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

[FINAL REPORT]

Summary Report

to

The Department of Agriculture and Fisheries Queensland

July 2020

by

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Acknowledgments

The authors would like to acknowledge the excellent co-operation received from Department of Agriculture and Fisheries (Queensland) management personnel and the Principal Investigators associated with the individual investments. Specific acknowledgments are mentioned in each of the appendices.

Acronyms & Abbreviations

BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CPMMV	Cowpea Mild Mosaic Virus
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
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. present value of benefits - present value of costs.
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: Delivery of superior forage cereal varieties for sub-tropical Queensland
- Investment 2: Measures to reduce the spread of Cowpea Mild Mosaic Virus in Queensland French Bean crops
- Investment 3: Transforming subtropical/tropical tree crop productivity
- Investment 4: Leading Sheep
- Investment 5: Genetic improvement of reproduction in tropical beef cattle
- Investment 6: Regional soil testing guidelines for the Northern Grains region

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 the Grains Research and Development Corporation, Hort Innovation, Australian Wool Innovation, and Meat and Livestock Australia. Other funding external to DAF included contributions by Heritage Seeds (Barenbrug Australia), the New South Wales Department of Primary Industries, the Queensland Alliance for Agriculture and Food Innovation, the University of Queensland, the University of New England (Animal Genetics and Breeding Unit), and Agforce.

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), outputs, activities, 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.

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. Total RD&E costs for each project included the investment in the project by DAF and others. The DAF contribution to the total investment made in each of the six projects/clusters varied from 20.2% to 59.3% (real, undiscounted dollar terms).

All investments were individual projects except the investment in Leading Sheep that involved a series of continuing projects over the period 2004 to 2021. 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.
- A lack of credible 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 2018/19 real dollar terms and discounted to 2019/20 (the year of analysis). 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 Total Investment by Project/Project Cluster

Investment Area	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**BCR**	**IRR (%)**	**MIRR (%)**
Delivery of superior forage cereal varieties for sub-tropical Queensland	10.03	1.60	8.43	6.27	95.0	13.3
Measures to reduce the spread of Cowpea Mild Mosaic Virus in Queensland French Bean crops	5.87	1.08	4.79	5.43	26.6	10.5
Transforming subtropical/tropical tree crop productivity	59.90	22.66	37.23	2.64	9.3	8.0
Leading Sheep	18.96	9.47	9.49	2.00	12.7	6.1
Genetic improvement of reproduction in tropical beef cattle	22.41	5.72	16.69	3.92	13.2	9.6
Regional soil testing guidelines for the Northern Grains region	32.68	2.65	30.03	12.32	42.5	14.5
Aggregate investment criteria	**149.85**	**43.18**	**106.67**	**3.47**	**14.2**	**10.2**

Investment Criteria for DAF Investment by Project/Project Cluster

Investment Area	PVB ($m)	PVC ($m)	NPV ($m)	BCR	IRR (%)	MIRR (%)
Delivery of superior forage cereal varieties for sub-tropical Queensland	4.13	0.66	3.47	6.27	95.2	14.3
Measures to reduce the spread of Cowpea Mild Mosaic Virus in Queensland French Bean crops	3.49	0.64	2.84	5.43	26.6	10.5
Transforming subtropical/tropical tree crop productivity	25.38	9.57	15.81	2.65	9.4	8.0
Leading Sheep	7.34	3.46	3.88	2.12	15.9	7.2
Genetic improvement of reproduction in tropical beef cattle	9.24	2.35	6.89	3.93	13.3	10.3
Regional soil testing guidelines for the Northern Grains region	6.61	0.55	6.07	12.12	39.1	14.0
Aggregate investment criteria	**56.20**	**17.23**	**38.96**	**3.26**	**13.8**	**9.9**

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 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 primary industries including livestock production including sheep and cattle (3 projects/investments), grains (1 project), and horticulture (2 projects, tree crops, bean crops). The investments were:

- Investment 1: A 5-year project relating to the delivery of superior forage cereal varieties for sub-tropical Queensland (DAFQ7958)
- Investment 2: A 3-year project relating to measures to reduce the spread of Cowpea Mild Mosaic Virus (CPMMV) in Queensland French Bean crops
- Investment 3: A 5-year project directed at transforming subtropical/tropical tree crop productivity - Small tree high productivity (AI13004)
- Investment 4: A 13-year series of projects relating to the Queensland sheep industry (Leading Sheep 1 to 5)
- Investment 5: A 6-year project enabling genetic improvement of reproduction in Tropical Beef Cattle (Repronomics)
- Investment 6: An 8-year project directed at regional soil testing guidelines for the Northern Grains region – (Deep P Soil Nutrition)

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. Methods

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 2018/19 real dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) and discounted to 2019/20 (year of analysis). 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. Total investment costs for each project included the expenditure on the project by DAF and the industry RDC (If 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.
- A lack of 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 first individually 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 the Appendix (Appendices A to F).

Table 1: Investment Criteria for 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 (%)
Delivery of superior forage cereal varieties for sub-tropical Queensland	10.03	1.60	8.43	6.27	95.0	13.3
Measures to reduce the spread of Cowpea Mild Mosaic Virus in Queensland French Bean crops	5.87	1.08	4.79	5.43	26.6	10.5
Transforming subtropical/tropical tree crop productivity	59.90	22.66	37.23	2.64	9.3	8.0
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Genetic improvement of reproduction in tropical beef cattle	22.41	5.72	16.69	3.92	13.2	9.6
Regional soil testing guidelines for the Northern Grains region	32.68	2.65	30.03	12.32	42.5	14.5
Aggregate investment criteria	**149.85**	**43.18**	**106.67**	**3.47**	**14.2**	**10.2**

Table 2: Investment Criteria for the DAF 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 (%)
Delivery of superior forage cereal varieties for sub-tropical Queensland	4.13	0.66	3.47	6.27	95.2	14.3
Measures to reduce the spread of Cowpea Mild Mosaic Virus in Queensland French Bean crops	3.49	0.64	2.84	5.43	26.6	10.5
Transforming subtropical/tropical tree crop productivity	25.38	9.57	15.81	2.65	9.4	8.0
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Genetic improvement of reproduction in tropical beef cattle	9.24	2.35	6.89	3.93	13.3	10.3
Regional soil testing guidelines for the Northern Grains region	6.61	0.55	6.07	12.12	39.1	14.0
Aggregate investment criteria	**56.20**	**17.23**	**38.96**	**3.26**	**13.8**	**9.9**

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 20.2% to 59.3% with a weighted average of 40.6% across all six investments (real, undiscounted dollar terms).

4. Conclusions

All six of the investments analysed provided positive NPVs at a 5% discount rate. The BCRs ranged from 2.00 to 12.32 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 regional soil testing guidelines in the Northern Grains region.

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 valuation frameworks used across the six individual evaluations.

Across the six investments the aggregate BCR for the total aggregate investment was estimated at 3.47 to 1, the aggregate IRR was 14.21%, and the aggregate MIRR 10.19%.

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

Appendix A: An Impact Assessment of DAF Investment in Delivering Superior Forage Cereal Varieties for Subtropical Australia (DAFQ7958)

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
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
MLA	Meat and Livestock Australia
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation

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 improved forage cereal varieties for subtropical Australia. The project was jointly funded by DAF and Heritage Seeds Pty Ltd and the research undertaken by DAF over the years ending June 2016 to June 2020. It should be noted that, as of October 2019, Heritage Seeds changed their name to Barenbrug.

The project was 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.

Benefits were estimated for a range of time frames up to 30 years from the last year of investment in the project (2019/20). Past and future cash flows in 2018/19 dollars were discounted to the year 2019/20 using a discount rate of 5% to estimate the investment criteria.

The cost-benefit analysis was conducted according to the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC) (CRRDC, 2018).

The investment in the project, its findings and resulting outcomes, have been important in continuing productivity gains for grazing enterprises (e.g. beef, dairy, and sheep) in the subtropical areas of southern Queensland and Northern New South Wales.

The principal impacts identified were of a financial/economic nature with implications for grazing systems in subtropical Australia. The impact valued is the increased herd performance and profitability for subtropical grazing systems where forage crops can play an important role.

Total funding from all sources over the project duration was approximately $1.60 million (present value terms). The value of total benefits estimated from the improved forage varieties produced was estimated at $10.03 million (present value terms). This result generated an estimated net present value of $8.43 million, and a benefit-cost ratio of 6.27 to 1.

There were several potential impacts identified that were not valued in monetary terms. These included the prospective future impact from release of a forage barley line, some environmental impacts due to reduced use of foliar fungicides, the regional community spillovers from the livestock producer gains emanating from the investment, and the scientific (plant breeding) capability and future capacity built by the investment. 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 to the evaluation. The impact valued is still deemed to represent the principal benefit delivered by the project.

2. Background and Rationale

Oats as a Forage Crop in Subtropical Grazing Systems

Oats are mostly grown for grain, grazing, or hay in temperate growing regions of Australia but there are also varieties adapted to production in subtropical regions. Forage oats are the principal type of oats grown in the subtropical regions of northern New South Wales (NSW) and central/southern Queensland (QLD).

The forage oats industry in subtropical areas is associated largely with several grazing industries. There are few official industry statistics on subtropical forage oats (e.g. areas grown and yields achieved). However, a previous ex-ante analysis undertaken in 2006 estimated the QLD annual forage oat area at 260,000 ha, spread across central and southern QLD and utilised by beef, sheep and dairy industries (Chudleigh and Smith, 2006). This previous estimate relied upon industry seed sales and anecdotal evidence of oats production provided by the Department of Agriculture and Fisheries QLD (DAF) and industry sources.

It is likely that the QLD average area of 260,000 ha remained steady or may have increased slightly since 2006 (Bruce Winter, pers. comm., 2020). Also, there is variation in area from one year to the next for various reasons such as differing seasonal conditions, rainfall timing, cattle prices and gross margins of dryland crops (Bruce Winter, pers. comm., 2020). Variation between seasons is not taken into account in the current valuation due to lack of available data. The average area for QLD is estimated as a conservative annual average of 260,000 ha per annum.

For subtropical northern NSW, it is estimated that the relevant area may be about 50% of the QLD area, adding a further 130,000 ha of forage oats in an average year (Bruce Winter, pers. comm., 2020).

Also, during the most recent research, development and extension (RD&E) project, breeding activity has extended to include forage barley, although no new varieties have yet been released. Forage barley areas are even more difficult to estimate but perhaps could total around 100,000 ha across QLD and NSW (Bruce Winter, pers, comm., 2020).

Other sources of seed for forage oats include varieties derived from other seed companies and include varieties from North America. However, many of these North American varieties are not as well adapted to local growing conditions and, as well, may succumb more rapidly to rust diseases in QLD conditions.

The importance of rust resistance in profitable cereal growing
Rust diseases historically have imposed a large cost on the Australian cereal industry through both yield reductions and a high cost of control via use of fungicides. This applies to both oat grain crops, as well as forage oats and dual purpose crops used for both forage and grain. For example, even with use of varieties with rust resistance, good cultural practices and the use of fungicides, rust diseases still result in estimated annual losses for the major cereal grain crop (wheat) of $147m per annum (Murray and Brennan, 2009). Without use of improved management practices, Murray and Brennan (2009) estimate the losses to the wheat industry alone would be $1.1 billion per annum (updated to 2015/16 $ terms). Other cereal crops are also affected by rust diseases; these include forage oats used for grazing purposes, with rust impacts both in terms of reducing dry matter production and forage quality.

In the past, rust resistant varieties of forage oats have provided only brief resistance as they have generally relied on single resistant genes that have been succumbed to mutations of the rust fungus. For example, 16 oat varieties released in QLD over a period of 10 years all succumbed to leaf rust, some within 1-2 years of release.

Since 1996 the DAF forage oats breeding activity has sought to achieve the “pyramiding” of a number of rust resistance genes into one variety to provide a more durable form of leaf rust resistance. This QLD objective of oats breeding is unique in Australia as it is not duplicated in other interstate oat breeding activities.

The release of new forage oat varieties by DAF that combine resistance to leaf rust as well as a high forage yield was expected to lift productivity when compared to susceptible varieties, as well as when compared to varieties released by other non-DAF origins. The benefit was expected to be most significant in southern and central QLD where leaf rust is endemic in most years.

As mentioned earlier, varieties of forage oats are available also from sources other than the DAF breeding program. Other varieties are mostly derived from North American sources and are not extensively evaluated for QLD growing conditions. While some varieties from non-DAF sources may maintain acceptable levels of rust resistance, they generally do not match the productivity or durability of locally developed and tested forage oats varieties.

3. Investment Details

Summary of Project Investment
The investment in the project assessed was made in the years ending June 2016 to June 2020. DAF was the lead research agency and Heritage Seeds P/L acted as an external funding agency. It should be noted that, as of October 2019, Heritage Seeds changed their name to Barenbrug. The DAF project code, title, key personnel, and funding period are summarised in Table A 1.

Table A 1: Summary Details for the Investment

Project Code	Title	Key Personnel	Funding Period
DAFQ7958	Delivering Superior Forage Cereal Varieties for Sub-tropical Australia	Bruce Winter, Senior Plant Breeder, Department of Agriculture and Fisheries, Queensland	Years ending June 2016 to June 2020

Logical Framework
Table A 2 provides a description of the project in a logical framework format.

Table A 2: Logical Framework for Project DAFQ7958: Delivering Superior Forage Cereal Varieties for Sub-tropical Australia

Overall Objective	The overall objective of the project is the selection, testing and release to industry of new commercial varieties of forage oat and other cereals with high levels of disease resistance, superior forage yield and improved agronomic characteristics.
Specific Objectives of DAF	1. Selection, testing and release to Heritage Seeds of two new forage oat cultivars with resistance to leaf rust, superior forage yield, and improved agronomic characteristics; 2. Identification of new genes conferring resistance to leaf rust, and transfer of these genes into elite breeding material that may be selected for commercial release following the completion of this project; 3. Evaluation of breeding lines of forage barley and other forage cereals for forage characteristics and identification of potential candidates for commercial release.
Specific Objectives of Heritage Seeds	1. Conduct field evaluation trials annually at their research sites in southern Australia in order to evaluate germplasm lines of forage oat and other cereals developed by the DAF research.
Activities and Outputs	*2015 Calendar year (includes first six months of DAFQ7958)* • The field program in 2015 included activity via the crossing nursery grow-out and phenology trials at Toowoomba, leaf rust screening nurseries at Toowoomba and Gatton, seed increase blocks at Wellcamp and Kingsthorpe, and cutting and demonstration trials at various locations. • The oat crossing program was completed with 54 successful crosses, 1,130 single plant selections identified with late maturity and leaf rust resistance, 86 advanced selections identified for Stage 1 yield testing, and 9 advanced selections identified for Stage 2 yield testing. • Seed stocks of advanced lines and breeder's seed of QA96 and QA112 were increased. • QA96 was on track for commercial release in 2017 with the variety name 'Wizard'. QA112 was the best performing advanced experimental line and was on track for commercial release in 2018. • The second year of field work was completed for the Grains Research and Development Corporation oat pre-breeding project in conjunction with the University of Sydney. • Evaluation of forage barley germplasm commenced. *Period ended June 2016*

	• Trial data from 2015 were analysed and an annual report submitted for the review meeting on 15 March 2016. • Detailed glasshouse screening of experimental lines was completed. • Oat cutting trials and forage barley trials were established at Wellcamp and Gatton. • Regional trials were established at Narrabri and Grafton. Rust nurseries were established at Gatton and Toowoomba and seed increases were effected at Wellcamp and Kingsthorpe, including bulk increases of QA112 and QA139. • The new variety QA112 was to be named as Warlock. • A block of the new variety Wizard was established at Toowoomba in preparation for the launch of this new variety later in 2016. • A 2016 edition of the Forage Oat Variety guide was published in January 2016. *Period ended December 2016* • The oat crossing program was completed with 73 successful crosses. • 100 advanced selections were identified for Stage 1 yield testing, and 10 advanced selections were identified for Stage 2 yield testing. • The best performing new experimental lines in yield trials were QA142 and QA145. • The new commercial variety Wizard was successfully launched at Toowoomba in August. • Forage barley lines were evaluated for forage yield and disease resistance, and two lines identified for potential commercial release. • Late in the season, a new leaf rust pathotype was identified on QA112 which delayed the planned commercial release of this variety (Warlock). *Period ended June 2017* • Trial data from 2016 were analysed. • Detailed glasshouse screening of experimental lines was nearly completed. • Oat cutting trials and forage barley trials were established at Wellcamp and Gatton. • Regional trials were established at Narrabri and Grafton. • Rust nurseries were established at Gatton and Toowoomba. • Seed increases were established at Wellcamp and soon to be planted at Kingsthorpe, including bulk increases of Wizard, QA142 and QA145 *Period ended December 2017* • The oat crossing program was completed with 60 successful crosses, 78 advanced selections were identified for Stage 1 yield testing, and 10 advanced selections were identified for Stage 2 yield testing. • The best performing new experimental line in yield trials was QA142. • Additional breeder's seed was produced for Wizard, QA142 and QA145. • Forage barley lines were evaluated for forage yield and disease resistance, and the line NRB140765 was identified for potential commercial release. • Late in the season, a new leaf rust pathotype was identified on Wizard which was reported as potentially reducing the longevity of this commercial cultivar.

	Period ended June 2018 • Trial data from 2017 were analysed. • Detailed glasshouse screening of experimental lines was completed. • Oat cutting trials were established at Wellcamp and Gatton and forage barley trials at Gatton and Wellcamp. • A regional trial was established at Grafton. • Rust nurseries were established at Gatton and Toowoomba. • Seed increases were established at Wellcamp and Kingsthorpe, including bulk increases of Warlock, QA142 and NRB140765. • A bulk area and demonstration trial was planted at Kingsthorpe for the upcoming launch of Warlock. *Period ended December 2018* • The forage oat and barley crossing program produced 71 successful crosses, with 1,160 single plant oat & barley selections taken. • Advanced selections (48) were identified for Stage 1 yield testing, and 20 advanced selections were identified for Stage 2 yield testing. • Additional breeder's seed was produced for Warlock, QA142 and NRB140765. • Forage barley lines were evaluated for forage yield and disease resistance. • There were several new leaf rust pathotypes present in the disease nurseries, for example, a new race virulent on the cultivar Bond; as a result, its status changed from resistant to susceptible reaction. • The new forage oat cultivar Warlock was released by the Minister of Agriculture at a field day at Kingsthorpe in August 2018. *Period ended June 2019* • Trial data from 2018 were analysed and an annual report submitted for the review meeting on 13 March 2019. • Detailed glasshouse screening of experimental lines was completed. • Forage oat cutting trials and forage barley trials were established at Wellcamp and Gatton. • Regional trials were established at Narrabri, Roma and Grafton. • Rust nurseries were established at Gatton and seed increase initiatives were undertaken at Wellcamp, including a small bulk increase of the barley experimental line NRB140408.
Outcomes	Forage Oats: QA96: Wizard has been successfully grown commercially since 2017. While older varieties are gradually being replaced by newer varieties such as Wizard, some older varieties persist long after they become susceptible to leaf rust; for example, the variety Genie was released in 2007 and became susceptible to leaf rust in 2011, but it was still selling well in 2018. QA112: Warlock was released in early 2019 but was susceptible to one pathotype of leaf rust when released commercially. However, Warlock still had a significant yield advantage over other commercial varieties. For this reason, the variety was released commercially but is restricted to sales in those areas where leaf rust incidence is less common e.g. western Downs and Maranoa regions (Bruce Winter, pers. comm., 2020). Lines QA142 and QA145. Both lines were targeted as potential releases and QA142 was progressed to parent seed production stage. However,

	QA142 was suspected of being susceptible to a new leaf rust pathotype in late 2018 and the line has since been discontinued. A different line (QA139) was selected as an alternative to QA142 and a final decision is pending on commercialisation in early 2020, with seed sales to commence in 2021 if commercialisation proceeds (Bruce Winter, pers. comm., 2020). Forage Barley: Lines of Forage barley: NRB 140765 and NRB 140408 NRB140765 has been discontinued due to a problem with its resistance to barley leaf rust. NRB140408 is likely to be released as an alternative but release will be delayed due to seed purity problems, with first commercial sales now likely in 2022 or 2023 (Bruce Winter, pers.comm.,2020).
Impacts	• Improved varieties of rust resistant forage crops available to, and grown by, subtropical livestock growers enabling the maintenance and/or improvement of productivity performance. • Increased awareness of subtropical growers of forage oats of the latest varietal information via the continuing update and publication of the Forage Oat Variety Guide (see for example Winter, 2019).

4. Project Investment

Nominal Investment
Table A 3 shows the annual investment in the project (cash and in-kind) by funding organisation and by year. The two funding organisations were DAF and Heritage Seeds P/L.

Table A 3: Annual Investment by Funding Organisation for Year ended June (nominal $)

Year	2016	2017	2018	2019	2020	Total
Heritage Seeds	160,774	158,049	162,537	167,078	175,755	824,193
DAF	110,081	112,668	115,315	118,025	120,798	576,887
TOTAL	270,855	270,717	277,852	285,103	296,553	1,401,080

Program Management Costs
For both the DAF and the Heritage Seeds investments, any management and administration costs for the project are assumed already built into the nominal $ amounts appearing in Table A 3.

Real Investment and Extension Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19 $ terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2019).

Extension activities included phone and email support for grower enquiries, preparation of publications and website maintenance, and occasional field days. This takes less than 5% of a Senior Plant Breeder's time and has been included in the DAF annual investment in Table A 3. Heritage Seeds also provide extension support to growers, as would other companies as part of product sales activity.

5. Impacts

Impact on Productivity and Profitability
The varieties released during the program are assumed to have provided an increase in forage yield over imported seed varieties and/or seed from other Australian sources. Also, the updates of the Variety Guides have improved producers' decision on preferred varieties to plant.

Environmental Impact
Leaf rust on forage oats can be controlled with foliar fungicides, but this comes with economic and environmental costs. The provision of forage oat varieties with genetic resistance helps to reduce use of fungicides and associated negative environmental impacts such as export of chemicals off-farm.

Social Impact
Any increase in productivity and profitability that benefits subtropical livestock producers that utilise forage crops will be shared along the supply chain with transport operators, processors and exporters. Further, positive spillover impacts will be experienced by regional communities connected with subtropical producers and their supply chains. The investment also has helped to maintain a high level of plant breeding capability within DAF.

Summary of Impacts
An overview of impacts in a triple bottom line categorisation is shown in Table A 4.

Table A 4: Categories of Impacts from the Investment

Economic	Environmental	Social
Increased productivity and profitability of QLD and northern NSW livestock producers that utilise forage crops. Associated productivity and profitability gains will be shared along the supply chains with transporters, processors, exporters etc. Maintained or increased sales of forage variety seed maintaining a contribution to profitability for Heritage Seeds.	Contribution to reduction in environmental impacts via reduced use of foliar fungicides.	Spillovers to regional communities in the subtropics from increased incomes for subtropical livestock producers and their associated supply chain businesses. Maintained/increased scientific and plant breeding capability and capacity in DAF.

Distribution of Benefits along the Supply Chains
Some of the potential benefits from the maintained/increased productivity/profitability of subtropical producers that utilise forage crops will be shared along the supply chain with processors, 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 subtropical livestock producers and Heritage Seeds. Some public benefits will be produced including spillovers to regional communities from enhanced farm and supply chain incomes, as well as a maintained/increased plant breeding capacity in DAF.

Impacts Overseas and in Other Australian States
It is unlikely that there will be any significant impacts overseas as the new lines and released varieties have been developed and tested only under Australian subtropical conditions. DAF varieties have been tested overseas through sister companies of Heritage Seeds and this has occasionally been successful. For example, Heritage Seeds (now Barenbrug) has recently signed a contract to market Wizard in South Africa through its sister company there. Sales volumes are likely to be small initially (perhaps 100 tonnes/annum) with potential to grow.

Some lines are also being sold into non-traditional Australian markets e.g. small amounts of Wizard and Warlock are being sold in Western Australia. These sales are likely to remain small in comparison to traditional areas (Bruce Winter, pers. comm., 2019).

Match with National and State Priorities
The Australian Government's Science and Research Priorities and Rural RD&E Priorities are reproduced in Table A 5. The investment is relevant to Rural RD&E Priorities 1 and 4 and to Science and Research Priority 1.

Table A 5: 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 A 6.

The investment addressed QLD Science and Research Priority 1. In terms of the guides to investment, the investment is likely to have a real future impact through improved feed resources available to subtropical livestock producers. The project was well supported and funded by others (Heritage Seeds) external to the QLD Government and had a distinctive angle as specific QLD livestock producers who grow forage crops will be a major recipient of the impacts.

Table A 6: 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 in Monetary Terms

The impact valued in the quantitative analysis is the contribution made by the increased productivity in QLD and NSW subtropical grazing industries from the new commercial forage varieties as well as up to date information on varietal performance, both of which can be attributed to the project investment. For such valuation purposes, it is difficult to aggregate across all of the relevant subtropical grazing industries (e.g. beef production, wool and sheepmeat production, and dairying), where the use of forage crops in autumn and winter may vary by industry and by the number of producers within each industry that use forage oats and other fodder crops.

Hence, the approach taken in the valuation is to assume a cost reduction for producers using the new varieties and variety information guide information, compared to the new varieties not being available or variety guides not being updated.

The per ha cost reduction is estimated from the increased yield of forage assumed for the new varieties. The cost of growing one ha of oats forage crop in QLD is based on an estimate of $345 per ha (Meat and Livestock Australia (MLA), 2011) expressed in 2011 $ terms; in 2018/19 $ terms this would be $384/ha ($345 x 1.1118). Assuming a 15% yield increase over what would have been achieved in the absence of the new varieties/updated varietal information, the new cost is estimated at $384/ha x (100/115) =$334/ha, a saving of $50 per ha. This saving is assumed for both QLD and NSW growers as the accrued benefits to producers in NSW would be similar to those estimated for QLD (Bruce Winter, pers. comm., 2020).

The total industry saving would be dependent on the area of forage oats that would grow the new varieties in the future. Assuming:

(a) the annual forage oats area in subtropical QLD and NSW remains at 390,000 ha (260,000 ha in QLD and 130,000 ha in NSW).
(b) the new Heritage Seeds varieties with the 15% yield increase are adopted by growers to a maximum of 15% of the 390,000 ha.
(c) Adoption of the new varieties commences in the 2017/18 year and reaches the maximum of 15% of the area in 4 years (58,500 ha in 2020/21).
(d) the impact of the new varieties/updated information produced by the project investment would gradually reduce from 2021 to zero by 2025 due to rust resistance breaking down, with no benefits accruing to the project investment assumed after 2025. This assumption is conservative as some of the better performing varieties may still be grown with the input from foliar fungicides.

A summary of all assumptions is presented in Table A 7.

Table A 7: Summary of Assumptions for Valuing Benefits

Variable	**Assumption**	**Source**
Without Project Investment		
Current annual area of oats forage crops in central and southern QLD	260,000 ha	Based on Chudleigh and Smith (2006)
Current annual area of oats forage crops in northern NSW	130,000 ha	Agtrans Research, based on input from Bruce Winter (pers. comm., 2020)
Total annual area of oats forage crops in QLD and NSW	390,000 ha	260,000 ha + 130,000 ha
Cost of growing an oats forage crop in Central Queensland	$384 per ha (2019 $ terms)	MLA (2011)
With Project Investment		
Increased yield of Heritage Seeds forage oat varieties	15% compared to alternatives in counterfactual	Agtrans Research
Forage oats cost savings to producers with new Heritage Seeds commercial varieties	$50 per ha	$384 per ha - $384 per ha x 100/115 - $384-$334
Maximum proportion of forage oats area contributed by new Heritage Seeds varieties	15%	Agtrans Research
Maximum area grown of new Heritage Seeds Varieties/Updated information due to investment	58,500 ha	15% of 390,000 ha
Maximum annual cost savings from new varieties	$2.925 m per annum	58,500 ha x $50 per ha
First year of new variety usage	2017/18	Agtrans Research

Year of maximum usage of new varieties	2020/21	
Last year of commercial life of new varieties due to rust and other new improved varieties becoming available	2024/25 (linear reduction to zero from 2020/21)	
Risk Factors		
Probability of outcome occurring (increased use of information and new varieties provided by the project)	90%	Agtrans Research
Probability of impact occurring given use of information generated	90%	Agtrans Research

Impacts not Valued in Monetary Terms
The impacts identified but not valued included:

- The reduction in negative environmental impacts from a reduction in use of foliar fungicides on some older varieties due to the availability of new varieties has not been valued. This was because data were not available on the extent of use of foliar fungicides and how this might be reduced due to the new varieties.
- The increased spillovers to regional communities from sustained or increased productivity for subtropical livestock producers who utilise forage crops in their production systems. 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 potential future contribution of forage barley line NRB140408 has not been valued due to some uncertainty for its potential release date.
- The increased profitability of marketing the new varieties by Heritage Seeds was not valued. This impact was not valued as it was assumed to have been at least partly offset by any increased seed costs to producers.
- The impact of increased or maintained plant breeding capability and capacity building for DAF. 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.

Counterfactual
It is unlikely that the resources requiring 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 set of expertise deployed in 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 (2019/20) to the final year of benefits assumed.

Investment Criteria
Table A 8 and Table A 9 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 A 9, has been estimated by multiplying the total PVB by the DAF proportion of real investment (41.2%).

Table A 8: Investment Criteria for Total Investment in the Project

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	3.68	10.03	10.03	10.03	10.03	10.03	10.03
Present value of costs ($m)	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Net present value ($m)	2.07	8.43	8.43	8.43	8.43	8.43	8.43
Benefit-cost ratio	2.30	6.27	6.27	6.27	6.27	6.27	6.27
Internal rate of return (%)	70.4	95.0	95.0	95.0	95.0	95.0	95.0
MIRR (%)	49.5	41.4	26.7	20.5	17.0	14.8	13.3

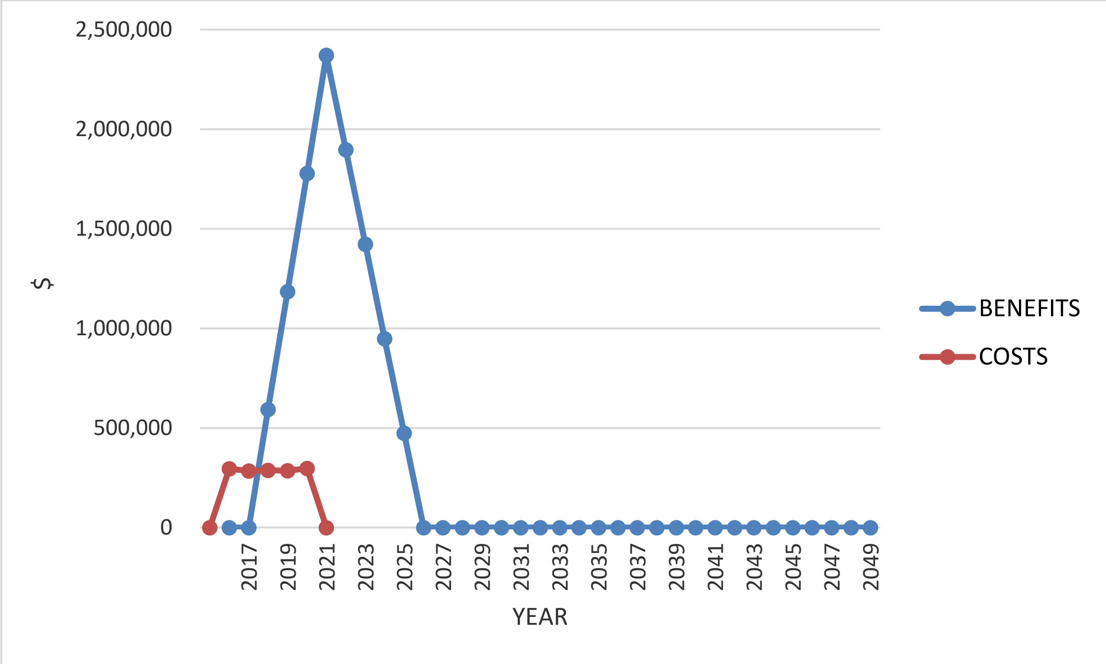
Table A 9: Investment Criteria for DAF Investment in the Project

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	1.51	4.13	4.13	4.13	4.13	4.13	4.13
Present value of costs ($m)	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Net present value ($m)	0.85	3.47	3.47	3.47	3.47	3.47	3.47
Benefit-cost ratio	2.30	6.27	6.27	6.27	6.27	6.27	6.27
Internal rate of return (%)	70.6	95.2	95.2	95.2	95.2	95.2	95.2
MIRR	n.s.	74.8	35.5	24.4	19.3	16.3	14.3

n.s. no solution

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 A 1.

Figure A 1: 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. Table A 10 presents the results that showed a low sensitivity to the discount rate, due to the relatively short period of benefits and the benefit period partial overlap with the investment cost period.

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

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	10.67	10.03	9.53
Present value of costs ($m)	1.45	1.60	1.77
Net present value ($m)	9.22	8.43	7.76
Benefit-cost ratio	7.36	6.27	5.39

A sensitivity analysis also was carried out on the increased yield growers obtained from the new varieties. Results are reported in Table A 11. The increase in yield of the new varieties for the project investment to break even was 2.1%

Table A 11: Sensitivity to Increased Yield of New Varieties
(Total investment, 30 years)

Investment Criteria	**Increased yield**		
	7.5%	**15% (Base)**	**20%**
Present value of benefits ($m)	5.37	10.03	12.82
Present value of costs ($m)	1.60	1.60	1.60
Net present value ($m)	3.77	8.43	11.22
Benefit-cost ratio	3.35	6.27	8.01

A sensitivity analysis then was carried out also on the maximum adoption level assumed for the new varieties (Table A 12). The maximum adoption level for the new varieties for the investment to break even was 2.4%.

Table A 12: Sensitivity to Maximum Adoption Level of New Varieties
(Total investment, 30 years)

Investment Criteria	**Maximum Adoption Level**		
	10%	**15%**	**20%**
Present value of benefits ($m)	6.69	10.03	13.38
Present value of costs ($m)	1.60	1.60	1.60
Net present value ($m)	5.09	8.43	11.78
Benefit-cost ratio	4.18	6.27	8.36

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 A 13). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table A 13: 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 output from the project was valued (productivity improvements from use of the improved new forage oats varieties).

Confidence in assumptions for the valuation was rated as Medium-Low as some of the assumptions associated with the improved varieties such as the overall yield improvement and extent of adoption were somewhat uncertain.

8. Conclusion

The investment in forage oat breeding by DAF over the years ending June 2016 to June 2020 has been successful and has provided positive impacts for QLD and NSW livestock producers.

The benefits delivered by the project will accrue predominantly to subtropical livestock producers. Some of these benefits are likely to be shared along the product supply chain due to increased economic activity in product transporting and processing. Some public benefits will be delivered via community spillovers from increased, or at least maintained, producer incomes, as well as a reduction in negative environmental impacts

The total investment in the project of $1.60 million (present value terms) has been estimated to produce total gross benefits of $10.03 million (present value terms) providing a net present value of $8.43 million, a benefit-cost ratio of 6.27 to 1 (using a 5% discount rate), a high internal rate of return of 95.0% and a modified internal rate of return of 13.3%.

The investment criteria reported are likely to have somewhat undervalued the full set of impacts delivered by the investment. This was because several benefits identified were not valued in monetary terms. For example, benefits accruing to any future release of a promising forage barley line were not included in the valuation of benefits. Also, any environmental benefits, the regional community spillover impacts arising from the livestock producer impacts, nor the increased/maintained plant breeding capability and capacity impacts delivered by the investment, were not valued.

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Appendix B: An Impact Assessment of DAF Investment into Characterisation of a Carlavirus in French Bean (VG15073)

Acknowledgments

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Abbreviations

ABS	Australian Bureau of Statistics
BCR	Benefit-Cost Ratio
CPMMV	Cowpea Mild Mottle Virus
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries – Queensland
GDP	Gross Domestic Product
IPM	Integrated Pest Management
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
NPV	Net Present Value
NSW	New South Wales
PVB	Present Value of Benefits
PVC	Present Value of Costs
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension

Executive Summary

The primary purpose of this assessment was to demonstrate that benefits have accrued from a specific DAF investment in the characterisation of a Carlavirus in French bean. The research was jointly funded by the Queensland Department of Agriculture and Fisheries (DAF) and Hort Innovation and spanned the period September 2016 to August 2019. The project was to characterise a new virus infecting French beans in South East Queensland, determine its distribution, develop management strategies and communicate strategies to growers. Investment totalled $916,903 and 59.3% of the total was provided by DAF.

The investment generated positive impacts for growers – a reduction in income loss caused by the virus. Other positive impacts included protection of jobs in regional packing plants, additional researcher and grower skill sets and positive spill-over benefits for regional communities.

In summary, the total investment of $1.08 million (present value terms) has been estimated to produce total gross benefits of $5.87 million (present value terms) providing a net present value of $4.79 million, a benefit-cost ratio of 5.4 to 1 (using a 5% discount rate), an internal rate of return of 26.6% and a modified internal rate of return of 10.5%.

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 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, 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 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

Background

Queensland (QLD) is the major producer of fresh market French beans (*Phaseolus vulgaris*) utilising the Lockyer and Fassifern Valleys for spring to autumn crops and the Bowen-Burdekin area for winter production. Fresh green bean production, including French beans and runner beans, had an Australia-wide value of $76.4 million in 2018 with QLD producing most of the crop. Production also occurred in NSW, Victoria, Tasmania and Western Australia (Hort Innovation, 2019).

In May 2016, bean crops in the Fassifern area of South East QLD had a high incidence of a virus disease which caused leaf mottling, severe pod distortion, and twisting and discolouration. Disease incidence exceeded 50% in crops in the infected area. Estimated total losses of between $300,000 and $400,000 were realised and were associated with abandoned crops, yield reduction and increased pack house labour to sort affected crops. Labour to sort crops, remove deformed pods and produce a saleable product was a large part of the additional cost incurred.

The virus isolated from infected plants was tentatively placed in the Cowpea Mild Mottle Virus (CPMMV) group of the genus Carlavirus. Viruses in the CPMMV group are transmitted by the silver leaf whitefly (*Bemisia tabaci*) and are seed transmitted in some legume species.

The South East QLD outbreak was the first record of a Carlavirus in legumes (*Fabaceae*) in Australia. A related virus was also detected in soybean in South East QLD at the same time.

Viruses in the CPMMV group are well established in other countries and have caused economic loss in bean and soybean crops in Argentina, Brazil, Indonesia, and Puerto Rico. CPMMV is currently considered to be a potential threat to the United States soybean industry.

The detection of the virus at a high incidence throughout one important bean production area was significant and was a potential economic threat to bean production in QLD and other Australian states.

Rationale for the investment
The extent and severity of the disease in beans required an urgent response to determine the precise identity of the virus, its host range, and transmission and distribution in QLD production areas.

Industry required an interim management plan to reduce virus inoculum and the future economic impacts of the disease. A broader management plan was to be based on information generated by the project.

3. Project Details

The project is described in a logical framework in Table B 1.

Table B 1: Project Logical Framework

Code and Title	VG15073: Characterisation of a Carlavirus in French bean.
Project Details	Organisation: DAF. Period: September 2016 to August 2019. Principal Investigator: Denis Persley.
Objectives	The objective of this project was to assist Hort Innovation to: 1. Better characterise a new Carlavirus infecting French beans, South East QLD. 2. Identify potential distribution and incidence of the virus in other French bean production regions of Australia. 3. Develop management strategies for the virus in bean production. 4. Provide information on the virus to growers, the vegetable industry, biosecurity agencies and other relevant groups.
Activities and Outputs	• Survey French bean production areas to determine the presence of CPMMV. • Complete a risk assessment to determine the presence of a virus insect vector and the risk of seed transmission of the virus. • Accurately identify the virus using molecular and serological work. Examine the relationship between QLD bean and soybean isolates. • Test virus host range including whether the virus is relevant to grain legumes, perennial species used for grazing and common weedy species. • Complete virus transmission studies focusing on silver leaf whitefly and virus transmission through the seed. • Prepare an initial management strategy to assist growers reduce sources of virus inoculum between crops and epidemics. Document potential modes of spread to other Australian bean producing regions. • Assess the resistance of the French bean varieties grown in Australia to the virus through both pot and field trials. Two sets of field trials were subsequently completed at the QLD Crop Development Facility, Redlands. • Assess the economic impact of the virus on both individual farms and the whole French bean industry. Assessment included the value of potential virus management options and responses. • The project delivered concise information on the nature, distribution, spread and biology of CPMMV; a management plan for growers; publications in refereed journals; a presentation to the Australasian Plant Pathology Society Conference; demonstration of the economic impacts

	of CPMMV; summaries of the above for industry communication and a final project report. • CPMMV occurs in all QLD bean production areas but not outside the state. CPMMV is only vectored by silver leaf whitefly which is not present in Victoria, Tasmania or Western Australia. There is a low risk of CPMMV infecting French bean crops in NSW where whitefly is present – beans do not move from QLD to NSW and this Carlavirus is not transmitted through seed. CPMMV host plants include bean, soybean, mung bean, cowpea and the perennial legume species Siratro, Glycine and Phasey bean. • CPMMV only becomes problematic when base levels of 5% reach 20% as they did in autumn 2016 and again in 2019 in the Fassifern Valley. CPMMV does not affect Fassifern Valley production during spring and summer. Lost production is associated with large whitefly populations in autumn. • Eighteen of 34 current French bean varieties used in QLD are somewhat CPMMV tolerant and use of less susceptible varieties is one component of the project-developed CPMMV management plan. Other components include introduction of biological control agents (IPM already practiced by Fassifern growers) or targeted chemical sprays and the planting of whitefly tolerant crops that attract the vector away from French bean (e.g. pumpkin). • The CPMMV Carlavirus is now well characterised in terms of biology, molecular and serological properties and epidemiology. • New scientific knowledge on the viruses present in French beans has been created including those with the potential to cause economic loss in other legume crops. • Project extension included communication of information updates on CPMMV and the CPMMV management plan via AUSVEG and vegetable levy funded initiatives. Information on the virus was included in industry production and crop protection guides. The project hosted regular field days and worked closely with regional grower groups.
Outcomes	• Australian bean growers have adopted integrated viral disease management strategies resulting in improved pack out, marketable yield and a general reduction in the impact of CPMMV Carlavirus on production.
Impacts	• Economic – reduction in French bean income loss caused by CPMMV Carlavirus (net of virus management plan implementation costs). • Economic – protection for jobs and income earned in regional towns packing beans that might otherwise have been lost without improved CPMMV management. • Increased capacity – additional virus classification skills developed by DAF staff. • Increased capacity – new networks of growers, researchers and seed companies that can work collaboratively to solve current and future industry challenges. • Increased capacity – additional virus management skills developed by growers. • Social – contribution to improved regional community wellbeing from spill-over benefits from more productive and profitable Australian bean growers.

4. Project Investment

Nominal Investment
Table B 2 shows the annual investment (cash and in-kind) for the project with funding provided by DAF and Hort Innovation.

Table B 2: Annual Investment in the Project for Years Ending June 2017 to June 2020 (nominal $)

Contributor	2017	2018	2019	2020	Total
DAF - cash	182,882	202,311	126,072	56,807	568,072
Hort Innovation - cash	112,301	124,232	77,416	34,883	348,832
Total	295,183	326,543	203,488	91,690	916,904

Source: signed project funding agreements.

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 B 2. The salary multiplier used by DAF was 2.85 (Wayne Hall, pers. comm., July 2017).

For the Hort Innovation investment, a management cost multiplier of 1.162 was applied to the Hort Innovation contributions shown in Table B 2. This multiplier was estimated from the share of ‘payments to suppliers and employees’ in total Hort Innovation expenditure reported in the Hort Innovation’s Statement of Cash Flows (Hort Innovation Annual Report, various years).

Real Investment and Extension Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19-dollar terms using the Implicit GDP Deflator index (ABS, 2019). Industry extension and communication costs were included as part of the project budget.

5. Impacts

An overview of potential impacts in a triple bottom line categorisation is shown in Table B 3.

Table B 3: Categories of Impacts from the Investment

Economic	Environmental	Social
Reduction in French bean income loss caused by CPMMV Carlavirus due to more effective CPMMV management. Protection for jobs and income earned in regional towns packing beans that might otherwise have been lost without effective CPMMV management. Increased confidence by bean growers in other states that the QLD outbreak is unlikely to spread to their regions.	Some reduction in the use of chemical sprays with the management plan focussing on integrated pest management.	Additional virus classification skills developed by DAF staff. New networks of growers, researchers and seed companies that work collaboratively to solve current and future industry challenges. Additional virus management skills developed by growers. Contribution to improved regional community wellbeing from spill-over benefits from more productive and profitable Australian bean growers.

Public versus Private Impacts
The impacts identified from the investment are mostly private in nature. Private impacts accrue to French bean growers in QLD in the form of improved pack out rates, marketable yield and a general reduction in the impact of CPMMV Carlavirus on production. Private benefits are realised in regional towns by those who retain employment packing French beans. Public impacts include capacity building in research staff and growers, development of effective industry networks and community spill-over benefits associated with the long-term productivity and profitability of QLD French bean growers.

Impacts Accruing to other Primary Industries
Characterisation of the CPMMV Carlavirus, understanding its distribution and incidence and development of a management strategy will generate knowledge that can be applied to a range of cropping and grazing industries that make use of legumes. Relevant species include soybean, mung bean, cowpea, Siratro, Glycine and Phasey bean.

Distribution of Benefits along the Green Bean Supply Chain
Some of the potential benefits accruing to French bean growers and packers in the form of avoided lost income will be shared along the supply chain with wholesalers, retailers and consumers.

Impacts Overseas
Viruses in the CPMMV group are well established in other countries and management strategies are either in place or have been developed or will need to be developed for the country's specific set of circumstances. Research results from this project are likely to have limited relevance overseas.

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 B 4. The investment in characterisation of the CPMMV Carlavirus in French bean is relevant to Rural RD&E Priority 2 and 4 and to Science and Research Priority 1.

Table B 4: 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 B 5.

Table B 5: 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. In terms of the guides to investment, the investment is likely to have a real future impact on the QLD French bean industry and, through Hort Innovation, was well supported by others external to the QLD Government.

6. Valuation of Impacts

Impacts Valued in Monetary Terms
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.

After review of project reports a single key impact was quantified – a reduction in French bean income loss caused by CPMMV.

Impacts not Valued in Monetary Terms
Not all impacts identified in Table B 3 could be valued in the assessment. Two impacts identified were not valued due to a lack of data (protection for jobs in bean pack houses, increased been growing confidence in other states) and other impacts were not valued due to the complexity of assigning monetary values to the impact (capacity built, creation of industry-researcher networks and increased regional income and employment).

Valuation of Impact 1: Reduction in French Bean Income Loss Caused by CPMMV
With the project generated management strategy for CPMMV in place, French bean growers are less likely to incur income losses associated with abandoned crops, reduced yields and increased pack house labour. The strategy consists of moving to French bean varieties that are more tolerant of CPMMV, introduction of readily available biological control agents, targeted chemical sprays (less likely as IPM already in place) and interspersing bean crops with crops that attract whitefly away from French beans. CPMMV tolerant varieties identified by the project include Outlaw, Cahill, Sybaris, Jaguar, Seminis BA 0958, Syngenta 4735, Messi, Syngenta 4734, Venice, Stanley, New Pioneer, Tasman and Greenleaf.

Attribution
The project was a 'standalone' piece of research that delivered and communicated outputs to growers. Consequently, 100% of impacts are attributed to VG15073.

Counterfactual
In the absence of VG15073 the assumption is made that it is 50% likely that another research project would have made progress understanding and addressing CPMMV.

A summary of project assumptions and data sources is provided in Table B 6

Table B 6: Summary of Assumptions for Valuing Benefits

Variable	Assumption	Source
WITHOUT PROJECT INVESTMENT		
Area of CPMMV affected French beam production prior to the project.	60ha per annum.	VG15073 final report notes that in 2016 there was 25ha of moderate loss, 30ha of severe loss and 5ha where no crop was recovered.
Maximum area of CPMMV affected French bean production.	1,000ha.	VG15073 final report notes that QLD green bean production area is approximately 4,000ha. Consultant estimate is that 50% of this area grows green beans in autumn when whitefly is problematic, and 50% of the green bean area is French bean (the balance

		being runner bean) (Hence, 4000ha x 50% x 50%= 1,000 ha)
Years required for CPMMV to reach maximum area affected in the absence of the project.	5 years.	Consultant estimate after reviewing project materials.
Average reduction in French bean income caused by CPMMV.	40%	VG15073 final report notes that in 2016 income losses varied from 25 to 100% with most loss in the 25 to 50% range.
Value of French bean income.	$2,600/ha	Price received for green beans of $1,520/t with cost of production of $1,000/t (ABARES, 2018) and an average yield of 5t/ha (DAF Gross Margin for Green Beans, Southern QLD). Note analysis assumes French bean price and production cost is the same as green beans.
WITH PROJECT INVESTMENT		
Additional cost to growers to implement CPMMV management strategy.	$100/ha	Consultant estimate and assumes minimal cost associated with switch to readily available CPMMV tolerant French bean varieties, fine tuning of the IPM system and the ready availability of whitefly biological control agents.
Year of first impact from the project.	2021	Consultant estimate assuming extension and adoption occurs within one year of project completion in August 2019.
Years from project completion when project findings begin to be superseded by new research.	20 years.	Consultant estimate assuming project findings are replaced with the products of new research e.g. new French bean varieties and/or whitefly control strategies.
Attribution of impacts to VG15073.	100%.	The project was a 'standalone' piece of research that delivered and communicated outputs to growers.
Probability of output	100%	Outputs have already been delivered.
Probability of impact	90%	There is some possibility that the strategy delivered as part of the project will not persist for the next 20 years.
Counterfactual.	50%.	In the absence of VG15073 it is 50% likely that another research project would have made progress with understanding and addressing CPMMV with the same outcomes and impacts.

7. Results

All past costs were expressed in 2018/19 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2019). 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 (2049/50).

Investment Criteria

Table B 7 and Table B 8 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 B 8, has been estimated by multiplying the total PVB by the DAF proportion of real investment (59.3%).

Table B 7: Investment Criteria for Total RD&E Investment in the French Bean Project

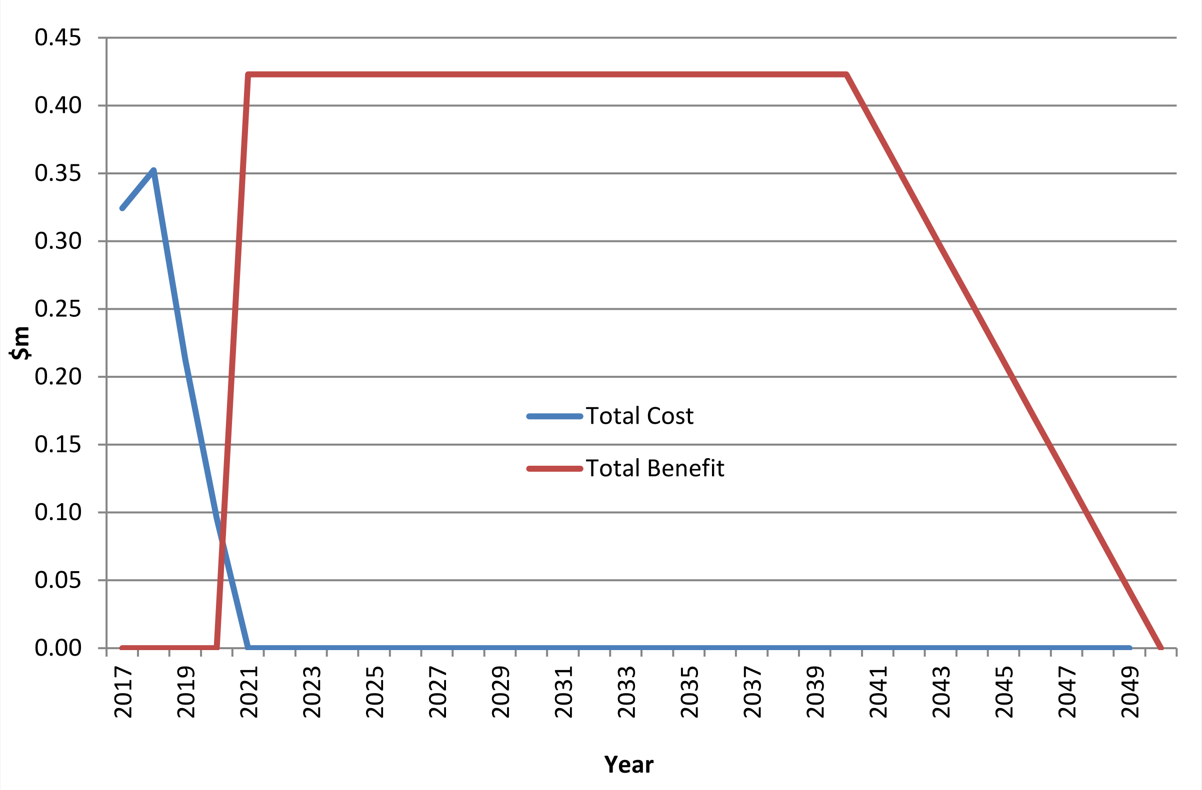
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	1.83	3.27	4.39	5.27	5.76	5.87
Present value of costs ($m)	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Net present value ($m)	-1.08	0.75	2.18	3.31	4.19	4.68	4.79
Benefit-cost ratio	0.00	1.69	3.02	4.06	4.87	5.32	5.43
Internal rate of return (IRR) (%)	negative	17.1	24.5	26.1	26.5	26.6	26.6
Modified IRR (%)	negative	12.1	14.3	13.5	12.5	11.5	10.5

Table B 8: Investment Criteria for DAF RD&E Investment in the French Bean Project

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	1.09	1.94	2.61	3.13	3.42	3.49
Present value of costs ($m)	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Net present value ($m)	-0.64	0.44	1.30	1.96	2.49	2.78	2.84
Benefit-cost ratio	0.00	1.69	3.02	4.06	4.87	5.32	5.43
Internal rate of return (IRR) (%)	negative	17.1	24.5	26.1	26.5	26.6	26.6
Modified IRR (%)	negative	12.1	14.3	13.5	12.5	11.5	10.5

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 B 1.

Figure B 1: Annual Cash Flow of Undiscounted Total Net Benefits and Total RD&E Investment Costs



Sensitivity Analyses
A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

Table B 9 shows that investment criteria are not overly sensitive to the discount rate and remain positive at a 10% discount rate, twice the rate of the base assessment.

Table B 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	10.36	5.87	3.81
Present value of costs ($m)	0.98	1.08	1.19
Net present value ($m)	9.38	4.79	2.62
Benefit-cost ratio	10.52	5.43	3.20

A sensitivity analysis was completed on the area of French bean production affected by CPMMV (Table B 10). Results show that with a halving of the area of crop at risk from a maximum of 1,000ha to 500ha, returns from the investment remain positive.

Table B 10: Sensitivity to Area of French Bean Production Affected by CPMMV (Total investment, 30 years)

Investment Criteria	Maximum Area of French Bean Production Affected by CPMMV in the Absence of the Project		
	500ha	1,000ha (base)	2,000ha
Present value of benefits ($m)	2.94	5.87	11.75
Present value of costs ($m)	1.08	1.08	1.08
Net present value ($m)	1.86	4.79	10.67
Benefit-cost ratio	2.71	5.43	10.85

A final sensitivity analysis was completed on the cost to French bean growers of implementing the CPMMV strategy developed as part of the project (Table B 11). Results show that even if implementation costs are increased from $100/ha (base) to $500/ha, investment costs exceed investment benefits.

Table B 11: Sensitivity to Grower Cost of Implementing CPMMV Management Strategy (Total investment, 30 years)

Investment Criteria	Cost to Growers of Implementing CPMMV Management Strategy		
	$500/ha	$100/ha (base)	$0/ha
Present value of benefits ($m)	3.37	5.87	6.50
Present value of costs ($m)	1.08	1.08	1.08
Net present value ($m)	2.29	4.79	5.42
Benefit-cost ratio	3.12	5.43	6.00

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 B 12). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table B 12: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium	Medium-High

Coverage of benefits was assessed as Medium. While the key economic benefit was quantified (reduction in grower income loss due to CPMMV), the benefit to employment in regional towns and other social/public benefits were not valued.

Confidence in assumptions was rated as Medium-High. Key assumptions applied in valuing impacts (French bean income and areas affected) were drawn from credible sources and based on a survey completed as part of the research project.

8. Conclusion

The investment in this project has delivered an integrated viral disease management strategy which has been adopted by QLD French bean growers. As a result of strategy adoption, growers have avoided loss of income caused by CPMMV. Other benefits include protection of jobs in regional packing plants, additional researcher and grower skill sets and positive spill-over benefits for regional communities.

In summary, the total investment in the project has produced several impacts and one of the key benefits has been valued. The total investment of $1.08 million (present value terms) has been estimated to produce total gross benefits of $5.87 million (present value terms) providing a net present value of $4.79 million, a benefit-cost ratio of 5.4 to 1 (using a 5% discount rate), an internal rate of return of 26.6% and a modified internal rate of return of 10.5%.

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Appendix C: An Impact Assessment of DAF Investment into Transforming Subtropical/Tropical Tree Crop Productivity (AI13004)

Acknowledgments

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Abbreviations

ABS	Australian Bureau of Statistics
AMIA	Australian Mango Industry Association
BCR	Benefit-Cost Ratio
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
NIS	Nut in Shell (macadamia)
NPV	Net Present Value
NSW	New South Wales
PVB	Present Value of Benefits
PVC	Present Value of Costs
QAAFI	Queensland Alliance for Agriculture and Food Innovation
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
UQ	University of Queensland

Executive Summary

The primary purpose of this assessment is to demonstrate that benefits have accrued from DAF investment into transforming subtropical and tropical tree crop productivity focusing on mango, macadamia and avocado. This investment was based on the success of similar research into temperate tree crop productivity. Through resources such as rootstock and planting systems trials, the subtropical and tropical tree crop project sought to understand the physiology underlying productivity and develop more productive orchard systems for growers.

The investment of $22.66 million in present value terms was assessed as providing monetary impacts of $59.90 million (present value terms), a net present value of $37.23 million, a benefit cost ratio of 2.6 to1, an internal rate of return of 9.3%, and a modified internal rate of return of 8.0%.

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 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, 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 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

Background

The productivity of subtropical/tropical tree crops such as macadamia, mango and avocado lags behind those of temperate tree crops such as apple. Over the least three decades apple productivity has increased more than three-fold, while productivity from macadamia, mango and avocado orchards has remained relatively static. Consequently, there seemed to be opportunity to adapt some of the underlying principles and practices from crops such as apple to the less well developed subtropical and tropical crops in Australia.

Macadamia has a current farm gate value of $297 million, production of 49,300 tonnes nut in shell (NIS) and an orchard area of 19,750 ha; yield per hectare is approximately 2.5 t/ha. Mango has a farm gate value of $204 million, production of 83,315 tonnes and an orchard area of 5,900 ha; mango yield per hectare is approximately 14 t/ha. Avocado has a farm gate value of $543 million, production of 77,000 tonnes and an orchard area of 8,900 ha; yield per hectare is approximately 8.6 t/ha. The average apple orchard yield is 30t/ha with best practice intensive operations yielding more than 60t/ha. Sources for the foregoing statistics include Hort Innovation, 2019; ABS, 2019; and AgEconPlus and Agtrans Research, 2019.

Rationale for the investment

The recent transformation of apple productivity has largely been a result of the adoption of high density 'small tree' planting systems that allow more efficient utilisation of light and higher early yields than more traditional low density 'large tree' planting systems. The vigour limiting rootstocks used in high-density orchards allow greater partitioning of resources to fruit production, precocious bearing and smaller, easier to manage trees. Pruning and training systems that help moderate the balance between vegetative growth and fruiting and that allow an optimal light environment to be maintained have kept pace with intensification. Understanding of the crop load and development of systems to manage crop load that reduce alternation of bearing and help maintain high fruit quality has also been important.

Project proponents believed that there was opportunity to adapt relevant concepts of orchard design and culture from temperate fruit production to subtropical/tropical tree crops. Such intensification needed to be undertaken for subtropical/tropical tree crops to be globally competitive, increase productivity and use input resources more effectively.

The project drew on many different scientific disciplines (genetics, physiology, molecular biology, canopy management and computational modelling) and integrated these different contributions into a systematic approach. The project was a partnership between the Department of Agriculture and Fisheries (DAF) Queensland (QLD), the QLD Alliance for Agriculture and Food Innovation (QAAFI) and the New South Wales (NSW) Department of Primary Industries (DPI).

The research was a long-term proposition due to the plant breeding/germplasm selection component, the long-term nature of tree crop research and the requirement to integrate multi-disciplinary research findings.

Macadamia, mango and avocado were used as model species in the knowledge that the outcomes of the project were also likely to be relevant to other subtropical/tropical horticultural tree crops.

3. Project Details

The project is described in a logical framework in Table C 1.

Table C 1: Project Logical Framework

Code and Title	AI13004: Transforming subtropical/tropical tree crop productivity.
Project Details	Organisation: DAF. Period: November 2013 to June 2019. Principal Investigator: John Wilkie, DAF
Objectives	The objective of this project was to improve the productivity of subtropical and tropical tree crops by designing more intensive orchard systems, understanding the physiology underlying productivity and assessing vigour managing root-stocks. Strategies were then to be developed to manage macadamia, mango and avocado: 1. Vigour – control by rootstock induced growth reduction and enhanced reproductive development, and/or by canopy manipulation; rootstock breeding and evaluation; and growth regulator application. 2. Architecture – understanding natural development patterns and fruiting; manipulation by pruning and/or training and associated responses of flowering and fruiting. 3. Canopy light relations – quantifying the role of light in canopy functions like flowering and fruiting; optimisation by pruning and/or training and associated responses of carbon partitioning (i.e. the process used by the tree to allocate the products of photosynthesis). 4. Crop load – understanding and managing crop load and associated effects on floral initiation, fruit set, irregular bearing and tree growth; and practical methods for load management.
Activities and Outputs	• Vigour management activities included a literature review on the mechanisms of vigour management in tree crops and the potential integration of vigour management strategies into intensive orchard systems. Research focussed on the development of rootstock/scion combinations, growth regulator management strategies, and the development of tree training and pruning recommendations. • Tree architecture research was largely undertaken by monitoring the vegetative, floral and fruiting development of a range of scion varieties (architectural types) in a range of training system and plant density

	treatments. Timing, location and extent of flowering, internode length, leaf area and component biomass were recorded using multi-scale tree graphs to specify location within the canopy. • Canopy light relation activities focussed on optimisation of the orchard light environment to improve yield. Data on the relationships between total light interception and orchard productivity were generated, differences in light distribution throughout the canopy were measured and the effect on fruit/nut load recorded. Data on how manipulations in tree structure alter the orchard light environment, productivity and fruit/nut quality were developed. • Development of crop load strategies required research to better understand the ability of the canopy to convert energy into harvestable fruit/nuts through inflorescence production, fruit set and retention, growth and development of fruit throughout the season and from the effect of one season's fruit load on the development of fruit load in the following season. • Planting system trials were established to begin to understand the interactions between vigour management, tree architecture, canopy light and crop load. Planting trials used a range of orchard configurations, tree structures, crop loads and vigour management systems to make progress toward the most productive and usable systems for growers. Post project completion trials were managed and monitored to learn more about mature orchard productivity. • Functional-structural plant models were developed and used as an integrative mechanism, drawing together knowledge on all research components. • Laboratory based research was initiated to better understand the genetics and physiology of the three tree species in relation to flower initiation, tree architecture, regular bearing and yield. Molecular markers were identified for different developmental and physiological processes. • Progress with the project was communicated to the three industries through media interviews (TV and radio), conference presentations, publications, workshops and annual orchard walks. Specific macadamia outputs • Comparison of the performance of high density macadamia orchards to industry standard orchards during the orchard establishment phase. • Identification of rootstocks influencing early vigour and scion precocity during the propagation phase (pre-trial planting). • Data on selective limb removal and growth regulators to improve productivity in an established high-density orchard. • Architectural responses to different pruning and tree training methods. • Canopy design and orchard constructions for improved light distribution. • Data on macadamia alternate bearing cycle. • Relative performance of selective limb removal and hedging strategies. • Development of various macadamia models (first flush, light, pruning response and tree structure/architecture). Specific mango outputs • Progress towards optimum high density orchard production systems. • Identification of candidate rootstocks for vigour control. • Data on the effect of canopy design and orchard construction on light interception during orchard establishment. • Data on vegetative and floral architectural development in response to management. • Data on the relationship between flowering and productivity.

	• Development of various mango models (first flush, light, pruning response, tree structure). • Negotiation of an agreement with India to share research findings and complete joint future projects. Specific avocado outputs • Comparison of the performance of high density avocado orchards to industry standard orchards during establishment phase. • High density avocado rootstock trial using both domestically available material and rootstocks imported from overseas. • An accepted methodology for architectural analysis of avocado. • Architectural responses to different pruning and tree training techniques. • Data on baseline relationships between light interception, canopy dimensions and yield. • Data on the relative importance of flowering, fruit set and growth on yield limitations and information on sustainable cropping levels. • Progress with the development of models for avocado (light, pruning response, structural/architectural).
Outcomes	• Progress toward modern, highly productive planting and management systems for macadamia, mango and avocado that can be adopted by industry. • Staff engaged in the project received training. There were more than 30 research staff engaged in the project across the three agencies. The project also funded the training of four PhD students (one each in macadamia, mango, avocado and one in molecular / generic regulation).
Impacts (potential)	• Economic – macadamia, mango and avocado orchards that generate significantly higher yields per hectare, yield sooner, offer more uniform production, improved fruit/nut quality, labour and management efficiency for growers. These positive impacts will not be achieved until further RD&E has been completed (a second project is planned) and will be net of orchard establishment and management costs. Potential impacts from this project and planned future investments may include: a lift in macadamia yield from an industry average of 2.5 t/ha nut in shell (NIS) to between 4 and 6 t/ha, mango yields that increase from an industry average of 14t/ha to between 34 to 47t/ha, and avocado yields that increase from 8.6t/ha to between 22 and 26t/ha. • Environmental – more intensive orchards that use less chemical, fertiliser and water. • Capacity – DAF, QAAFI and NSW DPI research staff with additional skill sets in genetics, physiology, molecular biology, canopy management and computational modelling. • Social – long term advancement of subtropical and tropical tree crops which will increase income and employment in subtropical and tropical regional Australia (spill-over impact).

4. Project Investment

Nominal Investment
Table C 2 shows the annual investment (cash and in-kind) for the project with funding provided by DAF, Hort Innovation, QAAFI and NSW DPI.

Table C 2: Annual Investment in the Project for Years Ending June 2014 to June 2019 (nominal $)

Contributor	2014	2015	2016	2017	2018	2019	Total
DAF (cash)	0	1,817,582	2,013,286	1,673,253	1,121,933	1,014,130	7,640,184
Hort Innovation (cash)	652,026	1,120,243	1,145,159	1,128,789	571,192	1,315,143	5,932,552
QAAFI (in-kind)	0	1,040,908	803,487	837,686	868,996	0	3,551,077
NSW DPI (in-kind)	0	75,000	51,215	51,214	51,215	0	228,644
Total	**652,026**	**4,053,733**	**4,013,147**	**3,690,942**	**2,613,336**	**2,329,273**	**17,352,457**

Source: project documentation (including the signed funding agreements).

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 C 2. The salary multiplier used by DAF was 2.85 (Wayne Hall, pers. comm., July 2017).

For the Hort Innovation investment, a management cost multiplier of 1.162 was applied to the Hort Innovation contributions shown in Table C 2. This multiplier was estimated from the share of ‘payments to suppliers and employees’ in total Hort Innovation expenditure reported in the Hort Innovation’s Statement of Cash Flows (Hort Innovation Annual Report, various years).

Real Investment, Further Research, Extension and Adoption Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19 dollar terms using the Implicit GDP Deflator index (ABS, 2019). Industry communication costs were included as part of the project budget. Additional research costs will be incurred further developing intensive orchard systems and incorporating project outputs into planting and management recommendations. Additional production costs will also be incurred by growers adopting and managing intensive orchard systems.

5. Impacts

An overview of potential impacts in a triple bottom line categorisation is shown in Table C 3.

Table C 3: Categories of Impacts from the Investment

Economic	Environmental	Social
Macadamia, mango and avocado orchards that generate significantly higher yields per hectare, yield sooner, offer more uniform production, improved fruit/nut quality, and increased labour and management efficiency for growers.	More intensive orchards that use less chemical, fertiliser and water.	DAF, QAAFI and NSW DPI research staff with additional skill sets in genetics, physiology, molecular biology, canopy management and computational modelling. Four PhD students trained. Long term advancement of subtropical and tropical tree crops which will increase income and employment in subtropical and tropical regional Australia (spill-over impact).

Public versus Private Impacts
The impacts identified from the investment are mostly private in nature. Private impacts will accrue to subtropical and tropical tree crop growers in the form of higher yields, yields delivered sooner in the tree's life, more even crops of better quality product, as well as labour and management efficiencies. Public impacts include less use of chemical, fertiliser and water, capacity building in research staff and community spill-over benefits associated with the long-term advancement of subtropical and tropical tree crop industries.

Impacts Accruing to other Primary Industries
While the project has focussed on macadamia, mango and avocado, findings are relevant to other horticultural tree and vegetable crops. For example, research completed on molecular regulation of flowering and branching will be relevant to a wide range of horticultural crops that share the same flowering genes.

Distribution of Benefits along the Subtropical/Tropical Tree Crop Supply Chain
Some of the potential benefits accruing to macadamia, mango and avocado growers in the form of higher yields will be shared along the supply chain with wholesalers, retailers and consumers.

Impacts Overseas
More intensive subtropical and tropical orchard systems will be relevant to macadamia, mango and avocado industries in other countries. Rootstocks and rootstock/scion combinations developed as part of this and a subsequent project will be intellectual property protected and earn royalties for the research funding partners.

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 C 4. The investment in subtropical and tropical orchard intensification is relevant to Rural RD&E Priority 1 and 3 and to Science and Research Priority 1 and 2.

Table C 4: 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 C 5.

Table C 5: 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. In terms of the guides to investment, the investment is likely to have a real future impact on subtropical and tropical tree crop profitability. The DAF investments were well supported by others external to the QLD Government and had a distinctive angle i.e. replication of 'step change' productivity gains realised by the temperate tree crop industries.

6. Valuation of Impacts

Impacts Valued in Monetary Terms
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.

After review of project reports a single set of key impacts was quantified – increased yield of high quality macadamias, mangoes and avocados.

Impacts not Valued in Monetary Terms
Not all impacts identified in Table C 3 could be valued in the assessment. Five impacts were not valued in the assessment due to a lack of evidence (more uniform crops, labour and management efficiencies), difficulty in quantifying the causal relationship and pathway between the project and the impact (environmental benefits associated with less chemical, fertiliser and water use) and the complexity of assigning monetary values to the impact (research capacity built and increased regional income and employment spill-overs).

Valuation of Impact 1: Increased Yield of High Quality Macadamias
While the project has not developed a complete intensive orchard system for the macadamia industry, measures identified during the project point to the potential for substantial increases in yield e.g. selective limb removal on its own was shown to increase yield from 2.5t/ha NIS to between 4 and 6t/ha NIS. In this analysis, a conservative 2t/ha NIS yield increase has been assumed. However, DAF advice is that this yield increase might not be achieved across the whole industry (John Wilkie, Researcher DAF, pers comm., June 2020).

Valuation of Impact 2: Increased Yield of High Quality Mangoes
Mangoes grown at high density and pruned to a central leader generated yields of between 34t/ha and 47t/ha compared to the industry average of 14t/ha. In this analysis, a conservative 12t/ha yield increase has been assumed for mangoes and this will be realised when investment in small tree research is complete.

Valuation of Impact 3: Increased Yield of High Quality Avocados
Avocados grown at high density with prospective rootstocks that manage vigour (e.g. 'Dusa' and 'Ashdot') generate superior yields. With additional research a yield increase from 8.6t/ha to between 22 and 26t/ha is credible. In this analysis a conservative 8t/ha yield increase is modelled. However, there remains a possibility that the yield increase might not be realised (John Wilkie, Researcher DAF, pers comm., June 2020).

Timing and Extent of Adoption
Project AI13004 has taken five years to complete (2013/14 to 2018/19). A second research project of similar duration will be required to deliver intensive orchard systems based on an improved understanding of subtropical/tropical tree crop physiology, vigour managing rootstocks and more intensive orchard systems (2019/20 to 2024/25). A further three years of extension, nursery propagation and planting will be needed before the first trees generate additional fruit/nut yield in 2029/30.

Adoption of new intensive orchard systems is assumed to peak in 2034/35, five years after the first crops generate additional yields in 2029/30. At this time adoption is forecast to account for 60% of total production – an estimate similar to the adoption rate of intensive orchard systems in the temperate fruit industries.

Attribution
Project impacts rely on the current project (AI13004), a second similar sized project, further extension, nursery investment and grower adoption costs. For this reason, a relatively modest 35% attribution factor has been assumed for AI13004.

Counterfactual
In the absence of the cross crop investment completed through Project AI13004, it is assumed still likely that individual agencies would have made 50% of the same progress with subtropical/tropical tree crop intensification.

A summary of project assumptions and data source is provided in Table C 6.

Table C 6: Summary of Assumptions for Valuing Benefits from Project AI13004

Variable	Assumption	Source
Impact 1: Increased Yield of High Quality Macadamias		
Macadamia orchard area in Australia.	19,750ha.	Hort Innovation, 2019.
Increase in macadamia yield when investment in small tree research is complete.	2t/ha of NIS yield.	Consultant assumption made after reviewing AI13004 reports.
Profit earned on additional macadamia yield.	$1,600/t.	Updated estimate based on a macadamia farm development model, prepared by DAF and retrieved at https://www.publications.qld.gov.au/dataset/agbiz-tools-plants-fruits-and-nuts/resource/30550a45-006a-40b6-8758-58786db7e526.
Impact 2: Increased Yield of High Quality Mangoes		
Mango orchard area in Australia.	5,900ha.	1,178,000 mango trees (Hort Innovation, 2019) at an average density of 200 trees/ha (Trevor Dunmall, previously IDO, AMIA pers. comm., August 2019).
Increase in mango yield when investment in small tree research is complete.	12t/ha.	Consultant assumption made after reviewing AI13004 reports.
Profit earned on additional mango yield.	$350/t.	Estimated from data supplied by Trevor Dunmall and cross checked with mango gross margin – Kensington Pride North QLD, prepared by DAF, Retrieved at https://www.publications.qld.gov.au/dataset/agbiz-tools-plants-fruits-and-nuts/resource/17689cf4-c81a-4f7d-aeb2-d3ff13d0fffc.
Impact 3: Increased Yield of High Quality Avocados		
Avocado orchard area in Australia.	8,900 ha.	Hort Innovation, 2019.
Increase in avocado yield when investment in small tree research is complete.	8t/ha.	Consultant assumption made after reviewing AI13004 reports.
Profit earned on additional avocado yield.	$1,000/t.	Updated estimate based on an avocado farm development model, prepared by DAF and retrieved at https://www.publications.qld.gov.a

		u/dataset/agbiz-tools-plants-fruits-and-nuts
Other Assumptions		
Year of first impact and share of macadamia, mango and avocado production adopting small tree research findings.	2029/30 5% of macadamia, mango and avocado production.	Consultant assumption: AI13004 has taken 5 years to complete (2014-19); a research project of similar duration is still required to deliver intensive orchard systems based on small trees (likely investment period 2020-25). A further three years of extension, nursery propagation and planting will be needed (2026-29) before the first trees generate additional yield in 2029-30.
Year of first impact and share of production adopting small tree research findings.	2029/30 5% of macadamia, mango and avocado production.	Consultant assumption made after review of intensive orchard adoption in the apple and pear industries (Reynolds and Wilson, 2015).
Year of maximum impact and share of production adopting small tree research findings.	2034/35 60% of macadamia, mango and avocado production.	Consultant assumption made after review of intensive orchard adoption in the apple and pear industries (Reynolds and Wilson, 2015).
Attribution of impacts to Project AI13004.	35%.	Consultant assumption based on estimated total investment in current project plus a new project of similar size that follows, as well as additional extension, nursery investment and grower adoption and associated production costs.
Probability of output.	75%	The project has already identified measures with the potential to increase macadamia, mango and avocado yield. However, it is not certain that a complete intensive orchard package can be developed. Intensification is dependent on genuine dwarfing rootstocks and these have not yet been identified.
Probability of impact	Macadamia: 75% Mango: 90% Avocado: 75%	It is not yet certain that yield gains will be replicated in a commercial setting and there are different probabilities of success for the three different tree crops.
Counterfactual.	50%.	In the absence of the major cross agency, cross crop investment completed through AI13004, it is still 50% likely that individual agencies would have made some progress with subtropical / tropical crop intensification.

7. Results

All past costs were expressed in 2018/19 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2019). 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 (2018/19) to the final year of benefits assumed (2048/49).

Investment Criteria
Table C 7 and Table C 8 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 C 8, has been estimated by multiplying the total PVB by the DAF proportion of real investment (42.4%).

Table C 7: Investment Criteria for Total RD&E Investment in Small Tropical Tree Project

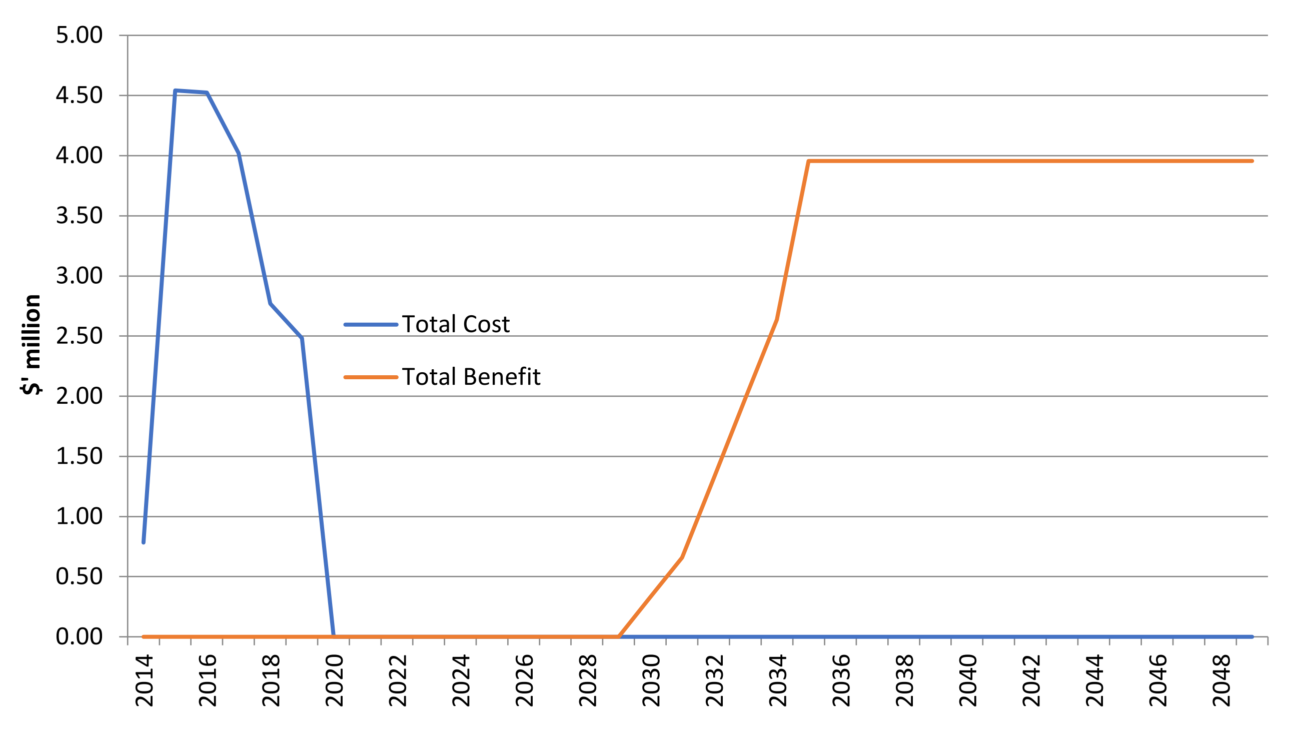
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.00	0.00	9.07	30.27	46.88	59.90
Present value of costs ($m)	22.66	22.66	22.66	22.66	22.66	22.66	22.66
Net present value ($m)	-22.66	-22.66	-22.66	-13.59	7.61	24.22	37.23
Benefit-cost ratio	0.00	0.00	0.00	0.40	1.34	2.07	2.64
Internal rate of return (IRR) (%)	negative	negative	negative	-1.6%	6.2%	8.4%	9.3%
Modified IRR (%)	negative	negative	negative	-1.0%	6.0%	7.5%	8.0%

Table C 8: Investment Criteria for DAF RD&E Investment in Small Tropical Tree Project

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.00	0.00	3.85	12.83	19.87	25.38
Present value of costs ($m)	9.57	9.57	9.57	9.57	9.57	9.57	9.57
Net present value ($m)	-9.57	-9.57	-9.57	-5.72	3.26	10.30	15.81
Benefit-cost ratio	0.00	0.00	0.00	0.40	1.34	2.08	2.65
Internal rate of return (IRR) (%)	negative	negative	negative	-1.5%	6.2%	8.4%	9.3%
Modified IRR	negative	negative	negative	-1.0%	6.0%	7.6%	8.0%

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 C 1.

Figure C 1: Annual Cash Flow of Undiscounted Total Net Benefits and Total RD&E Investment Costs



Sensitivity Analyses
A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values.

Table C 9 shows that investment criteria are sensitive to the discount rate. This is because there is a substantial lag between research investment (AI13004) and the generation of increased macadamia, mango and avocado yields in more productive orchards.

Table C 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	162.38	59.90	24.43
Present value of costs ($m)	19.12	22.66	26.76
Net present value ($m)	143.26	37.23	-2.33
Benefit-cost ratio	8.49	2.64	0.91

A sensitivity analysis was completed on the probability of the research investment generating substantially higher commercial macadamia, mango and avocado yield (Table C 10). Results show that investment will ‘breakeven’ when probability of yield increase is 30% for macadamia and avocado and 40% for mango.

Table C 10: Sensitivity to Probability of Substantially Higher Orchard Yields
(Total investment, 30 years)

Investment Criteria	Probability of Higher Yields in Commercial Orchards		
	Macadamia 30% Mango 40% Avocado 30% (breakeven)	**Macadamia 37.5% Mango 45% Avocado 37.5%**	**Macadamia 75% Mango 90% Avocado 75% (base)**
Present value of benefits ($m)	24.44	35.37	59.90
Present value of costs ($m)	22.66	22.66	22.66
Net present value ($m)	1.78	12.71	37.23
Benefit-cost ratio	1.08	1.56	2.64

A final sensitivity analysis was completed on the maximum share of macadamia, mango and avocado production adopting research findings (Table C 11). Results show that if the maximum adoption rate is halved from 60% to 30%, then investment benefits continue to exceed investment costs.

Table C 11: Sensitivity to Maximum Share of Orchard Production Adopting Research Findings (Total investment, 30 years)

Investment Criteria	Maximum Share of Production Adopting Research		
	Breakeven = 25%	**30%**	**60%(base)**
Present value of benefits ($m)	24.11	29.95	59.90
Present value of costs ($m)	22.66	22.66	22.66
Net present value ($m)	1.44	7.29	37.23
Benefit-cost ratio	1.06	1.32	2.64

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 C 12). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table C 12: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium	Medium

Coverage of benefits was assessed as Medium. While a key economic benefit was quantified (increased yield), a number of other impacts identified were not valued (yields delivered sooner in the tree's life, more even crops of better quality, and labour and management efficiencies). Also, environmental and social benefits were not quantified.

Confidence in assumptions was rated as Medium. Uncertain assumptions in relation to the probability of higher yields being achieved and the level of adoption of findings were tested by using sensitivity analysis.

8. Conclusion

The aim of this project was to transform productivity of subtropical and tropical tree crops, focusing on mango, macadamia and avocado. Temperate tree crops such as apple, increased productivity by intensifying the production system, and optimising and developing management strategies for key orchard system components such as vigour, the orchard light environment, tree structure and architecture and crop load. Through resources such as rootstock and planting system trials, this project sought to understand the physiology underlying productivity and develop more productive orchard systems for growers.

In summary, the total investment in the project has produced several impacts, one of which has been valued. The total investment of $22.66 million (present value terms) has been estimated to produce total gross benefits of $59.90 million (present value terms) providing a net present value of $37.23 million, a benefit-cost ratio of 2.6 to 1 (using a 5% discount rate), an internal rate of return of 9.3% and a modified internal rate of return of 8.0%.

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Appendix D: An Impact Assessment of DAF Investment in Leading Sheep

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Abbreviations

AWI	Australian Wool Innovation Limited
CBA	Cost-Benefit Analysis
CRC	Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries (Queensland)
DEEDI	Department of Employment, Economic Development and Innovation (Queensland)
GVP	Gross Value of Production
LS	Leading Sheep
MLA	Meat & Livestock Australia
QISN	Queensland Innovative Sheep Network
QLD	Queensland
PAP	Project Advisory Panel
RCC	Regional Coordinating Committee

Executive Summary

The sheep industry in Queensland (QLD) faces a number of challenges including rising costs of production, drought and other extreme weather events, and pest animals. Peak industry bodies and research organisations such as AgForce, Wool Producers Australia, the Sheepmeat Council of Australia, Australian Wool Innovation Ltd (AWI), Meat & Livestock Australia (MLA), and the Department of Agriculture and Fisheries QLD (DAF) have been investing in technologies, processes, training and development and infrastructure aimed at addressing such constraints and promoting productivity and profitability in the QLD sheep industry.

Knowledge and resources are shared with industry through a variety of mediums including online and face-to-face extension activities. AWI funds a series of state level grower networks that are fundamental to the spread of information and ideas, education and to the adoption of best practice. In 2004/05, AWI in association with DAF, funded the Leading Sheep program in QLD. Leading Sheep (LS) was developed to provide an education framework for leading the adoption of new technologies and practices to increase the productivity of the QLD sheep industry.

The investment in the Leading Sheep program (2004/05 to 2020/21) has delivered, and continues to deliver, a valuable, producer-driven network that facilitates the exchange of information and new knowledge and the adoption of best practice management and new technologies. Evidence of the value of the LS investment is demonstrated through the high participation rates within the QLD sheep industry (over 2,000 attendees at LS events in LS3 and LS4) and the number of producers implementing practice change influenced by the LS program.

The total investment in the LS Program (2004 to 2021) produced several impacts and the principal economic impact (increased productivity/profitability for QLD sheep producers) was valued. The total investment by all contributors of $9.47 million (present value terms) has been estimated to produce total gross benefits of $18.96 million (present value terms) providing a net present value of $9.49 million, a benefit-cost ratio of 2.0 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 12.7% and a modified internal rate of return of 6.1%.

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 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.

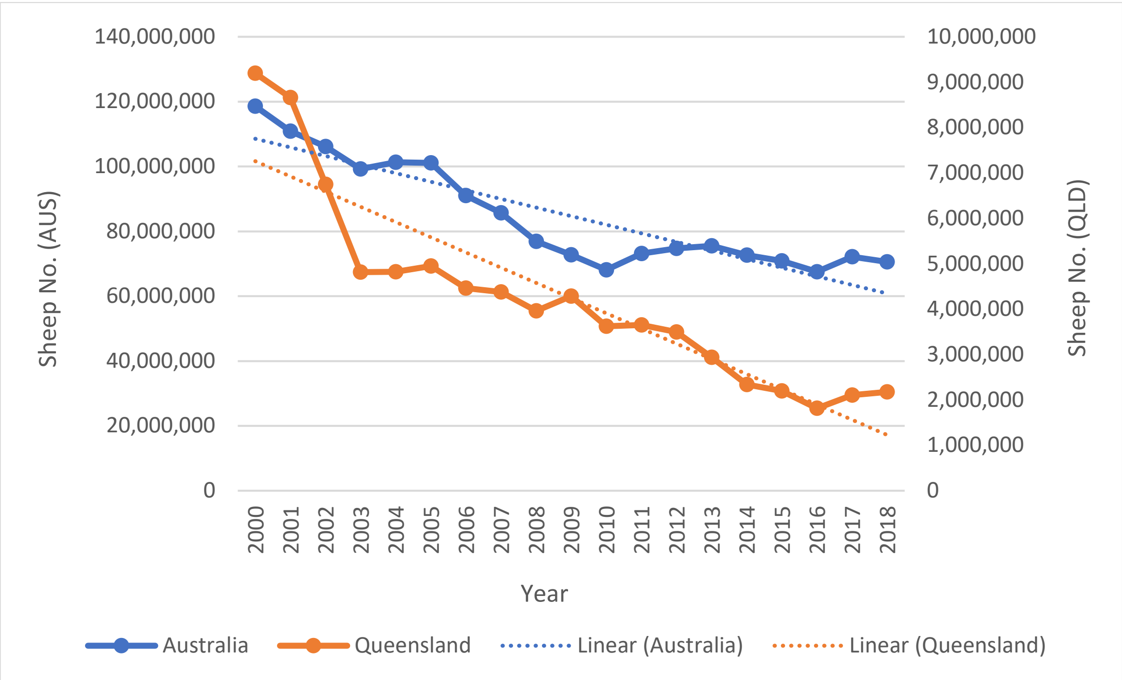
Some, but not all, of the impacts identified were then valued in monetary terms. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, or the likely low relative significance of the impact compared to those that were valued. The impacts valued therefore are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

2. Background and Rationale

Background

Queensland's sheep industry dates back to 1840 when an early pastoralist drove his flock of 6,000 sheep onto the Darling Downs. The sheepmeat and wool industries were highly successful in Queensland (QLD) and peaked around 1940 when the state's sheep population was approximately 25 million head (Australian Wool Innovation Ltd (AWI), 2019). However, sheep numbers in QLD have since declined dramatically and the state currently holds only 3.1% of the national flock (approximately 2.2 million head – sheapmeat and wool sheep) (MLA pers. comm., based on ABS data, 2020). Figure D 1 shows the number of sheep in QLD and in Australia for the recent period from 2008/09 to 2017/18.

Figure D 1: Sheep Numbers in Australia and QLD 2000/01 to 2017/18



Source: MLA pers. comm., based on ABS data, 2020.

The sheep industry (sheepmeat and wool) in QLD has faced a number of challenges including rising costs of production, drought and other extreme weather events, and pest animals (largely wild dogs). Peak industry bodies and research organisations such as AgForce, Wool Producers Australia, the Sheepmeat Council of Australia, AWI, Meat & Livestock Australia (MLA), and DAF have been investing in technologies, processes, training and development and infrastructure aimed at addressing such constraints and promoting productivity and profitability in the QLD sheep industry. Knowledge and resources are shared with industry through a variety of mediums including online and face-to-face extension activities.

Rationale for the investment
AWI funds a series of state level grower networks that are fundamental to the spread of information and ideas, education and to the adoption of best practice. In 2004/05, AWI in association with DAF, funded the Leading Sheep program in QLD. Leading Sheep (LS) was the product of a series of producer consultative forums that occurred during 2003/04 at the request of AWI. LS was developed to provide an education framework for leading the adoption of new technologies and practices to increase the productivity of the Queensland sheep industry.

3. Project Details

The LS investment is made up of five integrated project level investments supported by AWI, the Department of Agriculture and Fisheries Queensland (DAF) and AgForce, spanning a period from 2004/05 to 2020/21. The five contributing projects are:

1. EA051 Leading Sheep 1 (September 2004 to August 2007)
2. WP261 Leading Sheep 2 (September 2007 to December 2010)
3. WP465 Leading Sheep 3 (July 2011 to 30 June 2014)
4. ON-00326 Leading Sheep 4 (1 July 2015 to 1 August 2018)
5. ON-00560 Leading Sheep 5 (1 August 2018 to 31 July 2021)

Each subsequent LS investment built on the experience and activities of the preceding LS investment. The projects are described in a logical framework in Table D 1.

Table D 1: LS Program Logical Framework

Project Details	Organisation: DAF Period: September 2004 to July 2021. Project Leader(s): Geoff Knights (DAF, LS1 and LS2), Tony Hamilton/Nicole Sallur (DAF, LS3), and Nicole Sallur (DAF, LS4) and Andrea McKenzie/Jed Sommerfield (DAF, LS5).
Objectives	<u>LS1:</u> The aim of LS1 was to provide a framework for leading the adoption of new technologies and practices to increase the productivity of the Queensland sheep industry. Specific objectives of the LS1 investment were: 1. Provide an extension and adoption program for Queensland sheep and wool producers that does not currently exist in the marketplace; 2. Support a program of regionally specific activities in Queensland's four key wool producing areas (two events per region per year);

3. Use selected production benchmarks to measure changes in the management practices of 80 wool producers relating to reduced predation, higher reproduction rates, more valuable wool and meat, more effective parasite control and improved resource management, but not limited to these topics;
4. Involve 600 wool producers in regional activities that provide information on how to make productivity improvements on farm with a further 600 aware of the project; and
5. Contribute to the producer driven revitalisation of the Queensland wool industry by providing a single program to integrate a range of outputs aimed at improving aspects of wool production in Queensland.

<u>LS2:</u>
The goal of LS2 was to continue the positive work of LS1 and to provide an education framework for leading the adoption of new technologies and practices to increase the productivity of the Queensland sheep industry.

1. To have an extra 10% (80) of Queensland sheep producers implementing recognised environmental management systems in response to emerging international requirements. These will include:
   - Integrated Parasite Management
   - Mulesing alternatives
2. To enhance sheep and property management practices by having a total of 120 sheep producers in four regions undertaking one of the following:
   - seasonal forecasting tools
   - automatic handling and drafting
   - electronic sharing of information and data
   - breeding, selection and production management
   - sustainable resource use
3. To have 25% (200) of Queensland sheep producers improve the profitability and sustainability of their enterprise by:
   - responding to key profit drivers
   - managing pasture availability
   - feeding for production
   - confinement feeding
4. To reduce losses due to predation by providing support for participation in nil-tenure (no boundaries) integrated pest management control plans across regions for 25% (200) of sheep producers. These will include:
   - wild dogs
   - pigs
   - foxes

<u>LS3:</u>
The LS3 investment aimed to create a framework for supporting decision-making about technologies and practices to increase the profitability and productivity of Queensland sheep businesses. It aimed to achieve a high level of engagement with sheep businesses in Queensland to support their ongoing decision-making processes about productivity and profitability by working on the following priorities:

1. Predation

Local: facilitating the coming together of key stakeholders to plan and implement coordinated action at a local level which leads to lower predation.

State: utilising the LS model to share knowledge and information amongst stakeholders with state wide responsibility to improve efficiency of the effort to lower the impact of predation.

2. Animal nutrition

To improve the nutritional knowledge and skills of sheep producers to enable them to increase their lambing percentage, weaner performance and sheep survival during drought.

3. Animal health

To improve awareness of developments in animal health including genetic tools, alternatives to mulesing and new uses for old technology.

4. Business optimisation

To support landholders to develop their skills and knowledge to improve business performance.

To innovate the spread and use of communication and information management technologies that improve the effectiveness and efficiency of the industry.

5. Marketing and selling wool and sheep meat

To improve the confidence of sheep producers to make informed decisions about marketing of wool and meat by providing relevant knowledge and information.

<u>LS4:</u>
The overarching goal of the LS4 investment was to provide a proactive network of Queensland sheep and wool businesses; at the forefront of practical and relevant information and technology to equip progressive and thriving producers for the future.

Specific objectives of the LS4 investment were:

1. The Project Advisory Panel (PAP) and Regional Coordinating Committees (RCC) to proactively identify local, industry and producer priorities and collaborative opportunities to deliver timely information and outcomes to Queensland sheep and wool producers. The three priority areas are: pest animal management, health/nutrition and business performance.
   a. Improve the percentage of participants in Leading Sheep activities “very likely to make a change” from 38% by 2% per year to 44% by June 2018.
   b. Achieve an average satisfaction rating from Leading Sheep activities of at least 7/10 and to realise producer value of at least $700 on average per year.
   c. Increase participation in Leading Sheep by 25% (from 1281 in 2011-2015 to 1600 in 2015-2018) across the whole Queensland sheep and wool industry.

2. Promote to Queensland sheep and wool producers beneficial technologies which are currently being underutilised.

	a. Identify one beneficial new technology per year and conduct six events annually (two/region) to promote this technology. b. Publish at least one case study per year on a producer benefiting from the adoption of this technology. c. Instigate one Sheep Challenge by December 2016. Competitors (ranging from school age onwards) to identify an industry challenge and develop an innovative solution and potentially take it through to commercial release. 3. Create, identify and promote opportunities for future sheep and wool industry members to shape the direction of a thriving industry. a. Instigate a pilot youth mentoring program for three people (one from each Leading Sheep region) aged 18-39 either involved in or wanting to be involved in the sheep and wool industry. b. YouTube interviews with three young people involved in different aspects of the industry highlighting how they started out and what advice they would give to others starting out. c. Promote existing industry educational opportunities and resources for primary and secondary schools through Leading Sheep communication channels. <u>LS5:</u> The vision of the LS5 investment is the same as for the LS4 investment: to create a proactive network of Queensland sheep and wool businesses; at the forefront of practical and relevant information and technology to equip progressive and thriving producers for the future. The specific objectives and targets of the current LS investment (LS5) are as follows: 1. The project advisory panel and regional coordinating committees to proactively identify local, industry and producer priorities and collaborative opportunities to deliver timely information and outcomes to Queensland sheep and wool producers. The priority areas are pest animal management, drought planning, ewe and lamb survival and business performance. The following targets have been set in order to ensure these objectives are achieved: a. An increase of 15% of engaged farm businesses (100) achieving lamb marking rates at least 10% above their long-term average. b. An increase of 15% of engaged farm businesses (100) using targeted management practices to improve flock productivity e.g. condition scoring, supplementation. c. An increase of 30% engaged farm businesses (210) understanding the importance of knowing their cost of production. d. An increase of 15% of engaged farm businesses (100) using financial tools (e.g. cost of production) to improve their business performance. e. An increase of 10% of engaged farm businesses (70) using a documented drought preparation plan which identifies key decision dates and actions. 2. Encourage Queensland sheep and wool producers to adopt beneficial technologies which will improve their sheep productivity and labour

	efficiency. The following target have been set in order to ensure this objective is achieved: 2.1 An increase of 10% of engaged farm businesses (70) have introduced and are using at least one of these technologies on their property.
Activities and Outputs	**LS1 (September 2004 to August 2007)** Operationally, LS1 had four main components: • Four regional networks of producers each with a committee tasked with identifying and prioritising needs and building ownership, capacity and leadership skills; • A comprehensive communication and branding strategy to raise awareness and provide a clear point of contact; • A program of monitoring and evaluation spanning the usefulness of individual activities to on-farm practice change; and • A project management and stakeholder project advisory panel to provide strategic assessment and direction. • At the request of industry, the QLD program initially had four regions (Central West, South West, Southern Inland and South East) that were primarily based on land types and their location. • Four RCCs were selected and operated by producers with some guidance from regional extension officers. The main priority of the regional committees was to identify the needs of the regional groups and how best to address those needs. • Regional activities were organised to deliver information to producers in the local area and a major publicity campaign using state and regional outlets was conducted across the four regions. • The five key outcomes that were identified by LS1 as pivotal to improving productivity in QLD were: 1. Reduced predation, 2. Higher reproduction rates, 3. More valuable wool and meat, 4. More effective parasite control, and 5. Improved resource management. • A database of the regional networks was maintained and made it possible to readily make contact with producers. This network also facilitated the information of information in both directions. • The communication and branding strategy involved establishing an identity for LS1 then producing a flow of written material and resources for use by media outlets to promote and define the project. • The identity included a LS logo, slogan "Leading the way for a more profitable Queensland sheep and wool industry through new technologies, knowledge and skills", banners and a website. • The written material included media releases either promoting or reporting the outcome of events held in the four regions, longer features including profiles, and the publication of e-books including a Drought Survival Stories series. All relevant written material is available at www.leadingsheep.com.au • A 'change management practice' survey was developed by members of LS1. The first phone survey was carried out across the state on 92 randomly selected producers from the LS database in 2006. • In 2007 the phone survey was repeated by the private firm "I-View" on 72 of the previously 92 surveyed. Data to measure achievement of project objectives came from the evaluation of activities via the survey.

	• Data collection used evaluation content and processes specific to the activity at hand and which fitted the evaluation framework of LS. Initially, data was used to assess immediate effects. Later evaluation sought data on longer term effects of activities on participants.
	• A customised web-based evaluation tool was introduced in August 2006 and delivered a practical means of gathering evaluation material for both electronically and personally delivered activities. Since that time there have been 23 sets of data collected.
	• Under the LS1 investment the following outputs were achieved:
	• Between August 2005 and 2007, the LS1 extension program operated in four regions and evaluation strategies were used to gather data on practice change (adoption) in both the short term (aspirational) and longer term.
	• LS1 RCCs developed and delivered activities in response to their individual region's needs.
	• Attendance at LS events increased over the duration of the LS1 investment.
	• Producer satisfaction with wool values also increased.
	• Satisfaction by producers with actions to improve parasite management, wool value and natural resource management increased.
	• 571 individuals attended one or more of the activities run by the RCCs since the inception of LS1.
	• Greater than 90% of attendees at LS1 RCC events reported increased understanding of activity topics and gaining of new knowledge and skills in activities.
	• 87% of participants reported planning to use new knowledge and skills after the activities.
	• During the three years of funding, LS1 delivered a total of 75 activities to 1,291 attendees, covering primarily the areas of predators, reproduction, wool marketing, parasite control and resource management. Of these activities almost two thirds were face to face while the rest were either tele-workshops or used e-technology.
	
	<u>LS2 (September 2007 to December 2010</u>
	• The second phase of LS (LS2) aimed to increase the profitability and viability of QLD wool producers through innovative approaches to extension and technology adoption.
	• LS2 continued support for a regionally specific program model based on four areas of QLD: South-East (Traprock), Southern Inland (Box/Sandalwood), South-West (Mulga) and, North/Central-West (Mitchell Grass).
	• Each of these regions had a dedicated coordinator, extension officer and a regional committee to identify and prioritise issues and then plan, conduct and evaluate events based on these issues.
	• LS2 continued with the same operating model as LS1 but placed more emphasis on:
	  o Maintaining the partnership between AWI, AgForce, DEEDI (DAF) and producers;
	  o Establishing partnerships with other projects such as Making More from Sheep;
	  o Continued development of the LS website and database;
	  o Continued marketing of the LS brand;
	  o Further quantifying practice change against current outcomes; and

- Embracing innovative approaches identified by industry to maximise the likelihood of change such as:
    - electronic delivery by webinar technology;
    - engaging youth in the industry;
    - understanding key profit drivers; and
    - enhancing interpersonal skills.

- Each regional committee met face to face at least once each 12 month period while holding a number of supportive teleconferences.
- All regional coordinators and extension officers, as a group, along with the project manager also participated in monthly web-meetings to discuss and review activities that had been conducted and determine plans for the future.
- The producer driven committees, working with their regional networks, identified the technology that was most relevant to their area. Co-ordinators and extension officers then organised activities delivered via the most appropriate delivery method.
- Co-operation between regions often allowed a series of activities to be delivered on the same topic including sharing presenters.
- A professional media consultant was engaged to manage the major publicity campaign, using regional media outlets across the four regions. Information was broadcast so that producers knew of new technologies and those appropriate to emerging conditions, and also knew of activities available to them to build their skill and confidence in their application.
- LS2 focused on six innovative approaches to increase the potential impact of the project:
    1. E-savvy producers: Building producers' interest and skills in using online tools to overcome some of the distance barriers of living in outback QLD.
    2. Engaging youth, to secure the future of the industry: Partnering with educational institutions to raise the profile of the sheep industry with tertiary students from various disciplines and raise awareness of career opportunities.
    3. Efficiencies through synergy with other initiatives: Integrating the two projects, LS and Making More from Sheep.
    4. Collaboration with the Sheep Cooperative Research Centre (CRC) and other industry providers: With a particular focus on climate forecasting, automatic stock handling, genetics to improve management practices, and breech strike management and lice.
    5. Developing a strong foundation: Building producers' skills in stress management, business management, negotiation and leadership to grow the resilience and capacity of the industry generally.
    6. Cooperative approach to predator control: In highlighting the issue as a major limiting factor to the QLD sheep industry, LS led the development of a partnership approach, between all major stakeholders, to managing Wild Dogs.
- The collection of reliable data to inform AWI, AgForce, the PAP and DEEDI in their design of LS3 was achieved through a comprehensive survey of producers from all four regions.
- Benchmark survey data for LS2 was collected in 2011 to assess producer perceptions and practice changes in relation to the objectives of LS1 and LS2.
- LS2 delivered 84 activities over three years to 1,954 sheep and wool producers. The LS2 database showed that 801 different people attended at least one event.

	• 83% of attendees gained new skills or knowledge and 69% reported an intention to change their management practices. • A follow up survey indicated that 42% of attendees had changed practices on their property as a result of attending LS2 activities. • The survey also found that producer involvement with LS (LS1 and LS2) had increased between 2006 and 2011, especially in the areas of predators (up 22%) and parasites (up 20%). • Case studies of changes made by QLD producers were developed to demonstrate the potential impacts of the LS program to date. • Eight case studies with 14 practice changes were completed. The case studies estimated the dollar value of the benefits of each practice change influenced by the LS program. • A review of LS structure was conducted with regional coordinators, regional coordinating committees, DEEDI extension officers, the project manager and the PAP. • The main recommendation from this review was that the target regions be changed from four to three, by combining the Southern Inland and South East regions and leaving North/Central West and South West as they were. **<u>LS3 (July 2011 to June 2014)</u>** • LS3 aimed to continue the overall LS program and to support decision-making about technologies and practices to increase the profitability and productivity of QLD sheep businesses. LS3 was focused on the following priority areas: 1. Predation (local and state level), 2. Animal nutrition, 3. Animal health, 4. Business optimisation, and 5. Marketing and selling wool and sheep meat. • LS3 changed the regional structure as per the recommendations of the LS2 review to three regions: North/Central West, South West and South. • As for LS2, each region had a committee of producers and industry representatives who worked with a regional coordinator and DAF extension officer to identify and prioritise local issues. • Each regional committee met face-to-face at least once during the LS3 funding period, while holding a number of webinars/teleconferences throughout the project. • The committees raised ideas for regional activities and provided local input into potential presenters, locations and dates. The regional coordinator and extension officers then organised, promoted, delivered and evaluated the activities. • LS3 utilised a number of communication channels (website, media releases, emails, monthly e-newsletter, radio interviews and Queensland Country Life sheep supplement) to help promote project activities and build the public profile of the project. • A strong focus in LS3 was to utilise the updated LS website more effectively, especially the events calendar, online event registration and using the website as a storage point for many of the extension resources developed by LS, particularly recorded webinars. • A regular sheep feature (three times per year) in the Queensland Country Life newspaper was initiated based on the success of the DAF beef features. The feature, known as ‘Flock talk’, aimed to increase awareness

	of LS and was used as an alternate method of getting information out to producers.
	• LS3 project participants also met with the other AWI funded network projects across Australia once a year to share tools, learnings and experiences.
	• A number of new initiatives commenced in LS3, including:
	  o The QLD Innovative Sheep Network (QISN) – a network of young people working together to create opportunities and change, ensuring the ongoing prosperity of the QLD sheep industries.
	  o Financial support for QLD producers to attend national conferences.
	  o Around the Camp – a monthly e-newsletter highlighting current topics and events.
	  o Promotion of technical information and producer case studies via Flock talk, the LS website and emails to members of the LS database.
	  o Development of an evaluation and reporting spreadsheet to automate and simplify data collection and reporting for the LS program.
	• Overall, LS3 delivered 97 events to 2,853 participants; 62 of these events were face-to-face (1,997 participants) and there were 35 webinars (856 participants).
	• The evaluation surveys revealed that intention to make a change was lower for webinar participants compared with face-to-face events (56% versus 84%).
	• LS3 reported 1,505 people on its database; 70% of these were producers representing 681 farm businesses (45% of Queensland sheep businesses).
	• The evaluation showed 1,547 different people had attended at least one LS3 event; 71% (1,097) of participants had attended only one event.
	• Follow up phone surveys indicated that 40% of attendees had changed practices on farm as a result of LS3 activities.
	
	LS4 (July 2015 to August 2018)
	• This fourth project of LS focused on pest animal management, health/nutrition, business performance, beneficial technologies and opportunities for young industry members.
	• The format of the LS program for LS4 was the same as for LS3. Three QLD regions, each with a regional committee (mainly producers and industry representatives) worked with a regional coordinator and a DAF extension officer to identify and prioritise local issues.
	• Each regional committee met face-to-face at least once, while also holding a number of webinars or teleconferences (2-3/year) throughout the project.
	• All regional coordinators, extension officers and the project manager participated in monthly webinars to review activities, discuss future plans and share ideas between regions.
	• LS personnel also met with the other AWI funded network projects across Australia once a year to share tools, learnings and experiences.
	• LS4 utilised a number of communication channels and products (website, emails, monthly e-newsletter, media releases, case studies, radio interviews, *Queensland Country Life* sheep supplement, Facebook and YouTube videos as well as other service providers' newsletters, email distribution lists and Facebook pages) to help promote project activities and build the public profile of the project.

	• The LS website was used to promote events (with online registration) and as a storage point for the extension resources developed by LS, particularly recorded webinars, case studies and YouTube videos. • 'FlockTalk' (in the Queensland Country Life and published three times per year) was used to increase awareness of LS and as an alternate and specifically hard copy method of getting information out to producers. • A specific LS Facebook page was initiated during LS4 to capture those people who regularly utilise social media. • In December 2016, a desktop review of the LS evaluation plan, processes and progress to date was conducted by Dr Gerry Roberts (GR Consulting) to identify any gaps. The reviewer concluded that, overall, LS was tracking well on its delivery targets and project objectives. • As at 22 May 2018, the Leading Sheep database contained 1,962 people (up from 1,505 in LS3). Almost 70% of these were producers from 908 farm businesses representing 75% of the 1,203 sheep and lamb businesses in QLD (ABS, 2016/17). • LS4 delivered 48 events to 2,012 participants; a total of 33 face-to-face events with 1,579 participants and 15 webinars with 433 participants were delivered. • 1,342 different people attended at least one LS event during the LS4 funding period. • 64% of attendees reported actually changing on-farm practices due to the influence or support of LS activities. When asked about the extent to which LS influenced their decision to change, on average, producers rated the extent at 5.2 out of 10 (about half). • Narratives and case studies were developed to show specific examples of the impact of the investment. • Nineteen narratives and nine case studies were collected across the range of LS priority areas, but particularly pest animal management, sheep health and nutrition and beneficial technologies. • The narratives were collected and written by the project team, while Cox Inall Communications drafted the case studies based on leads identified by the project team. • A phone survey conducted by Coutts J&R in September 2017 highlighted that the two most common impacts of LS events on participants were: 1. Providing them with new information and understanding (73%), and 2. Helping them to meet other sheep and wool producers (64%). • Further, involvement with LS also was seen by many producers to have positively impacted their confidence in management choices made, supported the implementation of new management practices and triggered changes in decisions and management practices. • A 'Sheep and Wool Challenge' offering $10,000 in prize money was instigated through LS4. The challenge was designed to showcase innovative solutions to industry issues and included both open and secondary school categories. • However, despite widespread promotion across a range of channels there were only 12 entries in the secondary school category (with 11 of these from Victoria). The winning entries all came from Melbourne's Hillcrest Christian College. • A pilot mentoring program was initiated in partnership with the Agricultural Business Development Institute (ABDI) targeting wool producers aged 18-45 years. However, due to a lack of applications from the intended target audience the program was opened to all QLD wool producers.

	• Eight producers from four businesses were successful in obtaining a subsidy to attend the program, with LS investing a total of $11,000 for the program, along with each business investing $3,290 plus their time and travel to participate. • Participants attended three face-to-face workshops as well as one-on-one mentoring opportunities and teleconferences. **<u>LS5 (August 2018 to July 2021 – current program)</u>** • At the time of the current evaluation, LS5 was still underway. LS5 continued the LS program with the same operational structure as LS3 and LS4. • Project reporting to date indicated that from 1 November 2018 to 1 October 2019 a total of 5 face-to-face events and 1 webinar have been conducted involving 224 participants. • Communications were very active during the same period with Facebook followers growing to 1,307 as a result of 216 social media posts. • Three Queensland Country Life 'Flock talk' editions were published with opinions from service providers and producers on topics such as scanning, stocking rates and technology. The frequency of distribution was increased from three to six editions per year to improve timeliness of content. • The Around the Camp e-newsletter was distributed 14 times to 1,727 subscribers, plus four informative editions and several advertisements for events. • Of all events during LS5 to date, 54% of attendees rated their likelihood of making a change as likely or very likely and a total of 140 farm businesses attended LS events during the reporting period.
Outcomes	• The LS5 investment was ongoing as of June 2020 and continues to deliver grower focused extension events and activities. The following sections describe the actual and expected outcomes and impacts of the LS investment through to the end of LS5 in 2020/21. • The LS investment from 2004 to 2021 has created a network of producers, industry representatives, regional coordinators, extension officers and other industry stakeholders. • The LS network has facilitated information sharing between individuals and regions and promoted the adoption of best practice management and new technologies to improve the productivity and/or profitability of QLD sheep enterprises. • LS also pioneered the use of webinars in the agricultural industry in QLD. LS started with teleworkshops and telemeetings in November 2005 and progressed to webinars in April 2007. LS continues to use webinars as a low cost means of bringing expertise to the QLD sheep and wool industry as well as complimenting face-to-face extension activities (N. Sallur, pers. comm., 2020). • Awareness of LS has increased throughout the program leading to greater utilisation of available information and resources, and increased attendance at LS events. Attendance at LS events increased from just over 400 attendees during LS1 to over 2,000 attendees across LS events in LS3 and LS4. The LS database also grew from 1,505 members by 2015 to over 1,900 members in 2018/19. • More specifically, the LS investment has increased producer skills and knowledge with respect to: <u>LS1:</u> o Predation control measures

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Higher reproduction rates
The impact of sire selection on product value
Integrated parasite management
Tools to maximise profit while maintaining the natural resource base

<u>LS2:</u>

Implementation of recognised environmental management systems including:

Integrated parasite management, and
Mulesing alternatives.

Seasonal forecasting
Automatic handling and drafting
Electronic sharing of data and information
Breeding, selection, and production management
Sustainable resource use
Responding to key profit drivers, managing pasture availability, feeding for production, and confinement feeding
Integrated pest management for wild dogs, pigs and foxes

<u>LS3:</u>

Planning and implementing action to reduce predation
Nutrition to improve lambing percentage, weaner performance and sheep survival during drought
Awareness of developments in animal health including genetic tools, alternatives to mulesing and new uses for old technologies
Business performance and optimisation
Marketing of wool and meat

<u>LS4:</u>

Pest animal management
Animal health and nutrition
Business performance
Beneficial technologies
Emerging industry issues

<u>LS5:</u> (activities ongoing)

Lamb marking rates
Management practices to improve productivity
The importance of cost of production
Financial tools to improve business performance
Documented drought plans
Beneficial technology to improve productivity and efficiency

Short- and long-term practice change evaluation surveys of LS participants indicated that, for each LS funding period, between 40% and 65% of attendees actually made management practice changes that were influenced by, or supported by, the LS program.
Further, intention to implement change and/or utilise new knowledge and skills was recorded at up to 90% of attendees of individual LS events.
The LS program also has increased the knowledge and capacity of QLD sheep producers to implement change and increased confidence in management choices made by producers because leading to increased profitability and/or productivity.

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Increased profitability and/or productivity for QLD sheep enterprises through the implementation of best practice management and/or adoption of new technologies and processes supported and promoted by the LS program.

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	• Potentially, some contribution to improved environmental outcomes through increased awareness of environmental management issues and producers making timely pasture management decisions. • Potentially, some contribution to the maintenance of QLD sheep producers' social licence to operate through improved on-farm management including management of animal health and welfare, control of pests and diseases (including more efficient/effective use of chemical products and control of pest animals such as wild dogs and rabbits). • Potentially, some contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD sheep industry.

4. Project Investment

Nominal Investment
Table D 2 shows the annual investment (cash and in-kind) for the project with funding provided by AWI and DAF[1].

Table D 2: Annual Investment in Leading Sheep for Years Ending June 2005 to June 2021 (nominal $)

Year (ended 30 June)	DAF ($)	AWI ($)	Total ($)
2005	93,500	297,600	391,100
2006	93,500	315,400	408,900
2007	93,500	342,000	435,500
2008	178,416	143,785	322,201
2009	84,916	150,000	234,916
2010	84,916	100,000	184,916
2011	84,916	100,000	184,916
2012	168,006	150,000	318,006
2013	168,006	150,000	318,006
2014	168,006	150,000	318,006
2015	0	0	0
2016	113,675	155,000	268,675
2017	113,675	155,000	268,675
2018	113,675	0	113,675
2019	277,968	358,000	635,968
2020	164,293	203,000	367,293
2021	164,293	203,000	367,293
Totals	**2,165,259**	**2,972,785**	**5,138,044**

Source: AWI-DAF project agreements and the Leading Sheep 1-5 Summary Report 2005-2019, compiled by Andrea McKenzie, Jed Sommerfield and Nicole Sallur, October 2019.

[1] DAF includes its predecessor organisations such as DEEDI.

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 2. The salary multiplier used by DAF was 2.85 (Wayne Hall, pers. comm., July 2017).

For the AWI investment, a management cost multiplier of x1.098 was applied to the AWI contributions shown in Table 2. This multiplier was estimated from the share of 'support and administration expenses' in total AWI operating revenue reported in the AWI Statement of Comprehensive Income (AWI, 2019).

Real Investment and Extension Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19-dollar terms using the Implicit GDP Deflator index (ABS, 2019). The investment was almost entirely focused on industry extension and communication and included a high degree of industry participation thus, no additional extension costs were included.

5. Impacts

An overview of potential impacts in a triple bottom line categorisation is shown in Table D 3.

Table D 3: Categories of Impacts from the Investment

Economic	Environmental	Social
Increased profitability and/or productivity for QLD sheep enterprises.	Improved environmental outcomes through increased awareness of environmental management issues and producers making timely pasture management decisions.	Increased regional community wellbeing through spillover benefits of a more productive and profitable QLD sheep industry. Maintenance of QLD sheep producers' social licence to operate.

Public versus Private Impacts
The primary impacts identified from the LS investment are mostly private in nature. Private impacts are likely to accrue to sheep producers (sheep meat and wool) in QLD in the form of increased profitability. Public impacts may include spillover benefits associated with the long-term productivity and profitability of QLD sheep enterprises and building stronger and more resilient communities.

Impacts Accruing to other Primary Industries
While the information and activities provided by the LS investment are specifically targeted at the QLD sheep and wool industry, the methodology and principles are relatable across most primary industries, particularly grazing industries. This is especially true for business and financial management, decision making, technology, pest management and grazing land management information that LS promotes (Jed Sommerfield, pers. comm., 2020).

Distribution of Benefits along the Supply Chain
Private benefits from the LS investments will accrue, in the first instance, directly to QLD sheep producers. However, over time, benefits to producers will be shared across the sheep meat and wool supply chains according to the relevant elasticities of supply and demand.

Impacts Overseas

There are unlikely to be any significant impacts to overseas interests. However, knowledge sharing through international industry and/or researcher networks does occur as evidenced through LS webinar registrations and attendees, e-newsletter subscribers, Facebook followers and Podcast listeners (Nicole Sullur, pers. comm., 2020).

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 D 4. The investment in LS is relevant to Rural RD&E Priority 4, with some potential contribution to Priority 3, and to Science and Research Priority 1, with some potential contribution to Priority 2.

Table D 4: 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 D 5.

Table D 5: 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 the QLD sheep industry and, through AWI and AgForce, 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.

One primary impact of the LS investment was valued in monetary terms:

- Increased profitability and/or productivity for QLD sheep enterprises through the implementation of best practice management and/or adoption of new technologies and processes supported and promoted by the LS program.

Impacts not Valued in Monetary Terms
Not all impacts identified in Table D 3 could be valued in the assessment. 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 primarily 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 impact(s) valued.

The following impacts were not valued in the current analysis:

- Potentially, some contribution to improved environmental outcomes through increased awareness of environmental management issues and producers making timely pasture management decisions.
- Potentially, some contribution to the maintenance of QLD sheep producers' social licence to operate through improved on-farm management including management of animal health and welfare, control of pests and diseases (including more efficient/effective use of chemical products and control of pest animals such as wild dogs and rabbits).
- Potentially, some contribution to increased regional community wellbeing through spillover benefits of a more productive and profitable QLD sheep industry.

Impact Valued: Increased profitability and/or productivity for QLD sheep producers
The overarching purpose of the LS investment was to develop a producer-driven network designed to assist QLD's sheep and wool producers to improve their productivity and profitability. The LS investment from 2004 to 2021 delivered a wide range of resources and activities across a variety of issues and priority areas for QLD sheep producers. Key industry issues were identified regionally and included such topics as predation, animal health and nutrition, animal welfare, business management (including cost of production and financial tools), reproduction, drought preparation, parasite control, and labour efficiency.

Due to the range of potential drivers of increased profitability/productivity addressed by the LS investment (for example, increased lamb marking rates, reduced cost of production, improved wool quality, etc.), the valuation of impact centred on net farm income. Table D 6 shows the annual net farm cash income for QLD sheep producers for the period 2004 to 2018 (2019/20 dollar terms).

Table D 6: Net Farm Cash Income for QLD Sheep Producers (2004 to 2018)

Year	Net Farm Cash Income[(a)] ($)
2004	-35,795
2005	66,732
2006	-9,943
2007	28,425
2008	50,779
2009	53,221
2010	86,990
2011	95,505
2012	80,843
2013	58,975
2014	49,175
2015	45,346
2016	37,828
2017	109,678
2018	78,213
5yr Average	64,048

Source: AgSurf Data http://apps.agriculture.gov.au/agsurf/agsurf.asp
(a) Farm cash income is the difference between total cash receipts and total cash costs.

It is worth noting that prevailing climate conditions are a key factor affecting the variability of annual farm income and are beyond the control of individual producers. For example, 2010 to 2012 were wet years and correlate to higher levels of farm income whereas 2014 to 2016 were dry years and correlate to lower cash income (Jed Sommerfield, pers. comm., 2020). However, it was assumed that the LS investment has contributed to an increase in average net farm income for participating producers (that is, without the LS investment average net farm income would have been lower). At the end of the LS4 investment, the LS program had a database that included some 1,962 people. Approximately 70% were sheep producers (908) representing about 75% of the estimated 1,200 sheep and lamb businesses in QLD. Specific assumptions for the valuation are described in Table D 7.

Attribution
Evaluation surveys conducted within the LS program indicated that, where producers undertook practice change, they attributed approximately 50% of their decision to LS activities.

Counterfactual
It was assumed that, in the absence of the LS investment (2004 to 2021), the benefits estimated would not have occurred.

Summary of Assumptions
A summary of assumptions and data sources is provided in Table D 7.

Table D 7: Summary of Assumptions

Variable	Assumption	Source
With investment		
Total net farm income for QLD sheep producers	For the period 2004 to 2018 - See Table D 6: Net Farm Cash Income for QLD Sheep Producers (2004 to 2018) From 2019 onward – $64,048 (5yr average)	AgSurf Data – note these data refer to producers of sheep only and are used as an estimate of average farm income for sheapmeat and wool producers in QLD
Total number of sheep and lamb enterprises in QLD	1,721 in 2006/07 (end of LS1) 1,819 in 2010/11 (end of LS2) 1,511 in 2013/14 (end of LS3) 1,213 in 2017/18 (end of LS4)	ABS series 7121.0 (Agricultural Commodities) 2017/18
Number of enterprises participating in LS events/ making use of LS resources and information etc.	Linear increase from zero in 2004 to 571 in 2007 (end LS1) Linear increase from 571 in 2007 to 908 in 2018 (end LS4) Linear increase from 908 in 2018 to 1000 in 2021 (LS 5 target).	Agtrans Research based on LS1 to LS4 final reports and the LS 2004 to 2019 summary report.
Proportion of LS sheep enterprises implementing practice changes on farm	50%	Conservative estimate based on LS program evaluation surveys indicating 40% to 65% of surveyed LS attendees implementing change
Attribution of practice change to LS program	50%	Based on LS evaluation surveys indicating that surveyed producers rated the influence of LS at 5.2/10
First year of impact	2005/06	Second year of LS1
Year of maximum impact	2020/21	Final year of LS5 investment
Without investment		
Total net farm income for QLD sheep producers	5% less than the 'with' scenario	See Table D 6 – based on the fact that the LS program has contributed to increased productivity and profitability for participating producers that implemented practice changes
Other factors		
Probability of output.	100%	Outputs have already been delivered.
Probability of outcome	100%	Already allowed for in proportion of LS sheep enterprises implementing practice changes on farm
Probability of impact	90%	Agtrans Research – allows for exogenous factors that may affect realisation of impacts and also that the benefits

		estimated may not persist into the future

7. Results

All past costs were expressed in 2018/19 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2019). 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 D 8 and Table D 9show 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 D 9, was estimated by multiplying the total PVB by the DAF proportion of real investment (38.7%).

Table D 8: Investment Criteria for Total RD&E Investment in Leading Sheep (2004 to 2021)

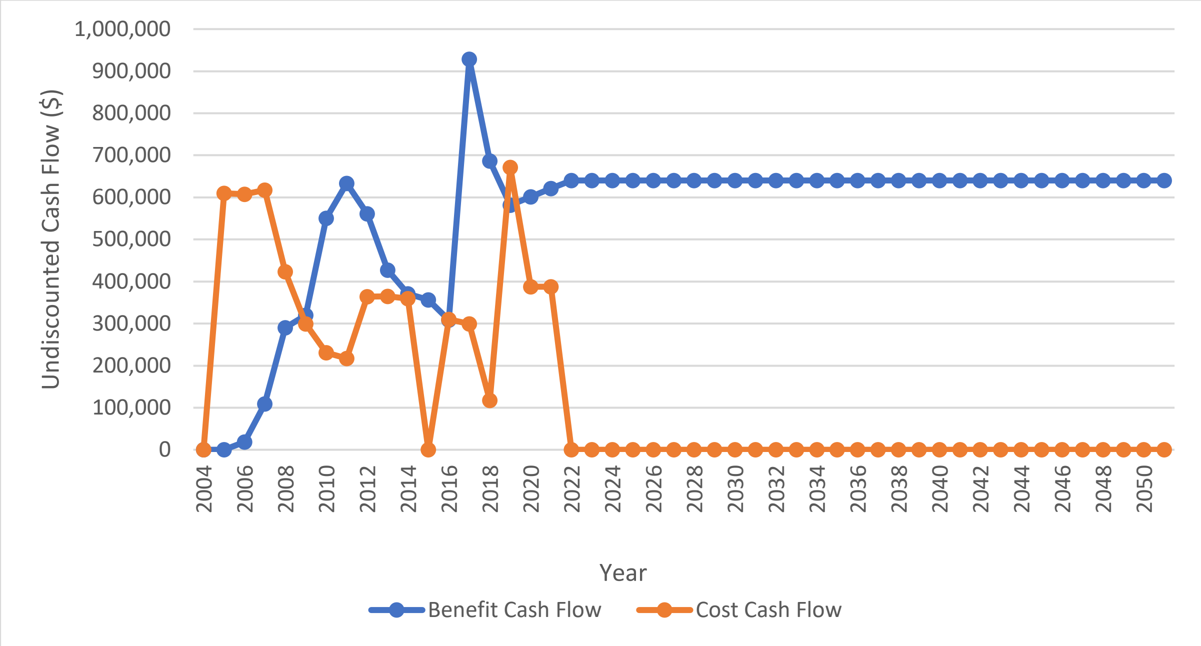
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	9.58	12.22	14.29	15.91	17.18	18.18	18.96
Present value of costs ($m)	9.47	9.47	9.47	9.47	9.47	9.47	9.47
Net present value ($m)	0.11	2.75	4.82	6.44	7.72	8.71	9.49
Benefit-cost ratio (BCR)	1.01	1.29	1.51	1.68	1.82	1.92	2.00
Internal rate of return (IRR) (%)	5.4	10.2	11.7	12.3	12.6	12.8	12.7
Modified IRR (%)	negative	9.8	9.3	8.3	7.4	6.7	6.1

Table D 9: Investment Criteria for DAF RD&E Investment in Leading Sheep (2004 to 2021)

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	3.71	4.73	5.53	6.16	6.65	7.04	7.34
Present value of costs ($m)	3.46	3.46	3.46	3.46	3.46	3.46	3.46
Net present value ($m)	0.25	1.27	2.07	2.70	3.19	3.58	3.88
Benefit-cost ratio	1.07	1.37	1.60	1.78	1.92	2.03	2.12
Internal rate of return (IRR) (%)	8.3	13.5	14.9	15.5	15.7	15.8	15.9
Modified IRR (%)	2.3	14.9	12.3	10.4	9.0	8.0	7.2

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 D 2.

Figure D 2: 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 D 10. The results show that the investment criteria had a moderate sensitivity to the discount rate.

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

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	26.58	18.96	18.27
Present value of costs ($m)	6.27	9.47	14.88
Net present value ($m)	20.31	9.49	3.39
Benefit-cost ratio	4.24	2.00	1.23

A sensitivity analysis was then completed on the assumed reduction in farm cash income that would have occurred for QLD sheep producers without LS program (Table D 11). Results show that the investment criteria were moderately sensitive to the assumed reduction in farm income without the LS program. This was expected as the assumed reduction was a key driver of the impact valuation. A break-even analysis indicated that the investment criteria would remain positive (BCR of 1) with a minimum reduction of approximately 2.5%. That is, for the producers that participated in the LS program and implemented practice change, if farm cash income was 2.5% lower without the LS investment the investment criteria would still have been positive.

Table D 11: Sensitivity to Reduction to Farm Cash Income without LS Program
(Total investment, 30 years)

Investment Criteria	**Reduction in Farm Cash Income WITHOUT LS Investment**		
	2%	**5% (base)**	**10%**
Present value of benefits ($m)	7.58	18.96	37.91
Present value of costs ($m)	9.47	9.47	9.47
Net present value ($m)	-1.88	9.49	28.45
Benefit-cost ratio	0.80	2.00	4.01

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 D 12). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made
Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table D 12: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium. While the principal economic benefit was quantified (increased profitability/ productivity for some QLD sheep producers), a number of social impacts were not valued.

Confidence in assumptions was rated as Medium-Low. Though key data and assumptions were drawn from credible sources (including ABS data and data from the LS program evaluation surveys), there were a number of potential drivers of the impact valued and thus the assumed magnitude of the impact was somewhat uncertain.

8. Conclusion

The investment in the Leading Sheep program (2004/05 to 2020/21) has delivered, and continues to deliver, a valuable, producer-driven network that facilitates the exchange of information and new knowledge and the adoption of best practice management and new technologies. Evidence of the value of the LS investment is demonstrated through the high participation rates within the QLD sheep industry (over 2,000 attendees at LS events in LS3 and LS4) and the number of producers implementing practice change influenced by the LS program.

The total investment in the LS Program (2004 to 2021) produced several impacts and the principal economic impact (increased productivity/profitability for QLD sheep producers) was valued. The total investment by all contributors of $9.47 million (present value terms) has been estimated to produce total gross benefits of $18.96 million (present value terms) providing a net present value of $9.49 million, a benefit-cost ratio of 2.0 to 1 (over 30 years using a 5% discount rate), an internal rate of return of 12.7% and a modified internal rate of return of 6.1%.

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Appendix E: An Impact Assessment of DAF Investment into Genetic Improvement in Tropical Beef Cattle (B.NBP.0759)

Acknowledgments

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Abbreviations

AGBU	Animal Genetics and Breeding Unit
AI	Artificial Insemination
CBA	Cost-Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
DAF	Department of Agriculture and Fisheries – Queensland
EBV	Estimated Breeding Value
GBLUP	Genomic Best Linear Unbiased Prediction
GDP	Gross Domestic Product
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
MLA	Meat and Livestock Australia
NT	Northern Territory
NSW	New South Wales
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
SNP	Single Nucleotide Polymorphism
SFF	Smart Futures Fund
UNE	University of New England
WA	Western Australia
VRRS	Victoria River Research Station

Executive Summary

The Report
This report presents the results of an impact assessment of a Queensland Department of Agriculture and Fisheries (DAF) investment in a project associated with genetic improvement of reproduction in tropical beef cattle. The project was jointly funded by DAF, Meat and Livestock Australia and the University of New England over the period 2014 to 2018.

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

Benefits were estimated for a range of time frames up to 30 years from the last year of investment in the project (2017/18). Past and future cash flows, expressed in 2018/19 dollar terms, were discounted to the year 2019/20 using a discount rate of 5% to estimate the investment criteria.

The cost-benefit analysis was conducted according to the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC, 2018).

Outputs and Outcomes
The investment in, and findings emanating from, the project have been important for the northern Australia cattle industry where improved genetics is one of the key avenues for productivity performance. The principal output from the investment has been a demonstration of the value of combining genotype information with phenotype information in the selection processes for bulls introduced into northern beef herds. The principal potential outcome from the investment has been the increased use of genotyping to increase the rate of genetic progress for improved reproductive performance of northern beef herds.

Impacts
The major impacts identified were of a financial/economic nature for beef cattle producers in the north of Australia. The important impact valued is the increased herd performance and profitability for some northern beef producers through the addition of new traits that can be considered in bull selection decisions.

Investment Criteria
Total funding from all sources for the project was approximately $5.72 million (present value terms). The value of total benefits from the Brahman component of the northern beef herd was estimated at $22.41 million (present value terms). This result generated an estimated net present value of $16.69 million, and a benefit-cost ratio of 3.92 to 1.

There were several other impacts identified that were not valued in economic terms. These included the contribution to any future impact on both Droughtmaster and Santa Gertrudis herds, Brahman herds currently not using bulls with Estimated Breeding Values (EBVs), the progress made in developing multi-breed EBVs, the regional community spillovers from the productivity and profitability components of the investment, and the strong platform developed for any follow on investment that might take place and where reference populations may be increased to provide even greater accuracy in EBVs. Hence, the investment criteria reported are likely to have undervalued the full set 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, Cooperative Research Centres (CRCs), State Departments of Agriculture, and some universities. This impact assessment uses Cost-Benefit Analysis 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, 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 likely low relative significance of the impact compared to those that were valued. The impacts valued therefore should represent the principal benefits delivered by the project.

2. Background & Rationale

The Size and Structure of the Northern Beef Industry
Some statistical data for the northern beef industry for the ten years ending June 2014 has been assembled as background information for the current analysis. In the three years ending June 2014 there were 8,450 northern beef cattle producing farms across Queensland (QLD), the Northern Territory (NT) and the northern part of Western Australia (WA). These farms are those that individually run more than 100 cattle and together make up close to 100% of the total northern beef cattle numbers of 12.56 million head (ABARES, 2015a). The average herd size over the three years was 1,486 head per farm, with farms with more than 1,600 head representing 73% of all cattle. Table E 1 provides northern beef herd numbers by year for adult females as well as for total beef animals including calves. More recent estimates of adult females were not available at the time of this assessment.

Table E 1: Adult Female and Total Cattle Numbers for Northern Beef Herd

Year	A. Adult females	B. Total cattle and calves	C. Estimate of weaning rate	Approximate total adult animals = B - (A x C)
2005	7,268,360	13,772,630	60%	9,411,614
2006	7,300,670	13,902,750	60%	9,522,348
2007	7,177,520	14,140,590	60%	9,834,078
2008	7,707,610	14,436,290	60%	9,811,724
2009	7,344,330	14,564,600	60%	10,158,002
2010	7,609,620	13,986,980	60%	9,421,208
2011	7,539,460	15,291,820	60%	10,768,144
2012	7,758,760	14,830,810	60%	10,175,554
2013	7,841,650	15,449,390	60%	10,744,400
2014	7,925,730	15,570,090	60%	10,814,652
Average	7,547,371	14,594,595	60%	10,066,172

Source: A and B: ABARES (2015b); Includes total QLD and NT numbers; WA north based on Pilbara and Kimberley where 33% of WA beef cattle are assumed located (ABS).
Source C: Agtrans Research

As no updated herd structure and size has been sighted, the herd size is assumed not to have change significantly in structure and size since 2014, except for the early 2019 flood in north QLD where a number of cattle were lost.

Current bull and cow selection processes

BREEDPLAN is the foremost aid used in improving selection of beef animals to enhance herd performance throughout Australia. It is a beef cattle performance recording and evaluation system that uses analytical software to produce Expected Breeding Values (EBVs) for young animals based on their parentage, performance records, and other information. The software is highly sophisticated and can accommodate up to 26 animal traits. BREEDPLAN has been developed and supported by scientists at the Animal Genetics and Breeding Unit (AGBU) located at the University of New England (UNE). AGBU is a joint venture between the New South Wales (NSW) Department of Primary Industries and UNE. Also, Meat and Livestock Australia (MLA) is involved by providing funding support to AGBU.

BREEDPLAN operates predominantly via a range of Australian breed societies, as well as other breed associations based in various countries around the world. There are currently up to 35 breed societies or associations using the BREEDPLAN technology in Australia.

Assessment of individual bull progeny is direct as the performance of their progeny can be recorded via the weight gains of their male progeny and culled female progeny that are not retained for breeding. Assessment of progeny from cows can be more difficult as data on their breeding performance can take a longer time to assemble.

Rationale for the project

The overall aim of the investment in project B.NBP.0759 was to increase performance and productivity of the northern Australia beef herd by increasing reproductive rates, a well-known limitation to the productivity of the northern beef herd due to management factors as well as the harsh physical environment. Improving genetic selection via examining differences in female fertility was seen as an opportunity to increase productivity.

This investment was to improve the evaluation of beef animals within the northern beef industry with an emphasis on female fertility characteristics. This was to be achieved by combining phenotype recording with information based on high density single nucleotide polymorphism (SNP) genotyping of well managed cattle on QLD and NT research stations.

Additional information was assembled from artificial breeding programs using Brahman, Santa Gertrudis and Droughtmaster sires. The project also benefited from partnerships with breed societies (including the Australian Brahman Breeders Association, the Droughtmaster Stud Breeders' Society and a consortium of Santa Gertrudis Research Herds). These partnerships allowed steer progeny from the project to be supplied to these industry groups for evaluation of important traits such as growth rate, and carcass and meat quality traits, enabled by financial support from the MLA Donor Company. Such information was then used in the project data analysis.

The project outcome was aimed at an increased accuracy of EBVs for female reproduction and other performance traits for young bulls. This was to allow better bull purchase decisions by seedstock producers and commercial cattle producers in northern Australia.

3. Investment Details

Summary of Project Investment
The investment in the project was made in the years ending June 2014 to June 2019. UNE, via AGBU, was the lead research agency and MLA the lead funding organisation. DAF was also involved in the project via a subcontract with UNE, as was the NT Department of Primary Industry and Fisheries. The project code, title, key personnel, and funding period are summarised in Table E 2.

Table E 2: Summary Details for the Investment

Project Code	Title	Key Personnel	Funding Period
B.NBP.0759	Accelerated genetic improvement of reproduction	Dr David Johnston, Principal Scientist, AGBU Tim Grant, Repronomics Operations Manager, DAF Dr Yuandan Zhang, Scientist, AGBU	June 2014 to June 2019

Logical Framework
Table E 3 provides a description of the project in a logical framework format.

Table E 3: Logical Framework for Project B.NBP.0759: Accelerated Genetic Improvement of Reproduction

Objectives	1. To genotype industry sires with high accuracy BREEDPLAN days to calving estimated breeding values EBVs. 2. To deliver high accuracy phenotyping for female reproduction traits. 3. To validate and enhance genomic selection for female reproduction in tropical breeds.
Activities and Outputs	**Objective 1: Genotyping industry sires** • Identification of high accuracy days to calving EBV sires from the BREEDPLAN database and sourcing of DNA samples was completed. • The sires were genotyped with 50K SNP chips. • For Brahman and Santa Gertrudis, the selection was based on EBVs where possible. • The sires of the heifers recorded for reproduction phenotypes were genotyped as part of the Smart Futures Fund (SFF) Project (Transformational Genomics and Beef Breeding Strategies project). • Approximately 20-50 sires per herd were genotyped for each of three breeds (Brahman, Santa Gertrudis, and Droughtmaster). **Objective 2: Delivery of high accuracy phenotyping for female reproductive traits.** • Existing young females (located at Victoria River Research Station (VRRS), also known as Kidman Springs), in the NT and QLD research stations of Brian Pastures near Gayndah and Spyglass near Townsville, were phenotyped using ovarian scanners to determine heifer age at puberty. • The assessment of females at Brian Pastures and Spyglass was carried out on 387 Brahmans, 357 Droughtmasters and 100 Santa Gertrudis.

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- Initial scanning occurred at Brian Pastures on 5 occasions and at Spyglass on 3 occasions. Carcass scanning for fat depth was also undertaken in conjunction with the ovarian scanning.
- All heifers and first calvers were naturally mated in large multi-sire contemporary groups.
- Data on calving (birth date), calf fate and udder score of dams were collected as were DNA samples for parentage verification and future genotyping.
- The majority of heritability of heifer age at puberty was captured by undertaking 3-4 ovarian scans per annum.
- Also, two rounds of artificial insemination (AI) were conducted at both research stations.
- Weaning data for calves were recorded including weaning weights, horn status, flight times, and coat score; the 2014 drop weaners included 195 Brahmans, 77 Droughtmaster and 68 Santa Gertrudis.

Objective 3: Validation and enhancement of genomic selection for female reproduction

- Existing females were used to validate the Beef CRC genomic prediction equations.
- Re-estimation of the Beef CRC genomic prediction equations was carried out from the above comparisons; this required a genome-wide association analysis (Genomic Best Linear Unbiased Prediction or GBLUP).
- The new equations were blended into BREEDPLAN EBVs for Brahmans and potentially for other breeds, depending on resultant accuracies.
- Young bulls in SFF herds, retained as replacement sires or available for sale after 12 months, were genotyped with 10K chips and submitted to BREEDPLAN to generate technically enhanced EBVs.
- The genomically enhanced EBVs and improved accuracies on large numbers of young bulls were used to demonstrate value of the use of phenotyping and genotyping.

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<tr><td>Outcomes</td><td>

- Close industry involvement during the project provided additional incentive for industry to further adopt such new tools to improve productivity.
- An Increased use of genotyping has occurred in northern beef herds, in conjunction with phenotyping, in order to improve EBVs and subsequent bull selection processes.
- The extent of genotyping in the Brahman herd has doubled in the three years since single-step was introduced and it is anecdotally noted and assumed this will continue to occur (Tim Grant, pers. comm., 2020).
- There is potential for the entire Brahman herd to benefit from genomic analysis to a certain degree within the next ten years. As breeds begin to require DNA parentage verification for sale animals, it will be entirely possible that all sale animals will have a suite of genomics based EBVs (Tim Grant, pers. comm., 2020).
- Genotyping has been, and continues to be, undertaken in the Santa Gertrudis and Droughmaster breeds. It is envisaged that the Santa Gertrudis breed will begin single-step genomic evaluations in the first half of 2020 and the Droughtmasters by the first half of 2021 (Tim Grant, pers. comm., 2020).
- The project has also initiated the development of multi-breed EBVs for northern Australia that will assist evaluation across breeds and also in crossbreeds; this ongoing development will facilitate wider selection opportunities in the future for northern beef herds.

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Impacts	• Increased productivity and profitability from changes in practices of some northern beef herd managers; this is likely to occur, particularly, in the short term, for those with Brahman breeding herds.

4. Project Investment

Nominal Investment

Table E 4 shows the annual investment in the project (cash and in-kind) by funding organisation and by year. The three funding organisations were MLA, UNE/AGBU and DAF. The MLA Donor Company contribution to the industry groups referred to earlier is not included here and is addressed later through the attribution factor.

Table E 4: Annual Investment by Funding Organisation and Year ended June (nominal $)

Year	2014	2015	2016	2017	2018	Total
MLA	295,195	300,809	270,586	276,358	279,810	1,422,758
UNE/AGBU	166,840	190,183	200,772	209,223	217,989	985,007
DAF	325,599	352,674	367,082	379,441	392,209	1,817,004
TOTAL ($)	787,634	843,666	838,440	865,022	890,008	4,224,769

Program Management Costs

For the DAF and UNE/AGBU investment, any management and administration costs for the project are assumed already built into the nominal $ amounts appearing in Table E 4.

For MLA investment, a management cost multiplier (1.126) was applied to the MLA contributions shown in Table E 4. This multiplier was based on information in the MLA Annual Report (2018/19).

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19 dollar terms using the Implicit Gross Domestic Product Deflator index (ABS, 2019). No additional costs of extension were included as the project already involved a high level of industry participation.

5. Impacts

Impact on Productivity and Profitability

The principal output from the investment has been a demonstration of the value of combining genotype information, in conjunction with phenotype information, in selection processes for bulls introduced into northern beef herds. The principal potential outcome from the investment is the increased use of genotyping to increase the rate of genetic progress for improved reproductive performance of northern beef herds.

Environmental Impact

Nil

Social Impact

Any increase in productivity and profitability that benefits northern beef producers will be shared along the supply chain with transport operators, processors and exporters. Further, positive impacts will be experienced by regional communities connected with producers and their supply chains.

Summary of Impacts
An overview of impacts in a triple bottom line categorisation is shown in Table E 5.

Table E 5: Categories of Impacts from the Investment

Economic	Environmental	Social
Increased productivity and profitability of northern beef herds, particularly those producers with Brahman breeds. Associated profits will be shared along the supply chains with transporters, processors, exporters etc. Contributions to potential future selection impacts for Droughtmaster and Santa Gertrudis breeds, as well as the improved selection decisions that may be delivered by the development of multi-breed EBVs.	Nil	Spillovers from increased pastoral property farm incomes and supply chain businesses to regional communities in northern Australia

Distribution of Benefits along the Beef Supply Chain
Some of the potential benefits from more profitable production of northern beef will be shared by producers along the beef supply chain with processors, exporters and consumers also gaining a share of the benefits.

Public versus Private Impacts
The impacts identified from the investment are predominantly private, accruing to northern Australia cattle producers, particularly those with Brahman herds. Such private impacts will likely be shared along their beef supply chains. Some public benefits will be produced including spillovers to regional communities from enhanced beef producer and supply chain incomes.

Impacts Accruing to other Primary Industries
There may be implications from the investment for carrying out similar collaborative projects and delivery of impacts from similar research and approaches for beef cattle in southern Australia.

Impacts Overseas
Beef producers in overseas countries are unlikely to benefit in the short term.

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 E 6. The investment is relevant to Rural RD&E Priorities 1 and 4 and to Science and Research Priority 1.

Table E 6: 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 E 7.

The investment addressed QLD Science and Research Priority 1. In terms of the guides to investment, the investment is likely to have a real future impact through improved confidence in the profitability of northern beef production. The project was well supported and funded by others external to the QLD Government and had a distinctive angle as the QLD beef industry will be a major recipient of the impacts.

Table E 7: 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 in Monetary Terms
The impact valued in the quantitative analysis is:

- Increased herd performance and profitability through the addition of new traits that can be considered in bull selection decisions.

The benefits that may accrue to individual producers will vary depending on the traits selected and their interaction with the interests of the specific production system being targeted. For example, some producers may see specific genetic improvements as assisting them with meeting specific production system priorities (e.g. daughters with higher calving ease) or time to target market weights (for examples, see BREEDPLAN Bull Selection Exercises, http://breedplan.une.edu.au/tips/Bull%20Selection%20Exercises.pdf).

For valuation purposes for the current investment, it is difficult to aggregate across all of the different interests in terms of their relevant frequencies and size of end-point gains. The alternative adopted here is to assume a generalised value of the new information for a proportion of producers across the northern herd (particularly Brahmans) who wish to consider the new trait information, as detailed in the following assumptions presented in the summary of assumptions in Table E 8.

Table E 8: Summary of Assumptions for Valuing Benefits

Variable	**Assumption**	**Source**
Counterfactual: Without Project Investment		
Average number of breeding cows in northern beef herds (2005-2014)	7.5 million	ABARES (2015) and assumed to be still relevant to the northern herd.
Proportion of commercial northern beef producers who currently purchase Brahman bulls with EBVs	50%	Agtrans Research after input from Tim Grant based on: -the number of Brahman bulls with EBVs being sold through saleyards, and -larger companies purchasing bulls via private sales now demand EBVs.
Estimated number of Brahman breeding cows currently serviced by bulls with EBVs	3,750,000	7.5 million x 50%
Additional gross margin for northern commercial beef producers who purchase bulls with EBVs	$2.0 per breeding cow	Estimate based on MLA (2015) and Banks (2016)
With Project Investment – Adoption		
Adoption: Proportion of commercial northern Brahman beef producers using EBVs (the 50%) and who indirectly	Commencing 2019 and increasing linearly to a conservative maximum	Agtrans Research, based on input provided by Tim Grant

increase their use of genotyping via seedstock producers to increase the rate of genetic progress that translates into improved reproductive performance of their beef herds	of 80% (of the 50%) by 2028	
With Project Investment – Impact		
The percentage increase in the additional gross margin ($2 per cow) without genotype information, due to improved selection decisions by seedstock producers and commercial producers from the lift in accuracies of EBVs that have been delivered by project B.NBP.0759	60%	Agtrans Research, based on input provided by Tim Grant
Additional gross margin due to improved EBV information from project B.NBP.0759	60% of $2 per cow =$1.20 per cow	Agtrans Research
Lag period between adoption and impact	5 years	Agtrans Research
Risk Factors		
Probability of outcome occurring (increased use of genotyping)	80%	Agtrans Research
Probability of impact occurring given increased use of genotyping)	90%	Agtrans Research
Attribution		
Attribution to Project B.NBP.0759	90%	Agtrans Research in recognition of the contribution from MLA Donor Company

Impacts not Valued in Monetary Terms

No impact has been valued for any contribution to changes in practices for Droughtmaster and Santa Gertrudis herd managers who purchase bulls with EBVs. Likewise, no impacts have been valued for Brahman herds where bulls with EBVs are not purchased currently. These impacts were not valued due to not being able to make credible assumptions about when they may be delivered, and the relevant contribution made by Project B.NBP.0759.

Another impact identified but not valued included the increased spillovers to regional communities from sustained or increased northern beef farm incomes and additional processing, servicing infrastructure and employment. 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 regions and the availability of time and resources for valuation.

Attribution
The attribution of the impacts to project B.NBP.0759 is assumed to be 90% to allow for the unspecified contribution of financial support to industry groups from the MLA Donor Company, and any additional costs incurred by the SFF project. However, it needs to be recognised that the 10% attributed to the MLA Donor Company may be generous. While the contribution allowed steer progeny from the project to be purchased and evaluated for various traits (e.g. growth rate, and carcass and meat quality traits), the contribution generated value in another project, demonstrating the value of integration and collaboration between projects.

Counterfactual
It is not likely that such investment requiring cooperation across a range of parties and interests would have been attempted in the absence of this project. Hence the impacts

7. Results

All costs and benefits were discounted to 2019/20 (the year of evaluation) 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 (2017/18) to the final year of benefits assumed.

Investment Criteria
Table E 9 and Table E 10 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 E 10, has been estimated by multiplying the total PVB by the DAF proportion of real investment (41.2%).

Table E 9: Investment Criteria for Total Investment in the Project

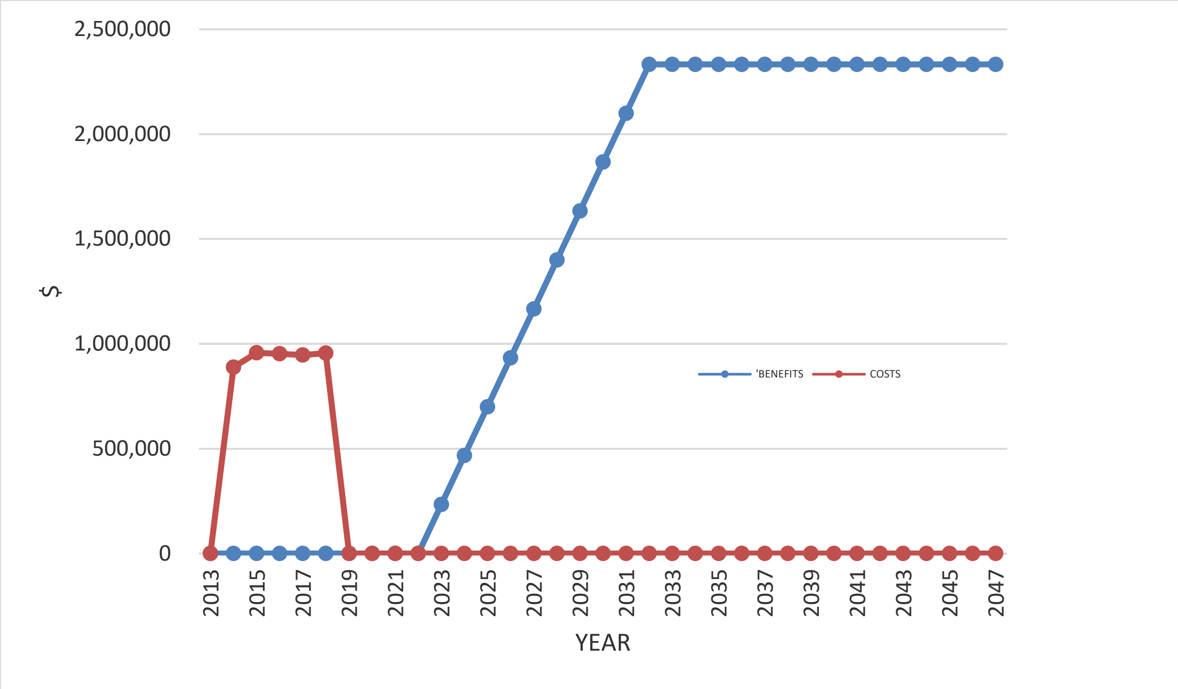
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.20	3.61	9.57	14.92	19.12	22.41
Present value of costs ($m)	5.72	5.72	5.72	5.72	5.72	5.72	5.72
Net present value ($m)	-5.72	-5.52	-2.11	3.85	9.21	13.40	16.69
Benefit-cost ratio	0.00	0.04	0.63	1.67	2.61	3.34	3.92
Internal rate of return (IRR) (%)	negative	negative	0.4	9.2	11.8	12.8	13.2
Modified IRR (%)	negative	negative	1.1	8.2	9.7	9.8	9.6

Table E 10: Investment Criteria for DAF Investment in the Project

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.08	1.49	3.95	6.16	7.89	9.24
Present value of costs ($m)	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Net present value ($m)	-2.35	-2.27	-0.87	1.59	3.80	5.53	6.89
Benefit-cost ratio	0.00	0.04	0.63	1.68	2.61	3.35	3.93
Internal rate of return (IRR) (%)	negative	negative	0.4	9.2	11.8	12.8	13.3
Modified IRR (%)	negative	negative	negative	9.3	10.8	10.7	10.3

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 E 1.

Figure E 1: 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. Table E 11 presents the results that show a high sensitivity to the discount rate. The high sensitivity is due to the assumption regarding the time period between the investment and the maximum benefit to the industry.

Table E 11: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	50.16	22.41	11.41
Present value of costs ($m)	4.70	5.72	6.93
Net present value ($m)	45.46	16.69	4.49
Benefit-cost ratio	10.67	3.92	1.65

A sensitivity analysis also was carried out on the increase in gross margin per cow with the use of genotype and phenotype information available for bull selection. The base assumption was a 60% increase in the $2 per cow gross margin when only the phenotype information was available. Results show a moderate sensitivity across the range of percentage increases tested.

Table E 12: Sensitivity to Percentage Increase in Annual Gross Margin per Cow with the Addition of Genotype Information (Total investment, 30 years)

Investment Criteria	**increase in Gross Margin per Cow Over Only Phenotype Information Being Available**		
	40%	**60% Base**	**80%**
Present value of benefits ($m)	14.94	22.41	29.88
Present value of costs ($m)	5.72	5.72	5.72
Net present value ($m)	9.22	16.69	24.16
Benefit-cost ratio	2.61	3.92	5.22

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 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 E 13). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table E 13: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium. The principal benefit was economic in nature and related to productivity changes by better delivering against specific production system priorities (e.g. daughters with higher calving ease) or time to specific target market weights. The other potential impacts identified but not valued included the possibility of the impacts occurring for the other two breeds and for Brahman herds where EBVs are not currently used, as well as the regional community benefit spinoff from the increased producer productivity and profitability.

Confidence in assumptions was rated as Medium-Low as the assumptions associated with some of the benefits such as adoption levels and the resulting value of the impact were uncertain.

8. Conclusion

The investment in the project “Investment into Genetic Improvement in Tropical Beef Cattle (2014 to 2019)” provided a significant step forward in progressing the value of BREEDPLAN.

The potential impact of the investment is likely to be an Increased use of genotyping in Australian northern beef herds, in conjunction with phenotyping, in improving EBVs and subsequent bull selection processes.

The benefits identified as likely to be delivered by the project will accrue to a proportion of northern beef producers. Some of these benefits are likely to be shared along the product supply chain due to increased economic activity in transporting, feedlotting, processing and live exporting. Some public benefits will be delivered via community spillovers from increased producer incomes.

The total investment in the project of $5.72 million (present value terms) has been estimated to produce total gross benefits of $22.41 million (present value terms) providing a net present value of $16.69 million, a benefit-cost ratio of 3.92 to 1 (using a 5% discount rate) and an internal rate of return of 13.2%.

There were several potential impacts identified that were not valued in economic terms. These included the contribution to any future impact on both Droughtmaster and Santa Gertrudis herds, as well as Brahman herds currently not using bulls with EBVs, but who may be expected to do so in the future. Likewise, any contribution of the project to future development of multi-breed EBVs has not been valued, nor the value of building a platform of reference populations that may be enhanced and used for even greater impact in the future. As well, the regional community spillovers from the productivity and profitability impacts of the investment were not valued. The investment criteria reported therefore are likely to have undervalued the likely full set of benefits delivered by the investment.

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Appendix F: An Impact Assessment of DAF Investment in MPCN II Regional Soil Testing Guidelines for the Northern Grains Region (UQ00063)

Acknowledgments

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Abbreviations

ANOVA	Analysis of Variance
CBA	Cost Benefit Analysis
CRRDC	Council of Rural Research and Development Corporations
Cu	Copper
DAF	Department of Agriculture and Fisheries (Queensland)
GDP	Gross Domestic Product
GRDC	Grains Research and Development Corporation
Ha	Hectare
IRR	Internal Rate of Return
K	Potassium
Kg	Kilogram
MAP	Monoammonium Phosphate
MIRR	Modified Internal Rate of Return
Mo	Molybdenum
N	Nitrogen
NSW	New South Wales
P	Phosphorus
PVB	Present Value of Benefits
QLD	Queensland
RD&E	Research, Development and Extension
S	Sulphur
T	Tonne
TSP	Triple Superphosphate
UQ	University of Queensland
Zn	Zinc

Executive Summary

A significant proportion of crop nutrient requirements in the northern grains region now are supplied by fertilisers and continued nutrient removal in grain cropping is expected to increase the incidence of deficiencies of key nutrients such as phosphorus, sulphur and zinc. Such nutrient depletion has resulted in increasingly complex nutrient management decisions for growers. Soil test information was highlighted as one of the key factors needed to identify nutrient constraints to crop productivity and subsequently to devise appropriate fertiliser programs. Project UQ00063 was funded to fill knowledge gaps about plant responses to supply of nutrients for the northern grains region in partnership with similar projects for the western and southern regions.

The evaluation approach followed general evaluation guidelines that now are well entrenched within the Australian primary industry research sector. The approach included both qualitative and quantitative descriptions that are in accord with the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (2018).

The investment in UQ00063 has delivered information and tools that producers in the northern grains region have used to improve fertiliser practices to improve crop yields. Further, the investment has provided growers with increased confidence to undertake deep phosphorus placement based on soil testing to improve soil quality, replenish long-term soil nutrient reserves and increase medium to long term crop performance.

The total investment in UQ00063 produced several impacts and the principal economic impact (increased productivity/ profitability for some northern grain producers) was valued. The total investment of $2.65 million (present value terms) has been estimated to produce total gross benefits of $32.68 million (median case, present value terms) (worst case PVB of $2.58 million, best case PVB of $64.5 million). The estimated benefits provided a median net present value (NPV) of $30.03 million (worst case NPV of -$0.07 million and best case NPV of $61.85 million), a median BCR of 12.3 to 1 using a 5% discount rate over 30 years (worst case BCR of approximately 1.0 and best case of 24.3), a median IRR of 42.5% (worst case 4.8% and best case of 65.3%) and a median MIRR of 14.5% (worst case of 2.4% and best case of 17.7%).

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

Background

The various chemical, physical, and biological properties of a soil interact in complex ways that determine its potential fitness or capacity to produce healthy and nutritious food. The integration of such properties and the resulting level of productivity often is referred to as 'soil quality' (Parr, Hornick, & Simpson, 1994). Soil texture, organic matter concentration and pH affect the concentration of available soil nutrients. In most soils these properties change with depth and subsoils are generally different to those of the topsoil. There can be a steep decline in nutrient concentrations and availability down the soil profile, especially for less mobile nutrients such as phosphorus (P) and zinc (Zn) (Agriculture Victoria, 2009).

The northern grains region in Australia occupies approximately 4 million ha across northern New South Wales (NSW), and southern and central Queensland (QLD). The cropping system is dominated by winter and summer cereals (wheat, sorghum and barley) with a relatively low frequency of grain legumes (chickpeas, and some mungbeans).The clay soils of the northern grains region (see Figure F 1 below) have historically been viewed as highly fertile soils with significant intrinsic nutrient reserves. However, continuous negative nutrient budgets[2] and declining soil organic matter have eroded those reserves such that successful crop production is increasingly reliant on fertilisers (Bell, Lester, Smith, & Want, 2012). Common nutrient deficiencies in the northern region´s broadacre grain areas are nitrogen (N), P, potassium (K) and Zn, while sulphur (S), copper (Cu) and molybdenum (Mo) may be also be lacking in some soil types and growing areas (Grains Research and Development Corporation (GRDC), 2016).

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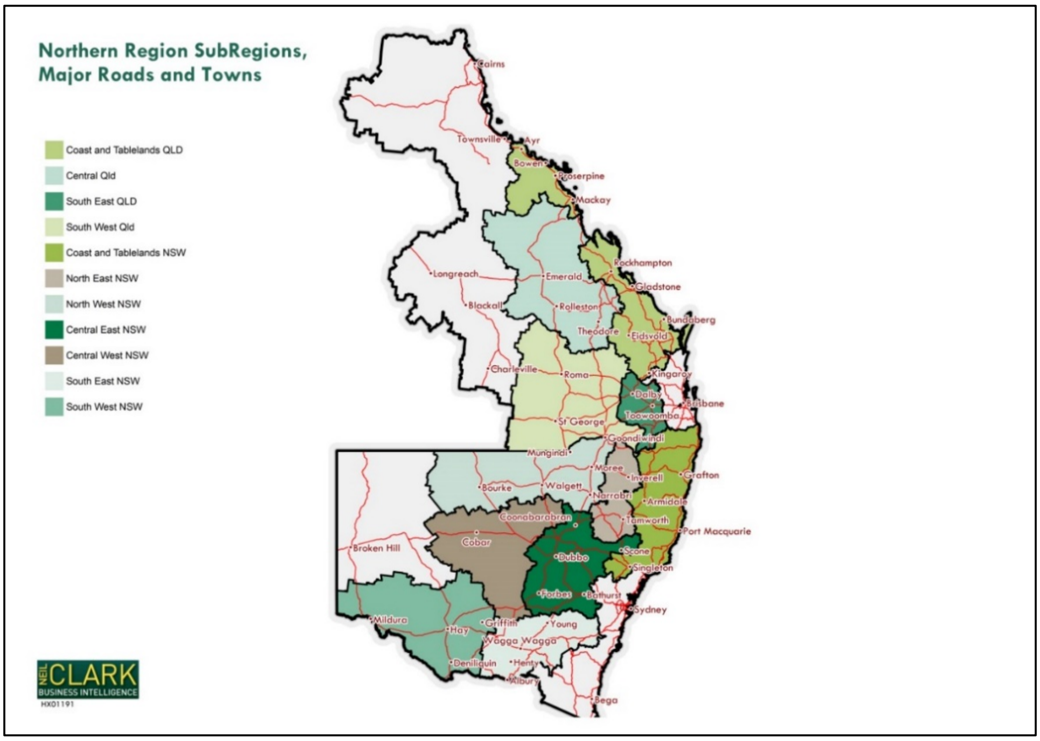
[2] Nutrient balances provide information about environmental pressures. A nutrient deficit (negative nutrient budget) indicates declining soil fertility (OECD, 2020).

Figure F 1: Northern Grains Cropping Region



Source: GRDC Growing Regions - https://grdc.com.au/__data/assets/image/0029/376463/Northern-Region-draft-1.jpg

Rationale for the investment

A significant proportion of crop N requirements in the northern grains region now are supplied by fertilisers. There also is widespread use of starter P and Zn fertiliser, while continued nutrient removal in grain is expected to increase incidence of deficiencies of other nutrients like K and S. Such nutrient depletion has resulted in increasingly complex nutrient management decisions for growers.

Soil test information was highlighted as one of the key factors needed to identify nutrient constraints to crop productivity and subsequently to devise appropriate fertiliser programs. The national database “Making Better Fertiliser Decisions for Crops” identified gaps in the knowledge about the relationships between soil tests and yield. Project UQ00063 was funded to fill knowledge gaps about plant responses to supply of nutrients for the northern grains region in partnership with similar projects for the western and southern regions.

3. Project Details

The project is described in a logical framework in Table F 1.

Table F 1: Project Logical Framework

<table>
<tr><td>Project Details</td><td>Organisation: Department of Agriculture and Fisheries QLD (DAF) – subcontracted by the University of QLD
Period: July 2012 to September 2020.
Project Leader(s): Mike Bell</td></tr>
<tr><td>Objectives</td><td>1. Conduct a minimum of two (2) fertiliser field trials in each of the regional centres of Central Qld, Western Downs/Maranoa and Darling Downs annually.
2. Conduct biomass sampling and grain yield assessments in a timely manner, and submit soil and plant samples for analysis.
3. Compile plant, soil and crop production data suitable for annual reporting, which is conducted early in the calendar year.
4. Participate in communication initiatives with industry (GRDC updates, grower workshops) as required.
5. Initiate or participate in the development of technical manuscripts to document scientific advances as appropriate.</td></tr>
<tr><td>Activities and Outputs</td><td>• Field research as part of UQ00063 commenced in the winter of 2012.
• Establishment of the field sites was staggered across the northern grains region from mid-2012.
• Sites for annual field trials were selected and were a mixed of carry-over sites from Project DAQ00148 and new sites. As of 2019, there were 30 P trial sites.
• Nutrient deficiencies at each site were characterised prior to the 2012/13 season and, at each site, efforts were made to initially address other potential nutrient limitations, identified by soil testing, by applying a basal application of N, K, S and/or Zn as appropriate.
• The trials consisted of rates of P fertiliser (0 to 60 or 80 kg P/ha) applied in deep bands (at ~20cm depth), typically at band spacings of 50cm, along with an untilled Farmer Reference treatment.
• All main plots were then split to annual ‘with’ or ‘without’ starter P fertiliser applications at planting at rates ranging from 6 to 10 kg P/ha.
• Crop choice at each site was dependent on the crop in the surrounding paddock (e.g. crop mix in the establishment years are shown in Table 1), and the residual benefit of the different rates of applied P was tracked through subsequent growing seasons.
• The initial experiments in 2012 (4 sites) used triple superphosphate (TSP) as the P source for deep treatments while subsequent sites used monoammonium phosphate (MAP). Due to poor efficacy at higher soil pH values, the TSP sites were not continued from 2016.
• Starter fertiliser applications were made at sowing either by the trial operators with small plot equipment, or by the growers who turned starter fertiliser on and off in planned strip-plot designs.
• Measurements of crop response typically comprised biomass cuts at physiological maturity, to determine crop growth response and nutrient acquisition.
• Yield effects of starter and deep P were determined using ANOVA[3].
• The original project was for five years (2012/13 to 2016/17), however a three year extension was funded so that the trials could continue to 2019/20, allowing the project team to continue to monitor a number of the trial sites and provide growers with better estimates of the likely length of</td></tr>
</table>

[3] ANOVA: Analysis of Variance

	residual P benefits. In 2019, some trial sites were harvesting their seventh crop with associated soil test-plant response data. • An additional series of trials was established from 2015 in core sites at Jandowae, Lundavra, Terry Hie Hie and Bellata under a linked project, UQ00078. These trials looked at placement strategies (rate x band spacing interactions, liquid v granular fertilisers, form of applied P, degree of soil disturbance/mixing, and effect of co-location of different nutrients). • Data from the field trials were entered in the Better Fertiliser Decisions for Crops database. • An ongoing extension program was undertaken to promote trial results and guidelines to 500+ growers each year. The program included at least two annual publications and a mix of electronic and paper delivery formats. Key results include: <u>Winter Cereals</u> • Winter cereals (wheat and barley) consistently responded to having both starter fertiliser applied at sowing and to application of deep P, with very few crops showing an interaction between starter and deep P. • The winter cereal results reduced fertiliser P management to two independent decisions in southern QLD: one about starter fertiliser use, and the other for deep Placement. • Yield gain when starter P was applied averaged 210 kg/ha (7.6%) across all sites for wheat and barley, compared to no starter fertiliser. • Further, assuming P costs of $3.60/kg and typical starter-P rates of 6-12 kg/ha, applications represent a cost of approximately $20 - $40/ha. This cost is easily returned by the $84/ha from an average 210kg yield gain. At current prices, the response to starter provides a positive economic return to growers and so should be considered as a part of normal recommended practice. Grain prices would have to fall to below $200/t before this yield benefit would not add extra profit from 12kg of P, and below $100/t for 6kg/ha of starter P to not be profitable. • Deep P at 20 kg P/ha applied as either TSP or MAP increased average grain yield at winter cereal sites by 9-13%. • With the MAP sites, increasing the deep P rate to 30 kg P/ha generated mean increases of 380 kg/ha (an additional 15% yield increase). <u>Chickpeas</u> • Like the situation with winter cereals, chickpeas exhibited a low frequency of starter x deep P interactions. • Chickpeas do not have an obligate requirement for starter application to set grain number (unlike cereal grain crops) and the very small number of responses to starter application across the trials was consistent with this. • However, there were situations where chickpeas were deep-sown into subsoils with very low available P, so the probability of starter P responses in such situations was greater. • The average chickpea yield without starter across all sites was 1,747 kg/ha, compared to 1,822 kg/ha with starter (a 75 kg/ha difference). • At a price of $800/t, the overall average of 75 kg/ha increase in chickpea yield easily covered the cost of $20-40/ha of starter P, and the observed upper end responses (yield increases of 300kg/ha) would generate over $200 in additional profit for growers.

	• To improve the reliability of starter P responses, the project recommended that growers consider further on-farm experimentation, especially comparing crop responsiveness under deep sowing or normal sowing conditions. • It was more difficult to make conclusive interpretations of deep P effects in chickpea crops, with only half of the trial crops (6 from 12) showing statistically significant responses to deep P. • Dry matter responses to deep P were larger and more consistent than grain responses with an average increase of 500 kg/ha (10%). • As the harvest index for pulse crops is not relatively constant (compared to grass crops), this suggests that growth responses to P are not necessarily translating into yield responses. • The project recommended further investigation into the relationship between P supply, biomass growth and grain yield in chickpea to explain these interactions. <u>Sorghum</u> • None of the sorghum crops grown in the study period (2013-14 to 2017-18) recorded any statistical effect of starter P application. • Average grain yields without/with starter application also indicated a negligible effect (3,404 kg/ha without vs 3,376 kg/ha with). • Warm soil conditions allowing rapid root expansion, combined with high potential evaporative loss in surface layers, may allow rapid early exploitation of P in the top soil layers but then limit the duration of access to the starter P band. • Deep P as MAP at 20 kg P/ha increased average grain yield by 311 kg/ha. • Application of 30 kg P/ha increased average yields slightly more with an average 372 kg/gain (11%). <u>Mungbean</u> • A very limited set of mungbean data made robust recommendations challenging. • Like sorghum and chickpea, starter P application showed negligible effects on mean yield (876 kg/ha without starter vs 908 kg/ha with starter). • Similarly, deep P provided only small average yield increases of 67 kg/ha. <u>Other</u> • An economic analysis of deep P was conducted as deep P involves large upfront costs (~$100/ha for 20kg P). • Of the 11 sites for deep P experiments, eight (8) had repaid the investment in 20 kg/ha P and returned increased profit within 2 years and 5 of those had managed to do so in the first year. • The 20 kg/ha P treatment at Jimbour West, which had 5 crops between winter 2014 and winter 2018, returned almost $800/ha in increased profit over this time period. • A contrast analysis comparing the factorial effects of +/- starter and +/- deep rip plus basal nutrients was conducted. • The approach focused on these treatments inside the broader yield data for the site and crop in that year. • Results of the analysis indicated there was no substantial impact of deep tillage and basal application on their own, relative to current grower practice. • Grain was analysed for nutrient composition to calculate nutrient export.

- Across the southern QLD trial program there were contrasting effects on grain P concentration between the grass and pulse species.
- For wheat and barley, 20 kg P/ha at depth increased grain P concentrations by an average of 150 mg P/kg (or 0.15 kg P/t).
- Grain P concentration in untilled farmer reference treatment plots averaged 2,260 mg P/kg (2.26 kg P/t) and with the 20 kg deep P/ha it increased to 2,410 mg P/kg (2.41 kg P/t).
- At average grain yields for 20 kg P/ha applied deep, only an additional 1.1 kg P/ha left the paddock compared to the treatment without deep P.
- Chickpea grain P concentrations showed greater responses to deep P applications, with 20 kg deep P/ha increasing grain P concentration by 330 mg P/kg (0.33 kg P/t).
- However, grain yield increases were smaller, so the change in P removed from the field with a 20 kg P/ha treatment was an increase of 1.2 kg P/ha, comparable to that of winter cereals.
- The small differences in P removal rates with deep P application suggested that it would be difficult to use “cheque book” accounting to monitor depletion of deep placed P treatments.
- The data also indicated that, while P applications can generate significant yield responses and improved profitability, they also were not having a large impact on crop P status.
- Grain P concentrations <2500-2900 mg P/kg are typically purported to indicate suboptimal crop P status in wheat, but even with a combination of deep P and starter P applications, average grain P concentrations still averaged only 2400 mg P/kg.
- These data highlighted the fact that once profile P becomes severely depleted, restoring soil P status with fertiliser applications is likely to be a slow process that requires careful ongoing management.
- The project developed four suggested treatments for growers to explore the effects of deep P application before commencing a wider program:
    - Treatment 1: current practice or “do nothing” (benchmark current system performance);
    - Treatment 2: the physical tillage of soil to a depth or roughly 20-25 cm, which simulates the deep placement operation without any fertiliser application.
    - Treatment 3: tillage with additional N. In many sites, N status is in equilibrium with the existing ‘normal’ yields from that field, and if deep P improves field yield potential, extra N has to be applied to achieve the higher yield target. Applying additional N alone in this treatment allows growers to separate responses from tillage, extra N, and extra N and P.
    - Treatment 4: deep P application. An application of 100-150 kg/ha of a MAP product with Zn is typically used. Suggested rates for use in strip trials are 20-30 kg P/ha of an ammonium phosphate-based product.
- Data from annual field trials provided soil test-plant response calibrations covering major gaps in the national database for the northern grains region. This covered soil testing procedures for sorghum, chickpeas and wheat.
- A deep P “How Often, How Much” online calculator was developed to help growers determine the optimal application of deep P. The calculator can be found at http://www.armonline.com.au/deepp/#!/. Outputs include expected $/ha net benefit, internal rate of return and payback probability. Key inputs include soil nitrogen and phosphorus test results, soil plant

	available water capacity, crop rotation, soil organic carbon (%), machinery costs (for deep P application), fertiliser prices and grain prices. • Using a case study with a deep-soil Colwell-P of 5 mg/kg in the Goondiwindi region, the project team compared the risk and benefit of applying amounts of P at depth for a "short-rotation" (3 years) against a "long-rotation" (7 years). • The results indicated that the optimal MAP rate was 135 kg/ha and 270 kg/ha for the short- and long-rotations, respectively, resulting in real-annual returns of \$43/ha/year and \$76/ha/year. • However, there was risk of a loss with the short-rotation (-\$14/ha/year) under the worst-case scenario (consecutive low-rainfall years). • Under the best-case scenario (high-rainfall years) the long-rotation resulted in higher net benefits (\$139/ha/year). • Due to the lower investment costs associated with the short-rotation, the expected return on investment was 142%, compared to 67% p.a. for the long-rotation. However, the short-rotation had the risk of a negative return on investment. • The payback period for both decisions was around 2-years. • It was important to note that the results changed significantly when biophysical or economic parameters changed. <u>K Trials</u> • Though the focus of the project was starter and deep applications of P, there also were a series of K trials conducted. • During the 2017/18 crop season, 6 residual K trials were monitored with 5 sites in QLD and one in NSW. This included two sites measuring residual responses from UQ00078 experiments at sites near Jandowae and Terry Hie Hie. • Of the 5 potentially responsive sites, three (all chickpea crops) responded positively to deep K bands, while the other two (wheat and barley crops at Comet River and Warra, respectively) were severely drought stressed and yielded poorly (similar to the P trials at both sites). • The responses to deep K bands represented 30-145% yield increases compared to the commercial standard at each site, and a more modest 15-30% compared to the zero K treatment that had been deep ripped and received basal nutrients at inception (including 20 kg deep P/ha). • Comparing the responses to banded P or K at common sites the responses to basal nutrients and ripping represented 71% of the overall advantage in the deep K sites, but only 54% of that in the deep P sites, suggesting that the addition of basal P without K (even though at only 20 kg P/ha) had a bigger impact on productivity than adding basal K without P. • This was consistent with observations that improving P status often improves root system vigour and K acquisition, whereas adding K has little or no effect on acquisition of P.
Outcomes	• Data from the field trials was used to provide soil test-plant response calibrations for the national database "Making Better Fertiliser Decisions for Crops". • Improved understanding of the relationship between starter fertiliser and deep P applications for winter cereals and pulses has led to improved utilisation of P fertilisers by growers. • Growers now are improving their use of soil testing to determine key soil constraints to improve crop performance.

	• Information on the potential costs and benefits (e.g. yield response, $/ha net benefit, payback period, etc.) of deep P applications, as well as the availability of the deep P calculator, has resulted in increased adoption of deep P applications across the northern grains region as producers are able to make fertiliser decisions with increased confidence. • Findings from UQ00063 have been used to inform work undertaken by linked project UQ00078 to develop fertiliser/nutrient placement strategies.

Impacts	• Increased productivity/ profitability for some Australian crop farmers (winter cereals and pulses) in the northern grains region. This impact is likely to be driven by:
	  o Improved utilisation of starter fertiliser and deep P applications resulting in increased average crop yields, and
	  o Increased adoption of deep P applications to improve soil quality and average crop yields across crop rotations.
	• Potentially, some negative environmental outcomes through increased use of fertilisers combined with deep rip disturbance leading to increased erosional risk and/or nutrient export off-farm (Mark Hickman, pers. comm., 2020).
	• Potentially, enhanced regional community wellbeing from spillover benefits of a more profitable and productive cropping industry in the northern grains region.

Source: Project documentation (e.g. UQ00063 progress/ milestone reports) provided by DAF and project updates published by GRDC: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/03/Deep P-update-2019-multi-year-grain-yield-impacts-and-economic-returns-for-southern-queensland-cropping

4. Project Investment

Nominal Investment
Table F 2 shows the annual investment (cash and in-kind) for the project with funding provided by GRDC, University of Queensland (UQ) and DAF.

Table F 2: Annual Investment in UQ00063 (nominal $)

Year (ended 30 June)	DAF ($ in-kind)	GRDC/ UQ ($)	Total ($)
2013	61,553	107,956	169,509
2014	36,428	120,835	157,263
2015	30,612	215,281	245,893
2016	65,943	231,401	297,344
2017	52,262	266,213	318,475
2018	94,799	285,109	379,908
2019	47,223	289,765	336,988
2020	46,770	155,232	202,002
2021	0	53,813	53,813
Totals	**435,590**	**1,725,605**	**2,161,195**

Source: AWI-DAF project funding agreements and DAF personnel

Program Management Costs
The management and administration costs for the project are assumed already built into the nominal dollar amounts appearing in Table F 2.

Real Investment and Extension Costs
For the purposes of the investment analysis, the investment costs of all parties were expressed in 2018/19-dollar terms using the Implicit GDP Deflator index (ABS, 2019). The project included ongoing extension activities and included significant interaction with industry, thus, no additional extension costs were included.

5. Impacts

An overview of potential impacts in a triple bottom line categorisation is shown in Table F 3.

Table F 3: Categories of Impacts from the Investment

Economic	Environmental	Social
Increased productivity/ profitability for some Australian crop farmers (winter cereals and pulses) in the northern grains region.	Potentially, some negative environmental outcomes through increased use of fertilisers combined with deep rip disturbance leading to increased erosional risk and/or nutrient export off-farm.	Potentially, enhanced regional community wellbeing from spillover benefits of a more profitable and productive cropping industry in the northern grains region.

Public versus Private Impacts
The primary impacts identified from the UQ00063 investment are largely private in nature. Private impacts are likely to accrue to crop producers (winter cereals and pulses) in the northern grains region in the form of increased productivity and/or profitability. Public impacts may include both a negative and positive impacts. Potential negative impacts include environmental outcomes from increased fertiliser use combined with deep rip soil disturbance and potential positive impacts include spillover benefits associated with the long-term productivity and profitability of northern grain industries.

Impacts Accruing to other Primary Industries
The information and activities provided by the UQ00063 investment were specifically targeted at the grain crop industries in the Australian northern grain region. Thus, it is unlikely that any significant impacts will accrue to other primary industries. However, project outputs could be used to inform similar research investments for other broadacre crops grown in similar soil types and climates.

Distribution of Benefits along the Supply Chain
Private benefits from the UQ00063 investment will accrue, in the first instance, directly to grain crop producers in the northern grains region. However, over time, benefits to producers will be shared across the grain supply chains according to the relevant elasticities of supply and demand.

Impacts Overseas
There are unlikely to be any significant impacts to overseas interests. However, knowledge sharing through international industry and/or researcher networks may occur.

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 F 4. The investment

in UQ00063 is relevant to Rural RD&E Priorities 3 and 4 and to Science and Research Priorities 1 and 2.

Table F 4: 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 F 5.

Table F 5: 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. In terms of the guides to investment, the investment is likely to have a real future impact on the northern grains industries and, through GRDC and UQ, 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.

One primary impact of the UQ00063 investment was valued in monetary terms:

- Increased productivity/ profitability for some Australian crop farmers (winter cereals and pulses) in the northern grains region driven by increased adoption of deep P applications to improve soil quality and average crop yields across crop rotations.

Impacts not Valued in Monetary Terms
Not all impacts identified in Table F 3 could be valued in the assessment. The following impacts were not valued in the current analysis:

- Potentially, some negative environmental outcomes through increased use of fertilisers combined with deep rip disturbance leading to increased erosional risk and/or nutrient export off-farm.
- Potentially, enhanced regional community wellbeing from spillover benefits of a more profitable and productive cropping industry in the northern grains region.

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 primarily to:

- The complexity of assigning monetary values to the impact (e.g. nutrient export off farm and the potential negative consequences),
- Uncertainty regarding the pathways to impact (e.g. the flow of benefits from more profitable producers through to regional community members), and
- The relative importance of the impact compared to the primary impact(s) valued.

Valuation of Impact: Increased productivity/ profitability for some grain crop producers in the northern grains region
The research undertaken by UQ00063 was part of a broader program of work aimed at improving fertiliser decisions for broadacre cropping across Australia. Further, UQ00063 built upon previous RD&E such as DAQ00148 (*Defining critical soil nutrient concentrations in soils supporting grains and cotton in Northern NSW and Queensland*) and DAQ1001 (*Developing diagnostic soil test*).

The research in UQ00063 represents an important step to increase adoption of deep placement of P fertiliser for grain crops for the northern grains region by increasing awareness of the importance of deep P reserves and demonstrating the longer-term economic benefits of deep P applications. Valuation of this benefit is based on the increased rotational gross margin available to growers adopting the new practice.

Average annual benefits will depend on the frequency of deep P applications and the length of crop rotation, and need to account for the cost of the technology investment by growers as deep P application involves large upfront costs (e.g. $160/ha for 20kg deep P (Somes, 2017)). A deep P case study, based on a paddock in the Goondiwindi region producing sorghum, chickpea and wheat, compared the risks and benefits of applying a low rate of MAP at depth for a 3-year “short-rotation” of sorghum, chickpea, wheat, wheat crops against a higher rate of MAP for a 7-year “long-rotation”. The study found that, based on the particular set of inputs (e.g. optimal application rates) and expected outcomes, the maximum median annual net benefit was $43/ha/year and $76/ha/year in the short and long rotations respectively. Further, under the worst-case scenario (a series of poor seasons) the long rotation gave a net return of $6/ha/year but the short rotation gave a negative return. Also, under the best case scenario (rain when you want it) the long rotation gave a net return of $150/ha/year compared to $139/ha/year for the short rotation (Zull, et al., 2015). However, it is important to note that the results would change when biophysical or economic parameters change.

Based on the case study findings, the valuation assumes a long rotation scenario with an average gross margin gain of between $6/ha/year and $150/ha/year (median of $76/ha/year). Further, it was estimated that the new practice would be applicable to 33% of the approximately 4 million ha of crop area in the northern grains region (Mike Bell, pers. comm., 2016). Specific assumptions for the valuation are presented in Table F 6.

Attribution
Given the range of RD&E investments that have contributed to the adoption of deep P applications for grains crops it was assumed that 50% of the benefits estimated were attributable to the specific investment in UQ00063.

Counterfactual
It was assumed that, in the absence of the UQ00063 investment, the benefits estimated would not have occurred.

Summary of Assumptions
A summary of assumptions and data sources is provided in Table F 6.

Table F 6: Summary of Assumptions

Variable	Assumption	Source
Average annual crop area in northern grains region	4 million ha	Agtrans Research based on ABS data (series 7121.0 Agricultural Commodities) and consultation with researchers. Includes cereals, pulses and oilseeds.
Applicable crop area for deep placement of P in northern region	33% of northern region crop area	Agtrans Research based on discussions with Mike Bell
Average annual net benefit from deep P application (long rotation – 7 years)	$6/ha/yr Worst case scenario (series of poor seasons)	Zull et al (2015). While these are net discounted values, they are used as a conservative estimate of an undiscounted value in the current analysis.
	$76/ha/yr Median scenario	
	$150/ha/yr Best case scenario (rain when you want it)	
First year of adoption	2016	Agtrans Research based on discussions with Mike Bell
Increase in adoption of deep P placement by growers in the northern grains region	5% of applicable area by 2024/25	
Attribution of benefit to UQ00063 investment	50%	

Risk Factors		
Probability of output	100%	Based on successful delivery of project outputs for UQ00063
Probability of outcome	100%	The probability of usage of project outputs is taken into account through the increase in adoption assumed.
Probability of impact	80%	Allows for exogenous factors that may affect realisation of benefits.

7. Results

All past costs were expressed in 2018/19 dollar terms using the Implicit Price Deflator for Gross Domestic Product (GDP) (ABS, 2019). 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
To demonstrate the range of potential results, investment criteria were estimated for three scenarios:

1. Worst case scenario – estimated net return of $6/ha/yr (series of poor seasons)
2. Median scenario – estimated net return of $76/ha/yr
3. Best case scenario – estimated net return of $150/ha/yr (rain when you want it)

Table F 7 (worst case), Table F 8 (median) and Table F 9 (best case) show the investment criteria estimated for different periods of benefits for the total investment.

Table F 7: Investment Criteria for Total Investment – Worst Case Scenario

Investment criteria	Years after last year of investment (2020/21)						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.34	0.91	1.43	1.83	2.14	2.39	2.58
Present value of costs ($m)	2.65	2.65	2.65	2.65	2.65	2.65	2.65
Net present value ($m)	-2.31	-1.74	-1.23	-0.83	-0.51	-0.27	-0.07
Benefit-cost ratio	0.13	0.34	0.54	0.69	0.81	0.90	0.97
Internal rate of return (IRR) (%)	negative	negative	negative	1.3	3.2	4.2	4.8
Modified IRR (%)	negative	negative	negative	0.2	1.6	2.2	2.4

Table F 8: Investment Criteria for Total Investment – Median Case Scenario

Investment criteria	Years after last year of investment (2020/21)						
	0	5	10	15	20	25	30
Present value of benefits ($m)	4.36	11.58	18.06	23.14	27.12	30.24	32.68
Present value of costs ($m)	2.65	2.65	2.65	2.65	2.65	2.65	2.65
Net present value ($m)	1.71	8.93	15.41	20.49	24.47	27.59	30.03
Benefit-cost ratio	1.65	4.37	6.81	8.72	10.22	11.40	12.32
Internal rate of return (IRR) (%)	25.9	40.5	42.2	42.4	42.5	42.5	42.5
Modified IRR (%)	188.2	52.0	33.0	24.6	19.8	16.7	14.5

Table F 9: Investment Criteria for Total Investment – Best Case Scenario

Investment criteria	Years after last year of investment (2020/21)						
	0	5	10	15	20	25	30
Present value of benefits ($m)	8.61	22.85	35.65	45.67	53.53	59.68	64.50
Present value of costs ($m)	2.65	2.65	2.65	2.65	2.65	2.65	2.65
Net present value ($m)	5.96	20.20	33.00	43.02	50.87	57.03	61.85
Benefit-cost ratio	3.25	8.62	13.44	17.22	20.18	22.50	24.31
Internal rate of return (IRR) (%)	56.7	64.6	65.2	65.3	65.3	65.3	65.3
Modified IRR (%)	743.7	76.7	44.1	31.6	24.8	20.6	17.7

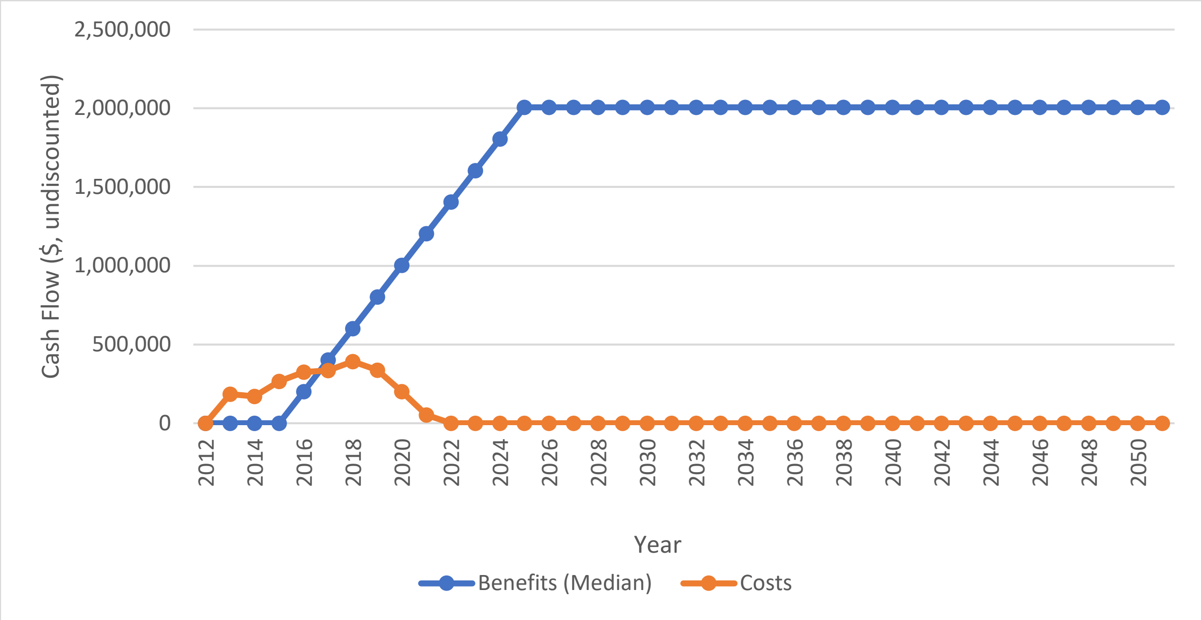
Table F 10 shows the investment criteria for the DAF investment only. The present value of benefits (PVB) attributable to DAF investment was estimated by multiplying the total PVB by the DAF proportion of real investment (20.2%).

Table F 10: Investment Criteria for DAF Investment – Median Case Scenario

Investment criteria	Years after last year of investment (2020/21)						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.88	2.34	3.66	4.68	5.49	6.12	6.61
Present value of costs ($m)	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Net present value ($m)	0.34	1.80	3.11	4.14	4.94	5.57	6.07
Benefit-cost ratio	1.62	4.29	6.70	8.58	10.06	11.21	12.12
Internal rate of return (IRR) (%)	22.7	36.8	38.7	39.0	39.0	39.0	39.1
Modified IRR (%)	159.9	48.7	31.4	23.6	19.0	16.1	14.0

The annual undiscounted benefit and cost cash flows for the total investment for the median scenario for the duration of the investment period plus 30 years from the last year of investment are shown in Figure F 2.

Figure F 2: 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 for the median scenario 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 F 11. The results show that the investment criteria had a moderate sensitivity to the discount rate.

Table F 11: Sensitivity to Discount Rate
(Total investment, Median Scenario, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	63.20	32.68	20.80
Present value of costs ($m)	2.27	2.65	3.11
Net present value ($m)	60.93	30.03	17.68
Benefit-cost ratio	27.86	12.32	6.68

A sensitivity analysis then was completed on the assumed increase in adoption of deep P placement for crop farms in the northern grains region for the median scenario (Table F 12). Results show that the investment criteria were moderately sensitive to the assumed increase in adoption of deep P placement.

Table F 12: Sensitivity to Increase in Adoption of deep P Placement (Total investment, Median Scenario, 30 years)

Investment Criteria	**Increase in Adoption of deep P Practices for the Northern Grains Region**		
	2%	**5% (base)**	**10%**
Present value of benefits ($m)	13.07	32.68	65.36
Present value of costs ($m)	2.65	2.65	2.65
Net present value ($m)	10.42	30.03	62.71
Benefit-cost ratio	4.93	12.32	24.64

Further, a break-even analysis across the worst, median and best case scenario indicated that the investment criteria would remain positive (BCR of 1) with a minimum increase in adoption of between 0.2% (best case) and 5.1% (worst case), with a median of 0.4%. That is, based on the assumptions made, the median investment criteria for UQ00063 would still be positive if an additional 0.4% of the applicable area in the northern region adopted deep P placements in a long rotation under the median case scenario (average seasons).

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 F 13). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table F 13: Confidence in Analysis of Project

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

Coverage of benefits was assessed as Medium-High. While the principal economic benefit was quantified (increased productivity/profitability for some northern grain producers), the potential environmental and social impacts were not valued.

Confidence in assumptions was rated as Medium. Though key data and assumptions were drawn from credible sources (including ABS data, published research and consultation with key project personnel) some assumptions were still uncertain.

8. Conclusion

The investment in UQ00063 has delivered information and tools that producers in the northern grains region have used to improve fertiliser practices to improve crop yields. Further, the investment has provided growers with increased confidence to undertake deep P placement based on soil testing to improve soil quality, replenish long-term soil nutrient reserves and increase medium to long term crop performance.

The total investment in UQ00063 produced several impacts and the principal economic impact (increased productivity/ profitability for some northern grain producers) was valued. The total investment of $2.65 million (present value terms) has been estimated to produce total gross benefits of $32.68 million (median case, present value terms) (worst case PVB of $2.58 million, best case PVB of $64.5 million). The estimated benefits provided a median net present value (NPV) of $30.03 million (worst case NPV of -$0.07 million and best case NPV of $61.85 million), a median BCR of 12.3 to 1 using a 5% discount rate over 30 years (worst case BCR of approximately 1.0 and best case of 24.3), a median IRR of 42.5% (worst case 4.8% and best case of 65.3%) and a median MIRR of 14.5% (worst case of 2.4% and best case of 17.7%).

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