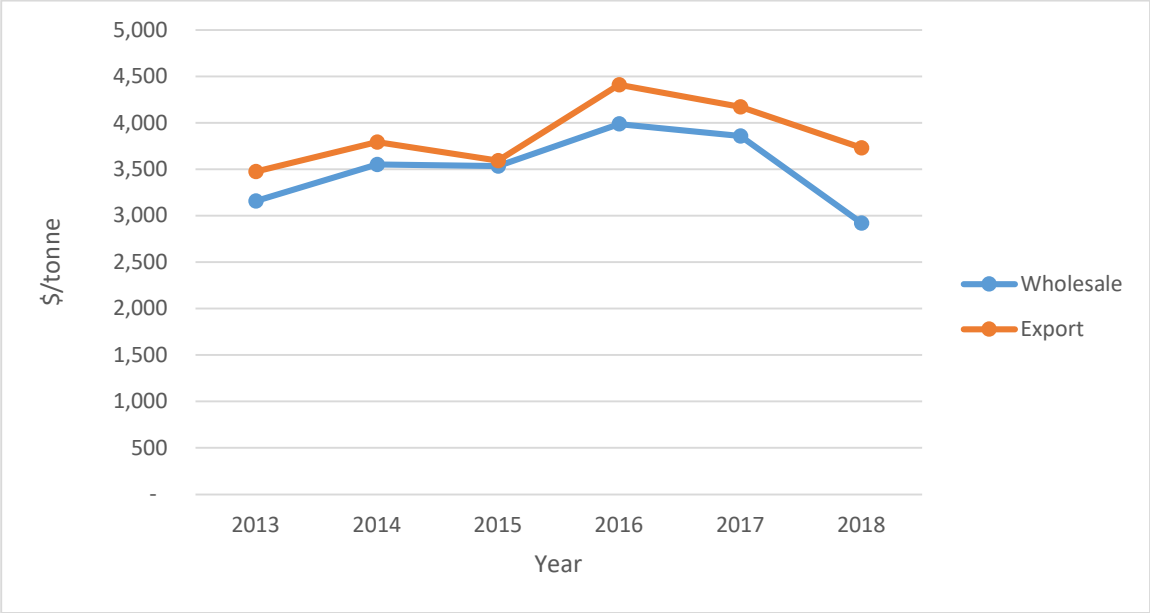
In general. the impacts valued have been driven by the higher quality of produce arriving in the markets of some Asian countries. This had led to increased trust and demand leading to monetary impacts such as increased margins/ additional sales as well as reduced costs of trade disputes.

Mango Impacts

For valuing the impact of Project AM15002 on the profitability of mango exports to Asia by Manbulloo, and potentially other exporters, key assumptions relate to the likely increase in the level of exports to China and South Korea through increased demand for a higher quality product at final consumption.

Figure E1 shows a marginally higher value for mango exports over the Australian mango wholesale price. The average value difference over the six year period 2013 to 2018 was $360 per tonne. The $360 difference was considered conservative by Manbulloo (Scott Ledger, pers. comm., 2019). The average difference over the past eight years (2013 to 2020) has been $519 per tonne (Table E7).

Figure E1: Australian Export and Wholesale Mango Values



Source: Hort Innovation

Table E7: Australian Total Mango Production and Exports

Year ended June	Total prod. (tonnes)	Value of farm prod. ($m)	Fresh supply (tonnes)	Fresh w/sale value ($m)	Fresh w/sale value ($/t)	Australian exports (fresh) (tonnes)	Fresh value of Australian exports ($m)	Fresh export value ($/t)
2013	57,196	146.3	50,146	158.3	3,157	4,604	16.0	3,475
2014	51,069	146.9	43,656	155.1	3,553	5,275	20.0	3,791
2015	66,087	190.7	56,220	198.6	3,533	7,012	25.2	3,594
2016	63,791	210.3	53,880	214.9	3,988	7,006	30.9	4,411
2017	61,474	195.7	52,017	200.6	3,856	7,120	29.7	4,171
2018	83,315	204.3	71,809	209.8	2,922	7,694	28.7	3,730
2019	74,920	198.6	63,957	201.5	3,151	8,221	30.7	3,734
2020	72,022	185.2	61,724	183.0	2,965	7,707	33.7	4,373

Source: Hort Innovation

Increased Value of Mango Exports to China and South Korea.
Mango exports from Australia to China and South Korea are not provided in the Hort Innovation Statistics Handbook rather they are included in the category ”other” and the other category averaged 1,667 tonnes per annum over the three year period 2018-2020.

Project AM15002 has contributed to another project involving Manbulloo funded under the Growing Queensland Food Exports (GQFE) program funded by DAF. The GQFE investment targeted an Increase in fresh mango exports to five target markets including South Korea, China, USA, Canada, and United Arab Emirates. The GQFE project targeted the development of product specifications, handling guides, and market specifications for fresh mangoes.

The monitoring of the supply chains by DAF via project AM15002 was reported to have led to an increase of 28% by Manbulloo in mango exports over the previous season to the five markets in 2018-19. It was expected that this increase by Manbulloo would lead also to a potential increase in mango exports by other exporters to these countries in the future.

For the purpose of the valuation of the contribution of project AM15002 to the increased exports by Manbulloo and others to South Korea and China in particular, it was necessary to make some assumptions about the previous exports of mangoes to China and South Korea (before project AM15002).

Nine years ago Manbulloo started exporting mangoes directly to South Korea and China. Since then exports have increased significantly due to gradual tariff reduction under the China-Australia free trade agreement and the Korea-Australia free trade agreement, Currently Manbulloo exports mangoes valued at about $2 million to South Korea, China, the US and Canada, with South Korea and China being the largest markets (Austrade, 2021). It is assumed that the value of exports to South Korea and China could therefore contribute $1.5 million in value of the $2 million of the Manbulloo exports.

Manbulloo’s mango exports are not a large proportion of total Australian mango exports, however, past Manbulloo initiatives have influenced a significant amount of exports by others. For example, previous to Project AM15002, Manbulloo itself has exported about 5% of total Australian mango exports (Scott Ledger, pers. comm., 2019). However, Manbulloo’s indirect influence on increasing growth of export markets has been far greater through its leadership and collaborative approach and its emphasis on developing the more difficult, but

somewhat higher value markets (Agtrans Research, 2019). This same influence is assumed to have occurred with the investment in AM15002.

The total value of all mango exports to South Korea and China pre AM15002 would therefore be significantly more than $1.5 million. A summary of the assumptions made to value the benefits from the impacts of Project AM15002 regarding the increase in the value of mango exports to China and South Korea is provided later in Table 12.

Reduced Costs of Trade Disputes Associated with Mangoes

A further impact from the closer monitoring during transport of fresh mangoes to Asia reported by Manbulloo and published by DAF shows a saving in dispute costs as estimated in Table E8.

Table E8: Reduced Costs of Trade Disputes for Manbulloo Mangoes Exported to Asia

Year	Dispute cost (no monitoring) (c/kg) (A)	Dispute cost with monitoring (c/kg) (B)	Cost of monitoring (c/kg) (C)	Total cost without monitoring (c/kg) (A)	Total cost with monitoring (B+C)(c/kg)	Overall net benefit (c/kg)
2017/18	6.0	6.0	7.0	6.0	13.0	-7.0
2018/19	6.0	4.8	6.0	6.0	10.6	-3.4
2019/20	6.0	2.2	4.0	6.0	6.6	-0.6
2020/21	6.0	1.0	3.0	6.0	4.0	2.0
2021/22	6.0	0.8	3.0	6.0	3.8	2.2

Source: Agtrans Research based on DAF (2020)
Note: 2.2 c/kg = 2200c/tonne = $22 per tonne

Table E9: Manbulloo Trade Dispute Costs and Benefits from Monitoring Mango Exports

Year	China (t)	South Korea (t)	Exports with added/saved trade dispute cost (%)	Applicable tonnage per annum (tonnes)	Net Cost per kg	Gain ($ per annum)
2017/18	105	60	0%	0	-7.0	-11,550
2018/19	270	150	20%	84	-3.4	-2,856
2019/20	225	205	40%	172	-0.6	-1,032
2020/21	225	205	50%	215	2.0	4,300
Annually Thereafter	225	205	60%	258	2.2	5,676

Source www.industry.mangoes.net.au for tonnages; other assumptions from Table E8.

Summerfruit Impacts

Australian summerfruit production and exports for the years for years ending June 2018 to 2020 are provided in Table E10.

Table E10: Australian Summerfruit Production and Exports

Year ended June	Total prod. (tonnes)	Value of farm prod. ($m)	Fresh supply (tonnes)	Fresh w/sale value ($m)	Fresh w/sale value ($/t)	Australian exports (fresh) (tonnes)	Fresh value of Australian exports ($m)	Fresh export value ($/t)
2018	153,148	397.8	106,684	391.7	3671.6	17,769	65.1	3663.7
2019	161,039	461.0	108,278	449.0	4146.7	23,045	89.0	4184.5
2020	137,716	413.9	92,447	394.8	4270.5	21,269	89.1	4189.2

Source: Hort Innovation

Key assumptions for valuing the impact of Project AM15002 on the profitability of summerfruit exports to Asia by Montague Fresh and potentially other exporters, relate to the likely increase in the volume and value of exports particularly to China through increased demand for a higher quality product at final consumption.

China has been the major market for exports of fresh Australian nectarines/peaches over the years ending June 2018 to 2020. For example, China imported 51% of Australian exports of peaches and nectarines (7,685 tonnes) in 2019/20 (Hort Innovation, 2020).

A summary of the assumptions made to value the benefits from Project AM15002 for summerfruit exports to China is provided in Table E12.

Lemon Impacts

Australian lemon and lime production and exports for the years for years ending June 2018 to 2020 are provided in Table E11.

Table E11: Australian Lemon and Lime Production and Exports

Year ended June	Total prod. (tonnes)	Value of farm prod. ($m)	Fresh supply (tonnes)	Fresh w/sale value ($m)	Fresh w/sale value ($/t)	Australian exports (fresh) (tonnes)	Fresh value of Australian exports ($m)	Fresh export value ($/t)
2018	65,236	139.9	61,364	170.8	2783.4	2,883	6.0	2081.2
2019	66,341	161.6	61,483	195.6	3181.4	3,394	7.2	2121.4
2020	71,432	152.3	64,205	180.6	2812.9	4,206	7.9	1878.3

Source: Hort Innovation(2020)

Key assumptions for valuing the impact of Project AM15002 on the profitability of lemon exports to Asia relate to the likely increase in the volume and value of lemon exports due to the project. Lemons accounted for 73% of fresh production of total lemon and lime production in 2020, and Queensland accounted for 54% of Australian production in 2020 (Hort Innovation, 2020). Asian countries, including Singapore and China, accounted for 65% of total Australian exports. A summary of the assumptions made to value the benefits from Project AM15002 for lemon exports to Asia is provided in Table E12.

A summary of all assumptions for valuing impacts from the investment for mango, summerfruit, table grapes and lemons is presented in Table E12.

Table E12: Summary of Assumptions for Valuing Impacts

Variable	Assumption	Source
Mango – increased value of exports		
Value of Manbulloo's fresh mango exports to China, South Korea, USA and Canada	$2 million per annum	Austrade (2021)
Value of fresh mango exports to China and South Korea by Manbulloo before project impact	$1.5 million per annum	Based on Austrade (2021) above and assuming that 75% of mango exports to USA, Canada, China and South Korea were destined to China and South Korea
Tonnage estimated to be exported by Manbulloo to China and South Korea before impact of the project.	343 tonnes per annum	$1.5 million divided by $4,373 per tonne (Table 7)
Tonnage estimated to be exported to China and South Korea by Australia before impact of the project	1,200 tonnes per annum	Analyst assumption, based on information and assumptions in Agtrans Research (2019)
Growth in Australian mango exports to China and South Korea due to project investment, commencing 2021	25% per annum for 10 years	Analyst assumption
Increase in price received compared to local Australian wholesale price	$500 per tonne	Analyst conservative assumption; based on the average difference over the past eight years (2013 to 2020) has been $519 per tonne
Mango – trade dispute impact on Manbulloo		
Year	Gain ($) (a)	Table E9
2017/18	-$11,550	
2018/19	-$2,856	
2019/20	-$1,032	
2020/21	$4,300	
Annually thereafter	$5,676	
Summerfruit (peaches and nectarines)		
Fresh summerfruit (peaches and nectarines) exports to China before project	7,685 tonnes per annum	Hort Innovation (2020)
Increase in exports to China due to Project investment	5% per annum for 10 years	Analyst assumption
Average export price achieved	$4189.2 per tonne	Table E9
Increase in price received compared to alternative exports from where fruit is drawn	2.5% of $4189.2 per tonne =$105 per tonne	Analyst assumption
Lemons		
Value of Australia lemon and lime exports in 2020	$7.9 m	Table E11
Lemons as percentage of lemons and limes	73%	Hort Innovation (2020)
Queensland lemons as % Australia	53%	

Exports to Asian countries as a percentage of total lemon and lime exports	65%	Conservative estimate based on Hort Innovation (2020)
Value of Queensland's lemon exports before impact of project	$1.99 m per annum	$7.9m x 73% x 53% x 65%
Increase in value of exports due to project	5%	Analyst assumption
Increase in value of exports due to project	$1.99 m x 5% per annum for five years and then stabilising	$1.99 m x 5% per annum =$99,500 per annum increase
Attribution and Risk Factors		
Probability of output	100%	Analyst assumptions
Probability of outcomes occurring	90%	
Probability of impact given successful outcome	90%	
Attribution to project investment	100%	

(a) Years of negative impact are due to cost of monitoring before the cost of trade disputes fell and therefore benefits from monitoring more than paid for the monitoring costs.

Impacts not Valued

The impacts identified but not valued included:

- The reduction in negative environmental impacts from a reduction in disposal costs of wasted or damaged fruit on arrival or in the importing supply chain has not been valued. This was because data were not available on the extent of such damage with and without the investment.
- The increased spillovers to regional communities from sustained or increased productivity of relevant fruit production in Australia. This impact was not valued as any increased economic activity and employment along the product supply chain would be difficult to value, given the number and spread of production systems, subregions, and the availability of time and resources for the evaluation.
- The impact of increased or maintained scientific capability and capacity building for government agencies and within some industries. This impact was not valued due to insufficient resources/time but more so the envisaged difficulty in assembling appropriate data, and/or the complexity of developing reliable specific assumptions to value such future impacts.

Furthermore, the role of Project AM15002 in spawning new supply chain projects as described in the logical framework has not been valued due to the lack of current data on the impacts and value of those projects.

Counterfactual

It is unlikely that the resources required or the expertise utilised in the project would have been available other than through this investment. Hence, such an investment is unlikely to have been attempted in the absence of the Hort Innovation funding and the scientific team assembled for the project.

7. 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 investment period plus 30 years from the last year of investment (2021/22) to the final year of benefits assumed.

Investment Criteria
Tables E13 and E14 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table E14, has been estimated by multiplying the total PVB by the DAF proportion of real investment (22.42%)

Table E13: Investment Criteria for Total Investment in Project AM15002

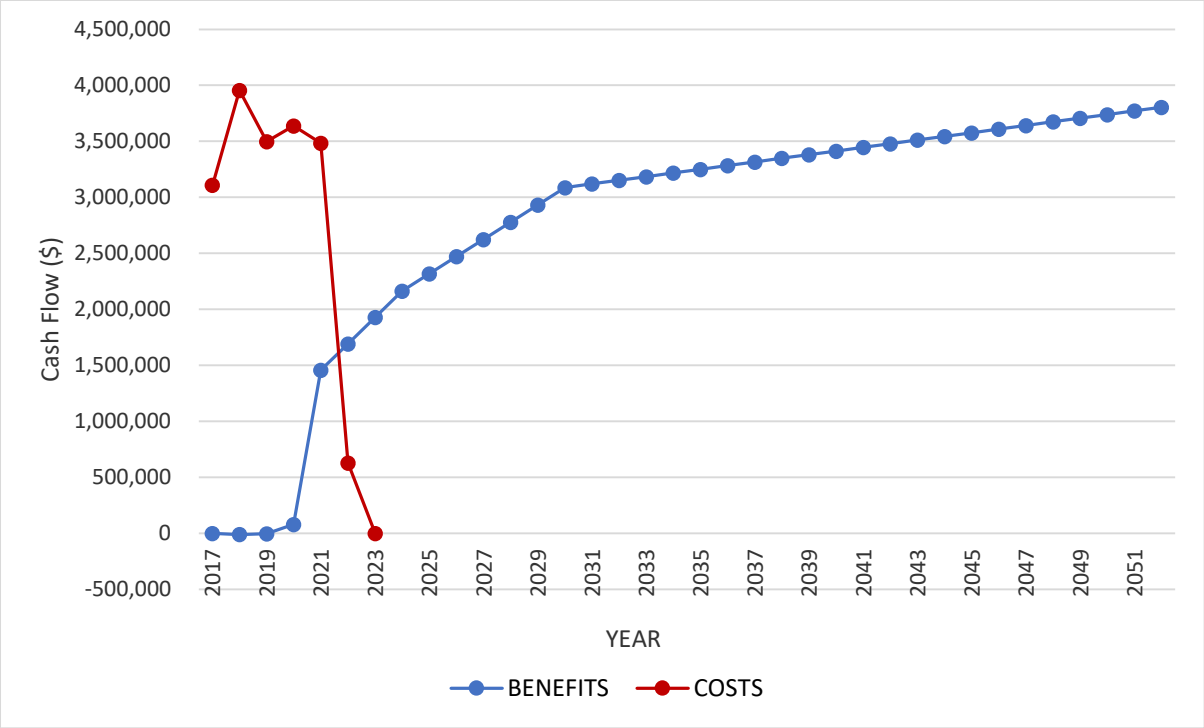
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	2.99	11.96	21.20	29.03	35.47	40.75	45.08
Present value of costs ($m)	19.16	19.16	19.16	19.16	19.16	19.16	19.16
Net present value ($m)	-16.17	-7.20	2.04	9.87	16.31	21.60	25.93
Benefit-cost ratio	0.16	0.62	1.11	1.52	1.85	2.13	2.35
Internal rate of return (%)	negative	negative	6.41	9.72	11.08	11.71	12.04
MIRR (%)	no solution	no solution	5.99	7.85	8.24	8.22	8.07

Table E14: Investment Criteria for DAF Investment in Project AM15002

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.67	2.68	4.74	6.49	7.94	9.12	10.09
Present value of costs ($m)	4.26	4.26	4.26	4.26	4.26	4.26	4.26
Net present value ($m)	-3.59	-1.58	0.48	2.23	3.68	4.86	5.83
Benefit-cost ratio	0.16	0.63	1.11	1.52	1.86	2.14	2.37
Internal rate of return (%)	negative	negative	6.52	9.86	11.22	11.96	12.18
MIRR	no solution	no solution	6.06	7.92	8.31	8.28	8.12

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure E2.

Figure E2: Cash Flow of Undiscounted Total Net Benefits and Total Investment Costs



Conservatism of Impact Valuation

It should be noted that the investment criteria reported above should be considered conservative for the following reasons:

- Any potential impacts generated from table grapes and vegetables were not specifically valued,
- Further, the net positive savings on trade disputes for exports other than Manbulloo mangoes were not valued.
- The reduction in negative environmental impacts from a reduction in disposal costs of wasted or damaged fruit on arrival or in the importing supply chain was not valued.
- The increased spillovers to regional communities from sustained or increased productivity of relevant fruit production in Australia were not valued
- The impact of increased or maintained scientific capability and capacity building for government agencies and within some industries.
- The contribution of Project AM15002 to the development of a series of new supply chain projects as described earlier.

Sources of Benefits
There were three sources of commodity benefits valued in the analysis. Table E15 shows estimates of the relative contribution from each source.

Table E15: Contribution of Source of Benefits to Present Value of Benefits (PVB)
(Total investment, 30 years)

Source of Benefit	PVB ($m	Proportion of Total PVB (%)
Mangoes	22.34	49.6
Summerfruit	16.74	37.1
Lemons	6.00	13.3
Total	45.08	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 16 presents the results that showed a moderate sensitivity to the discount rate, due to the relatively long period of benefits assumed

Table E16: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	99.66	45.08	24.93
Present value of costs ($m)	18.31	19.16	20.09
Net present value ($m)	81.35	25.93	4.84
Benefit-cost ratio	5.44	2.35	1.24

A sensitivity analysis also was carried out on the assumption of the probability of the outcomes occurring, that is, that the project outputs will be used by the relevant Australian horticultural industries. Results are reported in Table E17. The outcome probability could fall to 38% for the project benefits to still cover the investment costs.

Table E17: Sensitivity to Probability of Outcomes Occurring
(Total investment, 30 years, 5% discount rate)

Investment Criteria	Probability of Outcomes Occurring		
	50%	90% (Base)	100%
Present value of benefits ($m)	25.05	45.08	50.09
Present value of costs ($m)	19.16	19.16	19.16
Net present value ($m)	5.89	25.93	30.94
Benefit-cost ratio	1.31	2.35	2.62

Confidence Ratings
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 for the benefit valued, including the linkage between the research and the assumed outcomes and impacts.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table E18). 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 E18: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium. While there were several benefits identified but not valued, the principal economic outputs from the project were valued (profitability improvements for the mango, summerfruit and lemon industries.

Confidence in assumptions for the valuation was rated as Medium-Low as some of the assumptions associated with the improved gains to the three industries were somewhat uncertain as the project has not yet been completed.

8. Conclusion

The investment in monitoring and modelling of horticultural supply chains from Australia to Asian markets has been successful to date and is likely to provide positive impacts, particularly for Queensland and Victorian fresh fruit producers and exporters.

The benefits delivered by the project will accrue to members of the supply chains, both those firms centrally involved in the project as well as other supply chains. The key benefit will be derived from horticultural produce arriving in Asian countries with improved quality and longer lasting produce available to consumers. Some public benefits in Australia will be delivered via community spillovers from increased, or at least maintained, horticultural producer incomes and improved environmental outcomes through reduced horticultural production waste.

The investment in Project AM15002 was a large investment with over $17 million dollars expended in nominal dollar terms. The total investment in the project of $19.2 million (present value terms) has been estimated to produce total gross benefits of $45.1 million (present value terms) providing a net present value of $25.9 million, a benefit-cost ratio of 2.35 to 1 (using a 5% discount rate), an internal rate of return of 12.0% and a modified internal rate of return of 8.1%.

The investment criteria reported are likely to have somewhat undervalued the full set of impacts delivered by the investment. This was because several potential benefits identified were not valued in monetary terms. For example, benefits accruing to any future of monitoring technologies for shipments of table grapes and vegetable exports to Asian countries were not included in the valuation of benefits. Also, the regional community spillover impacts arising from the increased value of mangoes, summerfruit and lemons were not valued.

In addition, the success of the project has spawned a number of new projects that are based on the principles and learnings from AM15002.

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Appendix F: An Impact Assessment of DAF Investment into the Long-Term Grazing Trial at Wambiana QLD 1998-2022

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Abbreviations

BCR	Benefit-Cost Ratio
CBA	Cost Benefit Analysis
CDU	Charles Darwin University
CRRDC	Council of Rural Research and Development Corporations
CSIRO	Commonwealth Scientific and Industrial Organisation
DAF	Department of Agriculture and Fisheries
DES	Department of Environment and Science
GBRL	Great Barrier Reef Lagoon
GBRMPA	Great Barrier Reef Marine Park Authority
GLM	Grazing Land Management
IRR	Internal Rate of Return
JCU	James Cook University
MIRR	Modified Internal Rate of Return
MLA	Meat and Livestock Australia
NPV	Net Present Value
NQRBC	North Queensland Regional Beef Research Committee
PVB	Present Value of Benefits
PVC	Present Value of Costs
QLD	Queensland
R&D	Research and Development
RD&E	Research Development and Extension
RDC	Research and Development Corporation

TERN	Terrestrial Ecosystem Research Network
TS CRC	Tropical Savannas Cooperative Research Centre
UQ	University of Queensland
WGT	Wambiana Grazing Trial

Executive Summary

This impact assessment focuses on investment in a series of projects associated with the long-term grazing trial carried out at Wambiana station near Charters Towers in North Queensland. The investments span the period over the years ending June 1998 to June 2022. These sequential projects were all managed by the Queensland Department of Agriculture and Fisheries (DAF) and were addressed with funding input from both DAF and a range of other funding agencies.

The investment in the grazing trial at Wambiana has been critical in facilitating positive change in grazing management in north Queensland. The private sector beneficiaries from the investment in the grazing trial are primarily Queensland and other north Australian pastoral producers. The significant public benefits delivered were contributions to enhanced biodiversity and natural resource management, including improved water quality in watercourses and in runoff entering water of the Great Barrier Reef Lagoon (GBRL).

The total long-term investment in the Wambiana projects has produced a number of benefits two of which were valued in monetary terms. The total investment of $12.1 million (present value terms) was estimated to produce total benefits of $132.9 million (present value terms) providing a net present value of $120.8 million, a benefit-cost ratio of 11.0 to 1 (using a 5% discount rate), an internal rate of return of 25.9%, and a modified internal rate of return of 35.6%.

As there were several impacts identified that were not valued in economic terms (e.g. regional community spillovers and any changes made by grazing properties in jurisdictions other than in Queensland) the investment criteria reported are likely to have somewhat undervalued the full set of benefits delivered from the investment.

1. Evaluation Methods

The evaluation approach followed general evaluation guidelines that now are well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), Cooperative Research Centres, State Departments of Agriculture, and some universities. This impact assessment uses Cost-Benefit Analysis (CBA) as its principal tool. The approach includes both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The evaluation process involved identifying and briefly describing the seven project objectives, activities and outputs, and potential and actual outcomes and impacts. This was effected for each project. The principal economic, environmental and social impacts were then identified and summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the likely low relative significance of the impact compared to those that were valued. The impacts valued therefore are deemed to represent the principal benefits delivered by the project investments.

2. Introduction and Background

Background

Rainfall variability is a major challenge to sustainable and profitable beef production in northern Australia. Strategies such as stocking at long-term carrying capacity or varying stock numbers with available forage are recommended to manage for climate variability but had generally not been tested at a scale relevant to industry. In particular, the relative profitability of different strategies had not been objectively quantified, limiting adoption. Many managers thus were failing to manage for climate variability and tended to overstock and/or only respond to deteriorating conditions in a reactive fashion. This inevitably was resulting in economic loss, overgrazing, a decline in land condition and increased sediment delivery to the Great Barrier Reef Lagoon (GBRL).

The Wambiana Grazing Trial Initiative

To help address this issue, a large, long-term grazing trial was established in 1997 on 1,042 ha leased from the Lyons' family property Wambiana located near Charters Towers in North Queensland. The trial was established by the Department of Agriculture and Fisheries Queensland (DAF), complementing other long-term grazing trials conducted by the department in other regions of Queensland. The purpose of the trial was to quantify the effects of different grazing strategies on animal production, profitability and land condition in North Queensland.

The long-term project had a number of objectives:

1. Test the ability of different grazing strategies to cope with rainfall variability in terms of animal production, profitability, land condition and soil loss.
2. Develop grazing management strategies, guidelines and tools to assist beef producers manage for climate variability.
3. Physically demonstrate the long-term effects of these strategies to beef producers.
4. Increase the adoption of these improved management strategies to reduce risk, increase long term-profitability and improve land condition.

The Wambiana Grazing Trial also has been a platform for a number of collaborative, multi-disciplinary projects with a number of other agencies. These include:

- Runoff and water quality (Great Barrier Reef Marine Park Authority (GBRMPA), Department of Environment and Science (DES)).
- Soil C storage and greenhouse accounting (DES and DAF).
- Faunal biodiversity (CSIRO and James Cook University (JCU)).
- Nitrogen production by biological soil crusts (University of Queensland (UQ)).
- Soil health and rainfall infiltration (Charles Darwin University (CDU) and CSIRO).
- Nutrient cycling (Tropical Savannas Cooperative Research Centre (TS CRC)).
- Landscape selection by cattle (CSIRO).
- Remote sensing of ground cover and pasture yield (DAF and DES).
- Vegetation monitoring (Terrestrial Ecosystem Research Network (TERN)).

The project has run now for over 23 years and is in the last year of its current funding round. The trials have been critical in demonstrating the linkages between sustainable management and increased productivity and profitability in a variable climate. The findings have been communicated to industry through a wide range of extension activities undertaken by DAF, Meat and Livestock Australia (MLA) and various other agencies. The project has also provided essential enabling data for multiagency programs addressing key state priorities such as drought, climate change adaptation and reducing the impact of agriculture on the world heritage listed Great Barrier Reef.

The project is unique in being the largest and longest replicated grazing trial in Australia. Data from the project have been used to develop guidelines and decision tools to assist the northern beef industry manage more sustainably and profitably.

3. Investment Details

Summary of the Projects Assessed

The Project Codes, Titles, Project Leaders and Funding Periods are provided in Table F1. Logical frameworks describing the objectives, activities and outputs, and actual and potential outcomes and impacts for each of the individual projects are provided in Table F2.

Table F1: Summary of Wambiana Grazing Trial Projects Included in the Impact Assessment

Project Code	Title	Principal Investigator	Funding Period
Project 19	Coping with rainfall variability in the tropical savannas	Peter O'Reagain, DAF	1996 to 1999
No Project code	Profitable and sustainable grazing strategies for the seasonally variable tropical savannas	Peter O'Reagain, DAF(a)	2001 to 2004
NBP.318	Testing and developing principles and management guidelines for the sustainable management of the seasonally variable savannas	Peter O'Reagain, DAF	2002 to 2006
NBP.318 WAM	Testing and developing principles and management guidelines for the sustainable management of the seasonally variable savannas	Peter O'Reagain, DAF	2006 to 2008
B.NBP.0379	Wambiana grazing trial extension: Testing and developing grazing principles and management guidelines for the seasonally variable tropical savannas	Peter O'Reagain, DAF	2007-2010
B.NBP.0635 Wambiana Phase 2	Wambiana Grazing Trial Phase 2: Stocking and spelling strategies for improving carrying capacity and land condition in North Australian grazing lands	Peter O'Reagain, DAF	2010-2014
TF11.13: Grazing Strategy Demonstration	Demonstrating adaptive grazing management strategies for sustainable and profitable management	Dave Smith, DAF	2017-2020
B.ERM.0107	Wambiana Grazing Trial Phase 3: Stocking strategies for improving carrying capacity, land condition and biodiversity outcomes	Peter O'Reagain, DAF	2016-2017
B.ERM.0108 (b)	Wambiana - Grazing strategies and tools to improve profitability and land condition	Peter O'Reagain, DAF	2018-2021

(a) Over the period of the investment the Queensland Department of Agriculture and Fisheries (DAF) had a series of other names but the support function in relation to the Wambiana trial remained the same. In the interests of consistency the Department is termed 'DAF' throughout this assessment.

(b) B.ERM.0108 has not yet been completed.

Table F2: Logical Frameworks for the Series of Projects in the Investment

No code: Profitable and sustainable grazing strategies for the seasonally variable tropical savannas	
Project Details	Organisation: Department of Agriculture and Fisheries Period: 2001 to 2004 Principal Investigator: Peter O'Reagain, DAF
Rationale	Economic pressures in the northern beef industry were increasing the need to intensify by increasing stock numbers and increasing grazing pressure. However, this action was potentially risky, resulting in financial loss and natural resource degradation, particularly in low rainfall years. Varying stocking rates in relation to pasture availability and seasonal forecasts was viewed as a potential solution, but there was little information on how to implement such strategies and whether they would be successful in delivering improved profitability and sustainability.
Objectives	1. To test relative effects of different management strategies on resource condition and economic production. 2. To develop sustainable and profitable strategies for different land types in northern Australia. 3. To promote the adoption of such strategies via community driven extension and other grazier initiatives and projects.
Activities and Outputs	• A large grazing trial had already been established in north Queensland at Wambiana Station, south of Charters Towers. • Different grazing strategies were applied to ten 100 ha paddocks. • Grazing strategies included light, heavy, and variable stocking rates with some adjusted annually at the end of the wet season according to available herbage; other strategies included: stock numbers adjusted annually in October based on forecasts of the Southern Oscillation Index (SOI) for the coming wet season, as well as available herbage; another strategy included rotational wet season spelling. • Treatments were replicated and animals were weighed every 6 weeks while diet quality was assessed using near infrared spectrometry. • Pasture species, pasture production, basal ground cover, tree density and fauna biodiversity were recorded and monitored. • All management decisions were made by a 10-person Grazier Advisory Committee.
Outcomes	• Observations and comparisons between the different grazing strategies were produced that could be used in assessing performance in terms of pasture condition, livestock production, profitability, soil loss and biodiversity. • An increase in awareness of the relationship of grazing strategies to production and sustainability and some initial uptake of more responsive grazing strategies by some pastoralists. • Relationships and guidelines were developed from the trials that could be extrapolated to comparable land types in Northern Australia. • The site acted as a future research and learning facility via demonstration and various extension programs.
Impacts	• Increased average profitability by a very small number of northern Queensland graziers. • Some potential improvement in land condition and lowered soil and water export off properties by a very small number of north Queensland graziers.

NBP.318: Testing and developing principles and management guidelines for the sustainable management of the seasonally variable tropical savannas	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2002 to 2006 Principal Investigator: Peter O'Reagain, DAF
Rationale	This project extended the life of the Wambiana trial that was collecting essential data on the relationship between sustainability and profitability, and developing management guidelines using the data and relationships produced.
Objectives	1. Quantify the medium-term effect of different utilisation rates and grazing strategies on resource condition, animal production and economic return. 2. Identify key management principles for the sustainable management of tropical savannas. 3. Develop practical management guidelines that allow graziers to manage their natural resources in a sustainable and viable manner. 4. Develop practical decision tools that producers can use in pasture condition assessment and forage budgeting, using climate forecasts to adjust stock numbers and adjusting animal numbers in relation to feed supply. 5. Develop empirical relationships that relate pasture production, animal production and soil loss to pasture utilisation rate. 6. Make at least 60% of producers in the Burdekin and Flinders catchments aware of these principles, guidelines and decision tools.
Activities and Outputs	• Further development and description of relationships between grazing strategies, resource condition, profitability and sustainability. • Communication initiatives and materials including: o Presentation to Landcare groups o Site visits by graziers o Publications for producers o Consultation with the North Queensland Regional Beef Research Committee (NQRBC) and trials site visits by NQRBC o Publications by Meat and Livestock Australia (MLA)
Outcomes	• Increase in awareness by graziers of relationships between grazing strategies, production and sustainability. • Increased average profitability by a small, but increasing, proportion of northern Queensland graziers, particularly in the Burdekin and Flinders catchments. • Some small improvement in land condition and lowered soil and water export off grazing properties. • The site continued to act as a future research and learning facility via demonstration and various extension programs.
Impacts	• Increased average profitability by an increasing, but still very small, number of northern Queensland graziers. • Some improvement in land condition and lowered soil and water export off properties by an increasing, but still small, number of graziers, mainly in the Burdekin and Flinders catchments.

B.NBP.0379: Wambiana grazing trial extension: Testing and Developing grazing principles and management guidelines for the seasonably variable tropical savannas	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2007 to 2010 Principal Investigator: Peter O'Reagain, DAF
Rationale	MLA had previously co-funded the Wambiana grazing trial via NBP.318 as described earlier. The findings to date from the five stocking strategy treatments had been communicated to pastoralists via DAF, MLA's Beef Up forums and the EDGEnetwork Grazing Land Management (GLM) courses, as well as the trial site hosting two major field days each year. This new project assisted in continuing the trial for a further period to ensure results captured the effects of longer-term climate variability as well as planning a revised experimental design with new stocking rate treatments in line with how some better managers managed their land.
Objectives	1. To maintain the integrity of treatments at the trial site and collect critical data sets during the years ending June 2008, 2009 and 2010. 2. To provide a concise final report with updating of key data sets and discussion of changes, or otherwise, in performance of the grazing strategies. 3. To produce a series of 'Tips and Tools' that capture the key grazing management messages for industry benefit. 4. In cooperation with other extension efforts, to develop and implement a strategy to effectively communicate project outputs and to ensure their full integration with the GLM workshop, the Stocktake workshop and other relevant extension activities. 5. To contribute to the bioeconomic analysis of pasture-based production systems in northern Australia, leading to recommendations for on-going experimentation at Wambiana.
Activities and Outputs	• The research site and its trials were continued over the period, but data collection was concentrated on three critical data sets including: o Cattle liveweights o Pasture standing crop and composition at the end of the growing season o Permanent transect measures of plant species frequency at the end of the growing season. • Communication outputs were developed with regional extension staff including Tips and Tools, and steps to ensure full integration of the trial results with GLM and Stocktake. A large field day was also held in 2009. • Report for the first ten years of the trials, scientific papers, and a short project final report updating key data sets. • A 50 page 'Key learnings' book aimed at extension staff and more advanced land managers. • The project team contributed to a technical review to integrate key findings from other northern Australian grazing studies. • The project team also contributed to undertake a bioeconomic analyses and synthesis of pasture-based production systems for northern Australia; this led to recommendations for ongoing experimentation at Wambiana.
Outcomes	• An increase in communication pathways that reached an increasing proportion of northern Australian cattle producers. • A continuing increase in awareness by northern Australian graziers of relationships between grazing strategies, production and sustainability. • A small improvement in land condition and lowered soil and water export off some grazing properties.

	• A higher level of integration of findings from Wambiana and other northern grazing trials. • The site continued to act as a future research and learning facility via demonstration and various extension programs.
Impacts	• A further Increase in average profitability by a small number of northern Queensland and northern Australian graziers. • Some improvement in land condition and lowered soil and water export off properties by an increasing, but still small, number of northern Queensland and northern Australia graziers.

B.NBP.0635: Wambiana Grazing Trial Phase 2: Stocking and spelling strategies for improving carrying capacity and land condition in North Australian grazing lands	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2010 to 2014 Principal Investigator: Peter O'Reagain
Rationale	Earlier stages of the Wambiana trials had already demonstrated the linkages between moderate stocking, good land condition, reduced runoff and erosion, lowered risk and increased productivity and profitability. However, Phase 1 had not produced strong evidence of the benefits of flexible stocking rate strategies or rotational wet season spelling. Hence, Phase 2 also addressed the issues of flexible stocking rate strategies and rotational wet season spelling. The motivation was to develop additional productivity gains as well as minimise negative environmental impacts, particularly regarding water quality entering the GBRL.
Objectives	1. To quantify the impacts and economic cost-benefits of adaptive, flexible stocking and wet season spelling strategies on animal production, carrying capacity, productivity, profitability and water quality. 2. To quantify the long-term impacts of reduced land condition on carrying capacity, productivity, profitability and water quality. 3. To validate and improve the reliability of bioeconomic modelling using data from the grazing strategies tested at Wambiana in Phase 1 and 2. 4. To evaluate the implications of the Wambiana trial findings for a breeder-grower enterprise with economic modelling. 5. Develop recommendations (including decision rules and/or rules of thumb to: (a) Manage stocking rate over time, and (b) Implement wet season spelling for breeding and growing herds that will cost-effectively improve carrying capacity and/or land condition.
Activities and Outputs	• The baseline moderate and heavy-set stocked treatments remained the same while the wet season strategy was changed from a 3 to a 6 paddock system (more similar to what would happen on a commercial property). • Fire was introduced in 2011 across all treatments to suppress woody species. • The trial site also hosted a large field day following the 2010 Charters Towers Meat Profit day. • The two variable strategies were changed to flexible stocking with and without wet season spelling. • The flexible stocking and wet spelling strategies were managed adaptively based on seasonal conditions during the trial, experience obtained in Phase 1, producer expertise and preliminary modelling. • Data obtained included animal production, profitability at the paddock and

	modelled enterprise level (pasture composition changes, soil loss, runoff and the fire impact on woody species. • All management decisions were made in consultation with the Grazier Advisory Committee.
Outcomes	• Additional information available to northern pastoral managers influencing decisions regarding flexible stocking and wet season spelling strategies based on animal production profitability. • Additional information available on pasture composition, soil loss and export water quality in response to flexible stocking and wet season spelling strategies.
Impacts	• A further Increase in average profitability by an increasing number of northern Queensland and northern Australian graziers. • Some improvement in land condition and lowered soil and water export off properties by an increasing number of northern Queensland and northern Australian graziers.
B.ERM.0107 Wambiana Grazing Trial Phase 3: Stocking strategies for improving carrying capacity, land condition and biodiversity outcomes	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2016-2017 Principal Investigator: Peter O'Reagain, DAF
Rationale	Phase 2 of the Wambiana Grazing Trial had addressed the implications of flexible stocking rates and rotational wet season spelling strategies aimed at improving carrying capacity and land condition. However, the assessment had not been running long enough to yield robust findings and guidelines. Also, two additional projects had been included in the Wambiana trial site: • B.NBP.0555 aimed at improving the evidence base and modelling capacity underpinning recommendations for use of wet season spelling to recover poor condition grazing land. • ERM.088 determining whether a trade-off exists between economic performance, beef productivity, and land management for biodiversity. An external review of the Wambiana grazing trial (March 2014) reported that while the trial had largely achieved the original objectives, its continuation was recommended to allow completion of the embedded projects and permit a full assessment of the new treatments. Hence, an extension of the completion date from September 2016 to May 2017 was approved.
Objectives	1. To maintain existing treatments in the Wambiana grazing trial and continued data collection required to support the embedded projects. 2. To analyse the Wambiana animal production and pasture data to reveal new insights and testable hypotheses. 3. To undertake detailed modelling and economic analysis assessing the long-term profitability and sustainability of the different stocking strategies for a range of starting land conditions over a range of climate windows. 4. To outline draft extension messages based around the primary question for a grazier: whether current land condition influences the relative profitability and hence selection of different grazing strategies? 5. To convene the producer advisor group and other interested landholders to develop a design brief for information, products and decision tools that include herd management options in addition to changes in grazing management that

	meets business profit goals, achieves desired pasture composition and reduces soil loss. 6. To conduct a workshop with key stakeholders presenting the results of the above analyses and determining unanswered questions that create uncertainty in completion of the original objectives of the Wambiana grazing trial and make recommendations for any future work and appropriateness of use of the existing site.
Outputs	• Completion of the Phase 3 Wambiana Grazing Trial and two embedded projects. • Analyses of all data and development of recommendations and extension messages for the relative profitability of different stocking strategies that might, in turn, be dependent on current land conditions. • A Wambiana field day. • Development of a design brief for information, products and decision tools that included herd management options as well as changes in grazing management that meet business profit goals, achieves desired pasture composition and reduces soil loss. • A workshop with key stakeholders where o the results of the above analyses were presented. o unanswered questions were addressed. o recommendations were made for any future work and the use of the existing site. • Bio-economic modelling showed that enterprise profitability and sustainability were maximised when stocking rates were aligned with available forage. • It was concluded that enterprise profitability and land condition will be maximised with risk-averse, flexible stocking around long-term carrying capacity, coupled with wet season spelling.
Outcomes	• Additional information available to northern pastoral managers on the relative profitability of different stocking management strategies. • Improved extension messages for northern pastoral managers influencing decisions regarding flexible stocking and wet season spelling strategies.
Impacts	• A further increase in average profitability by an increasing number of northern Queensland and northern Australian graziers. • Some improvement in land condition and lowered soil and water export off properties by an increasing number of northern Queensland and northern Australia graziers.

TF11.13: Demonstrating adaptive grazing management strategies for sustainable and profitable management	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2017-2020 Principal Investigator: Dave Smith, DAF
Rationale	This project was funded to address the runoff of sediment into the GBRL from the extensive pastoral lands in northern Queensland. The project was identified at a Wambiana Grazing Trial workshop in 2016. Actions identified at the workshop included: • A new project to encourage pastoral managers to adopt better grazing management guidelines developed at the Wambiana trial by way of case studies and on-property demonstrations of the results that can be achieved. • Such approaches had been successfully demonstrated via MLA's Producer Demonstration Site program.

Objectives	The project was aimed at contributing to the Reef Plan objectives by demonstrating and hence increasing the adoption of improved grazing management in extensive grazing areas that lead to improved land condition and water quality outcomes.
Activities and Outputs	• Demonstration sites were developed on four grazing properties in priority sub-catchments in North Queensland. • The plot scale wet season spelling project (previously B.NBP.0555) was continued at the Wambiana Grazing Trial (WGT). • The demonstration sites were used as an extension hub to show how the sustainable grazing management practices developed at the Wambiana trial could improve land condition, animal production and profitability, as well as reduce water and soil loss to the off-farm environment. • The information from the demonstration sites was also used by the WGT project to adapt and refine their own recommendations.
Outcomes	• Participants in the four demonstration site producer groups have improved their knowledge and skills regarding best grazing practices. • It is likely that increased knowledge and skills by some land managers have been translated into management practice changes that otherwise would not have been made without the demonstrations and case studies.
Impacts	• Improved pastoral management for further properties in north Queensland grazing lands resulting in: o Increased business profitability, o reduced water runoff, and o improved quality of water entering the GBRL.
B.ERM.0108: Wambiana- Grazing strategies and tools to improve profitability and land condition	
Project details	Organisation: Department of Agriculture and Fisheries Period: 2018-2021 Principal Investigator: Peter O'Reagain, DAF
Rationale	Project B.ERM.0108 builds on previous Wambiana investments where it was shown that beef gross margins could be significantly increased by changing from heavier stocking rates to more sustainable moderate or flexible stocking strategies. This resulted from lower costs, including from the avoidance of drought feeding and increased individual animal production giving greater carcass values and shorter turnoff times. Improved individual animal production would also increase reproduction rates and lower mortalities in breeder herds. The project was funded to add to these findings through: o addressing more adaptive and flexible grazing management strategies, o integrating satellite monitoring with walk-over weighing and paddock data to assist with managing changing seasonal conditions, o demonstrating new grazing strategies and decision tools at four on-property demonstration sites, and o increasing adoption via demonstration and integration with new and existing extension programs.
Objectives (abbreviated)	1. To complete a full monitoring and evaluation plan to evaluate knowledge, attitudes, skills and aspirations of involved producers. 2. To develop four demonstration sites each managed by producers (TF11.13). 3. To conduct field days at each of the sites.

	4. To test different adaptive and flexible stocking management strategies relative to fixed moderate stocking. 5. To develop advanced decision support tools to manage the feedbase. 6. To test different wet season spelling strategies to regenerate land in poor condition. 7. To demonstrate potential improvements in land condition and profitability at a range of sites. 8. To develop a set of grazing management guidelines. 9. To develop and submit case study reports on each of the four demonstration sites, together with an overall summary report.
Activities and Outputs	• A plan and activities to evaluate changes in producers' knowledge and skills. • A major field day was held at the trial site in October 2019. • Development of producer-managed demonstration sites, including the holding of field days at each site. • Further testing of flexible stocking management strategies. • Development of advanced decision support tools. • Evaluation of different wet season spelling strategies. • Demonstration of potential profitability improvements for a number of sites. • Development of grazing management guidelines. • Development of individual case study reports and an overall summary.
Outcomes	• A framework and data for evaluating changes in the ability and intentions of producers to change management strategies. • It is likely that increased knowledge and skills by land managers have been translated into management practice changes that otherwise would not have been made without the demonstration sites, field days and case studies.
Impacts	• Increased number of pastoral managers in north Queensland grazing lands changing management practices, resulting in o Increased business profitability, o reduced water runoff, and o improved quality of water entering the GBRL.

4. Project Investment

Nominal Investment

Table F3 shows the nominal, annual investment (cash and in-kind) for the combined investment in the projects. The total investment is provided by financial year over the period 1998 to 2022 and is presented for DAF and other sources of investment.

Table F3: Annual Investment in the Wambiana Trial for Years ending June 1998 to 2022

Year ended June	DAF funding ($) (a)	Other funding ($) (b)	Total funding ($)
1998	63,551	240,000	303,551
1999	71,093	100,500	171,593
2000	73,521	100,500	174,021
2001	88,578	30,000	118,578
2002	94,694	56,229	150,.923
2003	75,115	133,679	208,794
2004	77,535	133,212	210,747
2005	79,955	115,233	195,188
2006	82,376	83,625	166,001
2007	84,796	69,356	154,152
2008	87,216	92,326	179,542
2009	89,637	50,000	139,637
2010	92,057	60,000	152,057
2011	94,478	207,000	301,478
2012	96,898	100,000	196,898
2013	99,709	95,000	194,709
2014	107,545	210,909	318,454
2015	111,343	0	111,343
2016	115,604	130,000	245,604
2017	120,415	72,922	193,337
2018	123,425	133,000	256,425
2019	124,851	189,262	314,113
2020	126,278	189,262	315,540
2021	128,653	189,262	317,915
2022	0	129,512	129,512
Total	2,309,323	2,910,789	5,220,112

(a) DAF Base operating

(b) Included funding from Drought Regional Initiative, National Heritage Trust, the TS CRC, Great Barrier Reef Marine Park Authority, MLA, and the Reef Plan Paddock to Reef project.
Source: Wambiana Operating Funding 1997-2021 (DAF, January 2021)

Program Management Costs

For the DAF investment the management and administration costs for the project are assumed already built into the nominal $ amounts appearing in Table F3. The salary multiplier that had been used by DAF (Wayne Hall, pers. comm., 2017) was a 2.85 multiplier for salaries contributed by DAF.

For the other investment, a management cost multiplier (1.0) was applied to all the other financial contributions shown in Table F3.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 $ terms using the Implicit Gross Domestic Product (GDP) Deflator index (ABS, 2021). No additional costs of extension were included as the project already involved a high level of industry participation through growers and existing extension services in Northern Queensland.

5. Impacts

The two principal impacts from the investment in the Wambiana Grazing Trials over the period examined have included:

- An increase in average profitability and reduced variability of annual net farm income of northern Australia cattle producers
- A decrease in land condition deterioration with reduced soil and water export from beef properties and reduced sediment and nutrient runoff entering the waters of the GBRL

Economic Impacts

The principal economic impacts from the investment have been:

(a) Improved average profitability for some North Queensland pastoral properties
(b) Reduced variability of income

Environmental Impacts

The principal environmental impacts from the investment have been:

(a) Improved land condition with improved biodiversity and reduced soil and nutrient loss
(b) Reduced export of soil and nutrients off north Queensland grazing lands with improved quality of runoff entering the GBRL

Social Impacts

Social impacts have been delivered primarily in the form of a follow-on from the positive environmental impacts, namely a reduced risk of loss of social licence for North Queensland beef producers. Additional social impacts have included:

(a) the spillovers to regional communities from increased grazing property incomes
(b) a contribution to postgraduate and undergraduate training and associated postgraduate awards

Summary of Impacts

An overview of impacts in a triple bottom line categorisation is shown in Table F4.

Table F4: Categories of Impacts from the Investment

Economic	Environmental	Social
Increased average net farm income of a proportion of beef cattle grazing properties in North QLD Contribution to Increased average net farm income of a proportion of beef cattle grazing properties located in other northern Australian jurisdictions	Reduced soil and water export and reduced biodiversity loss from grazing properties in North QLD and other northern Australian grazing areas Improved quality of water entering the GBRL	Reduced risk of loss of social licence to graze, particularly by North Queensland graziers Spillovers to regional communities from increased incomes of grazing properties and their input and product supply chains Contribution to postgraduate and undergraduate training and postgraduate awards

Public versus Private Impacts

The private impacts identified from the investment are accruing largely to North Queensland beef producers and their associated supply chains.

Public benefits have been produced in the form of spillovers to regional communities from the increase in beef producer incomes leading to higher regional economic activity and employment, as well as increased biodiversity and the reduced export of soil and nutrients to the GBRL.

Match with National and State Priorities

The Australian Government's Science and Research Priorities and Rural Research, Development and Extension (RD&E) Priorities are reproduced in Table F5. The investment in the Wambiana Trials has been relevant to Rural RD&E Priorities 3 and 4 and to Science and Research Priorities 1 and 2.

Table F5: Australian Government Research Priorities

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

(a) Source: Commonwealth of Australia, 2015
(b) Source: Office of the Chief Scientist (OCS), 2015

The QLD Government's Science and Research Priorities, together with the four decision rules for investment that guide evaluation, prioritisation and decision making around future investment are reproduced in Table F6.

The investment addressed QLD Science and Research Priorities 1, 3 and 6. In terms of the guides to investment, the investment is likely to have a real future impact through improved confidence in making changes to pastoral management strategies in North Queensland. The project was well supported and funded by others external to the QLD Government as illustrated by the number of external funders and the magnitude of their financial contributions.

Table F6: QLD Government Research Priorities

QLD Government	
Science and Research Priorities (est. 2015)	**Investment Decision Rule Guides (est. 2015)**
1. Delivering productivity growth 2. Growing knowledge intensive services 3. Protecting biodiversity and heritage, both marine and terrestrial 4. Cleaner and renewable energy technologies 5. Ensuring sustainability of physical and especially digital infrastructure critical for research 6. Building resilience and managing climate risk 7. Supporting the translation of health and biotechnology research 8. Improving health data management and services delivery 9. Ensuring sustainable water use and delivering quality water and water security 10. The development and application of digitally-enabled technologies.	1. Real Future Impact 2. External Commitment 3. Distinctive Angle 4. Scaling towards Critical Mass

Source: Office of the Chief Scientist Queensland, 2015

6. Valuation of Impacts

Impacts Valued

The impacts valued in monetary terms in this assessment include:

- An increase in average annual profitability accruing to some North Queensland beef grazing properties.
- A reduced risk of loss of social licence by North Queensland grazing properties

Impact 1: Increased Profitability of North Queensland Beef Properties

Key assumptions

- Proportion of graziers adopting by year
- Increase in profitability

The specific assumptions used in the assessment are provided In Table F7 below.

Risk Factors attached to assumptions

Probability of outputs: 100% (Wambiana trial results)

Probability of outcomes: 90% (Supporting evidence of numbers changing/adopting more profitable management systems)

Probability of impact given successful outcomes: 90% (Evidence of average income increase after adoption)

Due to the considerable evidence of positive change available from the project, the assumed probabilities of the above profitability gains and adoption assumptions having been achieved are reasonably high. The specific assumptions for these risk factors applied in the assessment, together with the assumption for the counterfactual (what would have happened without the Wambiana Trials) are provided in Table F7.

Table F7: Summary of Assumptions for Impact 1: Increased Average Profitability

Variable	Assumption	Source
Base industry data		
Area of Cape York and Queensland Gulf properties	13.87 m ha	DAF (2018)
Area of Central North properties	25.40 m ha	DAF (2018)
Total Area of Cape York and Central North properties	39.27 m ha	13.87+25.40
Extent of Maximum Adoption		
Extent of maximum adoption of lighter stocking rates and some form of wet season spelling	25% of potential total area in North QLD	DAF (2021)
Adoption and Impact Timing		
Year of first adoption	2002	Analyst assumptions
Year of first impact	2005	
Year of maximum adoption	2021	
Year of maximum impact	2025	
Gain in annual gross margin per ha from moderate stocking/more	$6/ha	DAF (2021)

sustainable strategies in North Queensland		
Risk factors		
Probability of output	100%	The Wambiana Trials have produced meaningful and adoptable outputs
Probability of outcome given the successful output	75%	There is strong evidence of significant adoption
Probability of impact given a successful outcome	75%	There is strong evidence of positive impacts given adoption
Counterfactual		
Proportion of adoption assumed that may have been delivered without the Wambiana Trials	25%	While there were various other programs promoting moderate/sustainable stocking, most programs were empowered by the supporting objective data produced by the Wambiana Trials. If the trials had not taken place, there would likely have been a much lower uptake of the improved grazing management strategies. In recognition of this likelihood, it was assumed in the assessment that 25% of the estimated adoption would still have taken place without the project investment.

Impact 2: Reduced Risk of Loss of Social Licence for North Queensland Grazing

The assumptions that drive this impact are provided in Table F8.

Table F8: Summary of Assumptions for Impact 2: Reduced Risk of Loss of Social Licence

Variable	Assumption	Source
Base industry data		
Average annual gross value of production (GVP) of QLD beef cattle	$5,206.2 million	5yr average based on ABS value of agricultural commodities data (2014 to 2018) (ABS, 2015 to 2019)
Proportion of GVP of QLD beef cattle derived from North Queensland	29%	Based on AGSURF data by region (average across 2015 to 2019) https://apps.agriculture.gov.au/agsurf/
Average annual gross value of QLD beef production in North QLD	$1,509.8 m	29% x $5,206.2 million
Profit as a proportion of GVP	10%	Agtrans Research, based on average profit as a proportion of total cash receipts for QLD beef producers (ABARES farm financial performance data 2017 to 2019)

Estimated annual average profit for North Queensland beef production	$150.98 m	$1509.8 million x 10%
Without investment in Wambiana Trials (Counterfactual)		
Proportion of North QLD beef industry at risk of loss of social licence and profitability without Wambiana Trials	20%	Analyst assumptions
Risk of loss of social licence for those susceptible	20%	
With investment in Wambiana Trials		
Proportion of North QLD beef industry at risk of loss of social licence and profitability with Wambiana Trials	20%	Analyst assumptions
Risk of loss of social licence	10%	
Year of first impact	2010	
Year of maximum impact	2019	
Probability of output	100%	The Wambiana Trials provided critical evidence of new management strategies improving land condition and biodiversity and reducing export of soil and nutrients to the GBRL
Probability of outcome	75%	
Probability of impact	75%	

Impacts Not Valued

The impacts identified but not valued include:

- Some increase in grower profitability in the Northern Territory and in northern Western Australia,
- Spillovers from increased grazing property incomes to northern Australian regional communities and along the input and product supply chains,
- Contribution to postgraduate and undergraduate training and postgraduate awards.

The reasons for not valuing these impacts were as follows:

An increase in grower profitability in the Northern Territory and in the north of Western Australia.
While there were likely to be some increases in profitability in these other northern grazing regions, they are likely to be less significant than in Queensland and associated accurate assumptions were more difficult to develop.

Increased regional community spillovers
Any increase in infrastructure and economic activity and employment along the product supply chain would be difficult to value, likely to be minor compared to the impacts valued and was considered beyond the scope of the current assessment.

Contribution to postgraduate and undergraduate training and postgraduate awards
This impact was not valued as without the Wambiana Trials, similar experiences may well have been gained via other visits and thesis topics.

7. Results

All past costs were expressed in 2019/20 dollar terms using the Implicit Price Deflator for GDP (ABS, 2021). 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 investment period plus 30 years from the last year of investment (2021/22) to the final year of benefits assumed.

Investment Criteria

Tables F9 and F10 show the investment criteria estimated for different periods of benefits for the total investment and the DAF investment respectively. The present value of benefits (PVB) attributable to DAF investment only, shown in Table F10, has been estimated by multiplying the total PVB by the DAF proportion of real investment (44%).

Table F9: Investment Criteria for Total Investment in the Series of Projects

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	3.46	19.27	46.32	78.22	108.53	132.88
Present value of costs ($m)	4.39	7.32	9.18	10.69	12.06	12.06	12.06
Net present value ($m)	-4.39	-3.86	10.09	35.63	66.16	96.48	120.82
Benefit-cost ratio	0.00	0.47	2.10	4.33	6.49	9.00	11.02
Internal rate of return (IRR) (%)	neg.	neg.	16.66	23.17	25.07	25.68	25.86
Modified IRR (%)	n.s.	14.03	neg.	neg.	268.12	57.99	35.65

n.s. no solution neg. negative

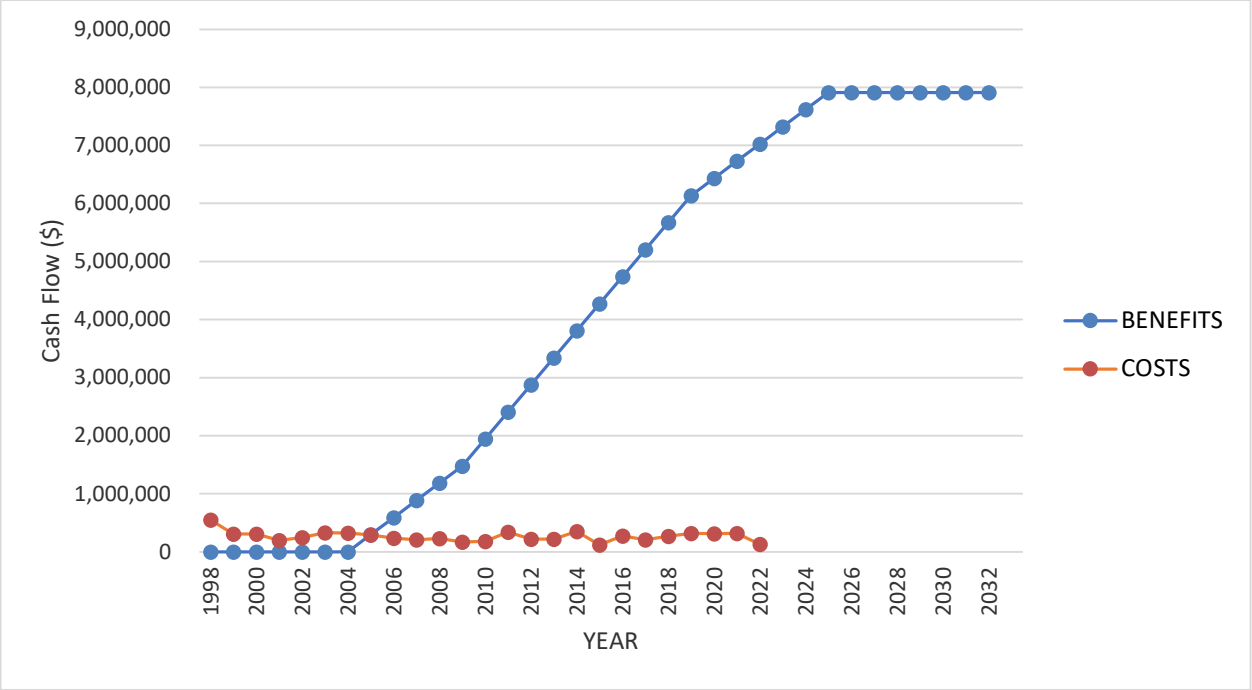
Table F10: Investment Criteria for DAF Investment in the Series of Projects

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	1.52	8.48	20.38	34.42	47.76	58.47
Present value of costs ($m)	1.79	3.02	3.91	4.69	5.22	5.22	5.22
Net present value ($m)	-1.79	-1.49	4.57	15.69	29.20	42.54	53.25
Benefit-cost ratio	0.00	0.50	2.17	4.34	6.60	9.15	11.20
Internal rate of return (IRR) (%)	neg.	neg.	18.27	24.88	26.74	27.30	27.46
Modified IRR (%)	n.s.	6.62	neg	neg	485.36	80.42	46.58

n.s. no solution neg. negative

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure F1.

Figure F1: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Sources of Benefits

There are two sources of benefits valued in the analysis. Table F11 shows the relative contributions to the PVB from each impact valued.

Table F11: Contribution to Total Benefits from Each Impact

Sources of Benefits	PVB ($m)	Proportion of Total PVB (%)
Impact 1 (profitability increase)	104.68	78.78
Impact 2 (reduced risk of loss of social licence)	28.19	21.22
Total	132.88	100.00

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 F12 presents the results that show the sensitivities of the investment criteria to the discount rate.

Table F12: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	143.25	132.88	136.87
Present value of costs ($m)	6.68	12.06	23.71
Net present value ($m)	136.57	120.82	113.16
Benefit-cost ratio	21.45	11.02	5.77

A sensitivity analysis was then carried out on the profitability gain assumption. Table F13 presents the results that show the investment criteria are relatively robust to the profitability assumption across the range tested. Even without any benefit from the reduced risk of loss of social licence, the profitability increase could fall to below $1 per ha and the investment would still break even.

Table F13: Sensitivity to Magnitude of Profitability Increase
(Total investment, 30 years, 5% discount rate)

Investment Criteria	**Profitability increase**		
	$3/ha	**$6/ha (Base)**	**$10/ha**
Present value of benefits ($m)	80.53	132.88	202.67
Present value of costs ($m)	12.06	12.06	12.06
Net present value ($m)	68.48	120.82	190.61
Benefit-cost ratio	6.68	11.02	16.81

Confidence Ratings and other Findings

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 F14). 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 F14: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium. The most significant benefit was related to profitability changes for Australian north Queensland beef grazing properties. The confidence in assumptions was rated as Medium-High. While some assumptions were well supported by existing data, the risk factors and counterfactual scenarios were reliant largely on assumptions by the analyst.

8. Conclusion

The investment in the series of grazing trials at Wambiana has been critical in facilitating positive change in grazing management in north Queensland. The total investment in the series of projects has produced a number of impacts, two of which were valued in monetary terms. The key impacts identified and valued from the investment include:

- private benefits captured by grazing properties and their supply chains driven by higher net farm incomes of beef producers
- public environmental benefits captured via improved land condition and reduced export of soil and nutrients to the GBRL

The total investment of $12.1 million (present value terms) was estimated to produce total benefits of $132.9 million (present value terms). This provided a net present value of $120.8 million, a benefit-cost ratio of 11.0 to 1 (using a 5% discount rate), an internal rate of return of 25.9%, and a modified internal rate of return of 35.6%.

As there were several impacts identified that were not valued in economic terms (e.g. regional community spillovers and any changes made by grazing properties in other than the Queensland jurisdiction) the investment criteria reported are likely to have somewhat undervalued the full set of benefits delivered from the investment.

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