SRDC Research Project
Final Report

Evaluation of Selected Project Clusters in the SRDC R&D Portfolio

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by

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Executive Summary

This report presents the results of economic analyses of clusters of investments within the Sugar Research & Development Corporation's (SRDC's) research and development portfolio.

The principal purpose of this economic assessment was to contribute to a process being undertaken for the Council of Rural Research & Development Corporations (CRRDC) that aims to demonstrate through examples the outcomes and benefits that have emerged or are likely to emerge from the 15 Rural Research and Development Corporations (RDCs). Valuation of these benefits, along with identification of investment expenditure, is required in order to demonstrate their contribution to Australian rural industry as well as environmental and social benefits to Australia.

Cluster selection satisfied the random selection process of the CRRDC. This entailed the definition of the population of projects in the program, clustering projects into groups, and a process of random sampling of the clusters so defined.

Information from the original project proposals in each cluster, milestone reports, final reports and other relevant reports were assembled with assistance from SRDC. Discussions were held with Principal Investigators for each research area as well as sugar industry personnel as appropriate.

Each of the analyses provides a description of the constituent project backgrounds, objectives, activities, costs, outputs, outcomes, and benefits. The benefits were described in a triple bottom line context. Some of the potential benefits were then valued in monetary terms.

The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate investment criteria of Net Present Value (NPV) and Benefit-Cost Ratio (B/C Ratio) at a discount rate of 5% real. The PVB and PVC are the sums of the discounted streams of benefits and costs. The discounting is used to allow for the time value of money, and the discount rate of 5% is that specified in the CRRDC guidelines. The Internal Rate of Return (IRR) was also calculated.

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions. Sensitivity analyses were undertaken in most cases for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Some identified benefits were not quantified mainly due to:

- A suspected, weak or uncertain scientific or causal relationship between the research investment and the actual R&D outcomes and associated benefits
- The magnitude of the value of the benefit was thought to be only minor

The table presents the investment criteria for each of the four clusters analysed at a 5% discount rate and expressed in 2010/11 dollar terms. Given the assumptions made for each evaluation, all cluster investments will produce positive net benefits over 30 years from the last year of investment.

Investment Criteria for Four Cluster Investments
(Total investment, discount rate 5%, 30 years from last year of investment)

Investment Cluster	PVB ($m)	PVC ($m)	NPV ($m)	B/C Ratio	IRR (%)
Managing climate variability and climate change	1.19	1.12	0.07	1.06	5.5
Implementing integrated farming systems to improve productivity and profitability	62.42	24.67	37.75	2.53	13.1
Managing and improving soil resources and nutrients	20.71	4.88	15.82	4.24	22.0
Managing water more sustainably	9.16	3.69	5.47	2.48	12.5

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Background

The Sugar Research & Development Corporation (SRDC) required cost-benefit analyses to be undertaken on a number of their past research investments.

The principal purpose of the economic analyses was to contribute to a process being undertaken for the Council of Rural Research & Development Corporations (CRRDC) that aims to demonstrate through examples the outcomes and benefits that have emerged or are likely to emerge from the 15 Rural Research and Development Corporations (RDCs).

Assessing the impact of investment in research is important as it can demonstrate to stakeholders that the research is making or is likely to make a difference and is providing benefits to industry, commerce and Australia's economic growth.

One method identified for improving the ability to report on the effectiveness of the research investment is to undertake some formalised investment analyses (cost-benefit analyses) in order to estimate the returns to investment. Such analyses take into account the time differences between when the investment occurs and when benefits accrue.

This analysis evaluates the benefits to be delivered from four clusters of project investments drawn at random across the SRDC portfolio.

Cluster selection satisfied the random selection process of the CRRDC. This entailed the definition of the population of projects in the SRDC portfolio that were completed over the period 2007/08 to 2009/10, clustering projects into groups, and a process of random sampling of the clusters so defined.

Objectives

The objectives of the project were:

- Undertake economic impact assessments on a number of randomly selected clusters of projects:
    - Managing climate variability and climate change
    - Implementing integrated farming systems to improve productivity and profitability
    - Managing and improving soil resources and nutrients
    - Managing water more sustainably
- Undertake the economic impact assessments via cost-benefit analysis and follow the original guidelines provided by the Council of Rural Research and Development Corporations

The project has achieved both of the above objectives.

Methodology

The population of projects was defined as those that had been completed in the period from July 2007 to June 2010. There were a total of 198 projects in the population, with a SRDC investment value of $24.1 million. The individual projects were then grouped into 38 clusters of investment. The number of projects in each cluster ranged from 1 project to 13 projects. It was noted that a number of the clusters were very small in value terms, and in fact the seven smallest clusters (by value) made up only 1% of the total investment in the portfolio of projects. These seven clusters were therefore excluded from eligibility for analysis. The remaining clusters were grouped into seven areas:

- Regional Futures Arena - Value chain integration (3 clusters)
- Regional Futures Arena - Farming and harvesting systems (13 clusters)
- Regional Futures Arena - Transport, milling and marketing systems (2 clusters)
- Emerging Technologies Arena - Genetics and breeding systems (3 clusters)
- Emerging Technologies Arena - Farming, harvesting, transport, milling and marketing systems (3 clusters)
- People Development Arena - Individual Capacity (3 clusters)
- People Development Arena - Social capacity (4 clusters)

When considering the distribution of the value of investment across the seven groupings, it was found that approximately 60% of the investment (by value) was in the ‘Regional Futures Arena – Farming and harvesting systems’ set of clusters. It was therefore decided that at least 2 of the 4 clusters randomly selected for analysis should be from the Regional Futures area to ensure the 4 clusters analysed were representative of the main areas in which SRDC was investing. The final resulting set of clusters included three from the Regional Futures –Farming and harvesting systems arena.

The details of the 31 clusters and the recommendations for stratification were forwarded to the Council of Rural R&D Corporations, who randomly selected four clusters for evaluation. The four clusters randomly selected are presented in Table 1.

Table 1: Clusters Randomly Selected for Evaluation

Cluster	No. of Projects	SRDC Value ($)
Managing climate variability and climate change	6	370,281
Implementing integrated farming systems to improve productivity and profitability	13	5,133,542
Managing and improving soil resources and nutrients	11	1,541,164
Managing water more sustainably	6	1,169,632

Together, the investment in these four clusters represented approximately 34% of the total SRDC investment in the portfolio of projects defined.

Each cluster of investment was evaluated through the following steps:

1. Information from the original project schedules, and any progress reports, final reports or other relevant reports and material was assembled with assistance from SRDC.
2. An initial description of the project background, objectives, activities, costs, outputs, and expected outcomes and benefits was drafted. Additional information needs were identified.
3. Where necessary, telephone contact was made with principal investigators or industry contacts and the draft sent to them for perusal and comment, together with specific information requests.

4. Further information was assembled where appropriate and the quantitative analysis undertaken.
5. Final drafts were passed by SRDC for comment.

The potential benefits from each cluster of investment were identified and described in a triple bottom line context. Some of these benefits were then valued.

The factors that drive the investment criteria for R&D include:

C	The cost of the R&D.
K	The magnitude of the net benefit per unit of production affected; this net benefit per unit also takes into account the costs of implementation.
Q	The quantity of production affected by the R&D, in turn a function of the size of the target audience or area, and the level of initial and maximum adoption ultimately expected, and level of adoption in the intervening years.
D	The discount rate.
T_1	The time elapsed between the R&D investment and commencement of the accrual of benefits.
T_2	The time taken from first adoption to maximum adoption.
A	An attribution factor 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 outcome being valued.
P	Probability of an R&D output, commercialisation etc. occurring. Can be applied when the research is not complete or when some further investment is required before the outputs of the research are translated into adoptable outcomes and extended to the industry.

Defining the ‘without R&D’ scenario to assist with defining and quantifying benefits is often one of the more difficult assumptions to make in investment analyses. The ‘without’ scenario (referred to here as counterfactual) usually lies somewhere between the status quo or business as usual case and the more extreme positions that the research would have happened anyway but at a later time; or the benefit would have been delivered anyway through another mechanism. The important issue is that the definition of the counterfactual scenario is made as consistently as possible between analyses.

The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate the investment criteria of Net Present Value (NPV) and Benefit-Cost Ratio (B/C Ratio) at a discount rate of 5% real. The PVB and PVC are the sums of the discounted streams of benefits and costs. The discounting is used to allow for the time value of money. The discount rate of 5% is that specified in the CRRDC guidelines. The Internal Rate of Return (IRR) was also calculated.

All dollar costs and benefits were expressed in 2010/11 dollar terms and discounted to the year 2010/11. A 30 year time frame for benefits was used in all analyses, with year ‘zero’ being the final year of investment in the R&D cluster. Costs for the R&D projects included the cash and in-kind contributions, as well as any other resources contributed by third parties (e.g. researchers or industry).

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Some identified benefits were not quantified mainly due to:

- A suspected, weak or uncertain scientific relationship between the research investment and the actual R&D outcomes and associated benefits.

- The magnitude of the value of the benefit is thought to be only minor.

Outputs

An analysis report summarising the objectives, activities, outputs, outcomes and benefits of each of the projects in a cluster is provided for each cluster. The benefits are described in a triple bottom line context. Each analysis report also describes the methods and assumptions used to calculate the costs and benefits for each cluster. These analysis reports are provided in Appendixes 1 to 4.

Table 2 summarises the benefits from investment in each of the four clusters. Each benefit is categorised as economic, environmental or social.

Table 2: Summary of Benefits for Four Clusters

Cluster	Benefits
Managing climate variability and climate change	Economic • Increased industry profitability including in wet springs via higher sugar content and reduced cane losses. • Reduced income variability from improved risk management. • Potential benefits to non-cane crops if the autumn forecast is shown to have relevant skill and value. • Improved effectiveness of future climate change research. Environmental • More sustainable production from reduced wet weather damage and from reduced losses of nutrients off-farm. • Reduced sediment and nutrients leaving farms lowering impacts on waterways (including positive impacts for fishing and tourism industries). Social • Improved grower-miller cooperation on the harvest start date. • Improved personal capacity of the sugar industry to manage climatic variability and climate change.
Implementing integrated farming systems to improve productivity and profitability	Economic • Decreased cost of production due to decreased fuel, chemical, fertiliser and labour costs. • Increased yield due to improved soil health. • Efficiencies in R&D expenditure (for R&D associated with increasing sugar yield). • Increased adoption of minimum tillage and wet season fallow management of non-cane crops in the Ord River Irrigation Area. Environmental • Enhanced future resource sustainability (soil and nutrients) on cane land. • Improved quality of water exported off-farm due to reduced nutrient and chemical run-off. • Reduced use of fuels and energy.

	<u>Social</u> • Increased capacity of growers to adopt new practices, and be involved in replicate trials. • Reduced chemical use potentially resulting in decreased likelihood of adverse health effects.
Managing and improving soil resources and nutrients	<u>Economic</u> • Input cost reduction for cane production. • Cane yield increases. • Potential increase in alternative use of cane trash. • Increased area of soybean crops lowering infrastructure costs and strengthening marketing. <u>Environmental</u> • Reduced loss of soil and nutrients from farm land. • Improved quality of water exported off-farm (soil and nutrients). <u>Social</u> • Increased industry research capacity. • Increased soil science capacity.
Managing water more sustainably	<u>Economic</u> • Avoided yield loss due to reduced groundwater levels. • Increased cane yield due to WaterSense. • Efficiency gains in R&D resource allocation. <u>Environmental</u> • Improved water quality in downstream ecosystems. <u>Social</u> • Avoided displacement of growers due to reduced groundwater levels.

Table 3 presents the investment criteria for each of the four cluster investments analysed at a 5% discount rate, when considering the total investment. Table 4 presents the investment criteria when considering the SRDC investment only.

Further details on each of these investments and the associated results are provided in the individual cluster reports (Appendices 1 to 4).

Table 3: Investment Criteria for Four Cluster Investments
(Total investment, discount rate 5%, 30 years from last year of investment)

Investment Cluster	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**B/C Ratio**	**IRR (%)**
Managing climate variability and climate change	1.19	1.12	0.07	1.06	5.5
Implementing integrated farming systems to improve productivity and profitability	62.42	24.67	37.75	2.53	13.1
Managing and improving soil resources and nutrients	20.71	4.88	15.82	4.24	22.0
Managing water more sustainably	9.16	3.69	5.47	2.48	12.5

Table 4: Investment Criteria for Four Cluster Investments
(SRDC investment, discount rate 5%, 30 years from last year of investment)

Investment Cluster	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**B/C Ratio**	**IRR (%)**
Managing climate variability and climate change	0.48	0.45	0.03	1.07	5.5
Implementing integrated farming systems to improve productivity and profitability	17.63	6.98	10.65	2.53	13.1
Managing and improving soil resources and nutrients	9.14	2.16	6.97	4.22	21.6
Managing water more sustainably	3.44	1.38	2.06	2.49	12.6

Intellectual Property and Confidentiality

There are no intellectual property or confidentiality concerns associated with this project.

Environmental and Social Impacts

There are no adverse or beneficial environmental or social impacts of conducting this project and/or implementing its findings.

Expected Outcomes

The individual cluster analyses will be submitted by SRDC to the CRRDC for inclusion in their summary of the assessment of the costs and benefits that have emerged or are likely to emerge from the 15 Rural Research & Development Corporations. This joint reporting by the Rural RDCs seeks to demonstrate the RDC contribution to Australian rural industry as well as environmental and social benefits to Australia.

SRDC can also make use of the analyses by extracting information from them for a range of reporting needs, including reporting progress against the R&D Plan and annual reports.

Future Research Needs

There are no future research needs recommended as a result of the project.

Recommendations

It is recommended that:

- The individual analyses of the four clusters of investment be submitted to the CRRDC.
- SRDC consider if there are any lessons learnt or implications for future funding from the findings on each of the individual projects with respect to outcomes and potential impact.
- SRDC continues to keep informed of the requirements of the CRRDC with respect to future reporting of economic, environmental and social impact.

List of Publications

There are no publications from this project.

Appendix 1: An Economic Analysis of the SRDC Investment in the "Managing Climate Variability and Climate Change" Cluster

Background

The extreme events of 2010 and 2011 including prolonged wet weather, record rainfalls, floods and cyclone Yasi were further reminders, if any were necessary, of the challenges the sugar industry faces from climate variability and climate change. SRDC has been a substantial investor since its inception in projects to give the industry better information to aid climate risk management. Most investment has been as a partner with other R&D Corporations in various phases of national programs including the current phase, the Managing Climate Variability Program (MCVP). There have also been investments by SRDC in various projects on seasonal climate forecasting and more recently on developing strategies to understand and manage climate change impacts. SRDC has conducted climate change workshops with industry and been a partner in national strategy development through the Climate Change Research Strategy for Primary Industries (CCRSPI).

The major impetus to invest in climate risk management came initially from the development over two decades ago of improved seasonal forecasts based on the Southern Oscillation Index (SOI). The SOI index refers to the Darwin Tahiti pressure difference and is also highly correlated with various indicators based on Pacific Ocean sea surface temperatures of El Niño and La Niña states (collectively termed ENSO – El Niño Southern Oscillation). The SOI has most skill as a seasonal forecast three months ahead but mainly over the latter half of the calendar year. The period of skill coincides with the harvest period. Not suprisingly the value of forecasts in harvesting decisions (Agtrans Research 2004) and in other decisions has been the subject of previous research (Everingham et al 2002). Heavy losses of the order of hundreds of millions of dollars have been recorded by the industry from wet weather damage and harvesting delays in extreme years such as 1998 and 2010. There has also been research in the drier areas on the value of seasonal forecasts in irrigation scheduling and by marketers to forecast the size of the crop and to plan shipping schedules.

Current seasonal forecasts are probabilistic forecasts of the period three months ahead. Forecasts made in autumn with a longer lead time would clearly be more valuable to enable earlier planning and for scheduling of mill maintenance, for example if a change to the start of the cane crushing season was envisaged. The climate cluster being evaluated includes a project on an autumn seasonal forecast and the potential value to growers and millers in the Herbert region from modifying the start of the cane harvest depending on an autumn forecast of rainfall later in the year.

Rainfall impacts and the potential value of forecasts will vary over the 2,000 km from the tropical cane areas to the subtropics in northern NSW. Using a simple water balance model, White (1970) showed that in the tropics, yields can be reduced in very wet years from the various impacts such as flood damage related to excess rainfall and lower yields from increased cloud cover reducing radiation. In contrast in drier years in central and southern areas, yields can be reduced if irrigation is limited. The model accounted for over 80 percent of yield variability in yields to that time at North Eton. For a wetter district such as the then Goondi mill near Innisfail, the rainfall surplus term alone accounted for over half the yield variation. This evaluation will concentrate on the Herbert but will estimate potential benefits for all areas. For the evaluation of the phase of MCVP which funded over 40 projects, benefits will be assumed proportional to the SRDC input.

The Cluster

Projects

Table 1 presents the details for the six projects included in the cluster. The first two projects account for most of the expenditure. The four smaller projects are on various aspects of planning research and strategies to better understand and adapt to climate change.

Table 1: Summary of Project Details

Project Number	Project Title	Other Details
CVA002	Managing Climate Variability Program	Organisation: Land and Water Australia Period: September 2003 to September 2007 Principal Investigator: Multiple
JCU027	Defeating the Autumn Predictability Barrier	Organisation: James Cook University of North Queensland Period: July 2006 to October 2009 Principal Investigator: Yvette Everingham
LWA002	National Climate Change Research Strategy for Primary Industries	Organisation: Land and Water Australia Period: September 2007 to June 2008 Principal Investigator: Multiple
SRD011	Climate Change Workshop	Organisation: SRDC with CSIRO Period: January 2007 to December 2007 Principal Investigator: SRDC Working Group
SRD026	Preparing the Sugar Industry for Climate Change and Emissions Trading Workshop	Organisation: SRDC / CCRSPI Workshop Period: June 2009 to August 2009 Facilitator/reporter: Russel Pattinson (Miracle Dog)
CSE021	Maximising the challenges and opportunities from climate change and ecosystem service payments for the Australian sugar industry	Organisation: CSIRO Period: July 2007 to August 2007 Principal Investigator: Dr Sarah Park

Project Objectives

Table 2 presents the objectives for each of the projects included in the cluster.

Table 2: Description of Project Objectives

Project Number	Objectives
CVA002 MCVP	• Develop a partnership including major rural R&D Corporations to invest in generic and industry specific research targeting priorities of the partners. • Conduct the Managing Climate Variability R&D Program (MCVP) to increase the capacity of Australian farmers and natural resource managers to manage risks and opportunities related to climate variability.
JCU027 Autumn Forecasting	• Assess by May 2007 as a first stage whether the Clarke and Van Gorder (2003) FSU (Florida State University) model can provide a useful prediction in autumn of the rainfall later in the calendar year. • If successful, assess the value of the forecast for Australian sugar industry

	planning particularly in relation to decisions made in relation to the harvest.
LWA002 RDC Research Strategy	• Collaborate with 14 other Rural R&D Corporations in development of a National Climate Change Research Strategy for Primary Industries (CCRSPI) which is coordinated between industries and regions. • Ensure more efficient and effective research, development and extension to address the challenges and opportunities of climate change for primary industries in Australia.
SRD011 Climate Change Workshop I	• Through consultation with the sugar industry and with the research community identify knowledge gaps and investment priorities for Research and Development relating to the challenges of responding to a changing climate.
SRD026 Climate Change Workshop II	• Review recent developments in climate change policy and identify research issues for SRDC. • Contribute to more informed decision-making so the industry is best placed to negotiate these challenges and opportunities.
CSE021 Climate Change Options and Ecoservices	• Undertake a study tour and seek information from other sugarcane-producing nations and land stewardship organisations to provide (a) greater clarity on current and potential ecoservices provided by sugarcane, and (b) increased awareness of climate change impacts and adaptation options unique to the Australian sugar industry.

Project Investment

Table 3 shows the annual investment by project for SRDC. Table 4 shows the annual investment by project for other investors (mostly in-kind resources from research organisations and industry). Table 5 summarises the total annual investment.

Table 3: Investment by Project by SRDC (nominal $)

Project Number	Year ending June						
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**TOTAL**
CVA002	35,000	40,000	40,000	40,000			155,000
JCU027				71,920	62,233	48,239	182,392
LWA002					3,280		3,280
SRD011					18,690		18,690
SRD026						6,021	6,021
CSE021					4,898		4,898
Total	35,000	40,000	40,000	111,920	89,101	54,260	370,281

Table 4: Investment by Project by Others (nominal $)

Project Number	Year ending June						
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**TOTAL**
CVA002[a]	47,695	50,220	92,955	101,038	40,437		332,345
JCU027				65,780	67,753	69,786	203,319
LWA002							
SRD011							
SRD026							
CSE021					6,763		6,763
Total	47,695	50,220	92,955	166,818	114,953	69,786	542,427

[a] Note that the values do not include the contributions of other core funders to CVAP; funding from 'others' was taken as a proportion of the total 'other' (non-core) funding in the same proportion that SRDC investment made up of the total funding from the core investors.

Table 5: Summary of Annual Investment by SRDC and Others (nominal $)

Year ending June	SRDC	Others	Total
2004	35,000	47,695	82,694
2005	40,000	50,220	90,220
2006	40,000	92,955	132,955
2007	111,920	166,818	278,738
2008	89,101	114,953	204,054
2009	54,260	69,786	124,046
Total	370,280	542,427	912,707

Outputs

Table 6 provides a brief summary of the activities and outputs for each of the projects.

Table 6: Summary of Project Activities and Outputs

Project	Activities and Outputs
CVA002 MCVP	• Managed the SRDC contribution to the MCVP. • With MCVP partners, funded 43 MCVP projects targeting partner priorities to achieve three key outputs: 1. Increased adoption (Major national regions and industries) 2. Increased adoption (Natural resources management) 3. Improved seasonal climate forecasts • Completed generic projects including improvements to climate and evaporation data used as inputs in crop simulation models used in the sugar industry, and also projects *Improving prediction of the Northern Australian wet season* and *Incorporating climate change in catchment management strategies*. • In relation to the sugar industry specifically, funded the project JCU20 to review a range of seasonal forecast systems to assess whether the approaches being used in the sugar industry based on SOI phase forecasts were appropriate compared with possible alternative forecasts including consideration of decadal variability.
JCU027 Autumn Forecasting	• Stage 1 demonstrated that an autumn forecast of the temperature of the Niño 3.4 region in the central Pacific using the FSU model was considered to have adequate hindcast skill in forecasting SON (September to November) rainfall at key Australian sugar industry locations. • In stage 2, 14 meetings involving over 100 growers, millers and other industry personnel at Tully, Ingham, Plane Creek and in northern NSW demonstrated the potential to use the autumn forecast to take advantage of forecast wet or dry conditions in a wide range of decisions. • Development of the approach into a RAIN FORECASTER package together with an Australian Society of Sugar Cane Technologists (ASSCT) publication (Everingham et al 2009) that overviews its capabilities.

	• Publications of the approach in industry and international journals (Everingham et al 2011) showed the potential value of the forecasts in rescheduling the start of the harvest based on changes in cane sugar content. The Osborne et al (2011) paper on use of forecasts was recognised as the top student paper at the ASSCT.
LWA002 RDC Research Strategy	Overall, six strategies were developed building on those already developed by some RDCs including SRDC. The process included a comprehensive report (CCRSPI 2008) on the following activities across the 15 RDCs involved: • Compilation of current knowledge, research gaps and a list of projects. • Establishment of an expert Reference Group. • Interviews with industry organisations, state government representatives and Rural R&D Corporations. • Compilation of 63 submissions. • Commissioning a report from CSIRO on adaptation. • Commissioning a report to position Australian primary industries to respond to a future national greenhouse emissions trading scheme.
SRD011 Climate Change Workshop I	• Organised a project team and undertook a scoping study using Maryborough as a case study of potential climate change impacts across the value chain and at regional level. • Ran a regional workshop on the study. • Conducted a strategic vision workshop to identify regional and industry level responses. • Conducted an industry workshop to refine industry and regional strategies and develop research priorities. • Promoted a publication on the project (SRDC 2007) which was also based on CSIRO project CSE019.
SRD026 Climate Change Workshop II	• Conducted a workshop with Commonwealth agencies to determine implications of recent climate change policy initiatives on SRDC research priorities. • Provided a forum for updates on recent research on emissions, particularly nitrous oxide, adaptation (in a high carbon dioxide environment) and life cycle analysis.
CSE021 Climate Change Options and Ecoservices	• Brief summary report produced on major issues faced by a number of sugar producing nations to climate change and potential adaptation options. From this, appropriate adaptation strategies for the Australian sugar industry were identified. • Brief summary report produced on ecoservices identified in European crop production and remuneration options via stewardship payment frameworks. From this, potential ecoservices provided by the Australian sugar industry were identified. • International contacts and collaborative links in areas of ecoservices and climate change established to enable future feedback and an information network. • Journal publications produced on (a) climate change impacts and adaptation options for the Australian sugar industry, and (b) applicability of European model of stewardship payments to Australian agriculture.

Outcomes

A brief summary of outcomes by project is provided in Table 7.

Table 7: Summary of Project Outcomes

Project	Outcomes
CVA002 MCVP	• Improved risk management from increased adoption of a range of tools and information sources on managing aspects of climate variability. • Increased capacity to direct generic national research to sugar industry priorities.
JCU027 Autumn Forecasting	• Depending on adoption by growers and millers, improved management of seasonal (SON) rainfall extremes during the harvest period later in the year by using a seasonal forecast system across the autumn barrier. • Understanding the impact of rainfall in El Niño and La Niña seasons on cane sugar content and the scope to adapt the timing of the cane harvest to optimise sugar content.
LWA002 RDC Research Strategy	• More efficient and effective national research for adapting to climate change and to mitigate emissions based on better coordinated industry and cross-sectoral strategies developed in consultation with industry, policy agencies and research organisations. • Increased capacity of the rural research sector to collaborate effectively with CSIRO, Bureau of Meteorology, Commonwealth and state government agencies, and universities on climate change research.
SRD011 Climate Change Workshop I	• Recognition that many knowledge gaps can be best filled through the enhancement of existing R&D activity, and by ensuring a climate change perspective is inherent across the SRDC research portfolio. • Increased capacity to plan more efficient and effective industry research for adapting to climate change and reduce industry vulnerability. • Increased industry capacity to explore the opportunities and risks associated with climate change.
SRD026 Climate Change Workshop II	• Increased industry understanding of the national climate change policy environment as a basis for better integrated SRDC research planning.
CSE021 Climate Change Options and Ecoservices	Increased knowledge will enable the following ecoservices outcomes: • Greater clarity on current and potential environmental benefits of sugarcane landscapes, particularly compared to other land uses. • More informed research and strategic policy planning on issues related to ecoservices (e.g. stewardship payments) and future land use. • Capacity to influence attitudes in the broader community towards support of payments for the provision of ecoservices. The climate change outcomes are: • Increased awareness by sugar industry stakeholders of impacts of

	climate change and adaptation options in other sugar producing nations via regional seminars. • Clearer understanding of the unique opportunities and challenges faced by Australian sugar production to better inform future R&D.

Benefits

A brief summary of benefits by project is provided in Table 8.

Table 8: Summary of Cluster Benefits

Project	Benefits
CVA002 MCVP	• Increased industry profitability from improved climate risk management based on the increasing range of generic tools developed by MCVP.
JCU027 Autumn Forecasting	• Increased grower and mill profitability through improved early knowledge of the SON seasonal rainfall outlook over the harvest season with future benefits dependent on increasing industry awareness and adoption of the autumn forecast. • Potential in future for environmental benefits, for example through reduced wet weather damage and from rescheduling farming operations including fertiliser timing. However the recent review (Van Grieken et al 2010) of management practices relevant to water quality issues does not mention seasonal forecasts.
LWA002 RDC Research Strategy	• More efficient and effective research for adapting to climate change and to mitigate emissions based on increased capacity for sugar industry research to be better integrated with national approaches.
SRD011 Climate Change Workshop I	• More efficient and effective research for adapting to climate change across the sugar industry value chain and at a regional level.
SRD026 Climate Change Workshop II	• Increased sugar industry understanding of climate change challenges and opportunities as a basis for research planning.
CSE021 Climate Change Options and Ecoservices	• Increased capacity to source environmental benefits from ecosystem services from sugarcane landscapes. • Increased capacity to reduce impacts of climate change by understanding adaptation options in other sugar producing nations.

Summary of Benefits
A summary of the principal types of benefits associated with the outcomes of investment in the cluster of projects is shown in Table 9.

Table 9: Categories of Benefits from the Investment

Levy Paying Industry	Spillovers	
	Other Industries	**Public**
Economic Benefits		
Increased industry profitability including in wet weather via higher sugar content and reduced losses. Reduced income variability from improved risk management.	Potential benefits to non-cane crops if the autumn forecast is shown to have relevant skill and value.	Improved effectiveness of future climate change research.
Environmental Benefits		
More sustainable production from reduced wet weather damage and from reduced losses of nutrients off-farm.	Reduced sediment and nutrients leaving farms lowering impacts on waterways (including positive impacts for fishing and tourism industries)	Reduced sediment and nutrients leaving farms lowering impacts on waterways
Social Benefits		
Improved grower-miller cooperation on the harvest start date. Improved personal capacity of the sugar industry to manage climatic variability and climate change.		

Public versus Private Benefits
The majority of the benefits were private in nature, with benefits mostly relating to higher cane prices from higher sugar content and reduced harvesting costs in wet years. The public benefits relate to improved effectiveness of public investment in climate change R&D and the potential for reducing nutrient export to waterways.

Distribution of Benefits along the Sugar Supply Chain
The benefits from the projects in this cluster will be shared along the cane supply chain with farmers, harvesters, transporters, and mills all benefiting.

Benefits to other Primary Industries
There could be limited benefits to other primary industries from the cluster investment if they determine that the autumn forecast has potential skill for their situation.

Benefits Overseas
There will be no benefits to overseas consumers or producers of sugar.

Additionality and Marginality
Supporting these studies was a medium level priority for SRDC. If public funding of SRDC were reduced, it is likely that only the smaller projects would still have been funded, particularly those involving national collaboration and those developing strategies for climate change research.

Further detail is provided in Table 10.

Table 10: Potential Response to Reduced Public Funding to SRDC

1. What priority were the projects in this cluster when funded?	Medium (for the majority of the projects)
2. Would SRDC have funded this cluster if only half of public funding of SRDC had been available?	Some with reduced funding for most projects.
3. Would the cluster have been funded if no public funding for SRDC had been available?	Only smaller projects of high industry priority or essential national collaboration

Match with National Priorities
The Australian Government's National and Rural R&D Priorities are reproduced in Table 11.

Table 11: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The projects in the cluster contribute to National Research Priorities 1 and 3, and Rural Research Priorities 1 to 4. Some contribution would also be made to the two supporting priorities.

Quantification of Benefits

The six projects in the cluster consist of a SRDC contribution to MCVP, a project on rainfall predictability, and four small projects on aspects of climate change strategic planning of R&D. The first two projects are the major investments accounting for over 90 percent of the total investment. Benefits will be quantified for the first two only and they consist of increased profitability from use of seasonal forecasts. The valuation will concentrate on the autumn barrier project (JCU027). The MCVP project has been subject to a comprehensive evaluation in 2007 and the values developed in that evaluation are used here.

CVA0002 – Managing Climate Variability Program (2003-2007)
SRDC has been an investor in the MCVP since its inception in 1992. The investment in this cluster was for the phase of MCVP from 2003 to 2007. This phase was the subject of an evaluation

(Agtrans Research and AGEC Consulting 2007) of the projects. SRDC was one of eight partners in MCVP. Investments by the partners in MCVP together with matching funding from research agencies resulted in over $15 million invested in a wide range of generic projects and projects where benefits were targeted at stakeholders of the partners. The partnership structure was based on partner expectations and judgements that their benefits would be proportional to their input. There was however no attempt to conduct the elaborate accountability estimates that would have been required to confirm an equitable outcome.

The MCVP phase included one project targeted at the sugar industry and others on research of more general applicability to a number of industries. The project JCU20 reviewed a range of forecast systems and confirmed that the approaches being used in the sugar industry were appropriate compared with possible alternative forecasts and taking account of decadal variability. Expenditure of the order of $70,000 was funded by MCVP and was equivalent to about one half of the SRDC contribution to MCVP of $155,000. The SRDC contribution was equivalent to 2.2 percent of the partner contributions to MCVP. Benefits attributable to SRDC were therefore estimated at 2.2 percent of the benefits estimated for MCVP. The time series of benefits from the previous evaluation was used.

JCU027 – Defeating the Autumn Predictability Barrier
The estimates of benefits for the Australian sugar industry will draw on previous evaluations done on the use of the autumn forecast for forecasting SON rainfall for the Herbert River region around Ingham which accounts for about 14 percent of the Australian crop The key assumption was that a forecast in autumn of the likely ENSO state in winter and spring will be of value in a range of decisions made by growers and millers. The benefit to be estimated is additional to benefits from the current well known use of the SOI based on the increase in forecast skill through the latter half of the calendar year. Agtrans Research (2004) has undertaken an evaluation for SRDC of benefits from the use of an SOI forecast. The project was CTA036 which led to a further project CSE004 on yield forecasting for marketers. The estimates in this evaluation are consistent with those used for the evaluation of CTA036. As the JCU027 project did not target industry forecasts for marketing, it was assumed that there were no benefits to be assessed from that source.

Accurate autumn forecasts would enhance forward planning for the cane harvest which starts mid-year and continues for up to five months. In years when a wet SON end of harvest is forecast, industry could implement plans to minimise delays due to wet weather conditions, for example changes applying to a varying extent in different regions include:

- growers could plan to harvest flood prone blocks earlier, particularly younger ratoons to protect them from wet weather harvesting, and also to minimise areas of standover cane,
- growers could plant with less ground cover, or plant into mounds,
- growers could change schedules and practices to ensure they could include a summer crop such as soybeans,
- irrigation schedules could be changed for example to ensure crop establishment, and
- millers could reschedule maintenance programs and start dates for the season to optimise sugar content and to minimise wet weather delays.

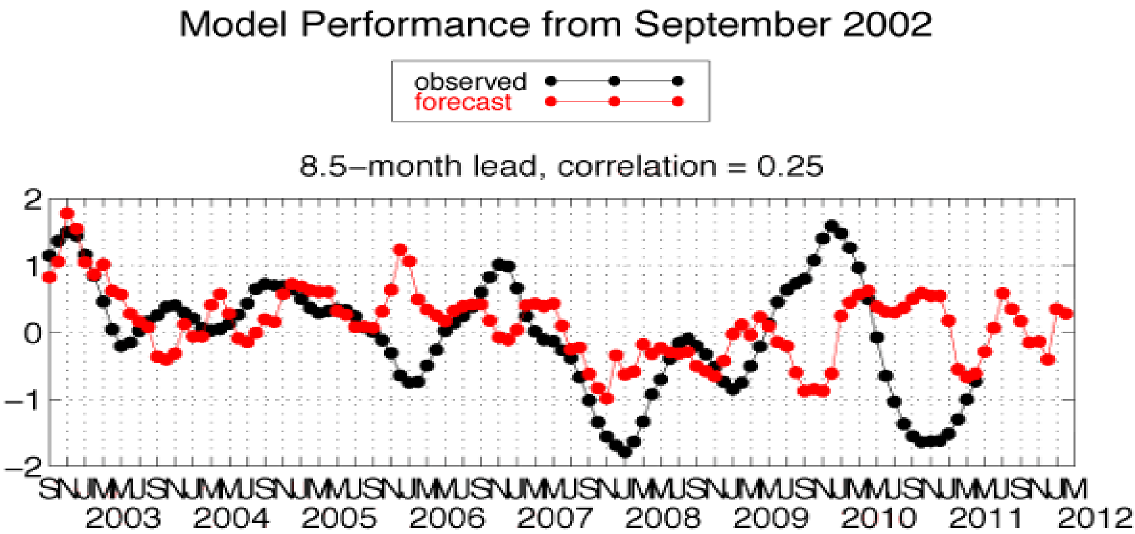
Research in the JCU027 project on the FSU forecast has concentrated on the value on the last point – rescheduling the start date of the harvest.

<u>The autumn forecast</u> - The forecast used was developed by Clarke and Van Gorder (2003) using the current ocean temperature, indices of windstress in the Indo-Pacific region and a measure of the volume of warm water in the equatorial Pacific. Their model predicts ocean temperatures in the Niño 3.4 region of the central Pacific which is an accepted indicator of ENSO. The temperature

anomalies from average are used as an index of El Niño or La Niña conditions, and are highly correlated with the SOI. The model was developed over the period from 1981 to 2001 and has been used operationally since. The period was limited by the availability of data. Comparisons with other models showed that the FSU model was equal or superior (Everingham et al 2008). However the comparison was for forecasts pooled for each month at varying lead times. Therefore this may not be an indicator of superiority in the Australian autumn.

Performance of the FSU model since 2002 is shown in Figure 1 for a lead time of 8.5 months. The observations and forecasts are of Niño 3.4 temperature anomalies. A warm anomaly greater than 0.5 ˚C is indicative of an El Niño situation, and in general reduced rainfall probabilities in the case of eastern Australia. Autumn forecasts of anomalies later in the year are included in Figure 1. Although a limited sample in some respects, the graph suggests reduced performance over the last decade, particularly compared with the graph in Everingham et al 2008 showing that the FSU model up to 2001 was equal or superior to other models.

Figure 1 Performance of the FSU model over the period since 2002



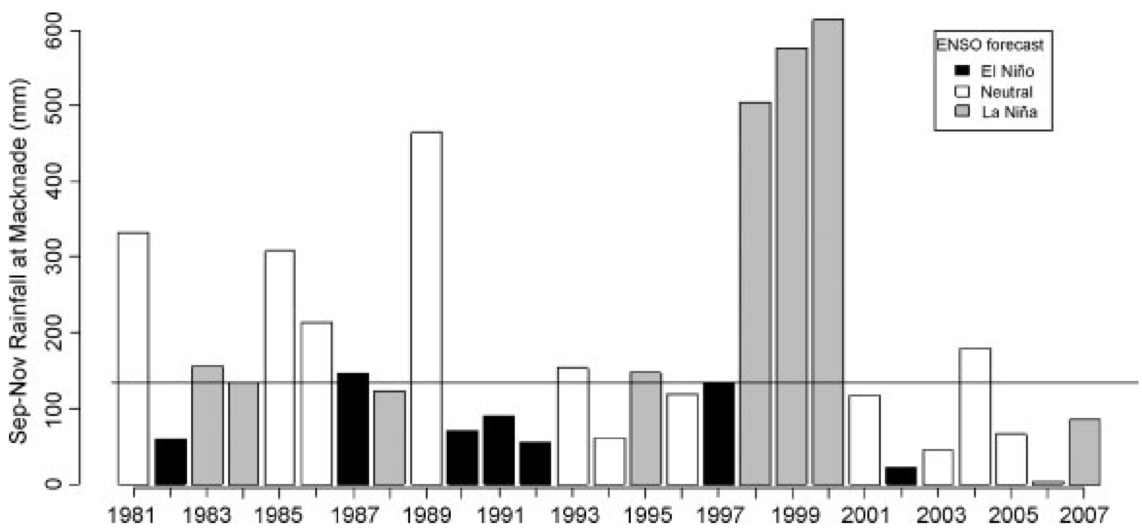
Source: http://ocean.fsu.edu/faculty/clarke/clarkeelnino.html

The hindcast performance of the model in forecasting SON rain at Macknade based on an autumn forecast is shown in Figure 2 and summarised in Table 12. The performance data is clearly of fundamental importance in showing how skilful the forecast is and in shaping user perceptions of how the forecast can be used (skill is the technical term similar to the common usage of accuracy; skill is a measure of the extent to which the model performs better than chance). The forecast methodology and the Macknade example have been published in international climate science journals, a strong endorsement of the approach. In addition the FSU forecast has continuing credibility as one of eight statistical forecasts presented in monthly ENSO advisories (IRI 2011) which also summarises the performance of 15 dynamic models. The latter, whilst more complex are increasingly favoured to the extent that they are not considered as subject to artificial skill and they are more likely to adequately account for decadal and climate change influences. Regression models such as the FSU one have been developed on a training set and need independent data to build confidence in their ongoing skill. (The FSU model was subject to cross validation which aims to account for artificial skill).

In relation to the running of the FSU model since 2002 in independent mode, and as was shown in Figure 1, the performance was summarised as : "*there does seem to be decadal variability in the amount of time one of our crucial predictors leads major El Nino indices. …The lead time since we* *began our forecasts operationally has been much smaller than the previous 20 years and I think that this has contributed enormously to our less than stellar results since we began forecasting operationally"* (personal communication, Alan Clarke, 2011).

A potential user of the forecast would note in Figure 2 the excellent performance from 1990-92 (El Niño years) and from 1998 to 2000 (La Niña years). Less obvious are the six La Niña forecasts when the outcome was rainfall about average or below. These forecasts would have been effectively false alarms, and probably costly if action had been taken in anticipation of a La Nina. Also notable are the three much wetter than average events in the 1980s when the forecast was for neutral ENSO conditions. Table 12 shows more clearly that over the period analysed the El Niño forecast performs much better than the La Niña. Only one third of the La Niña forecasts were in the 'much above' category, a proportion not much different to chance.

Figure 2: Rainfall Forecasts



In Figure 2, the heights of the bars represent total SON rainfall measured at the Herbert rainfall station (Macknade) between the years 1981 and 2007. The horizontal line is located at 134 mm which represents the SON median rainfall amount. The bars are shaded according to the SON ENSO forecast issued by Clarke and Van Gorder (2003) at the end of January (reproduced from Everingham et al 2011).

Table 12: Performance of End of January FSU Forecasts of SON Rainfall at Macknade

SON Rainfall in Relation to the Median	**FSU ENSO Forecast made end of January (numbers in bold are of correct forecasts)**			**Total**
	El Niño	Neutral	La Niña	
Much greater than	0	4	**3**	7
Near Median	2	**4**	4	10
Much less than	**5**	3	2	10
Total	7	11	9	27

Source: Summarised from Figure 2 (from Everingham et al 2011)

The results in Table 12 contrast with those reported for a SON rainfall index for stations around Mourilyan (Everingham et al 2008). For an analysis up to 2004, six out of seven La Niña forecasts made in January had an outcome of above average spring rainfall. The contrast simply reinforces that results will vary spatially and will depend on the length and period of record. Further, the FSU forecast was developed on data to 2002.

Benefits in the Herbert region - Clarke et al (2010) developed a method to translate the FSU forecast of ENSO 3.4 to a forecast of SON rainfall on Australia's north east coast. Tests showed some skill particularly in the north. The method was used by Everingham et al (2011) to estimate possible benefits for the Herbert region from changing the start of harvest to optimise cane value as determined by sugar content which determines the value of the harvested cane. The method took harvesting delays from rainfall events into account. In a further analysis by Osborne et al (2011), soil type was shown to be an important factor in determining the additional profit.

Sugar content varies over the harvesting season in a pattern related to the ENSO state. For example the optimal start date for 1997 (forecast of an El Niño) was two weeks later than the optimal for 1998 (forecast of a La Niña). Everingham showed the average value of the strategy based on the autumn forecast was about one half a million dollars annually, a small gain relative to the value of the crop of about $150 m in the Herbert region. The economic analysis did have some limitations including the limited benefit under the assumptions of a perfect forecast. However, what were clear were the differences in the optimal start date between El Niño and La Niña years.

By interviewing individual farmers, Antony et al (2002) estimated that improved management practice influenced by seasonal climate forecasts in the very wet La Niña year of 1998 would have saved more than $1.7 million by planning for wet conditions, and by harvesting during wet weather with greater urgency. That estimate was based on using an SOI forecast mid-year. The benefits from the autumn forecast will mostly be additional to those available with the now well known SOI.

There is likely to be reluctance by the industry to change the harvest date unless there is increased confidence in the skill of the autumn forecast. For this evaluation it is assumed that the potential benefits from using the autumn forecast need to be halved to allow for a conservative reaction by industry to changing the harvesting season and other measures.

Potential Benefits in other Australian Sugar-producing Regions. Potential skill of the autumn forecast has been analysed for northern NSW (Everingham et al 2007). The January forecast of rainfall at three locations in the sugar cane producing areas appeared to be particularly useful for a La Niña forecast of rainfall over the harvest season, but not for an El Niño one, as was the case in the Herbert. This pattern is not unexpected and is consistent with knowledge of the differing spatial and seasonal impacts of ENSO events. The analysis by Everingham et al (2008) of the pattern for seven rainfall indices covering regions from Mossman to Northern NSW showed that the autumn forecasts had potential in all districts. There were variations as to whether the El Niño or La Niña forecast was more skilful and there were some districts where the forecasts were not quite as skilful, particularly Mackay. Generally the January forecast was superior to the February and March forecasts. There was a potential problem for user confidence and confusion in that in 5 of 24 years analysed the forecast changed over the January to March period. In 1986 the forecast over those three months would have gone from neutral to El Niño to neutral. There is also the complex question of joint and sequential use of the autumn forecast with a later mid-year forecast based on the SOI which could be conflicting, or at least confusing.

Published studies referred to previously indicated potential benefits:

- for the FSU autumn forecast for the Herbert, $0.5 million annually from changing to an optimum harvest time in relation to the sugar content, and

- the use of the SOI for the Herbert to reduce losses by $1.7 million in the exceptional wet of 1998 from saving plantings that would have failed, from reducing soil compaction and other benefits.

The benefits of the forecast have not been estimated in other regions. There do not appear to be major differences in skill. The impacts will differ and the potential to use an autumn forecast for a wider range of decisions will vary. For example irrigation scheduling could change for Mackay and Bundaberg growers. A simple approach of scaling up benefits will be used in this analysis based on the Herbert accounting for 15 percent of Australian production.

Adoption – Cane growers have been rapid adopters of the seasonal forecasts that were widely publicised during the 1990s. The evaluation of MCVP (Agtrans Research and AGEC Consulting 2007) quoted surveys of adoption as measured by the extent to which Australian farmers generally took seasonal forecasts into account in their farm decisions. By 2002 a little over a decade after they were made routinely available, sugar and cotton were the only major Australian rural industries with over 60 percent adoption (by the simple measure of taking forecasts into account). An analysis of the level of industry adoption showed as expected that the level of skill of SOI forecasts depended on the forecast skill in the regions where the industry was located. Also the high levels achieved should also be attributed to the intensive campaign in Queensland particularly during the 1990s which included a number of drought years. However in the La Niña year of 1998, actual adoption by a sample of cane farmers in the Herbert in terms of using a specific SOI forecast to change farm practices was reported to be only about 10 percent (Antony et al 2002). But for many growers, that would have been their first experience of a major La Niña forecast.

Given the mid year forecast of the exceptional La Niña of 2010, there would now be much higher awareness of at least the potential value of an autumn forecast. But in the absence of a concerted industry-wide campaign to promote the autumn FSU forecast, widespread adoption could not be assumed. More experience in its use may increase confidence in its value. Figures 1 and 2 cast some doubt on its recent skill which is reinforced by the comment of *"less than stellar recent performance*" from the FSU forecast developer. Given the probabilistic nature of seasonal forecasts, confidence can only develop slowly and to some extent randomly. Individual events add little information and may well detract. Notwithstanding that, and as an indicator of the level of demand, the project achieved widespread publicity in early 2007 from a La Niña forecast prior to the decision to proceed to Stage 2, (JCU027 Milestone 3 report); for example "*In March 2007, the newly adapted model made history when it predicted a La Niña in the second half of the year".* In the event, there was a late and mild La Niña but few cane growing areas experienced problems from an about average spring season except in northern NSW. The forecast therefore faces two risks; first on the ENSO state and then one on the distribution of rainfall for a given ENSO state.

The autumn forecast now competes with many other readily available sources of information on atmospheric and oceanic indicators of ENSO. Interpretation is rarely straightforward. The 2010 La Niña was exceptional as measured by the extreme SOI from September 2010 to April 2011 but less so if measured by ocean temperatures. The Bureau of Meteorology has a monthly summary currently of eight ocean or coupled ocean/atmosphere climate models that take into account complex physical ocean processes (http://reg.bom.gov.au/climate/ahead/ENSO-summary.shtml). They no longer monitor statistical models such as the FSU forecast. In relation to ENSO forecasts generally, Townsville researchers Halide and Ridd (2008) analysed the performance of a very simple statistical model in predicting the future monthly Niño 3.4 index using only past monthly Nino 3.4 data. They concluded that even complicated ENSO models do not significantly outperform very simple ENSO models (the FSU model was not included, presumably because the period of record was too short). No model showed superior skill to a random forecast when the lead time was seven months.

Contact with a number of industry members from growing, harvesting and milling sectors did not suggest that there had been any sustained or general use of the autumn FSU forecasts (see Acknowledgements Section for those contacted by telephone and email). Despite papers at industry conferences inviting more general industry interest, the approach does not appear to be routinely promoted apart from efforts in northern NSW (Everingham et al 2007) and to a lesser extent around Tully. The record rains in the summer of 2010/11 extended to northern NSW. McGuire (2011) in the Condong newsletter for growers quotes problems from wet fields including in land preparation, planting, fertilising, weed control and harvesting. The newsletter further states that forewarned is forearmed and growers should follow a reliable seasonal forecast recognising that the 2010/11 La Nina was correctly predicted in mid 2010. Sources of ENSO forecasts are listed but the autumn forecast was not included.

The MCVP with SRDC as a partner sponsors a program of selected farmers in the role of Climate Champions (Climatekelpie 2011) to strengthen communication between farmers and climate scientists. There are two canegrowers in the program, one from Ingham and one from the Tweed, who were familiar with a range of forecasting tools but although aware in general terms of the autumn forecast, they had not made use of it. Overall and taking into account the Antony et al (2002) estimate that 10 percent of Herbert growers acted on the La Niña forecast in 1998, a reduced maximum level is assumed for the industry for the autumn forecast. A level of 5 percent is assumed to be reached over the period from 2010 to 2015 and then reduce to zero by 2020. The autumn statistical forecast is likely to be displaced and made redundant by dynamic forecasts which better account for climate change and decadal variability.

Summary of Assumptions
A summary of the key assumptions made is shown in Table 13.

Table 13: Summary of Assumptions

Variable	Assumption	Source
MCVP Benefits Proportion attributable to SRDC Investment	2.2%	Benefits proportional to the SRDC investment of 2.2% of the total as estimated by Agtrans Research and AGEC Consulting (2007)
JCU027 Benefits Herbert Region Theoretical benefit (changing harvest start) Factor (for conservative industry response)	 \$0.5 m pa 0.5	 Everingham et al (2009) Author estimate
Australian Sugar Industry Benefit	Scaling up based on Herbert Region accounting for 15%	Author estimate based on mill production data
Adoption Pattern (% of Industry) Start Year (0%) Maximum (5%) End Year (0%)	 2010 2015 2020	 Author estimates consistent with Antony et al (2002) but level and period reduced to account for the limited promotion of the FSU-based autumn forecasts.

Results
All past costs and benefits were expressed in 2010/11 dollar terms using the CPI. All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high 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 (2008/09) to the final year of benefits assumed.

Investment criteria were estimated for both total investment and for the SRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. As reported in Tables 14 and 15, the investment criteria were only positive for an investment period of 25 years or more.

Table 14: Investment Criteria for Total Investment for Each Benefit Period
(discount rate 5%)

	Years from last year of investment (2008/09)						
Criterion	**0**	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.06	0.43	0.80	0.94	1.05	1.13	1.19
Present value of costs ($m)	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Net present value ($m)	-1.05	-0.69	-0.31	-0.18	-0.07	0.01	0.07
Benefit–cost ratio	0.06	0.38	0.72	0.84	0.94	1.01	1.06
Internal rate of return (%)	neg	neg	0.3	2.8	4.3	5.1	5.5

Table 15: Investment Criteria for SRDC Investment for Each Benefit Period
(discount rate 5%)

	Years from last year of investment (2008/09)						
Criterion	**0**	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.03	0.17	0.33	0.38	0.42	0.46	0.48
Present value of costs ($m)	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Net present value ($m)	-0.42	-0.28	-0.12	-0.07	-0.03	0.01	0.03
Benefit–cost ratio	0.06	0.38	0.72	0.85	0.94	1.02	1.07
Internal rate of return (%)	neg	neg	0.3	2.8	4.3	5.1	5.5

There are two benefits valued in the analysis. Table 16 shows the estimates of the relative contribution from each source.

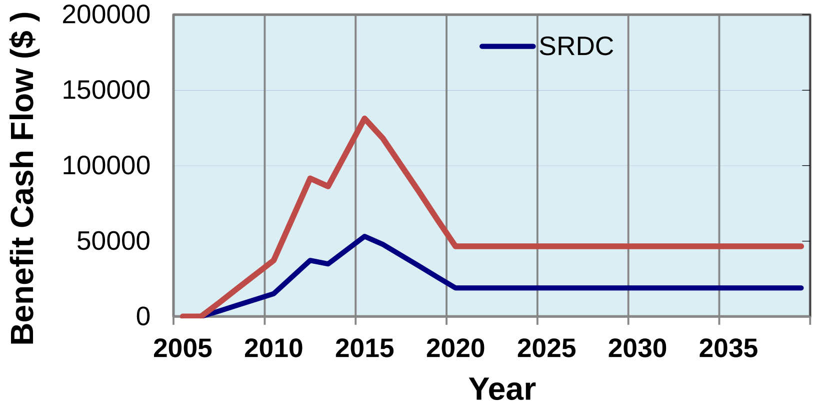
Table 16: Contribution of Source of Benefits to Present Value of Benefits

	Contribution to Benefits (Present Value)	
Source of Benefit	**Value ($m)**	**Share (%)**
Managing Climate Variability Program (CVA002)	0.83	69
Defeating the Autumn Predictability Barrier (JCU027)	0.37	31
Total	1.2	100

The quantified benefits address the Rural Research Priorities 1 to 4.

The annual net benefit undiscounted cash flows for both total investment and SRDC investment for the 30 year period from the year of first investment are shown in Figure 3.

Figure 3: Annual Cash Flow of Benefits



Sensitivity Analyses
Table 17 presents the sensitivity of the results to the discount rate. The sensitivity analysis was performed with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 17: Sensitivity to Discount Rate
(Total investment, 30 years)

Criterion	**Discount rate**		
	0%	5% (base)	10%
Present value of benefits ($m)	1.83	1.19	0.89
Present value of costs ($m)	0.92	1.12	1.35
Net present value ($m)	0.90	0.07	-0.46
Benefit-cost ratio	1.98	1.06	0.66

Sensitivities based on halving and doubling the estimated benefits are shown in Table 18.

Table 18: Sensitivity to Halving and Doubling Benefits
(Total investment, 30 years)

Criterion	**Benefits**		
	Halved	Base	Doubled
Present value of benefits ($m)	0.59	1.19	2.37
Present value of costs ($m)	1.12	1.12	1.12
Net present value ($m)	-0.53	0.07	1.25
Benefit-cost ratio	0.53	1.06	2.12
Internal rate of return (%)	neg	5.5	13.6

Confidence Rating

The results produced are highly dependent on the assumptions made, many 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 19). 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 19: Confidence in Analysis of the Climate Cluster

Coverage of Benefits	Confidence in Assumptions
Medium	Medium

Conclusions

The analysis indicates that for the two projects evaluated the investment is only slightly ahead of a break-even level. The total investment of $1.12 million (present value terms) has been estimated to produce gross benefits of $1.19 million (present value terms) providing a net present value of $0.07 million and a benefit cost ratio of 1.06 to 1 (over 30 years, using a 5% discount rate).

There were small projects on climate change not included on the basis that they were essentially strategic projects concentrating on developing a new research area where the benefits are long term and subject to a high level of uncertainty.

Considering first the benefits from the investment in the national program, MCVP, the benefits were simply estimated on a proportional basis from the SRDC contribution of 2.2 percent. The overall MCVP evaluation resulted in a benefit cost ratio of 1.7 to one (6% discount rate). The period evaluated was for investments over the period from 2003 to 2007, after the period of rapid adoption in earlier phases of the program dating back to the early 1990s. Some decline in performance was therefore seen as possible particularly as there were some concerns based on perceptions of the value of statistical forecasts based on the SOI. More strategic investments by MCVP in dynamical models for seasonal forecasting had yet to show superiority.

For the second project, the investment by SRDC in the autumn barrier project was not viewed in this evaluation as likely to result in major benefits. The two related issues were:

- likely perceptions of the limited skill of the FSU forecast used, particularly over the last decade, and
- the lack of promotion to increase industry awareness and adoption.

However, from an ex ante perspective on the decision to invest, the investment would have been viewed as likely to result in substantial benefits. There was every indication that the FSU forecast appeared to be very promising in meeting the industry demand for a better long lead forecast on early summer rain disrupting the harvest.

The final report for the project did recommend more widespread promotion but a judgement may have been made that the likely skill and potential adoption would not warrant further investment.

An alternative investment would be in interpreting the performance and increasing industry awareness of the wider range of long range forecasts now available.

The FSU forecast had been published in leading journals and had credibility. But if a decision was made now on investing in a long lead forecast, it is likely that several candidates would have been considered, and a less risky approach adopted. Information is readily available, for example on the performance of the Bureau of Meteorology POAMA model. Grey and Souness (2011) in reviewing performance of climate models in forecasting the exceptional La Nina of 2010 noted that three models including the European Centre for Medium-Range Weather Forecasts were "*the first models to pick La Nina pretty right in April, some four months out*". Stone (2011) whilst noting the improved performance of dynamical climate models considered that the long-standing Bureau and SOI-based statistical forecasts remained as the key tools in north-eastern Australia. However, they usually only forecast major ENSO developments a season ahead and from mid-year.

Events such as the exceptional La Niña of 2010 coupled with increasing concerns on the impacts of climate change will continue to increase sugar industry demand for improved information for climate risk management. Improved longer lead forecasts of ENSO remain one of the highest priorities for climate research globally. Determining the value of ongoing efforts to forecast across the autumn barrier is likely to remain an industry priority to assist in adapting to climate change.

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Appendix 2: An Economic Analysis of SRDC Investment in the "Implementing Integrated Farming Systems to Improve Productivity and Profitability" Cluster

Background

The Sugar Yield Decline Joint Venture (SYDJV) was established in 1993 as a joint venture between SRDC, BSES, CSIRO, and the Queensland Government Departments of Primary Industries and Natural Resources. It was funded in response to concerns that since the 1970's there had been a plateau in productivity (sugar yield per harvested hectare) in the sugarcane industry. The SYDJV consisted of a multi-disciplinary research and development program that sought to identify the causes of the yield decline, and develop solutions to the problem. Prior to this there had been efforts to tackle the issue, particularly from BSES, however these efforts were not multi-disciplinary and focused on root pathogens alone.

Phase 1 of the SYDJV ran from 1993 to 1999 and focused on identifying and understanding the problems contributing to yield decline. It concluded that poor soil health was a major contributor to the problem and that it had largely been due to land being under long-term sugar monoculture. Phase 2 ran from 2000 to 2004 and focused on identifying how the soil deficiencies and poor soil health could be improved. A series of farming practices were identified that when practiced either individually or together can lead to improvements in soil health and therefore yield increases. The practices include legume breaks, controlled traffic farming and minimum/zero tillage. Together these practices were integrated to form a 'new farming system'.

A number of extension activities to demonstrate and promote the recommended new farming system were integrated into Phase 2 of the SYDJV, however there was still significant work needed to further encourage adoption of the new farming system and its individual components. A number of projects were funded by SRDC that sought to continue to develop the practices of the new farming system for individual regions and soil types, as well as demonstrate to growers that the new farming system is applicable to their district. In addition, further extension efforts were funded as part of these projects.

A number of projects have been included in this cluster for analysis. A significant number of these projects are Grower Group projects, where groups of growers were directly involved in developing and trialling the practices on their farms. In addition to projects aimed at further developing and extending the outputs of the SYDJV, there are some other projects included in the cluster that also take a systems approach to issues in the sugar industry.

The Cluster

Projects

Table 1 presents the details for each of the 13 projects included in the farming systems cluster.

Table 1: Summary of Project Details

Project Number	Project Title	Other Details
NSC005	Implementing an integrated sugar system in NSW	Organisation: NSW Sugar Milling Cooperative Period: July 2003 to June 2006 Principal Investigator: Richard Beattie
BSS269	A new cropping system for the Central District	Organisation: BSES Ltd Period: July 2004 to October 2008 Principal Investigators: Chris Aylward and Errol Sander
CSE012	Adopting systems approaches to water and nutrient management for future cane production in the Burdekin	Organisation: CSIRO Sustainable Ecosystems Period: July 2004 to May 2008 Principal Investigators: Peter Thorburn
BSS286	Improved sugar-cane farming systems	Organisation: BSES Ltd Period: July 2005 to August 2008 Principal Investigators: Alan Garside and Mike Bell
CSE014	Increased CCS, cane yield and water use efficiency by exploiting interactions between genetics and management	Organisation: CSIRO Sustainable Ecosystems and CSIRO Plant Industries Period: July 2005 to August 2009 Principal Investigator: Geoff Inman-Bamber
WAA003	Evaluation and implementation of modified farming systems in the Ord River Irrigation Area	Organisation: Department of Agriculture and Food Western Australia Period: July 2005 to August 2009 Principal Investigators: Joe Sherrard, Bill Webb and Paul Mock
GGP004	Implementation of improved sugarcane farming systems in the Clare area of the Burdekin District	Organisation: Mulgrave Integrated Group Period: July 2005 to May 2007 Principal Investigator: Paul Hatch
GGP007	Controlled traffic farming systems for the North Coast Grower Group	Organisation: Mackay Area Productivity Services (for North Coast Grower Group) Period: July 2005 to February 2008 Principal Investigator: John Fox
GGP008	Overcoming barriers to controlled traffic adoption – managing traffic during conversion to controlled traffic farming systems	Organisation: Plane Creek Sustainable Farmers Inc Period: July 2005 to May 2007 Principal Investigator: Brian Stevens
GGP012	Researching soil health and economics of two farming systems in the Herbert River District	Organisation: New Farming Initiative Group Period: September 2006 to October 2008 Principal Investigator: Michael Waring
GGP020	Beach Sand to Black Clay – adapting technology and best	Organisation: Mackay Area Productivity Services (for Homebush Innovative

	practice for Homebush farming conditions	Farmers) Period: October 2006 to September 2008 Principal Investigator: Tony Bugeja
GGP022	Optimising benefits of GPS integration into Controlled Traffic Farming (CTF) System	Organisation: Deguara Harvesting Period: July 2006 to February 2008 Principal Investigator: Gerry Deguara
GGP026	Implementation of a 2 metre farming system in Far North Queensland (FNQ)	Organisation: Singh Harvesting Group Period: September 2006 to December 2008 Principal Investigator: Rajinder Singh

Project Objectives

Table 2 presents the objectives for each of the projects included in the cluster.

Table 2: Description of Project Objectives

Project Number	Objectives
NSC005 Integrated system NSW	This project aims to increase the profitability and long-term sustainability of the NSW sugar industry which is moving towards utilising the whole-of-cane crop for electricity generation and sugar. This move will require marked changes to the farming system, harvesting, transport and mill operations. Specific objectives are to: • Assess and demonstrate the viability of alternative cropping systems for the NSW sugar industry that incorporate the principles of controlled traffic/permanent bed systems bringing about a reduction in crop damage during wet weather harvesting and under the more trafficked field conditions that will occur with whole-of-crop harvesting. • Implement a sustainable farming system compatible with the NSW Sugar Milling Cooperative (NSWSMC) cogeneration project to maximise sugar and energy production. • Identify and extend best management practice for cropping, harvesting and transport systems in the NSW industry compatible with sugar and energy production.
BSS269 Cropping system Central District	The project aims to increase productivity, economic viability, sustainability and environmental responsibility of growers in the Central District through adoption of cropping system changes as recommended by the Sugarcane Yield Decline Joint Venture (SYDJV). This will be achieved by: • Facilitating establishment of New Cropping System trials with both existing and new productivity groups, by providing equipment and technical guidance. • Developing best practice guidelines for dual-row cropping systems (weed control, irrigation, grub control, variety selection and nutrition). • Developing ‘cost of production comparison models’ and a ‘system changeover kit’ to facilitate decision making and system change. • Monitoring and evaluating the environmental performance of the new system in terms of runoff water quality. • Targeting 1,000 ha planted under the new cropping system by 2008 (in the Central District). • Conduct state-wide extension in year 4.

CSE012 Water and nutrient management in Burdekin	The main objectives of the project are to: • Develop a range of proven farm management options for improved water, nutrient and crop management that will maintain or increase profitability, whilst controlling rising water tables, reducing the risk of irrigation-induced salinity and improving off-farm water quality. • Carry out assessments of the economic feasibility of the proven farm management options within the context of future water pricing and water allocation scenarios in the Lower Burdekin. • Establish industry reference sites with grower participation to provide robust benchmarks and to assist in the dissemination of project learnings. • Broaden and strengthen industry-led innovation and change processes (e.g. Cane Productivity Initiative) to promote best management practice in irrigation. • Synthesise and package project results and learnings derived from the Cane Productivity Initiative to extend improved water and nutrient management options to other districts.
BSS286 Improved sugar-cane farming systems	• Promote further development and adoption of the new farming system developed by the SYDJV. • Provide technical support to related projects and personnel, such as Future Cane, Back on Track, New Farming Systems for Central Queensland, Cane Grub Management in New Sugarcane Farming Systems. • Coordinate the activities of the various farming system projects being supported by SRDC, BSES, DPI&F and DAFF. • Continue research activities to fill knowledge gaps necessary for better adoption of the new farming system. • Continue large-scale, commercially oriented, farming-system experiments now under way in the SYDJV.
CSE014 Genetics x management	To increase sugar yield per hectare through increased CCS and cane yield by capitalising on better understanding of the interactions between genetics and management. Specifically: • To better understand the interactions between sugarcane genetics (gene expression) and environment (including management) with respect to sugar accumulation (which is a current gap in knowledge of sugarcane physiology). • To improve variety choice and cane management for increased CCS and cane yield. • To determine improved selection systems to identify elite varieties with desired characteristics. • To develop novel irrigation strategies to prevent lodging and maximise CCS. • To promote better management practice for maximising sugar yield and reducing water use.
WAA003 Modified farming systems in the ORIA	• Introduce to the Ord River Irrigation Area (ORIA) modified farming systems as identified by the SYDJV Project. • In partnership with industry, establish and assess these systems with a view to adoption. • Improve environmental management to minimise off-farm impact with benefit to the wider community. • Systems to assess to include:

	○ Fallow management including use of legumes ○ Minimum/zero tillage planting using a double disc opener planter ○ Green cane harvesting and green cane trash blanketing ○ Diversifying the income stream by selling baled cane trash or legumes for fodder and/or mulch
GGP004 Clare – Burdekin district	The project seeks to achieve: • Improved sustainability and profitability for (initially) group members and secondly for the wider industry at a district level. • Better adoption of best management practices from SYDJV and more faith in research. • Reduced cane loss and dirt at harvest. • To share the burden of trial work amongst a group and then communicate results honestly and openly, including failures as well as successes.
GGP007 CTF North Coast Grower Group	• The project seeks to implement and trial farming systems that incorporate the practices of controlled traffic, minimum tillage and crop rotations. • The North Coast Grower Group will combine their resources and efforts to develop and implement a new farming system that utilises the bulk of their existing equipment, improves the management of their natural resources and reduces their cost of production. • The group will combine the results of their trials to identify a farming system that is sufficiently robust to handle the variations experienced in the North Coast (seasonal conditions, soil types, farm layouts and variable equipment) and improve the financial sustainability of the group members.
GGP008 Managing traffic during CTF conversion	• To overcome a key practical barrier preventing many growers and harvesting contractors from converting to controlled traffic farming systems (CTFS) and overcoming problems incurred by growers presently converting to CTFS.
GGP012 Soil health and economics – Herbert River district	This project seeks to achieve: • Group collaboration – this will aid the acquisition of the necessary infrastructure and enable the full utilisation of existing equipment and knowledge resources. • Comparison of soil health of the two farming systems. These soil tests have not previously been undertaken in the Herbert and will provide a benchmark of current soil health. The test includes physical, biological and chemical components. • Determine which aspects of the 1.9 metre dual row farming system suit the Herbert district. • Demonstrate the economics of two farming systems (regional standard and 1.9 m dual row/break crop fallow). • Group skills will be developed through shared knowledge, utilising the expertise of consultants, building organisation skills and through first hand participation.
GGP020 Beach Sand to Black Clay	• The project aims to adapt latest technology and best practice to suit the soil types found in the Homebush/Sunnyside district, and evaluate the cost and benefit of adopting these technologies and practices. • The project will: ○ Refine and assess planting systems to address a number of issues ○ Conduct a cost-benefit analysis on the adoption of available

	technology and best practice o Conduct a 'pre-plant' fertiliser trial in conjunction with CSR and IAR o Refine soybean planting methods o Establish and monitor soybean variety trials in conjunction with DPI&F o Refine nitrogen applications to plantcane after soybean crops o Increase grower's capacity to produce robust and sustainable cane crops • The research, trials and evaluations conducted in this project will help the growers adapt new technologies and farming practices to a very variable farming environment. • The group's skills and knowledge will be developed through participation in the planning, design, establishment and evaluation of the trials and trial results. • Additionally, the group will participate in a number of other capacity building activities such as seminars/workshops, regular shed meetings and farm walks, GIVE days, and training as needed. • The group will also work closely with other grower groups in the industry to share information and resources.
GGP022 GPS Integration to CTFS	• Maximise CTF systems by improving haulout (tractor/trailer) operation to ensure trailer unit travels on compacted interspace from immediate point of block entry; and maintains this path until trailer unit exits the block (a 40 metre delay occurs between when the tractor enter/exits the block and when the trailer unit follows in a straight line; meaning trailer unit is travelling across beds before aligning directly behind the tractor). • Project seeks to design, construct and trial innovative mechanics allowing the trailer unit to be steered independently of the tractor; thereby allowing the haulout unit to travel on compacted interspace from immediate point of entry and maintain this path until point of exit. • Skills developed by interacting with those external resources engaged to participate in project activities.
GGP026 2m farming system in FNQ	• The aim of this project is to implement harvester modifications in a manner which allows manufacturers to incorporate them during production. This would allow transition from 1.5m to 2.0m at low cost. • In 2006 group members in the Arriga area of Tableland Mill will trial plantings on 2.0m. • Growers will compare the 2.0 metre system with the conventional system. • Financial ($) and production (t/ha) data will be collated to compare the productivity and profitability of the two systems.

Project Investment

Table 3 shows the annual investment by project for SRDC. Table 4 shows the annual investment by project for other investors (mostly in-kind resources from research organisations and industry). Table 5 summarises the total annual investment.

Table 3: Investment by Project by SRDC (nominal $)

Project Number	**Year ending June**							
	2004	2005	2006	2007	2008	2009	2010	Total
NSC005	111,000	76,000	76,000	50,000	25,000	25,000	0	363,000
BSS269	0	150,000	104,253	116,014	47,756	71,632	0	489,655
CSE012	0	220,343	218,920	225,514	87,908	82,908	48,954	884,547
BSS286	0	0	469,644	562,199	457,947	219,813	104,000	1,813,603
CSE014	0	0	202,041	313,815	261,788	140,110	35,000	952,754
WAA003	0	0	65,810	98,633	55,570	55,570	0	275,583
GGP004	0	0	36,000	1,000	3,000	0	0	40,000
GGP007	0	0	40,000	19,000	18,000	0	0	77,000
GGP008	0	0	22,000	16,000	0	0	0	38,000
GGP012	0	0	0	25,700	19,700	6,000	0	51,400
GGP020	0	0	0	30,000	36,000	4,000	0	70,000
GGP022	0	0	0	20,000	5,000	0	0	25,000
GGP026	0	0	0	18,000	27,000	8,000	0	53,000
Total	111,000	446,343	1,234,668	1,495,875	1,044,669	613,033	187,954	5,133,542

Table 4: Investment by Project by Others (nominal $)

Project Number	**Year ending June**							
	2004	2005	2006	2007	2008	2009	2010	Total
NSC005	82,562	56,529	56,529	37,190	18,595	8,595	0	270,000
BSS269	0	433,771	301,479	335,490	138,101	207,146	0	1,415,986
CSE012	0	810,460	805,226	829,480	323,341	304,950	180,061	3,253,520
BSS286	0	0	1,136,968	1,361,035	1,108,650	532,148	251,775	4,390,577
CSE014	0	0	432,311	671,475	560,152	299,796	74,890	2,038,624
WAA003	0	0	277,986	416,632	234,731	234,731	0	1,164,081
GGP004	0	0	44,500	750	0	0	0	45,300
GGP007	0	0	69,000	0	0	0	0	69,000
GGP008	0	0	21,400	4,000	0	0	0	25,400
GGP012	0	0	0	25,000	28,400	7,800	0	61,200
GGP020	0	0	0	103,500	72,800	600	0	176,900
GGP022	0	0	0	0	32,750	0	0	32,750
GGP026	0	0	0	62,000	48,000	0	0	110,000
Total	82,562	1,300,760	3,145,449	3,846,553	2,565,521	1,605,766	506,727	13,053,338

Table 5: Summary of Annual Investment by SRDC and Others (nominal $)

Year ending June	SRDC	Other	Total
2004	111,000	82,562	193,562
2005	446,343	1,300,760	1,747,103
2006	1,234,668	3,145,449	4,380,117
2007	1,495,875	3,846,553	5,342,428
2008	1,044,669	2,565,521	3,610,190
2009	613,033	1,605,766	2,218,799
2010	187,954	506,727	694,681
Total	5,133,542	13,053,338	19,651,788

Outputs

Table 6 provides a brief summary of the activities and outputs for each of the projects.

Table 6: Summary of Project Activities and Outputs

Project	Activities and Outputs
NSC005 Integrated system NSW	• Trials were established in all 3 milling areas in NSW to compare various controlled traffic row spacing with conventional configurations. • Comparisons were also made in the trials between zero-till planting, controlled traffic and legume fallowing. • There was a concerted extension effort to promote the adoption of farming systems incorporating the use of GPS with machinery modifications developed to suit the new system. There were two field days held with more than 200 people participating at each field day. • It was found that the adoption of controlled traffic cropping systems does not result in loss of productivity, and that dual row configuration is the optimal option for the region.
BSS269 Cropping system Central District	• On-farm trials, including 14 row-spacing trials were established. All trials were conducted in various Central mill districts. The trials showed that row spacing has little or no effect on yield. • Three legume fallow trials were conducted and it was concluded that growing a fallow soybean crop can reduce the total cane-growing cost by $50-80 per ha (due to nitrogen savings). • Water quality trials were conducted at six sites and focused on differences in nitrogen, phosphorus and turbidity under different farming systems. • Cane grub control management strategies that were promoted in New Farming Systems (NFS) were trialled. These trials were coordinated with SRDC project BSS266 and results were reported as part of that project. • An 8-page booklet titled “Growing soybeans in a cane rotation” was published in 2005 to aid growers in the growing of fallow legume crops. • A system ‘change over kit’ of 6 fact sheets was published in a special edition of the BSES Bulletin (it was a ‘how to’ kit not a

	'why to' kit). • An extension program was established, with 43 group extension activities conducted such as shed meetings, bus tours, field days and information days across all districts of the Central cane-growing region including the Proserpine, Mackay and Sarina districts. • In the fourth year of the project the NFS project team had completed a state-wide extension program where they met with all of the extension officers and agronomists from BSES, as well as staff from agencies such as QDPI&F FutureCane and the productivity service agencies. • A machinery loan service was established to allow growers to trial the system with limited or no investment in new equipment. The equipment available included a dual-row double-disc-opener cane planter, soybean planter, bedformer, ripper, elevator extensions, and a transport trailer. • 13 grower surveys were completed during the life of the project in order to give the project team an understanding of the practices being undertaken by the growers. For the growers of the NFS Group this included an initial baseline survey at the start of the project, a mid project evaluation (2006), a final project baseline survey (May 2008), and grower practices and areas of land planted surveys (May 2006, November 2006, June 2007). For all growers in the Mackay Sugar area the surveys were a mid-project evaluation (2006), a survey of growers' awareness of the project (Feb 2007), a survey of area planted to CT systems (Dec 2008) and a comprehensive survey of grower practices that was conducted during shed meetings held in Feb-Mar of 2006, 2007 and 2008. • Of interest from the surveys was that 75% of growers felt that the system was working well on their farm and all growers were still making changes to the system. • The surveys found that most growers were aware of the project and saw the benefits of it.
CSE012 Water and nutrient management in Burdekin	• Water, nitrogen and herbicide losses were measured at three sites in different parts of the Burdekin region, covering a range of soil types and irrigation management systems. • The data were used to parameterise the APSIM-Sugarcane cropping systems model and develop complete water and N balances for each of the three crops measured at the site. The model was then used to predict 'missing' data that was not captured due to heavy rainfall or equipment malfunction. • It was found that N losses in runoff were relatively small, and that more N was lost via deep drainage than runoff at all sites. This was consistent with known groundwater nitrate contamination issues in the region. Herbicide losses were similar to those measured previously. • Nine farms were used to demonstrate the water quality and productivity benefits of various farm management practices. • To assess water quality and economic benefits of different farm management practices, relevant practices were grouped into Classes from A to E, following the 'A to D' framework adopted in the

	Great Barrier Reef (GBR) wide water quality planning processes. The practices fell into the areas of irrigation practices, nutrient and fertiliser management, herbicide/pesticide management, and sediment management.
	• Participative workshops involving farmers, extension staff and a range of other stakeholders in the region were held in order to group the practices into the A to E classes. Classes E to C are commonly practiced in the region; Class B is similar to the currently promoted and industry supported 'best practice'; Class A is possible future best practice currently under experimental investigation.
	• Long term simulations of each management class were used to provide a quantitative evaluation of their effectiveness for delivering water quality benefits in the region.
	• The predictions were then used to examine the relationship between adoption of different management classes in the region, and resulting regional N loads.
	• A regional N load 'calculator' was developed for combining predicted loads for each soil type and the area of the soil with different sub-regional patterns of management class adoption.
	• Detailed information on costs of the range of potential management options carried out on Burdekin farms was obtained through in-depth interviews with collaborating farmers. The data were then cross-referenced with the DPI&F economic modelling tool to ensure accuracy, and gross margins were calculated for each of the management classes (A to E) on each soil type (defined as value of crop produced minus variable input costs of the management options associated with each management class).
	• In summary, the recommended management strategies to achieve water quality goals were:
	    o Reduce the amount of irrigation applied through better control of irrigation timing and the amount of water applied at each irrigation
	    o Increased evapotranspiration through better crop growth
	    o Fertilise to replace N or to realistic yields
	    o Account for additional N sources (organic N and/or groundwater N)
	    o Increase N uptake through better crop growth
	    o Minimise runoff and deep drainage
	    o Minimise erosion
	    o Minimise herbicide applications by reducing weed populations (targeted spraying, controlling seed banks, trash blanketing, etc)
	    o Maximise efficacy of product use (timing and manner of application, post-application management)
	    o Avoid cultivations
	    o Maintain surface cover
	• In order to focus on the two primary water quality issues in the region (nitrogen and herbicide runoff) the definition of management practices for classes E to A combined decreasing tillage intensity and reducing N application rate.

	• A number of recommendations were made with respect to future research needs including the need to develop and test 'A Class' future practices and information on interactions between irrigation management and water quality, and denitrification and nitrous oxide emissions in the region.
BSS286 Improved sugar-cane farming systems	• Two major experiments were established in the southern (Bundaberg) and northern (Ingham) cane growing regions. The experiments included various treatments including sugarcane monoculture; maize and soybean break treatments; two different tillage treatments (tilled and direct planted); and differing nitrogen rates in the plant crop and first ratoon. • The results from the two experiments were mixed, and demonstrated the fragility of mineral nitrogen to environmental conditions. It was found that the realisation of benefits of large quantifies of N contributed by legumes and/or N fertiliser will be very environment dependent and further R&D was recommended on strategies to best manage N in different environments. • Experiments involving row spacing and tillage that were established in Mackay and Ingham as part of SYDJV Phase 2 were continued and modified. There were mixed results with respect to yield response to tilled versus compacted land. In some cases significant cane yield increases were evident in plant crops, but not in the first and second ratoons. In other cases there was only limited benefit evident. The results showed that responses to tillage treatments vary with different environments (soil, climate, etc). Despite this the results clearly showed the adverse effect of compaction on productivity. • Row spacing experiments were carried out to confirm that moving from 1.5 metre spacing to 1.8 or greater spacing in order to allow controlled traffic did not adversely affect yield. This was confirmed, and it was also found that there was no interaction between variety type and the response to row spacing. • A number of soil biology experiments were carried out based around the use of nematodes (both parasitic and beneficial) as biological indicators, and the experiments focused on their response to various breaks, organic matter inputs, nutrients and tillage. It was found that populations of free-living nematodes increase rapidly when high levels of soybean residue are incorporated into soil; and that there seems to be a close relationship between the population of free living nematodes and nitrogen mineralisation. • A number of recommendations for further research were made with respect to nematodes, including the mechanisms by which lesion nematodes are enhanced by tillage and suppressed in non-disturbed soils and the reasons for the reductions of populations of root knot and lesion nematodes when mulching with sugarcane trash. • A grower reference group was established that provided valuable input to the project. • There were a large number of publications from the project, including in peer-reviewed journals and conference proceedings. • A large number of field days and group meetings were held to promote the outcomes of the SYDJV.

	• There was collaboration with the QDPIF/BSES FutureCane Program and annual meetings were held with that program to allow the project to understand where to focus to better facilitate adoption of the 'new' system. FutureCane was the major extension vehicle for the SYDJV outputs.
CSE014 Genetics x management	• Seven controlled glasshouse experiments were conducted to study the genotype x environment (GxE) interaction on sucrose accumulation. • A process level model was built to account for allocation of products of photosynthesis to internodes. • Four field plot experiments were conducted to assess the GxE impact on lodging. • A series of workshops, presentations, papers and surveys were conducted to communicate and evaluate findings from the project. • Five journal papers and six refereed conference papers were produced, as well as a final report. • The key findings from the project were: o Reduced vegetative growth (stalks and leaves) without a matching reduction in photosynthesis increases sucrose yield and sucrose content. o Irrigation could be applied so as to regulate vegetative growth down by about 30%, during dry periods throughout the crop cycle, without an equivalent reduction in photosynthesis or biomass accumulation, leading to higher sucrose content and higher sucrose yield. o Differences in sucrose accumulation between high- and low-sucrose clones were not due to differences in the rate of photosynthesis. o Clones with low sucrose content can accumulate sucrose equivalent to a highly selected, high sucrose clone, albeit in only a limited number of basal internodes, suggesting that the maximum amount of sucrose that can accumulate in stalk tissue is not the limiting step in sucrose accumulation. o The difference between high- and low sucrose clones could be explained purely by the partitioning of carbohydrates between storage and growth. o Erect and retarded crops can 'catch up' with more advanced and lodged crops after the wet season but this did not favour clones that were more prone to lodging. o A mathematical model was developed to explain observations of sucrose accumulation in internodes of clones varying widely in sucrose content. The model supported the hypothesis that sucrose accumulates after other priorities for carbohydrate have been met. o The findings of the mathematical model indicated that genes controlling the level of demand for non-sucrose carbohydrate priorities are as important as those for sucrose accumulation in storage tissue. o In some soils, growers could reduce irrigation amounts considerably without significant yield loss. o Lodging can be delayed by withholding irrigation to some

	extent before the wet season. o WaterSense can be used to help growers to irrigate for maximum CCS and to reduce lodging.
WAA003 Modified farming systems in the ORIA	• SYDJV farming systems practices considered likely to be suitable for Ord conditions and as having potential for significant impact on industry performance were identified. These included minimum tillage, cover crop fallows, green cane harvesting and controlled traffic farming. • Trials on these practices were carried out, with demonstration areas, trials on farms managed by growers, and conventional trials managed by researchers all being established. • Comparative economic analysis was used to identify financial benefits attributable to adoption. • The trials found that the adoption of the practices would lead to net benefits as a result of reduced costs, reduced soil and nutrient loss, and increased yields. • The trials were successful in demonstrating to growers the benefits which could be realised through adoption of these practices. • Throughout the project results were communicated to all stakeholders including SRDC, Ord River Sugar, BSES, the Ord Irrigation Cooperative, the Ord Catchment Reference Group and the Department of Agriculture and Food Western Australia. • The project and trials were terminated early due to the closure of the Ord sugar industry. • A final report for the project was produced.
GGP004 Clare – Burdekin district	• Visits were made to other farmer groups in Burdekin, Mackay and Herbert who had experience with planting onto preformed beds. This resulted in a number of ideas that were incorporated into the trials. • Equipment required to conduct the trials was purchased. • A plant trial was conducted that compared mound plantings of 1.52 metre single row and 800 mm dual rows on 2.0 metre centres. • Information was collected (e.g. input costs, yields) that was used for an economic assessment by QDPI&F using the FEAT program. This compared the system to conventional system costs and production. • A final report was produced that reports lessons learned with respect to bed forming, dual row dimensions, mound profile and compaction. • A Mulgrave Integrated Group (MIG) field day was held to coincide with the harvesting of the trial and over 40 people attended representing both farmers and agribusiness. • MIG hosted approximately 20 farmers from the Mossman GenNext group to tour the trial. • As part of the Precision Ag Forum held at the Australian Agricultural College Corporation Open Day, a farm visit to the trial site was held, with approximately 110 attendees.
GGP007 CTF North Coast Grower	• Three varieties of soybeans were trialled (Leichardt, YY and Stuart) and it was found that each variety suited different blocks or situations better than others.

Group	• All soybean varieties trialled produced suitable nitrogen fixation for the following cane crop. • There were found to be similar yield results for both conventional and controlled traffic systems with all three soybean varieties, and it was therefore confirmed there was no yield loss from moving to controlled traffic. • Financial analysis was carried out to determine differences between costs of establishment and growing costs between controlled traffic and conventional systems. • It was found to be uneconomic to apply any nitrogen fertiliser on a plant cane block following soybean, and that the crop was easier to harvest because it was not lodged. • Lower rates of potassium on a plant cane block achieved higher yields but the reasons for this are unclear. • Different planting techniques (dual row and wide shute) in a controlled traffic situation produced the same yield. • It was recommended that more work be done to investigate the potential for lower plant rates. • A final report was produced. • A number of trial visits and presentations at field days and workshops were made to communicate the results of the trials. Feedback was obtained on the field days to improve future similar events.
GGP008 Managing traffic during CTF conversion	• During the 2005 harvest season a number of technologies were developed by growers and harvesters for adapting harvester elevators to make them suitable for wide row controlled traffic farming systems. • In 2006 the group was successful in developing adaptations for harvesters that are low cost and light weight and allow harvesters and haulouts to stay on the controlled traffic path while harvesting. Two options were developed and refined: (1) Elevator paddle, (2) Elevator extension. Both options were extensively trialled until desirable results were achieved. • The technology required modification to both the paddle and extension itself, plus modifications to the harvester and the operation of the harvester. • The group undertook numerous communication activities to promote the outcomes of this project. Communication activities included: displays at BSES field days, on-farm demonstrations, presentations at a number of workshops, hosting numerous bus trips/field tours organised by central region industry bodies, several articles in the CANEGROWER magazine, production of “Effective Bin Filling” information sheet (2006), “Effective Bin Filling in Controlled Traffic” 2006 Field Day Handout.
GGP012 Soil health and economics – Herbert River district	• Trials were established to compare the soil health of the two farming systems. These soil tests had not previously been undertaken in the Herbert and sought to provide a benchmark of current soil health. The test included physical, biological and chemical components. • The trials were used to demonstrate the economics of two farming systems (regional standard and 1.9m dual row/break crop fallow)

	• Group skills were developed through shared knowledge, utilising the expertise of consultants, building organisation skills and through first hand participation. • The trial site consists of three replications, two treatments and one variety. The trial was marked out with GPS to include 9 rows of pre-formed mounds at 1.9m and 11 rows of conventional at 1.55m spacing. • The key finding of the project was the similar average gross margins for the conventional and new farming system treatments. Potentially higher future input costs will favour the new farming system economically, with greater average gross margins expected compared to a conventional farming system. • The new farming system produced an average 0.5 unit CCS less sugar than conventional farming. The cause of this statistically significant difference is unclear and warrants further investigation. • Essentially, no significant difference was observed in soil health parameters (biological, physical and chemical) between treatments over the 14 month testing interval. • The new farming system displayed positive trends of increasing pH, increasing organic carbon and higher cation exchange capacity. The project had a relatively short testing interval and longer term soil testing would likely create more meaningful soil health results. • It was recommended that continued soil heath testing and economic analysis is needed to achieve the full benefit from this project and that it would be inappropriate to draw any firm conclusions on the comparison of these two farming systems from this study of only two years. • A Working Together Forum for 15 growers was held on the 29th of January 2007. • A progress report displaying results for soil analysis was provided to growers in December 2007 through the Herbert Soil Health Forums. • A presentation on the project was made at the SRDC regional workshop in 2008. • A contract harvester forum was held at Aquallini's shed on the 2nd of May 2008. Ten farmers and harvester operators attended the forum. The forum discussed elevator extension, width of harvester fronts, base cutter angles and height control, along with mound profile when harvesting dual and single row cane. • A roving field tour was held on the 31st of March 2008 in conjunction with FutureCane. The New Farming Initiative Group (NFIG) trial was one of the sites visited. • Presentations were made at GIVE Mackay 2008 and 2009 on the project and its results.
GGP020 Beach Sand to Black Clay	• The Homebush Innovative Farmers group conducted a number of trials to adapt the latest technology and best practices to suit the soil types found in the Homebush/Sunnyside district. • The project found that planting rates as low as 3.7 tonnes per hectare produced similar yields to planting rates of 7 tonnes per hectare

	• Pre-planting application of LOS+P in combination with GPS guidance and EM mapping had no detrimental effect on cane and sugar yield, but delivered significant cost savings. • It was found that southern bred soybean varieties had some quality advantages, but no yield advantage, and produced less biomass and presented some harvesting issues. • A cost-benefit analysis was conducted that showed that the technology adoption and practice change was cost-effective.
GGP022 GPS Integration to CTFS	• Modifications were made to the axles of a haulout trailer to reduce the distance to align the trailer axles with the tractor. This distance was successfully reduced from 31 metres (without steerable trailer axles) to 8 metres (with trailer steering) when the haulout is turned and realigned into the row. • Trials were carried out in the Mackay region to test the difference in compaction between the rear steerable unit and the conventional unit for both the grow zone and the inter-row zone. • Within the grow zone (800mm dual row) there was 25% compaction using the conventional axle and 0% compaction using the rear steerable axle. Within the remaining area there was 75% compaction using the conventional axle and 20% compaction using the rear steerable axle. • A demonstration of the technology was conducted for 27 growers and harvesting contractors, and the unit was displayed at a Mackay BSES Ltd field day.
GGP026 2m farming system in FNQ	• There was a desire to adopt a 2m spacing model, with dual rows of 0.8m spacing in FNQ, however there were problems with the ability of available harvester technology to operate in this model. • The group modified a 2005 Cameco 3510 cane harvester and used it to harvest approximately 300,000 tonnes of cane over three seasons (2006, 2007 and 2008). In the first year all cane harvested was single row cane on 1.62 m spacings, but over the next two years there were increasing amounts of 2m/0.8m cane harvested. • The modified harvester performed reliably over the three seasons and it is capable of handling a range of row spacings from 1.5 m singles through to 0.8m duals on 2m spacings. • Replicated trials were carried out to compare the 2.0 m system with the conventional 1.62 m single row system in terms of cost savings, yield gains, and other benefits in FNQ conditions. • There were a number of field days and visits to the trial sites organised, as well as presentations regarding the project.

Outcomes

A brief summary of outcomes by project is provided in Table 7.

Table 7: Summary of Project Outcomes

Project	Outcomes
NSC005 Integrated system NSW	• Due to the success of GPS guidance systems in the trials, the NSW industry has established a GPS base station network with coverage of all three mill areas. • The entire harvesting fleet in Broadwater and Condong has been set up with GPS guidance, with a number of units also set up on growers' tractors. • Adoption of the new types of systems (e.g. zero-till, controlled traffic, legume fallow) increased considerably across all three mill areas from 2003 to 2007. • In Condong the adoption rate of controlled traffic farming increased from 15% in 2003 to 32% in 2007; in Broadwater it increased from 4% in 2003 to 16% in 2007; in Harwood from 3% in 2003 to 26% in 2007.
BSS269 Cropping system Central District	• The machinery loan scheme allowed growers to trial practices without expensive capital investments. • Almost 2,000 hectares were planted to the new farming system in the Mackay region in 2007, with additional areas planted in the Sarina and Proserpine regions • In total, at the completion of the project the Mackay region had over 5,000 hectares of cane grown on controlled-traffic systems with row spacings of 1.8 metres or more. • The grower surveys found that the greatest benefits of the project identified were the ability to mix with other growers who were trialling the new system, as well as the use of the project equipment to trial the system. • Only 50% of those surveyed who had adopted the new system had used the borrowed equipment, indicating that the growers had purchased their own equipment to establish the new farming practices. • 66% of growers surveyed had a CTF system on their farm, and 85% had grown fallow legumes, indicating that some components of the NFS were being adopted more rapidly than others.
CSE012 Water and nutrient management in Burdekin	• Practices demonstrated at the trial sites were subsequently adopted by the farmers at those sites. For example one farmer who trialled minimum tillage fertilising with a stool splitter and increased irrigation inflow rates to reduce deep drainage subsequently adopted the practice over this entire farm. • The regional N load 'calculator' was used in collaboration with the North Queensland Dry Tropics regional natural resource management group to determine targets for the adoption of the different practices to meet regional water quality objectives in the Burdekin Water Quality Improvement Plan. The identified practices were the basis for practice change incentive funding in

	the Reef Rescue program. This ‘calculator’ has now been improved and is being widely used to underpin further research by BSES, DERM and NRM Groups into assessing water quality practices on a field scale throughout coastal Queensland (from Bundaberg to Far North Queensland). • The expert opinion groups formed by the project estimated that 50-60% of farmers were practicing Class D activities, with fewer practicing Classes E and C. It was determined that the water quality target should require that N loads be reduced by 20% (predicted N loads reduced to 4400 t/year for the region) by 2013. There were many different combinations of management practice adoption that could meet the target. One example was having a net shift of 10% of farmers from Class E to Class B practices. • An event was held in the region to showcase the project with approximately 50 farmers and 30 other stakeholders attending the event. Results of the project were also communicated at dedicated field days and meetings within the Burdekin Cane Productivity Initiative, in relevant regional training workshops (e.g. four ‘Focus on Water’ meetings and 13 ‘Nutrient Management Workshops’). • A survey of 35 growers was undertaken at the start of the project to survey growers on their understanding, knowledge, attitudes, skills and aspirations in regard to water and nutrient management. The survey group was selected from growers whose farms were in the district where project activities were centred, as well as growers in two outlying districts. Near the end of the project (Feb 2008) 28 of the growers were resurveyed to determine any changes in practices or attitudes over the life of the project. The key findings were: o At the start and the end of the project the majority of farmers (over 90%) were aware of environmental and water quality issues and aspired to manage their farm to reduce environmental impact. o There was an increase in the awareness of ground water quality in the region over the life of the project. o There was a 41% increase in the number of growers who use water tests to determine irrigation water quality. o Approximately 60% of those surveyed had undertaken some practice change to improve irrigation efficiency (e.g. change furrow shape, change cup size, change inflow rate). o Of the water quality projects operating in the Burdekin at the time CSE012 was the best known. Of those surveyed 72% believed the project had enabled them to learn new practices to help them farm sustainability and profitably; and 54% believed the project had helped them become aware of new practices to reduce environmental impact. o There was little difference in survey responses from farmers in the districts where project activities were centred when compared with the two outlying districts. • A water quality BMP brochure was derived from the project results and distributed widely • The approach and techniques established in CSE012 underpin the work currently taking place as part of the Reef Rescue monitoring

	program from Bundaberg to the Wet Tropics (Steve Attard, pers comm., 2011).
BSS286 Improved sugar-cane farming systems	• Interactions with staff from FutureCane and other farming system projects helped to ensure that adoption of the new farming system will be achieved. • Access to the Farm Economic Assessment Tool (FEAT) developed by the FutureCane team contributed to the economic analysis of experiment results, and being able to demonstrate a lower cost of production has been a valuable tool for encouraging adoption of the new farming system. • The grower reference panel was valuable in highlighting issues being faced with adoption of the new farming system and contributed practical ideas to trial works. The panel was also used to extend the results of the trials back to each region. • The adoption of legume fallow cropping increased in all regions from 2003/04 to 2009/10. The level of adoption in individual regions in individual years was influenced by many factors including the price received for soybeans, the price of nitrogen fertiliser, the timing of the on-set of the wet season and the timing of the end of the sugarcane harvesting season. • The adoption of reduced tillage practices such as zonal or zero tillage is increasing but has been slow. It is expected to increase further as growers have accessed zonal tillage equipment through ReefRescue funding. • Controlled traffic is being adopted in all regions, and there is evidence that this increase will continue for a number of years.
CSE014 Genetics x management	• The project has provided sound physiological explanations for differences in sucrose accumulation and sucrose content among sugarcane clones and cultivars. This identified priorities for where research at cellular and sub-cellular levels should be directed, as well as the relative importance of this level of investigation compared to studies at the whole plant level. At least two subsequent projects have been funded by SRDC as a result of these recommendations including CSE023 (feedback inhibitors) and CPI018 (elevated CO2). • The papers from the project that were published in a special issue of Field Crops Research in 2005 have been cited 131 times (at the time of writing of the final report) and have an impact factor of 7.2. This is more than three times the impact factor for the journal itself. • A modelling framework was developed that identified the pathway to long-term benefits through linking knowledge across different levels of organisation of the plant. This model has continued to be used and refined in a range of ongoing CSIRO research. • One practical application of the project was the potential use of WaterSense to control elongation growth, lodging and CCS in farming practice. However, this practice needs further trialling in the field before adoption will occur (Geoff Inman-Bamber, pers comm., 2011).

<table>
<tr><td>WAA003 Modified farming systems in the ORIA</td><td>
Growers who participated in the project developed an improved understanding of the requirements for managing for change and for planning for improved outcomes.
Growers developed an understanding of developing and managing research trials.
The project found that growers could achieve a net benefit equivalent to $45 per hectare per annum for cover cropping with zero-tillage when compared with traditional planting practices; and an additional $40 per hectare per annum attributable to a reduction in soil and nutrients lost through erosion and run-off. Further benefits were to be expected through increased yields associated with improved soil and water management.
There has been no adoption of the practices on sugar crops due to the closure of the industry in the Ord.
A number of the practices assessed are being used by Ord growers in the production of crops other than cane (e.g. improved wet season fallow management combined with minimum tillage). This was due to the demonstration of reduced erosion from wet season cover crops.
</td></tr>
<tr><td>GGP004 Clare – Burdekin district</td><td>
The MIG has eleven members with 4 farming enterprises and collectively the MIG manages approximately 1,800 hectares of sugarcane in the Mulgrave area, near Clare in the Burdekin.
During the life of the project all members adopted the pre-formed bed mound system. The table shows the adoption of different systems during the life of the project

<table>
<tr><th>Planting year</th><th>Single row conventional system (ha)</th><th>Single Row Mound system (ha)</th><th>Dual Row Mound system (ha)</th></tr>
<tr><td>2006 (actual)</td><td>121</td><td>76</td><td>37</td></tr>
<tr><td>2007 (actual)</td><td>0</td><td>246</td><td>53</td></tr>
<tr><td>2008 (proposed)</td><td>0</td><td>202</td><td>138</td></tr>
</table>

The growers participating in the trial developed an appreciation of the skills required for setting up on-farm trials and developed significant skills in this area.
The trial increased confidence within the MIG and other farmers across the district that the Sugar Yield Decline Joint Venture research is applicable.
</td></tr>
<tr><td>GGP007 CTF North Coast Grower Group</td><td>
The project emphasised to growers the importance of replication in trials in order to produce reliable results on which to base farm management decisions; and also the importance of record keeping with respect to trials.
Growers’ capacity to interpret results from other research trials was increased.
Growers understanding of their costs of production increased.
As a result of the trials nearly all group members converted to a controlled traffic system in 2007 (approximately 150 ha of group members plant cane were planted to wide row spacings, representing 60% of the total group members plant cane (baseline was 0%)). These levels of adoption have been maintained.
</td></tr>
</table>

	• There was strong interest in the region for growers to plant soybeans or other legume fallows, and a seed planter has been purchased by the group. However unfavourable weather conditions means that there are yet to be any successful plantings. • During the life of the project there was an increase in controlled traffic systems by farmers in the surrounding area who are not part of the project. These growers would have been partly influenced by the project results.
GGP008 Managing - traffic during CTF conversion	• During 2006 the harvester that the elevator was to be fitted to was expected to harvest approximately 15,000 tonnes that season, 75% of which was to be dual row on 1.83m row spacings. • As a result of this project, the group now has no difficulty in delivering cane to the haulout while maintaining a controlled traffic farming system. The options developed by this project are suitable for all harvesting conditions, including steep sloping ground. • At the time of the final report (May 2008) the group was are aware of approximately 15 harvesters with paddle rollers fitted and 4 with conveyor extensions fitted following interaction with the group members and their work. Over 150 growers and harvester owners from Queensland and New South Wales had visited farms of the group members to view the work undertaken in the project.
GGP012 Soil health and economics – Herbert River district	• The New Farming Initiative Group (NFIG) consists of six members and has approximately 600ha of sugarcane farming land in the Herbert region. • The capacity of growers to be involved with and understand replicated trials has been increased. • The confidence of growers to adopt changes recommended by the YDJV has increased.
GGP020 Beach Sand to Black Clay	• The capacity of growers to conduct on farm research was developed, and the group was successful in obtaining funding for a second Grower Group Innovation Project on precision agriculture. • The project has influenced an increase in adoption of new farming systems in the region through testing and confirming the cost saving options.
GGP022 GPS Integration to CTFS	• The modified steering option was made available as an optional extra on new units produced by the partner manufacturing and hydraulic companies involved in the trial. To date, no new units have been sold due to the cost of the adaptation. • The information was extended from the Deguara Harvesting group to the Blackburn Harvesting Group. • The single modified unit continues to be used by Deguara Harvesting and harvests approximately 300 ha per annum (Gerry Deguara, pers comm., 2011)
GGP026 2m farming system in FNQ	• All members of the Singh Harvesting Group have adopted the 2 metre configuration. Growers in neighbouring regions in FNQ have also adopted the 2 metre configuration, and some of these growers have been partially influenced by the trial.

Benefits

A brief summary of benefits by project is provided in Table 8.

Table 8: Summary of Cluster Benefits

Project	Benefits
NSC005 Integrated system NSW	• An economic analysis undertaken as part of the project indicated that by adopting a controlled traffic, reduced tillage, legume fallow system, on a 72 ha farm, a grower will improve gross margins by $12,857 when compared to a conventional system. • There are environmental benefits from the adoption of controlled traffic, minimum tillage and legume fallow systems such as reduced nutrient, soil and chemical runoff.
BSS269 Cropping system Central District	• Increased adoption rate for CTF, wider rows, dual rows, legume fallows and other practices recommended by the SYDJV as part of the New Farming System. • Adoption of such practices results in reduced costs (e.g. harvesting, planting, fertiliser, chemicals etc) and sometimes in increased yields. • Potential environmental benefits include reduced energy consumption and chemical usage and improved water quality. • The capacity of growers to undertake and interpret trials has been increased.
CSE012 Water and nutrient management in Burdekin	• An example of benefits at one trial site were provided where minimum tillage, fertilising with a stool splitter and increased irrigation inflow rates resulted in yield increases of approximately 25% (increase from 114 t/ha in 1st ratoon crop to 143 t/ha in 2nd ratoon under changed practice). • A new strategy for irrigation application was devised to allow for adoption of trash blanketing. Adoption of trash blanketing led to increased numbers of beneficial nematodes, lower weed pressure and weed control costs, and 10-20% increased yield in comparison blocks. • An economic model was used to calculate increases in annual gross margins as a result of moving 'E' grade practices to 'A' grade practices for four soil types. The results showed significant increase in gross margins as a result of such improvements in practices (e.g. improvements of approximately $400/ha per annum) • Adoption of the higher grade practices will minimise nutrient and fertiliser runoff to waterways, including the Great Barrier Reef. There are increasing societal expectations in this area. This benefit will extend beyond the Burdekin, due to the work in CSE012 underpinning the ongoing Reef Rescue monitoring and further research from Bundaberg to the Wet Tropics.
BSS286 Improved sugar-cane farming systems	• Production costs are substantially reduced when legume fallows, reduced tillage and controlled traffic are adopted. • Adoption of the new farming system principles leads to improved soil health (chemical, physical and biological properties), contributing ultimately to yield increases and a farming system that

	is more robust and resilient to climate variability. • Adoption of the new farming system contributes to improved water quality leaving the farm, and therefore assisting in the industry meeting the environmental requirements for agriculture in the GBR catchments.
CSE014 Genetics x management	• In the shorter-term the benefits from this project relate to efficiencies in the breeding program and research aimed at understanding the role of genes or markers in relation to individual traits. • In the longer-term the benefits from this project relate to the breeding of varieties with higher sugar yield potential, as a result of improved understanding of the plant physiology that takes into account GxE interactions. • In the future there may be reduced use of irrigation water from use of WaterSense, and subsequent reduced drainage and runoff.
WAA003 Modified farming systems in the ORIA	• Due to the closure of the industry, there is no impact on the sugar industry. • There are likely to be impacts from the adoption of wet season cover crops and minimum tillage for growers of other annual crops influenced by this project.
GGP004 Clare – Burdekin district	• The trial and subsequent economic analysis concluded that adoption of pre-formed beds will reduce input costs for the plant crop. For example: o Land preparation costs reduced from $265/ha in the conventional practice down to $131/ha o General growing costs reduced from $209/ha to $108/ha o Irrigation costs reduced from $394/ha to $305/ha
GGP007 CTF North Coast Grower Group	• Financial analysis showed there to be a cost saving in the plant cane from moving from conventional systems to controlled traffic, however the ratoons had an almost identical cost of production. There is potential cost savings in harvesting however these were not examined. • Gross margins of plant cane were typically $200 to $250 per ha greater for the new system compared to conventional systems. • The reduced costs are influenced by reduced nitrogen inputs and improved field efficiencies (from less rows per hectare requiring less input costs). • Other benefits included: o Improved moisture infiltration as a result of the change to CT o Improved soil health and reduced soil erosion o Reduced chemical and nutrient movement off-farm o Reduced fuel consumption and reduced fertiliser requirements o Improved capacity of growers with respect to undertaking and understanding research trials. o Increased time for leisure o Improved community perception of the sugar industry
GGP008 Managing	• The availability of the technology has contributed to the increased adoption of CTF systems, without the purchase of new machinery.

traffic during CTF conversion	• Benefits of CTF include saved establishment costs, saved fuel and chemical costs, reduced chemical and fertiliser use • There is improved safety for machinery operators harvesting wider row spacings on sloping fields because of improved machine stability.
GGP012 Soil health and economics – Herbert River district	• This project will increase the uptake of several best management practices which are considered to reduce the loss of sediment, chemicals and nutrients from cane lands as well as significantly improve soil fertility due to a healthier soil in terms of its physical, chemical and biological components.
GGP020 Beach Sand to Black Clay	• A cost-benefit analysis conducted as part of the project found that on a 460 hectare farm there was a total one-off capital cost of $72,600 to adapt the recommended system, and that there was an annual total saving of $$73,052 across the farm due to savings in planting costs, herbicides, and harvesting costs. This was calculated to equate to a $2/t saving on cost of production.
GGP022 GPS Integration to CTFS	• If adopted, the change to the equipment will reduce the compaction of soil in the turn-out zone, and therefore improved the ability of the controlled traffic farming groups to eventually move to complete zero till farming system. • The changes to the equipment also led to reverse filling potential which will contribute to making the modification commercially viable in the future as harvesting could be 10% to 15% more productive because of the elimination of the turning around time for the haulout units. • Increased field efficiency will contribute to reduced fuel consumption, time of operation and effort.
GGP026 2m farming system in FNQ	• Increased adoption rate for CTF, wider rows, dual rows and other practices recommended by the SYDJV. • Adoption of such practices results in reduced costs (e.g. harvesting, planting, fertiliser, chemicals etc). • Examples of efficiencies include a 25% increase in planting area per day and 20% time saving in harvesting. • Environmental benefits include reduced energy consumption and chemical usage • The capacity of growers to undertake and interpret replicated trials has been increased.

Table 9 summarises the major benefit types, and the contribution of each project to that benefit. It also identifies the regions to which the benefits apply.

Table 9: Summary of Contribution of Each Project to Major Benefit Types

Project	Increased adoption of SYDJV recommended practices	Increased yield	Reduced costs	Improved water quality	Building capacity of growers	Regions impacted
NSC005 Integrated system NSW	√		√	√		NSW
BSS269 Cropping system Central District	√	√	√	√	√	Central
CSE012 Water and nutrient management in Burdekin	√	√	√	√		Burdekin
BSS286 Improved sugar-cane farming systems	√	√	√	√		Whole industry
CSE014 Genetics x management		√				Whole industry
WAA003 Modified farming systems in the ORIA					√	Ord
GGP004 Clare – Burdekin district	√		√	√		Burdekin
GGP007 CTF North Coast Grower Group	√		√	√	√	Central
GGP008 Managing traffic during CTF conversion	√		√			Central
GGP012 Soil health and economics – Herbert River district	√	√	√	√		Herbert
GGP020 Beach Sand to Black Clay	√		√			Central
GGP022 GPS Integration to CTFS	√		√			Central
GGP026 2m farming system in FNQ	√		√		√	North Queensland

In addition to the key benefits identified above, there are a number of other benefits including:

- Reduced energy consumption and chemical usage, resulting in environmental and social benefits
- Efficiencies in research costs through the strategic setting of priorities as a result of increased understanding of GxE interactions

Summary of Benefits

A summary of the principal types of benefits associated with the outcomes of investment in the cluster of projects is shown in Table 10.

Table 10: Categories of Benefits from the Investment

Levy Paying Industry	Spillovers	
	Other Industries	**Public**
Economic Benefits		
Decreased cost of production due to decreased fuel, chemical, fertiliser and labour costs Increased yield due to improved soil health Efficiencies in R&D expenditure associated with increasing sugar yield	Increased adoption of minimum tillage and wet season fallow management of non-cane crops in the Ord River Irrigation Area	Efficiencies in R&D expenditure associated with increasing sugar yield
Environmental Benefits		
Enhanced future resource sustainability (soil and nutrients) on cane land		Improved quality of water exported off-farm due to reduced nutrient and chemical run-off Reduced use of fuels and energy
Social Benefits		
Increased capacity of growers to adopt new practices, and be involved in replicate trials.		Reduced chemical use potentially resulting in decreased likelihood of adverse health effects

Public versus Private Benefits
The benefits are both public and private in nature. The private benefits relate mostly to reduced costs of production, increased yields, and increased capacity of growers. The public benefits include reduced use of fertilisers, fuels, energy and chemicals which result in environmental and social benefits.

Distribution of Benefits along the Sugar Supply Chain
The benefits from the projects in this cluster will be shared along the cane supply chain, but will mostly accrue to farmers and harvesters

Benefits to other Primary Industries
There will be some limited benefits to other primary industries (horticulture) in the Ord River Irrigation Area from one of the investments in the cluster.

Benefits Overseas
There will be no benefits to overseas consumers or producers of sugar.

Additionality and Marginality
Supporting these studies was a high level priority for SRDC, with a large number of projects being funded in this area. If public funding of SRDC were reduced, it is likely that a significant number of the projects would still have been funded, although perhaps to a lesser extent or over a longer period of time.

Further detail is provided in Table 11.

Table 11: Potential Response to Reduced Public Funding to SRDC

1. What priority were the projects in this cluster when funded?	High (for the majority of the projects)
2. Would SRDC have funded this cluster if only half of public funding of SRDC had been available?	Yes, but possibly to a lesser extent or over a longer time period
3. Would the cluster have been funded if no public funding for SRDC had been available?	Yes, but possibly to a lesser extent or over a much longer time period

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 12.

Table 12: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The projects in the cluster contribute to National Research Priority 1, and Rural Research Priorities 1 and 3. Some contribution would also be made to the two supporting priorities.

Quantification of Benefits

The benefits quantified in this analysis relate to the benefits from an increase in adoption of a number of practices promoted by the Sugar Yield Decline Joint Venture (SYDJV). These practices include minimum tillage, controlled traffic farming, wide and dual row planting, use of trash blanketing and use of a legume break. The investments in this cluster were largely focused on continuing to further refine and promote the adoption of these practices. It did this through trialling and demonstrating the practices in individual regions, as well as working to refine the practices and equipment required to ensure adoption in a number of regions.

The benefits quantified in this analysis are the yield increases and cost reductions that will accrue to those growers who have adopted new farming system practices as a result of the projects in this cluster. It should be noted that some significant adoption of these practices had already occurred (and would have continued to occur) even without this cluster of projects, due to previous investment in developing and promoting these practices. It is only the benefits from the assumed additional adoption to this cluster of projects that are valued here.

In addition, the benefits from improved water quality associated with project CSE012 specifically, as well as from the increased adoption of SYDJV practices generally, are also quantified.

The major benefits not quantified include:

- Efficiencies for R&D planning in the area of GxE interactions and sucrose accumulation
- Potential yield increases from more effective breeding as a result of improved knowledge of GxE interactions
- Potential environmental and social benefits from reduced chemical, fuel and energy use

Reduction in Cost of Production

An economic evaluation was undertaken on the first two phases of the SYDJV by Agtrans Research in 2007 (Agtrans Research, 2007). The assumptions used in that analysis are used as the starting point for quantifying the benefits from this cluster of projects. Many of the assumptions made in the earlier analysis with respect to the value of the impact of a number of recommended practices are robust enough to be maintained in the current analysis. In addition, assumptions that were made regarding adoption in that analysis need to be considered to ensure no double counting of impact occurs.

It is not possible here to calculate the individual benefits of adopting individual practices in specific regions, and identify the specific rates of adoption in each region applicable to these individual projects. Rather the approach is taken to assume an average increase in yield, or reduction in costs across the industry as a result of adopting a ‘package’ of such practices. An average potential increase in adoption that might have resulted from these projects was then assumed in order to estimate the aggregate industry impacts. The assumptions surrounding the likely benefits and adoption are described below.

Value of impact of new practices

Many of the projects in this cluster have used economic models to quantify the potential cost savings or yield increases as a result of the adoption of specific combinations of practices in specific regions. For example:

- In project NSC005 it was estimated that there was an improved gross margin of $12,857 for a 72 ha farm ($178.57 per ha) from adoption of a controlled traffic, reduced tillage, legume fallow system.
- For project CSE012 in the Burdekin there was one example of adoption of minimum tillage in combination with a number of other changed practices resulting in a 25% cane yield increase. There was another example of a 10-20% yield increase due to trash blanketing.
- Project GGP004 (based in the Burdekin) found that adoption of mound systems could lead to reductions in land preparation costs (reduced from $265/ha to $131/ha); reductions in general growing costs (reduced from $209/ha to $108/ha); and reductions in irrigation costs (reduced from $394/ha to $305/ha).
- Project GGP007 based in the Central region found that converting to controlled traffic (including wide row spacings and legume fallows) resulted in increased gross margins of $200-$250 per ha (due to reduced nitrogen inputs and improved field efficiencies).
- Project GGP020 based in Mackay calculated that there was an annual saving of $74,052 on a 460 ha farm from a $72,600 capital investment.

In the 2007 analysis of the SYDJV carried out by Agtrans Research it was calculated that the average annual cost savings due to adoption of a soybean legume crop (green fallow, not harvested for grain) in combination with minimum tillage was approximately $211 per annum for every hectare of soybeans planted (benefit per ha of legume averaged over the life of the rotation). This was calculated based on a six year rotation (plant crop, 4 ratoons, 1 soybean fallow). It included benefits from a 22.5% yield increase in the cane crop, and reduced costs from the reduced need for nitrogen application in the plant and first ratoon crop following the legume crop. The additional costs of planting and managing the legume crop were allowed for, as were the costs of losing a year of sugar yield by moving from a 5 year rotation to a 6 year rotation (for those who weren't having a bare fallow). In addition to the benefit from adoption of a legume crop, the benefits from adopting minimum tillage in the absence of a legume crop were also valued in the 2007 analysis. It was estimated that the average benefit per hectare from adopting minimum tillage only was $120/ha. This benefit was due to a combination of increased yield, and reduced fuel and labour costs. In the 2007 analysis there was no benefit calculated for the adoption of controlled traffic.

As can be seen from the 2007 analysis and the examples above, the practices recommended by the SYDJV can be adopted in a number of combinations, and the benefits from the adoption of such are highly variable. In addition, some of the practices such as controlled traffic require significant capital investments. The benefits are also highly dependent on climate, soil type, farming system (e.g. irrigated vs non-irrigated) and the combination of practices adopted. The benefits also vary depending on seasonal conditions.

Having considered the 2007 analysis and the examples of benefits from the projects in the cluster (NSC005, GGP004, GGP007, GGP020) it can be calculated that the average cost reduction is in the order of $200/ha. However, these cost reductions were calculated using different methods, and some are based on very particular circumstances and on one to two years of data. In addition, some may not allow for the capital investment required in order to adopt some of the practices. It is therefore assumed for this analysis that an average reduced cost from adopting a 'typical' combination of practices in a 'typical' area might be $180/ha. In some circumstances the benefit will be much higher, and in some years much lower. This is also an assumed annual average across all phases of a rotation. The benefit is assumed to allow for improvements such as yield increases, reduced fertiliser costs, reduced fuel costs and reduced labour costs. It also takes account of the amortised cost of any capital investment in tractors etc required to adopt controlled traffic. It is assumed this level of benefit accrues to the grower from the first year of adoption of new practices.

Adoption assumptions

The earlier analysis of the impact of the SYDJV (Agtrans Research 2007) reported that in 2000/01 there were a total of 1,473 hectares of soybeans grown on sugarcane farms, and in 2007, there had been an increase to 8,300 hectares of legume fallow being grown. In 2007, it was estimated that the area of land under legume fallows would increase by 1,000 hectares per year, resulting in an assumed area of legumes of 31,300 ha per annum in 2029/30. It was assumed that 100% of this adoption would be attributable to Phases 1 and 2 of the SYDJV. Therefore, any assumed adoption from the current cluster of investments should be over and above this level of 1,000 ha per annum.

It was further assumed that there was about 10,000 hectares under minimum tillage (or similar practices) in 2006/07, and that this area would increase by 2% of plant area per annum where a legume break is not used. This was to be equivalent to 23,000 hectares in 2029/30. It was assumed that 90% of this adoption would be attributable to Phases 1 and 2 of the SYDJV.

The final report for BSS286 (Salter et al, 2010) presents adoption data for the practices of legume fallow, zonal tillage and controlled traffic by region. This information is presented in Figures 1 to 3.

Figure 1: Percentage of fallow land planted with a legume crop
(Source: Salter et al, 2010)

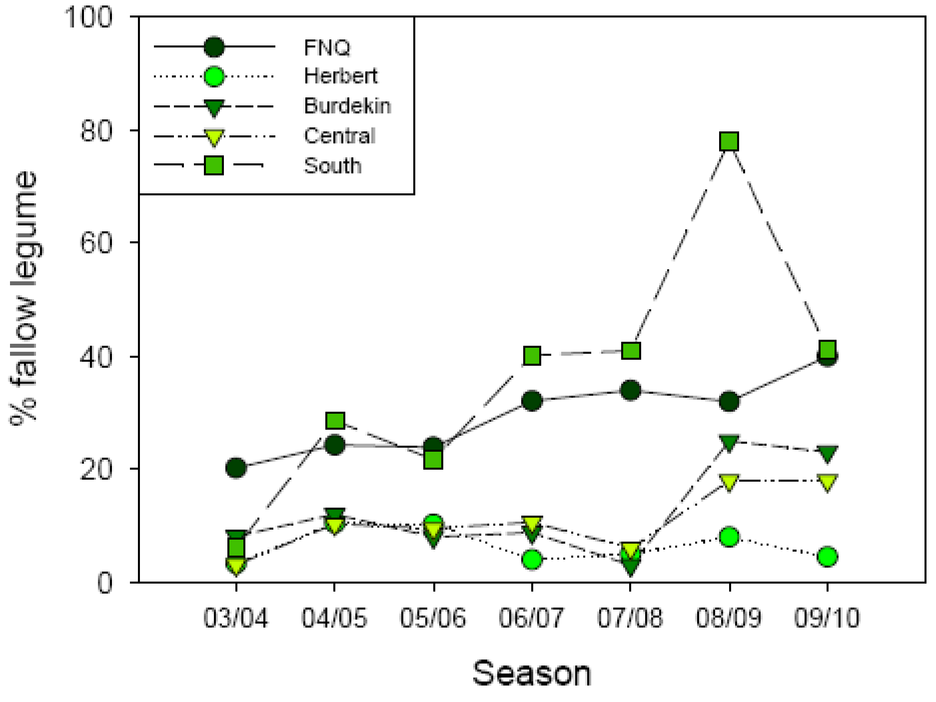


Figure 2: Percentage of total area, including all crop classes, established using zonal tillage (Source: Salter et al, 2010)

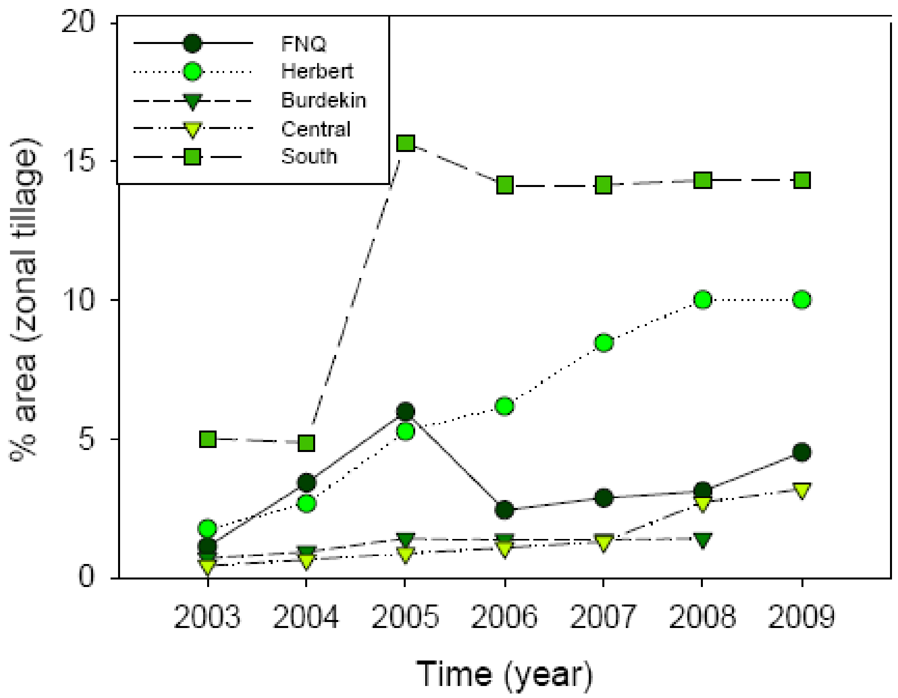
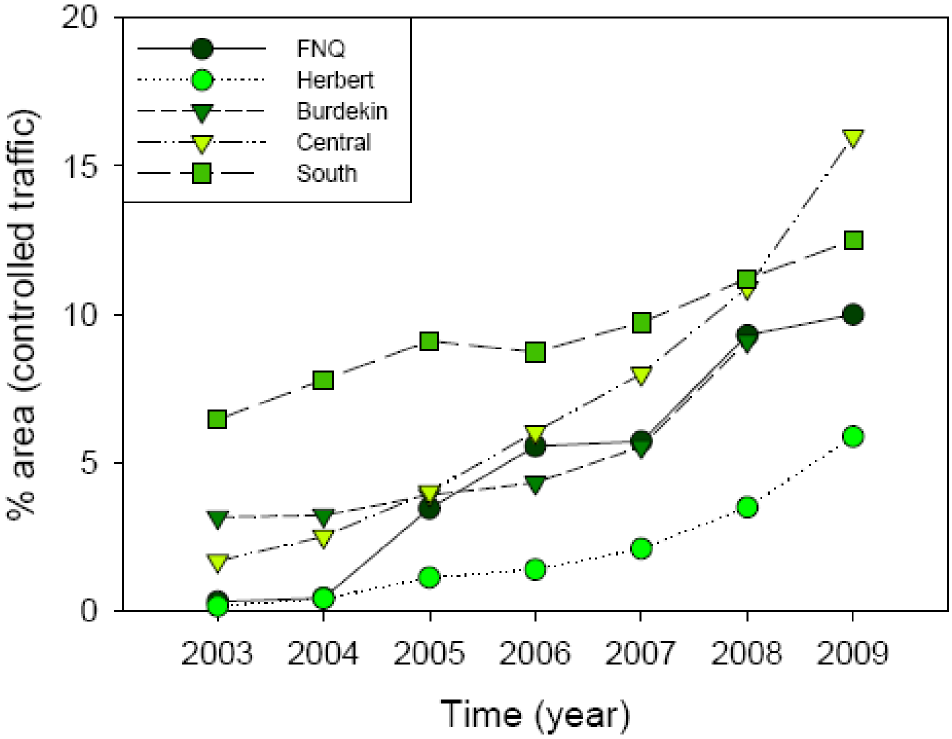


Figure 3: Percentage of total area (including all crop classes) using controlled traffic farming systems (Source: Salter et al, 2010)



The information presented in these graphs, was combined with data from the CANEGROWERS organisation data on the annual area of cane harvested, and it was determined that the level of adoption since 2007 has been higher than that assumed would occur as a result of Phases 1 and 2 of the SYDJV when the 2007 analysis was undertaken. Given the evidence of adoption specifically due to some of the projects in this cluster provided earlier in the outcomes section, it can be assumed that these projects have contributed to the increase in adoption over what had been predicted.

The data indicates that on average across the Queensland industry, the adoption of all three practices has increased in all regions. The cluster of projects focused on all regions (including NSW) but there was much less emphasis on the southern Queensland region, where adoption of the practices was already fairly significant. Even when the southern region is excluded from the data, the increases are still significant.

Despite the above graphs, it is still difficult to make a definitive estimate of the adoption of the practices recommended by the SYDJV. This is largely due to growers adopting different combinations of the practices over different time periods, as suits their individual climate and soil type etc. In addition, some adoption statistics are reported as the percentage of fallow ground, some are reported as the percentage of cane planted in that year, and some are presented as the percentage of total cane grown in that year.

From the graphs and the CANEGROWERS data it could be estimated that in the three years to 2009 the average annual increase in the area of adoption of legume fallows in Queensland was about 3,000 hectares, and the adoption of minimum tillage was about 1,100 hectares. The average annual increase in the adoption of controlled traffic over the same period was approximately 6,400 hectares. These are estimates only, and it is not known how much of these areas overlap. In addition the variation from year to year was significant. These estimates do not allow for NSW adoption (NSW makes up about 5% of the total industry).

As noted earlier, the benefit assumed is for the adoption of a typical ‘package’ of practices recommended by the SYDJV that suits the particular farm type, and delivers a ‘typical’ cost saving per ha of cane that has been subject to change. Therefore the adoption rate assumed refers to the adoption of this typical ‘package’ bearing benefits of $180 per ha, rather than any specific practices. Based on the estimates of annual adoption above, it is assumed that the level of adoption of the ‘typical’ package increases by 3,500 hectares per annum.

The level of adoption assumed however needs to allow for the fact that other investments were occurring at this time, and that not all additional adoption over the SYDJV Phases 1 and 2 impact should be attributed to this group of projects. Allowances also need to be made for attributions to past and future investments in refining and promoting the adoption of such practices.

For the purpose of this analysis, it is assumed that a maximum of 50% of the 3,500 hectares of annual adoption can be attributed to this cluster of projects. This maximum level of attribution to this cluster will apply from 2006/07 (fourth year of investment in the cluster) and will continue until 2013/14 (five years after the year of final investment in the cluster). Following this, the attribution to this cluster of projects will decline by 5% per annum until 2023/24 when the attribution will have reduced to zero. It is assumed that over this time period the overall adoption level to which the attribution applies will remain constant at 3,500 ha per annum. Despite no new adoption being attributed to the cluster of projects after this time, the benefits from those hectares of land already adopting changed practices due to the cluster of projects will continue. Cumulatively, this will result in the changes being adopted on an additional 22,000 hectares of land due to these projects over the period 2007 to 2024.

Water Quality Benefit
This benefit was valued based on a recent study that applied choice modelling to assess community values for reduced agricultural emissions that would improve water quality and therefore improve coral health in the Great Barrier Reef (GBR) (Windle and Rolfe, 2010). Changes in agricultural emissions were presented in the choice modelling survey as ‘water quality units’ where one unit was equivalent to the reduction of 100,000 tonnes of sediment, 200 tonnes of nitrogen and 46 tonnes of phosphorus. The survey was completed by households from coastal GBR communities, Brisbane, Melbourne and Perth. The results indicate that households were willing to pay $2.40 (in Brisbane), $4.09 (in Perth), $4.35 (in Melbourne) and $5.55 (in coastal GBR communities), every year for five years to generate an annual improvement of one water quality unit in the GBR catchment area for 25 years. These values aggregate to a national benefit of $23.6 million per annum.

For the purposes of this analysis, it is assumed that a 5% improvement of one water quality unit will be achieved as a result of the projects in this cluster. That is, an annual reduction of 5,000 tonnes of sediment, 10,000 kg of nitrogen and 2,300 kg of phosphorus. The benefit of a 5% improvement of one water quality unit is therefore $1.18 million per annum for five years (5% of $23.6 million). It is assumed that there is no cost to the growers for achieving this benefit, as it is assumed that the practice changes leading to the improved water quality will largely be adopted for the purposes of achieving yield increases and cost reductions, with the improved water quality a spin-off from that change.

The benefits are assumed to begin in the year ending June 2011, the year after the last year of investment.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 13.

Table 13: Summary of Assumptions

Variable	Assumption	Source
Annual area of new land adopting a 'typical' package of practices (2007 to 2024)	3,500 hectares	Agtrans assumption, after considering data from Canegrowers Annual Reports (2008 and 2010) and BSS286 Final Project Report
Maximum attribution of adoption to this cluster of investment	50%	Agtrans assumption, after considering data from Canegrowers Annual Reports (2008 and 2010) and BSS286 Final Project Report
Years of maximum attribution of adoption to this cluster of investment	2006/07 to 2013/14	Agtrans assumption
Decline in attribution per annum after maximum influence ceases	5% reduction per annum	Agtrans Research
Annual benefit from adoption of 'typical' package of practices	$180/ha	Estimated based on the average cost reduction estimated from projects NSC005, GGP004, GGP007 and GGP020 as well as the 2007 analysis of the SYDJV (Agtrans Research, 2007)
Value of 1 water quality unit improvement in the Great Barrier Reef	$23.6 million per annum for five years	Windle and Rolfe (2010)
Proportion of 1 water quality unit gained due to projects	5%	Agtrans Research
Value of gain	$1.18 million per annum for five years commencing 2011	$23.6m x 5%

Results

All past costs and benefits were expressed in 2010/11 dollar terms using the CPI. All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high 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 (2009/10) to the final year of benefits assumed.

Investment criteria were estimated for both total investment and for the SRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria are reported in Tables 14 and 15. The results show that when considering benefits over 30 years, the benefit-cost ratio is 2.5 to 1.

Table 14: Investment Criteria for Total Investment and Total Benefits for Each Benefit Period (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	3.48	18.70	30.87	41.78	50.39	57.14	62.42
Present value of costs ($m)	24.67	24.67	24.67	24.67	24.67	24.67	24.67
Net present value ($m)	-21.20	-5.97	6.20	17.11	25.72	32.46	37.75
Benefit–cost ratio	0.14	0.76	1.25	1.69	2.04	2.32	2.53
Internal rate of return (%)	negative	negative	8.2	11.2	12.3	12.9	13.1

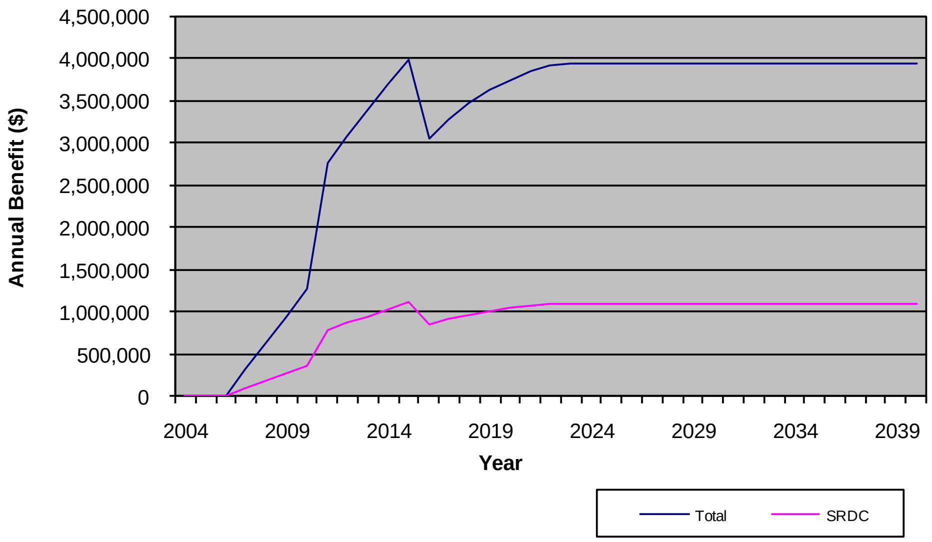
Table 15: Investment Criteria for SRDC Investment and Benefits to SRDC for Each Benefit Period (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.98	5.28	8.72	11.80	14.23	16.14	17.63
Present value of costs ($m)	6.98	6.98	6.98	6.98	6.98	6.98	6.98
Net present value ($m)	-5.99	-1.69	1.74	4.82	7.26	9.16	10.65
Benefit–cost ratio	0.15	0.76	1.25	1.69	2.04	2.32	2.53
Internal rate of return (%)	negative	negative	8.2	11.2	12.3	12.9	13.1

The quantified benefits address the productivity and adding value and natural resource management Rural Research Priorities. The productivity benefit (cost reduction) provided 91% of the total benefits valued and the NRM benefit (water quality) provided 9% of the total benefits valued.

The annual net benefit undiscounted cash flows for both total investment and SRDC investment for the 30 year period from the year of first investment are shown in Figure 4.

Figure 4: Annual Cash Flow of Benefits



Sensitivity Analyses
Table 16 presents the sensitivity of the results to the discount rate. The sensitivity analysis was performed on the total investment with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 16: Sensitivity to Discount Rate
(30 years, total investment)

Criterion	Discount rate		
	0%	5%	10%
Present value of benefits (m$)	115.84	62.42	40.65
Present value of costs (m$)	20.30	24.67	29.83
Net present value (m$)	95.54	37.75	10.81
Benefit cost ratio	5.71	2.53	1.36

Table 17 presents the sensitivity of the results to the assumed cost reduction due to the adoption of the 'typical' package. The sensitivity analysis was performed with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values. The cost reduction at which the investment breaks-even is $43 per ha.

Table 17: Sensitivity to Assumed Productivity Benefit
(30 years, total investment, 5% discount rate)

Criterion	Benefit per ha		
	$100	$180	$250
Present value of benefits (m$)	37.06	62.42	84.61
Present value of costs (m$)	24.67	24.67	24.67
Net present value (m$)	12.69	37.75	59.94
Benefit cost ratio	1.50	2.53	3.43
Internal Rate of Return (%)	8.3	13.1	16.4

Table 18 presents the sensitivity of the results to the assumed increase in the area of annual adoption of the 'typical' package. The number of hectares adopted per annum at which the investment breaks-even is 1,184 hectares.

Table 18: Sensitivity to Assumed Annual Level of Adoption
(30 years, total investment, 5% discount rate))

Criterion	Hectares adopted		
	2,000	3,500	5,000
Present value of benefits (m$)	37.97	62.42	86.88
Present value of costs (m$)	24.67	24.67	24.67
Net present value (m$)	13.30	37.75	62.20
Benefit cost ratio	1.54	2.53	3.52
Internal Rate of Return (%)	8.5	13.1	16.7

Confidence Rating
The results produced are highly dependent on the assumptions made, many 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 19). 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 19: Confidence in Analysis of Integrated Farming Systems Cluster

Coverage of Benefits	Confidence in Assumptions
High	Medium

Conclusions

The projects in this cluster have contributed to an increased understanding of the benefits to be gained from adoption of a range of practices developed and recommended by the SYDJV. A large number of trials have been carried out and some technologies and equipment have been further developed and trialled. Significant efforts were made to extend the results of the trials to growers. Together, this cluster of projects has contributed to, and will continue to contribute to, significant increases in the level of adoption of the practices recommended by the SYDJV. The adoption of such practices provides benefits to growers as a result of yield increases, and saved costs (including saved fertiliser, fuel and labour costs). The adoption of such practices also contributes to improved water quality off-farm through reductions in nutrient and sediment run-off. The cluster of projects has helped build the capacity of growers to design and be involved in replicated trials.

The total investment of $25 million (present value terms) has been estimated to produce gross benefits of $62 million (present value terms) providing a net present value of $38 million and a benefit cost ratio of 2.5 to 1 (over 30 years, using a 5% discount rate). This estimate is an underestimate of the total benefits since the benefits from Project CSE014 have not been quantified due to the strategic nature of the project and the associated uncertain and long-term benefits.

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Steve Attard, CSIRO Ecosystem Sciences
Gerry Deguara, Deguara Harvesting
John Fox, Mackay Area Productivity Services
Geoff Inman-Bamber, CSIRO Plant Industry

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Final reports to SRDC for all projects

Appendix 3: An Economic Analysis of SRDC Investment in the "Managing and Improving Soil Resources and Nutrients" Cluster

Background

The types of soils supporting Australian sugarcane production include highly fertile deep krasnozem soils, moderately deep to shallow duplex podzols and podzolics and alluvial soils on the floodplains of coastal rivers (ANRA, 2000).

The SRDC investment in the Soil Resources and Nutrients cluster is a mixture of soil resource and management projects that range from small to large investments and across a range of project topics and types. The four types of projects in which SRDC invests are all represented in this cluster of projects (scholarships, capacity building, grower group innovation projects, and research projects).

The cluster includes three student projects, aimed at building future research capacity in the area of soils. There was one travel support project, again aimed at building capacity in soil mapping. Soil mapping is becoming highly relevant to the sugar industry as variable rate technology becomes more widespread.

There were six grower group projects, where growers conduct their own research and development activities in their own district. Finally, there was only one research project, the traditional and largest avenue for SRDC's R&D investments. Although only one project of this type was included in the eleven projects, it made up over two thirds of the total SRDC funding in the cluster.

There were linkages between one of the student projects and the principal CSIRO project on nitrogen management. Also the capacity building project for soil mapping was highly relevant to two of the grower group projects.

While most of the projects addressed productivity changes on farm, most of the projects also had natural resource management outcomes in term of reduced soil and nutrient export off-farm. The industry undertakes significant cultivation activities and uses large quantities of fertilisers so the potential for soil and nutrients entering waterways is significant. The industry has addressed this threat admirably in past years through such practices as trash blanketing, minimal tillage and strategic use of and placement of fertiliser. However, more can be done and these projects should assist in this regard. This is vitally important as the sugar industry is the largest cropping activity in the Great Barrier Reef Catchment.

The Cluster

Projects

Table 1 presents the details for each of the 11 projects included in the Soil Resources and Nutrients cluster.

Table 1: Summary of Project Details

Project Number	Project Title	Other Details
STU039 Nitrogen in GCTB	The availability of nitrogen in green cane trash blanketed (GCTB) soils in the wet tropics and its impact on productivity and profitability	Organisation: University of Queensland Period: March 2001 to February 2009 Principal Investigator: Elizabeth Meier (PhD student)
STU040 Soil Bulk Density	Measuring soil bulk density in the field	Organisation: University of Queensland Period: July 2004 to May 2008 Principal Investigator: Jason Perna (Honours student)
STU050 Acid Sulfate Soils	Microbiology of acid sulfate soils in agricultural environments	Organisation: Australian National University Period: July 2004 to May 2008 Principal Investigator: Mira Durr (PhD student)
CSE011 Nitrogen Management	Improved environmental outcomes and profitability through innovative management of nitrogen	Organisation: CSIRO Sustainable Ecosystems Period: July 2004 to May 2008 Principal Investigator: Peter Thorburn
GGP015 Mill Mud Applicator	Development of a precision mill mud applicator for a new farming system	Organisation: Maryborough Advanced Growers Group Period: July 2006 to June 2008 Principal Investigator: Jeff Atkinson
GGP017 Soil Health	Improving soil health in undulating dryland farms in the Central region	Organisation: Conningsby Dryland Farmers Group Period: July 2006 to June 2008 Principal Investigator: Rino De Boni
GGP018 Variable Rate Technology	Nutrient management from variable rate technology in a control traffic system by the Oakenden Grower Group	Organisation: Oakenden Grower Group Period: July 2006 to December 2008 Principal Investigator: John Muscat
GGP023 Managing Yield Variability	Utilising available technology to better manage yield variability within blocks	Organisation: Blackburn Harvesting Period: July 2006 to June 2008 Principal Investigator: Lee Blackburn
GGP034 By-product Processing	Profits through Recycling: Pilot processing of sugar industry and community by-products to improve on-farm sustainability	Organisation: Advanced Nutrient Solutions (Central Region Innovation and Support Group) Period: July 2007 to June 2010 Principal Investigator: Neal Ross

GGP035 Implement Coulters	Developing implement coulters for volcanic red soils	Organisation: Innisfail Babinda Innovative Farmers Period: August 2007 to January 2008 Principal Investigator: Miles Darveniza
DPI019 Soil Mapping	Improving knowledge for statistical analysis of high resolution soil mapping data	Organisation: Queensland Department of Primary Industries and Fisheries Period: January 2008 to May 2008 Principal Investigator: Angela Reid

Project Objectives

Table 2 presents the objectives for each of the projects included in the cluster.

Table 2: Description of Project Objectives

Project Number	Objectives
STU039 Nitrogen in GCTB	• To investigate the effect of retaining trash on the nitrogen content of sugarcane soils in the Australian wet tropics, and the implications of such changes on profitability and productivity.
STU040 Soil Bulk Density	• To adapt an existing laboratory based model/mathematical equation to predict the soil bulk density for application in the field following loading of a particular soil.
STU050 Acid Sulfate Soils	• To investigate the microbial community in acid sulphate soils including community structure, functional capacity for transforming iron, sulphur and nitrogen and identification of bacterial and archaeal species.
CSE011 Nitrogen Management	• The broad aim of this project is to reduce nitrogen (N) fertiliser applications on sugarcane farms to decrease production costs to growers and abate nitrogen losses to the environment. Specifically, this aim will be achieved through developing and implementing the 'replacement concept' of N management by: • Better defining the amount of N lost through harvested cane, trash burning (where applicable) and unavoidable environmental losses in different regions (from the wet tropics to NSW), under different conditions (e.g. irrigation and dryland) and different farm management practices. • Demonstrating that replacing these losses provides a reliable and profitable cane supply. • Developing methods for accounting for N contributions from organic sources such as mill mud or fallow legumes to sugarcane N supply. • Applying and refining in-mill and other methods of monitoring the N status of sugarcane crops. • Developing the knowledge base within the grower and advisor community to underpin adoption of the 'replacement' N management practices. • Defining benchmarks for the industry and broader community of the amount of N needed for sustainable sugarcane production.
GGP015 Mill Mud Applicator	• To design and manufacture a precision applicator to apply mill mud in a band in between dual rows 800 mm apart on a 2 metre controlled traffic farming system covering three complete beds and a swath width of 6m to overcome the current problem of inefficient application and field

	compaction. • To evaluate yield data collected through a trial comparing varied rates of band application and conventional practice. • To evaluate the economics of band application compared to conventional practice including results of the yield data. • To communicate the outputs of the project to other growers in the region and to growers in other regions.
GGP017 Soil Health	• To improve the condition of soil for the following cane crop by introducing break crops. • To investigate zero tillage options in undulating soil conditions to reduce erosion. • To compare the benefits of different rotational crops/legumes to soil health in relation to nitrogen fixation, organic matter and soil borne diseases (pachymetra and nematodes). • To reduce input costs in the production cycle, and compare costs for different rotational crops/legumes. • To test the suitability of a minimum/zero till planter in various soil types for cane and break crop planting. • To increase the flexibility of the break crop planting window by reducing the reliance on, and associated risks with, weather conditions.
GGP018 Variable Rate Technology	• To determine the benefits of a nutrient management system in a controlled traffic farming enterprise in an environmentally sustainable manner. • To determine the costs and benefits by comparing conventional nutrient application to variable rate application. • To compare different legumes and the impact on the following cane crop. • To determine the difference between narrow chute planting and wide chute planting.
GGP023 Managing Yield Variability	• To gain information on the different layers of information collected at a block level to allow site specific crop management.
GGP034 By-product Processing	• To investigate a process to accelerate improved soil health using farm and mill by-products. • To increase the skills and knowledge of canegrowers to understand soil dynamics by conducting field trials. • To demonstrate the soil microbe relationship to soil health using analytical soil assays. • To pilot the development of a composting system for the Queensland sugar industry. • To provide robust data and information for further scientific study that includes in-depth scientific analysis of soil health benefits and further investigation of application rates.
GGP035 Implement Coulters	• To research different options currently in the marketplace to replace traditional coulters used on farming implements used in red volcanic soils such as ripper coulters, fertiliser applicators and Confidor Guard applicators that tend to merely push the green trash blanket instead of cutting through it. • To purchase selected equipment and modify/develop this equipment for this particular soil type.

DPI019 Soil Mapping	• To attend the First Global Workshop on High Resolution Digital Soil Sensing and Mapping held in Sydney in 2008. The aim of the workshop was to identify technologies for measuring and predicting key soil properties.

Project Investment

Table 3 shows the annual investment by project for SRDC. Table 4 shows the annual investment by project for other investors (mostly in-kind resources from research organisations and industry). Table 5 summarises the total annual investment.

Table 3: Investment by Project by SRDC (nominal $)

Project	Year ended 30th June										
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
STU039	2,475	7,425	7,425	8,662	0	0	0	0	0	0	25,987
STU040	0	0	6,000	0	0	0	0	0	0	0	6,000
STU050	0	0	0	0	32,000	32,000	32,000	6,500	0	0	102,500
CSE011	0	0	0	0	258,000	271,869	286,337	289,463	0	0	1,105,669
GGP015	0	0	0	0	0	0	26,700	5,700	0	0	34,400
GGP017	0	0	0	0	0	0	23,000	9,000	0	0	32,000
GGP018	0	0	0	0	0	0	32,000	35,000	3,000	0	70,000
GGP023	0	0	0	0	0	0	22,875	22,625	0	0	45,500
GGP034	0	0	0	0	0	0	0	40,000	36,000	4,000	80,000
GGP035	0	0	0	0	0	0	0	36,000	4,000	0	40,000
DPI019	0	0	0	0	0	0	0	1,108	0	0	1,108
Total	2,475	7,425	13,425	8,662	290,000	303,869	422,912	445,396	43,000	4,000	1,541,164

Table 4: Investment by Project by Others (nominal $)

Project	Year ended 30th June										
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
STU039	0	0	0	0	0	0	0	0	0	0	0
STU040	0	0	0	0	0	0	0	0	0	0	0
STU050	0	0	0	0	0	0	0	0	0	0	0
CSE011	0	0	0	0	346,026	364,627	384,031	388,224	0	0	1,482,908
GGP015	0	0	0	0	0	0	18,300	8,700	0	0	27,000
GGP017	0	0	0	0	0	0	23,108	60,333	0	0	83,441
GGP018	0	0	0	0	0	0	47,592	44,370	2,620	0	94,582
GGP023	0	0	0	0	0	0	85,375	5,625	0	0	91,000
GGP034	0	0	0	0	0	0	0	111,703	53,666	1,368	166,737
GGP035	0	0	0	0	0	0	0	10,000	3,000	0	13,000
DPI019	0	0	0	0	0	0	0	1,779	0	0	1,779
Total	0	0	0	0	346,026	364,627	558,406	630,734	59,286	1,368	1,960,447

Table 5: Summary of Annual Investment by SRDC and Others (nominal $)

Year ending June	SRDC	Other	Total
2001	2,475	0	2,475
2002	7,425	0	7,425
2003	13,425	0	13,425
2004	8,662	0	8,662
2005	290,000	346,026	636,026
2006	303,869	364,627	668,496
2007	422,912	558,406	981,318
2008	445,396	630,734	1,076,130
2009	43,000	59,286	102,286
2010	4,000	1,368	5,368
Total	1,541,164	1,960,447	3,501,611

Outputs

Table 6 provides a brief summary of the activities and outputs for each of the projects.

Table 6: Summary of Project Activities and Outputs

Project	Activities and Outputs
STU039 Nitrogen in GCTB	• The study used field studies of nitrogen dynamics, laboratory studies of nitrification processes and APSIM modelling to analyse different trash management practices. • The observations made from the simulation study indicated that soil nitrogen concentrations were greater in trash retained than in burnt trash management systems. However, the difference was not reflected in the yield responses for nitrogen due to immobilisation of nitrogen fertiliser in the trash blanket and uptake of N by the crop. • Elizabeth Meier was awarded a PhD.
STU040 Soil Bulk Density	• The honours thesis was not received by SRDC so the following is based on a progress report. • A model was developed that could predict for a soil of known soil water content, texture and organic matter content, the expected bulk density of the soil resulting from a load (such as a tractor or harvesting equipment). • The scholarship resulted in the ability to assess compaction impacts of land preparation for planting cane. • Jason Perma successfully completed his honours thesis in 2003 and was employed by BSES Ltd until early 2011 and now works for Macarthur Coal.
STU050 Acid Sulfate Soils	• Conducted laboratory work at CSIRO campus at ANU and field work on 3 separate cane farms in northern NSW. • A major finding was the presence of a previously unrealised diversity of Archea present within acid sulphate soils. • The Archea are fundamentally involved in the biogeochemical cycling of sulfur, iron and nitrogen in a number of habitats. • The information was then linked to the soil properties under sugar

	cane to better understand biological nutrient cycling in acid sulphate soils. • Mira Durr was awarded a PhD and is now employed by AQIS.
CSE011 Nitrogen Management	• A baseline survey of nitrogen application rates from participating farms was conducted in 2004. • On-farm trials were conducted for three years, including both a ‘replacement nitrogen’ method and traditional methods of N management, along with trials by Bundaberg Sugar of greater experimental rigour. • Methods for monitoring crop N status focusing on leaf N and CAS-NIR monitoring of cane and juice N, were assessed against direct measurements in the trial plots and other blocks. • Activities were undertaken that tested capabilities for representing legumes and mill mud, the main sources of organic nitrogen in cropping systems modelling. • Annual workshops with growers to report and discuss the results of all approaches to N management were conducted. • Regional grower/extension groups were established to provide local forums for discussion about the project and N fertiliser management. • The project found that there was less N in harvested cane (~0.5 kg t-1 compared with 0.9 kg t-1) than previously thought, although amounts in trash were similar. Thus N removed through harvesting (and burning) the crop is less than anticipated and so losses to the environment are greater. Because of the lower N in cane than previously thought, the N lost to the environment will be greater than previously estimated. • The nitrogen replacement (NR) system proposes that replacing these losses provides a reliable and profitable cane supply. In 11 experiments cane yields were generally similar in the NR treatment and under farmers’ conventional N management, despite the fact that N applications were on average 64 kg ha^{-1} lower in the NR treatments. • It was estimated that N lost to the environment was ~40% less in the NR treatment than the conventional applications. There was a trend for yields in the NR treatments to be lower than those in conventional applications in the first crop after the treatments were imposed, with yields either ‘catching up’ or exceeding those at higher N rates in later crops. This catch-up even occurred at a site where N in soil was deliberately run down prior to establishment of the NR treatment. • The results suggest that, if assessed over the medium- to long-term, the ‘replacement rate’ in the NR system (1 and 1.3 kg N t^{-1} in trash blanketed and burnt cane, respectively) provides a benchmark for the industry and broader community of the amount of N needed for sustainable sugarcane production. • Nitrogen contributions from organic sources, such as mill mud or fallow legumes, were shown to be greater, and last for more cane crops than previously thought. • Better management of N will be supported by widespread, cost

	effective monitoring of N stress in crops and such monitoring needs to be explored further. • N stress was more accurately assessed comparing values against those from crops with known N deficiency or sufficiency, rather than predetermined benchmarks. Thus they are better as relative indicators than absolute ones. • Two national symposia (with a total of 39 papers delivered) and three 'high-level' industry workshops were primarily organised by the project team.
GGP015 Mill Mud Applicator	• The project showed that by applying mill mud in a band with machinery that fits in with a controlled traffic system, significant savings can be made as a fixed quantity of the mill mud delivered can be applied to a greater area of cane. • An economic analysis tool was constructed demonstrating savings that were verified in the plant crop with yields being recorded in the next few seasons to assess if there is a difference in subsequent ratoons. • There was considerable potential for reducing off-farm nutrient loss by use of the system, although this was not tested in the project.
GGP017 Soil Health	• Planting rotational break crops was carried out and various planting equipment was assessed. Results were evaluated and field days hosted. • The break crop trials showed that Leichhardt out-performed Ashgrove, Stuart and Bunya varieties of soybeans with wet weight biomass yields of over 12t/ha and total N of over 250kg/ha in one trial. • In the plant cane comparison trial, the zero tillage plots proved to be most profitable with the highest yields, lowest input costs, and highest profit of $352/ha compared with the full cultivation plots which returned only $141/ha. • A range of zero tillage break crop planters were inspected and trialled, with required modifications identified. The project identified a deficiency in existing minimum tillage cane planter designs when it comes to heavy clays and other difficult soil types.
GGP018 Variable Rate Technology	• The variable rate strips achieved an increase in return of harvested cane of between $209 and $446 per ha due to the lime placement. • There was concern with the accuracy of conventional testing which did not pick up the lack of nutrients (calcium) in the paddock; the electromagnetic induction mapping process established that calcium was under the critical value. • There were four legume rotational crops planted including Ashgrove, Sun Hemp, Guar, and Leichardt, in replicated trials as a rotational crop. Sun Hemp gave an impressive performance. • Cane was planted after harvest and after harvesting all costs were collated and the legume crops indicated an increase in return of $193 per hectare above a bare fallow alternative. • The wide chute billet planter in this trial was compared with a narrow chute with the wide chute showing an increase of $537.80 per hectare after levies and harvesting deductions. • Also, there were three different GPS systems investigated and a

	factsheet on different GPS systems was presented as an Appendix in the report.
GGP023 Managing Yield Variability	• Assembly of a number of different layers of information such as, satellite imagery, Electromagnetic Induction Mapping “soil”, Yield Mapping, soil analysis and leaf analysis, management of the nutrient applied, and the gross margins achieved. • Identification of the cause of yield variation between and within blocks. • Information system to allow a change from traditional input management (e.g. generic application of nutrients and chemicals) to a highly strategic, site-specific application of required inputs.
GGP034 By-product Processing	• Successful production of humified compost production derived from locally produced by-products (farm and mill by-products). • Successful trial of application methods and recording of impacts. • Comparisons between compost, compost plus granular fertiliser and granular treatments alone as nutrient sources showed there were minimal productivity differences.
GGP035 Implement Coulters	• Identification and purchase of preferred commercial coulter option. • Successful trial comparison of the daybreak coulter implement against current disc coulter implements used in the region. • Analysis of the data shows that the daybreak coulters produced higher stalk counts and therefore have a higher yield potential than standard coulter systems in red soil. • A series of recommendations for further improvement to the coulter.
DPI019 Soil Mapping	• Attendance at the workshop allowed Angela to improve her knowledge on statistical methods for spatial sampling and statistical analysis including the latest methods for prediction methods and how to relate satellite images to soil survey data.

Outcomes

A brief summary of outcomes by project is provided in Table 7.

Table 7: Summary of Project Outcomes

Project	Outcomes
STU039 Nitrogen in GCTB	• The results suggest that N fertiliser rates might be reduced in the wet tropics, given the low use efficiency by crops from fertiliser and high soil N concentration. • The study provided important information for the sustainability of the sugar industry in the wet tropics due to potential minimisation of negative environmental effects of nitrogen fertiliser. • SRDC acknowledged the suggestions made for further research, particularly the need to expand the research to other regions. • The findings may encourage more canegrowers to use trash for other purposes rather than retain it for nitrogen supply.
STU040 Soil Bulk Density	• Potentially, the model could be used to design rules of thumb that can in turn be used to avoid soil compaction and improve soil structure on cane growing soils.

	• Potentially, researchers and engineers can use the proposed model when designing machinery or new farming practices with the knowledge that they can predict the soil bulk density that will result from new designs. • To the knowledge of Jason Perna, the model has not been used (Jason Perna, pers. comm., 2011).
STU050 Acid Sulfate Soils	• The findings indicated an underlying relationship between sulphur and nitrogen cycles. • The industry now has an improved understanding of microbial soil interactions and some indications on how to better manage acid sulphate soils in the future. • The research produced the first catalogue of species present in acid sulphate soil and provides a basis for future research, particularly to understand the cycling of sulphur and nitrogen in a complex environment. • There were no direct management changes to acid sulphate soils as a result of the research as there was little extension. • However, the research findings have been used as a building block for further research in soil biology and soil biogeochemistry.
CSE011 Nitrogen Management	• Redefined N management recommendations for the sugar industry. • Growers and advisors having a better understanding of the amount of N lost during the growth and harvest of a crop and the amount of N that can be supplied to crops by soils of a range of regions. • Community and growers knowledgeable about the amount of N fertiliser required to grow a sugarcane crop without either (1) polluting the environment, or (2) degrading soil quality by running down N in soil organic matter. • Sugarcane production systems with improved profitability and in better harmony with the environment and society's expectations. • The workshops together with regular interaction with regional groups and collaborating farmers helped develop a knowledge base to underpin adoption of the 'replacement' N management practices. • The results suggested that the N loss to the environment was in the order of 0.8 kg N per tonne of cane. • Adoption of the nitrogen replacement approach could reduce these surpluses by 0.3 kg per tonne of cane or 10,000 tonnes of N per annum across the whole industry. • Impacts have included early adoption of the NR system by farmers, and the NR inclusion as an 'A-Class' practice in a number of Water Quality Improvement Plans, and independent testing of the system by BSES Ltd.
GGP015 Mill Mud Applicator	• Potential cost savings of acquiring mill mud (transport and spreading costs only paid by grower) per ha of cane planted. • Assumes cost of spreading is the same with the new spreading system and that controlled traffic systems are used. • Most of the mill mud in the Maryborough mill area is now spread in this way. • Savings of $6.63 per tonne of mill mud is estimated for 80% of the 33,000 tonnes of mill mud from the Maryborough Mill.

	• The cane regions of Isis (50%) and Mackay (60%) have also adopted the applicator system for spreading mill mud (Jeff Atkinson, pers. comm., 2011).
GGP017 Soil Health	• The project assisted Farleigh & Coningsby growers to select, and successfully grow dryland soybean break crops. • The findings demonstrated the cost savings and improved soil management offered by zero/minimal tillage practices. • Growers have gained valuable skills in cost comparison trials, and appropriate trial designs, which will be of assistance as they continue to adapt their farming systems. • Rino de Boni and one other cane farmer have directly benefited from the project and now grow soybeans regularly and reduce nitrogen fertiliser inputs (Rino de Boni, pers. comm., 2011)
GGP018 Variable Rate Technology	• Increased adoption of variable rate applications of lime that have provided increased yields and reduced input costs resulting in higher profitability. • Increased adoption of rotation crops instead of bare fallow. • Increased use of the wide chute planter with improved yields and profitability. • These technologies have all been taken up by the Oakenden group to varying extents; other producers in the Central Region have also been influenced (John Muscat, pers. comm., 2011).
GGP023 Managing Yield Variability	• Capacity for change and confidence enhanced via direct involvement of growers in all activities undertaken. • Strengthened partnership between the grower group and Mackay Sugar Co-operative therefore influencing a wider number of growers. • Working relations between Blackburn Harvesting and Deguara Harvesting groups. • The results achieved by utilising available technology to better manage yield variability within blocks has been adopted over a farming area of the group of about 800 ha due to the increased confidence achieved by conducting this project. • Savings in input costs such as fertiliser, lime and ash. • The group has also now undertaken that complete record keeping will be utilised and this will lead to better management decisions to be made at a block level. • The reduction in fertiliser and herbicide applied represent positive environmental outcomes.
GGP034 By-product Processing	• Knowledge and skills in compost production were strengthened and extended. • A two year time frame as characterised by these experiments was considered inadequate to detect differences in productivity. • A project with a longer time frame was recommended and has been funded by SRDC (John Ross, pers. comm., 2011). • While compost is not being used on a commercial basis to date, results are encouraging in that the compost treatment is the only treatment that has delivered all nutrient analyses to be above critical levels, based on three years of leaf analysis results. • Soil organic matter after 2 years is improving only slowly and is

	expected to take up to 7-10 years to increase significantly (John Ross, pers. comm., 2011).
GGP035 Implement Coulters	• Use of best management practice is now possible with red volcanic soils. • Initiative and planning skills of group members improved to a level where they can acknowledge success of coulters and adapt current implement to complete application of insecticide (Confidor Guard ®). • Successful demonstration of coulters and other techniques learnt in the project to other district growers. • Improvement of grower skills in agricultural mechanisation, tillage, erosion control and project management. • Potential for improvement of water quality in farm runoff through reduced disturbance of the trash blanket. • The group aims to further trial the coulters and collect data on water quality and yield response from sub-surface fertiliser application. • The improved coulters are now being used for about 80 ha of plant cane per annum within the group; a further small number of coulters have been sold in the Tully region and other north Queensland districts (Miles Darveniza, pers. comm., 2011). • Additional cane yields are being experienced at an average of about 5 tonnes per ha due to the coulter by allowing Confidor to be used to control cane grubs (Miles Darveniza, pers. comm., 2011).
DPI019 Soil Mapping	• Capacity building and expansion of Australian and international professional networks. • Enhanced input and data analysis for Project BPS001 (Identifying management zones within cane paddocks: an essential foundation for precision sugarcane agriculture).

Benefits

A brief summary of benefits by project is provided in Table 8.

Table 8: Summary of Cluster Benefits

Project	Benefits
STU039 Nitrogen in GCTB	• Increased scientific and research capacity in soil management. • Potential for reduced N fertiliser use in the wet tropics with budgetary savings and reduced N loss to the environment. • Potential for encouragement of higher value uses for trash.
STU040 Soil Bulk Density	• Increased scientific and research capacity in soil management. • Potential for improved soil structure on some cane producing soils from improved timing of planting operations and improved machinery design, both with positive yield impacts.
STU050 Acid Sulfate Soils	• Increased scientific and research capacity in soil management. • Platform on which to launch further research aimed at better understanding of soil microbe functional groups with potential to develop applications to better manage acid sulfate soils.
CSE011	• Decreased sugar production costs from reduced use of nitrogen

Nitrogen Management	fertiliser. • Reduced nitrogen loss to the environment with reduction of impact on the Great Barrier Reef ecosystems. • More flexible use of cane trash.
GGP015 Mill Mud Applicator	• Reduced cost of production of cane (plant crop) due to reduction in mill mud received per ha without compromising cane yield. • More plant cane is benefiting from mill mud with savings in fertiliser costs. • Likely reduction in nutrient loss off-farm due to mud not being applied in wheel tracks.
GGP017 Soil Health	• Increased use of break soybean crops with subsequent yield increases and nitrogen savings for cane crop following. • Potential lowering of off-site impacts.
GGP018 Variable Rate Technology	• Increased use of break crops, wide chute planters and variable rate technology. • Increased profitability of those in the group who have changed practices. • Reduced export of excess nutrients off-farm.
GGP023 Managing Yield Variability	• Reduced cost of inputs enhancing net returns per ha of cane. • Reduced export of excess nutrients off-farm.
GGP034 By-product Processing	• Capacity in compost making and interest in use of compost strengthened. • Potential for reducing inorganic fertiliser use and costs in the longer term.
GGP035 Implement Coulters	• Improved cane yield due to ability to use liquid Confidor against cane grubs in red volcanic soil types. • Also provides ability to apply fertiliser into subsoils. • Potential improvement in water quality running off farms due to lesser disturbance of the trash blanket.
DPI019 Soil Mapping	• Enhanced analysis of management zones that could potentially lead to improved benefits to zonal management practices and minimisation of costs of detailed soil surveys. • Potential minimisation of off-site impacts such as leaching by better matching nutrients to plant demand.

Table 9 summarises the major benefit types, and the contribution of each project to that benefit. It also identifies the potential regions to which the benefits apply.

Table 9: Summary of Contribution of Each Project to Major Benefit Types

Project	**Cost reduction including yield increases**	**Improved soil and fertiliser management including reduced soil and nutrient export**	**Potential for new product development**	**Strengthened industry research capacity**	**Strengthened scientific R&D capacity**
STU039	X	X	X		X
STU040					X
STU050		X			X
CSE011	X	X	X		
GGP015	X	X		X	
GGP017	X	X		X	
GGP018	X	X		X	
GGP023	X	X		X	
GGP034			X	X	
GGP035	X	X		X	
DPI019	X	X			X

Summary of Benefits
A summary of the principal types of benefits associated with the outcomes of investment in the cluster of projects is shown in Table 10.

Table 10: Categories of Benefits from the Investment

Levy Paying Industry	**Spillovers**	
	Other Industries	**Public**
<u>Economic Benefits</u>		
Input cost reduction for cane production Cane yield increases Potential increase in alternative use of cane trash	Increased area of soybean crops lowering infrastructure costs and strengthening marketing	
<u>Environmental Benefits</u>		
Reduced loss of soil and nutrients from farm land		Improved quality of water exported off-farm (soil and nutrients)
<u>Social Benefits</u>		
Increased industry research capacity		Increased soil science capacity

Public versus Private Benefits
The majority of the benefits were private in nature, with benefits mostly relating to saved cane production costs and improved yields. The public benefits relate mainly to environmental benefits from reduced nitrogen use and improved soil management producing improved quality of water exported off-farm. Some scientific capacity building benefits can also be classified as public benefits.

Distribution of Benefits along the Sugar Supply Chain
The benefits from the projects in this cluster will be captured mainly by cane producers with harvesters, transporters, mills and marketers all potentially benefiting to lesser degrees.

Benefits to other Primary Industries
The soybean industry and those associated with other break crops may benefit.

Benefits Overseas
There will be no benefits to overseas consumers or producers of sugar.

Additionality and Marginality
Supporting these studies was a high to medium level priority for SRDC, partly due to the need to further reduce potential environmental impacts as well as reduce costs. If public funding of SRDC were reduced, it is likely that a significant number of the projects would still have been funded, although perhaps to a lesser extent or over a longer period of time.

Further detail is provided in Table 11.

Table 11: Potential Response to Reduced Public Funding to SRDC

1. What priority were the projects in this cluster when funded?	Medium to High (for the majority of the projects)
2. Would SRDC have funded this cluster if only half of public funding of SRDC had been available?	Yes, but possibly to a lesser extent or over a longer time period
3. Would the cluster have been funded if no public funding for SRDC had been available?	Yes, but possibly to a far lesser extent or over a much longer time period

Match with National Priorities
The Australian Government's National and Rural Research Priorities are reproduced in Table 12.

Table 12: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The projects in the cluster contribute to National Research Priorities 1 and 3, and Rural Research Priorities 1 and 3. Some contribution was made also to the two supporting priorities.

Quantification of Benefits

There are five groups of benefits valued in this analysis. These are:
- Cost reductions from lower fertiliser nitrogen use without cane yield or quality penalties
- Improved water quality from reduced soil and nutrient export off-farm
- Cost reduction in the transport and spreading of mill mud
- Higher farm gross margins from increased use of break crops, variable rate technology and use of wide chute planters
- Increased cane yields from the use of disc coulters

The benefits identified but not quantified include:
- Enhanced industry capacity to undertake research
- Capacity building in soil science
- Potential for new product development such as compost
- Reduced costs of soil surveys

Reduced nitrogen use for the same yield
The use of the nitrogen replacement system did not affect yields, despite the fact that N applications were on average 64 kg per ha lower. Also it was estimated that the N losses to the environment were about 40% less in the nitrogen replacement treatment.

The assumption is made that the information will result in an average reduction of N fertiliser application of 40 kg per ha for a proportion (2.5%) of canegrowing land over five years commencing in 2009. It is assumed this involved no additional costs and has been driven by the information presented and a general raising of industry awareness rather than specific application of the nitrogen replacement strategy.

Improved water quality from improved soil and nutrient management practices
This benefit was valued based on a recent study that applied choice modelling to assess community values for reduced agricultural emissions that would improve water quality and therefore improve coral health in the Great Barrier Reef (Windle and Rolfe, 2010).
Changes in agricultural emissions were presented in the survey as 'water quality units' where one unit was equivalent to the reduction of 100,000 tonnes of sediment, 200 tonnes of nitrogen and 46 tonnes of phosphorus. The survey was completed by households from coastal Great Barrier Reef communities, Brisbane, Melbourne and Perth. The results indicate that households were willing to pay \$2.40 to \$5.55, every year for five years to generate an annual improvement of one water quality unit in the Great Barrier Reef catchment area for 25 years. These values aggregate to a national benefit of \$23.6 million per annum.

For the purposes of this analysis, it is assumed that a 2.5% improvement of one water quality unit will be achieved as a result of the projects in this cluster. That is, an annual reduction of 2,500 tonnes of sediment, 5 tonnes of nitrogen and 1.15 tonnes of phosphorus. The benefit of a 2.5% improvement of one water quality unit is therefore \$590,000 per annum for five years (2.5% of \$23.6 million). The costs of making these water quality improvements have been taken into account in evaluating the associated industry benefits from the practice changes.

Potential for a cost reduction in the transport and spreading of mill mud (Maryborough)
The Maryborough Advanced Growers Group has led this innovation that has spread to other mill areas such as Isis and Mackay (Jeff Atkinson, pers. comm., 2011). The innovation has allowed mill mud application rates to be reduced without any cost or yield penalties. This has allowed the cost of transport and application per ha to be reduced and the mill mud available is now able to be used on more plant cane areas. It is assumed that 80% of the Maryborough mill mud is now spread this way with savings of over \$6 per tonne.

Increased use of variable rate technology, break crops and wide chute planters (Oakenden Grower Group)
Three practice changes associated with this project were valued with different areas affected and grower benefits and costs for each. Although adoption of the wide chute planter has spread to other areas, a conservative assumption of the area affected by the project itself has been made. The largest benefit for this project came from the adoption of the wide chute planter. An attribution to other factors affecting the practice changes has been made.

Blackburn Harvesting Group: Increased use of variable rate technology by members of the Blackburn Harvesting Group has occurred due to their project. This has resulted in input costs savings to growers in the group as well as other growers in the central region. Only benefits to the growers directly involved in the group are included in the analysis. The additional investment costs in auto steer and variable rate control have been included.

Conningsby Dryland Farmers Group: Two farms in the Conningsby Dryland Farmers Group have directly benefited from the investment in break crops with each growing about 40 ha of soybeans or other green manure crop every year and reporting increased yields and reduced nitrogen fertiliser requirements for their subsequent cane crops.

Increased yields from ability to use Confidor Guard (Innisfail Babinda Innovative Farmers)
Increased yields averaging 5 tonnes per ha have been derived from the use of the disc coulters, benefiting around 80 ha of cane per annum.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 13.

Table 13: Summary of Assumptions

Variable	**Assumption**	**Source**
Cost savings from reduced nitrogen use from N replacement strategy		
N saved	40 kg per ha	Based on 64 kg average reduction (CSE011 Final Report)
Value of N	$1.08 per kg	Based on urea value of $500 per tonne
Average cane area in Australia (2009, 2010, 2011)	373,000 ha	ABARES (2011)
Proportion of cane area reducing N application rate	2.5%	Agtrans Research
Improved water quality		
Value of 1 water quality unit improvement in the Great Barrier Reef	$23.6 million per annum for five years	Windle and Rolfe (2010)
Proportion of 1 water quality unit gained due to projects	2.5%	Agtrans Research
Value of gain	$590,000 per annum for five years commencing 2009	$23.6m x 2.5%
Mill mud spreading efficiencies (Maryborough)		
Maryborough mill mud production	33,000 tonnes per annum	Final Report for Project GGP015
Saving per tonne of mill mud spread with applicator?	$6.63 per tonne	Final Report for Project GGP015
Proportion of Maryborough mill mud spread with new applicator	80%	Agtrans Research after discussion with Jeff Atkinson
Increased use of break crops, variable rate technology and wide chute planters (Oakenden)		
Variable rate		
Area benefiting	600 ha plant cane per annum	John Muscat, pers. comm., 2011
Benefit gained	$327 per ha	Final Report for Project GGP018
Capital cost of variable rate controller plus auto steer	$40,000 based on 10,000 tonne cane farm (123 ha based on yield of 81 t per ha)	Lee Blackburn, pers. comm., 2011
Amortised value of capital investment	$5,419 per 10,000 tonne cane farm	Amortisation factor of 0.13548 (10% discount rate and 15 year life)
Annual satellite imagery and mapping costs	$2,500 per annum based on a 10,000 tonne cane farm (123 ha)	Agtrans Research after discussion with Lee Blackburn
Attribution to project	40%	Agtrans Research

Rotation crops		
Area benefiting	1,000 ha per annum	John Muscat, pers. comm., 2011
Benefit gained	$193 per ha of break crop (green manure crop)	Final Report for Project GGP018
Attribution to project	40%	Agtrans Research
Wide chute planter		
Area benefiting	1,000 ha per annum	John Muscat, pers. comm., 2011
Gross benefit per ha	$537 per ha plant cane	Final Report for Project GGP018
Additional cost of billets	3 tonnes per ha @ $35 per tonne = $99 per ha	John Muscat, pers. comm., 2011
Modification of planter	Capital cost of $1,500	John Muscat, pers. comm., 2011
Amortised value of planter cost	$203 per annum per 10,000 tonne cane farm	$1,500 amortised per 10,000 tonnes cane farm at 10% over 15 years
Attribution to project	40%	Agtrans Research
Increased use of break crops (Conningsby)		
Increased area of break crops (soybeans) due to the project	80 ha per annum	Rino de Boni, pers. comm., 2011
Financial benefit gained	$345 per ha of soybeans (based on soybeans sold for grain and includes cane yield increases and nitrogen savings)	Agtrans Research (2008)
Increased use of variable rate technology (Blackburn Harvesting Grop)		
Area of cane in group that has benefitted	800 ha per annum	Lee Blackburn, pers. comm., 2011
Average input cost savings per ha	$200 per ha input costs saved	Agtrans Research after discussions with Lee Blackburn
Capital cost of variable rate controller plus auto steer	$40,000 based on 10,000 tonne cane farm (123 ha based on yield of 81 t per ha)	Lee Blackburn, pers. comm., 2011
Amortised value of capital investment	$5,419 per 10,000 tonne cane farm	Amortisation factor of 0.13548 (10% discount rate and 15 year life)
Annual satellite imagery and mapping costs	$2,500 per annum based on a 10,000 tonne cane farm (123 ha)	Agtrans Research after discussion with Lee Blackburn
Improved disc coulters (Innisfail Babinda Innovative Farmers)		
Area of cane in group that has benefited	80 ha per annum	Miles Darveniza pers. comm., 2011
Increase in cane yield	5 tonnes per ha on average	Miles Darveniza pers. comm., 2011
Average value of cane	$35 per tonne	Agtrans Research
Added harvesting costs	$6.15 per tonne	Agtrans Research

Results
All past costs and benefits were expressed in 2010/11 dollar terms using the CPI. All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high 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 (2009/10) to the final year of benefits assumed.

Investment criteria were estimated for both total investment and for the SRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria are reported in Tables 14 and 15.

Table 14: Investment Criteria for Total Investment and Total Benefits for Each Benefit Period (discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**	**30 years**
Present value of benefits ($m)	1.71	8.64	12.35	15.25	17.53	19.31	20.71
Present value of costs ($m)	4.88	4.88	4.88	4.88	4.88	4.88	4.88
Net present value ($m)	-3.17	3.76	7.46	10.37	12.64	14.43	15.82
Benefit–cost ratio	0.35	1.77	2.53	3.12	3.59	3.95	4.24
Internal rate of return (%)	negative	16.5	20.4	21.5	21.8	22.0	22.0

Table 15: Investment Criteria for SRDC Investment and Benefits to SRDC for Each Benefit Period (discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**	**30 years**
Present value of benefits ($m)	0.76	3.81	5.45	6.73	7.73	8.52	9.14
Present value of costs ($m)	2.16	2.16	2.16	2.16	2.16	2.16	2.16
Net present value ($m)	-1.41	1.65	3.28	4.57	5.57	6.36	6.97
Benefit–cost ratio	0.35	1.76	2.52	3.11	3.57	3.94	4.22
Internal rate of return (%)	negative	16.1	20.0	21.1	21.5	21.6	21.6

There are seven benefits valued in the analysis. Table 16 shows the estimates of the relative contribution from each source.

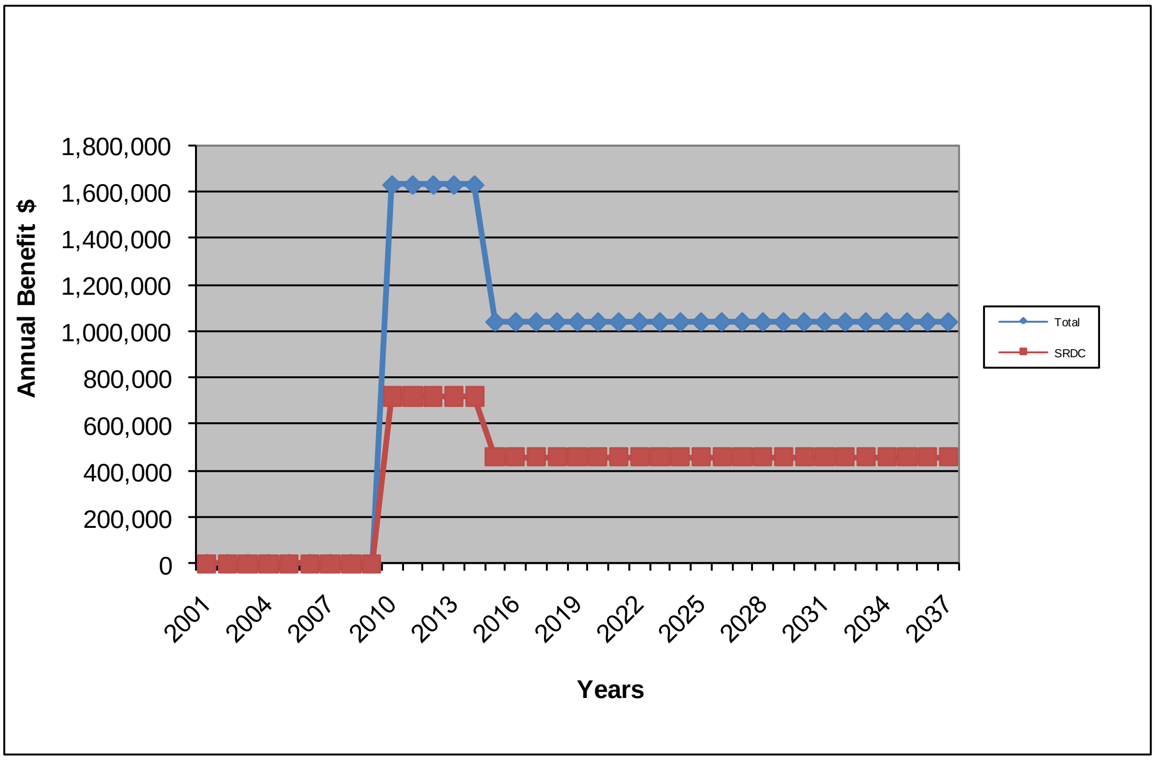
Table 16: Contribution of Source of Benefits to Present Value of Benefits

Source of Benefit	**PVB Contribution ($m)**	**PVB Contribution (%)**
Saved nitrogen fertiliser (CSE011 and STU039)	6.97	34
Improved water quality (most projects)	2.82	14
Mill mud spreading efficiency (GGP015)	3.01	15
Increased use of break crops (GGP017)	0.47	2
Increased use of variable rate technology, break crops and wide shute planters (GGP018)	5.37	26
Increased use of variable rate technology (GGP023)	1.87	9
Use of disc coulters (GGP035)	0.20	1
Total	20.71	100

The quantified benefits address two Rural Research Priorities: productivity and adding value, and natural resource management.

The annual net benefit undiscounted cash flows for both total investment and SRDC investment for the 30 year period from the year of first investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Benefits



Sensitivity Analyses
Table 17 presents the sensitivity of the results to the discount rate. The sensitivity analysis was performed with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values. The investment criteria are not particularly sensitive to the discount rate.

Table 17: Sensitivity to Discount Rate
(Total investment, 30 years)

Criterion	**Discount rate**		
	0%	5% (base)	10%
Present value of benefits ($m)	35.21	20.71	14.64
Present value of costs ($m)	3.96	4.88	5.99
Net present value ($m)	31.25	15.82	8.66
Benefit-cost ratio	8.90	4.24	2.45

The benefit of saved nitrogen fertiliser would have covered the total investment costs for the cluster on its own. The nitrogen saving per ha could have fallen to 28 kg per ha and the single benefit would have still covered the cost of the total investment. Project GGP018 would also have just covered the total investment costs on its own.

Confidence Rating
The results produced are highly dependent on the assumptions made, many 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 18). 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 18: Confidence in Analysis of Managing and Improving Soil Resources and Nutrients Cluster

Coverage of Benefits	Confidence in Assumptions
High	Medium

Conclusions

The SRDC investment in the Soil Resources and Nutrients cluster has been successful in delivering in economic terms benefits to both the sugar industry and the wider community. The cluster of eleven projects covered a mixture of both small and large soil resource and management projects. The four types of projects in which SRDC invests are all represented in this cluster of projects (scholarships, capacity building, grower group innovation projects, and research projects).

The majority of the benefits identified were private in nature, with benefits mostly relating to saved cane production costs and improved margins and yields. The public benefits related predominantly to environmental benefits from reduced nitrogen use and changed soil management practices leading to improved quality of water exported off-farm.

Only some of the benefits identified were valued in this economic assessment. Hence, the quantitative results are probably conservative.

The total investment of $4.9 million (present value terms) has been estimated to produce gross benefits of $20.7 million (present value terms) providing a net present value of $15.8 million and a benefit-cost ratio of 4.2 to 1 (over 30 years, using a 5% discount rate). The internal rate of return was 22%.

Of particular note were the six grower group projects where total funding of only $800,000 (nominal terms and only slightly more in present value terms) provided an estimated total benefit of about $11 million in present value terms. The grower group projects made up less than 25% of the cluster funding but contributed at least 50% of the total benefits attributed to the overall cluster investment.

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John Muscat, Oakenden Growers Group
Jason Perna, Environmental Officer, Macarthur Coal
John Ross, Advanced Nutrient Solutions (Central Region Innovation and Support Group)

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Final Reports to SRDC for all projects.

Appendix 4: An Economic Analysis of SRDC Investment in the "Managing Water More Sustainably" Cluster

Background

The Managing Water More Sustainably cluster includes six projects funded by SRDC. Two of the projects addressed the groundwater problem in the Burdekin whilst another two projects addressed water quality in the Herbert sugarcane area. A web-based irrigation scheduling and planning tool (WaterSense) was promoted in one of the projects and the remaining project supported an R&D workshop to identify water management priorities.

The groundwater problem refers to the rising groundwater table in the Burdekin River Irrigation Area. The Burdekin dam commenced operation in the late 1980's and resulted in a large area of land being cleared and converted to irrigation. This influx of water has caused groundwater levels to rise alarmingly over the past 20 years (Danzi, 2009). More recently, the above average rainfall has also had a major influence on rising groundwater levels (Connell, 2009). High groundwater levels pose a number of issues for landholders in this area, including lost production from water logging and secondary salinisation (Connell, 2009). If the groundwater problem is not rectified, it is likely that some land will be rendered unviable for farming.

The Herbert sugarcane area is located adjacent to the Great Barrier Reef lagoon. The Great Barrier Reef was the first coral reef ecosystem in the world to receive World Heritage status in 1981 (Great Barrier Reef Marine Park Authority, 2011). Good water quality is identified as the reason why the Great Barrier Reef is one of the most beautiful, diverse and complex ecosystems in the world. However, the quality of water entering the Great Barrier Reef has been declining over the last decade (Great Barrier Reef Marine Park Authority, 2011). Sediment and nutrient emissions in agricultural runoff have been identified as the key contributors to poor water quality. As the sugar industry is the largest cropping activity in the Great Barrier Reef Catchment, water quality presents one of the most important environmental issues facing the Herbert sugar industry.

WaterSense is a web-based irrigation scheduling and planning tool developed by CSIRO Sustainable Ecosystems to deliver improved water management for the sugarcane industry.

The Cluster

Projects

Table 1 presents the details for each of the six projects included in the Managing Water More Sustainably cluster.

Table 1: Summary of Project Details

Project Number	Project Title	Other Details
CG013	Growers working together to improve water quality in the Herbert Sugar Industry	Organisation: CANEGROWERS Herbert River Period: July 2005 to August 2008 Principal Investigators: Tim Wrigley, Peter Sheedy and Andrew Wood
CG018	A review of institutional arrangements in the Burdekin	Organisation: CANEGROWERS Period: March 2006 to April 2007

	Irrigation Area with a view to managing sustainable farming practices in the region	Principal Investigators: Eric Danzi
BBF001	Pilot area-wide natural resource management group - building grower capacity to understand and better manage groundwater	Organisation: Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC) Inc. Period: July 2006 to August 2009 Principal Investigators: Adam Connell
BSS297	Delivering web-based irrigation management	Organisation: BSES Limited Period: July 2006 to September 2009 Principal Investigator: Trevor Willcox
SRD021	Water Management Workshop 2007	Organisation: SRDC Period: December 2007 Principal Investigator: Les Robertson
CG020	Workshop to promote on-farm water quality testing by growers	Organisation: CANEGROWERS Period: January 2008 to August 2008 Principal Investigator: Tim Wrigley

Project Objectives

Table 2 presents the objectives for each of the projects included in the cluster.

Table 2: Description of Project Objectives

Project Number	Objectives
CG013 Water quality monitoring in Herbert	• To establish grower-participatory water quality monitoring in up to five representative sugarcane sub-catchments within the Herbert. • To establish rapid feedback processes for the water quality results from caneland runoff where growers are providing the information to other growers. • To increase awareness of the relationship between land management practices and water quality. • To establish baseline data so that improvement plans can be developed as part of a Farm Management System (FMS). • To improve the level of consultation and collaboration between Herbert landholders and all groups with an interest in sustainable land management, including regulatory authorities. • To validate best management practices and risk management procedures, developed in project BSS268, for minimising off-site nutrient movement for the soil types in the focus sub-catchments.
CG018 Groundwater management in Burdekin	• To review the institutional arrangements in the Burdekin River Irrigation Area (BRIA) with a view of managing sustainable farming practices in the region.
BBF001 Groundwater management in Upper Haughton	• To identify potential salinity problems. • To identify changes in groundwater levels. • To create a model of the aquifer for the Upper Haughton area from the data collected. • To provide grower information and resources (e.g. monitoring equipment) to better manage groundwater.

	• To improve communication and understanding between growers, researchers and organisations.
BSS297 Web-based irrigation management	The general objective was: • To facilitate grower uptake of irrigation planning and scheduling tools developed by the CSIRO Sustainable Ecosystems (CSE) 'Beyond Case Studies' project CSE009. Specific objectives include: • To evaluate 'Cane Optimiser' and 'WaterSense' irrigation-management tools with grower-based on-farm groups in five sugar irrigation regions. • To develop skills and techniques in the use of management aids to maximise efficiencies of best-management irrigation practice (BMP) for irrigation scheduling. • To minimise potential environmental impacts of irrigation by enhancing awareness of contributors to the transport of nutrients and pesticides through runoff and deep infiltration. • To build capacity and understanding of operational procedures and relationships between web-based irrigation management tools and BMP for irrigators, advisors, technicians, agribusiness and consultants through provision of training. • To communicate project outcomes through group activities, information services, demonstrations, field days and media. • To evaluate possibilities for strategically located, commercial, web-based irrigation advisory services.
SRD021 Water management R&D workshop	• To identify the R&D priorities for water management across the sugar industry.
CG020 Water quality monitoring workshop	• To promote the positive outcomes arising from the SRDC-funded project CG013 as well as highlight the value of other grower-led water quality monitoring programs being run in the Burdekin, Innisfail, Mackay and Babinda.

Project Investment

Table 3 shows the annual investment by project for SRDC. Table 4 shows the annual investment by project for other investors (mostly in-kind resources from research organisations and industry). Table 5 summarises the total annual investment.

Table 3: Investment by Project by SRDC (nominal $)

Project Number	**Year ending June**					
	2006	2007	2008	2009	2010	Total
CG013	114,450	97,026	79,937	0	-70,335	221,078
CG018	16,000	0	39,675	35,000	25,000	115,675
BBF001	0	106,880	105,699	65,092	17,000	294,671
BSS297	0	95,000	121,737	142,526	75,551	434,814
SRD021	0	0	3,459	0	0	3,459
CG020	0	0	5,000	4,600	0	9,600
Total	130,450	298,906	355,507	247,218	47,216	1,079,297

(a) $20,000 was paid in the year ending June 2010 however $90,335 was returned as unspent funds

Table 4: Investment by Project by Others (nominal $)

Project Number	Year ending June					
	2006	2007	2008	2009	2010	Total
CG013	265,533	225,108	185,460	0	46,401	722,502
CG018	42,617	0	105,676	93,224	66,589	308,106
BBF001	0	265,863	262,925	161,916	42,287	732,991
BSS297	0	0	0	0	0	0
SRD021	0	0	0	0	0	0
CG020	0	0	12,500	11,500	0	24,000
Total	308,150	490,971	566,561	266,640	155,277	1,787,599

Table 5: Summary of Annual Investment by SRDC and Others (nominal $)

Year ending June	SRDC	Other	Total
2006	130,450	308,150	438,600
2007	298,906	490,971	789,877
2008	355,507	566,561	922,068
2009	247,218	266,640	513,858
2010	47,216	155,277	202,493
Total	1,079,297	1,787,599	2,866,896

Outputs

Table 6 provides a brief summary of the activities and outputs for each of the projects.

Table 6: Summary of Project Activities and Outputs

Project	Activities and Outputs
CG013 Water quality monitoring in Herbert	• Eleven growers volunteered to participate in the project. • Eleven water quality monitoring sites in small catchments within the Herbert sugarcane area were established. • A series of simple tools were developed for measuring sediment and nutrients in drainage water leaving the farms. • Growers at each site collected and analysed water samples for three years. • Growers also maintained records of on-farm practices that may impact on water quality, such as tillage, fertilising, land levelling and herbicide applications. • If water quality measurements exceeded desirable water quality levels, growers reacted quickly to seek possible explanations for the elevated readings. • Growers received training in water sampling and storage procedures and in the use of nutrient test strips and other equipment. • A water analysis laboratory was set up so that the measurements taken by the growers would be validated. • Occasional samples were sent to a NATA accredited laboratory for further validation of the nutrient determinations but also for measurements of pesticide residues. • A monitoring and evaluation workshop was conducted in the Herbert to provide an introduction and background to the project, explain the role that Herbert growers would play in the project, identify the critical success

	factors and ensure that all participating growers clearly understood and were supportive of the issues and strategies that needed to be managed to ensure that the project was successful. • The Herbert Water Quality Consultative Group was established to facilitate the sharing and exchange of information. • The project was evaluated at its commencement and conclusion by the growers involved. • A mid-term evaluation was conducted by members of the Herbert Water Quality Consultative Group. • A literature review of publications relating to water quality in the Herbert River district was conducted. • A Field Guide to Water Quality Monitoring was compiled and published. • The project activities and results were communicated through a wide range of activities, including meetings, presentations, training workshops, articles and conferences papers. • The project team hosted a water quality monitoring workshop for canegrowers. It was funded separately by SRDC (see project CG020 for more details). • The project team won the 2007 SRDC Excellence in Regional Innovation Award for the Herbert region. • The participating growers were awarded the Herbert Grower Group Innovation Award for 2006. • The project made three recommendations for further research: o An evaluation study of current water quality monitoring projects located in the Herbert, Burdekin, Mackay, Isis, NSW and Babinda regions. The study was to consider why growers choose to participate, what do they like about the activity, what do they need to do to keep them engaged and what are the best ways of generating interest amongst other growers so that the project can be expanded. o A training course for growers and coordinators of water quality monitoring projects. The training could cover suitable locations for monitoring water quality, monitoring techniques, quality control, record keeping and interpretation of results. o Evaluate test strips for analysing agricultural chemicals in farm drainage water. The project would review what is available and test the accuracy and effectiveness of products for the rapid determination of on-farm water quality. • Other recommendations include: o To continue the project and seek funds to maintain a part-time and locally-based project coordinator, and to purchase additional consumables for monitoring water quality. o To extend the project to include at least 50 participants located in all parts of the district. o To validate more of the results by sending water samples to accredited laboratories for both nutrient and herbicide analyses. o To generate more publicity about the project in order to raise awareness amongst canegrowers and the community.
CG018 Groundwater management in Burdekin	• The project achieved its original objective to review institutional arrangements and commenced implementing the plan (developed in this project). The implementation was considered beyond the realistic scope of

	the original project. • The project funded a consultant (John Williams Scientific Services Pty Ltd) to undertake an analysis of the current state of the BRIA groundwater system and to make recommendations on what needs to be done in the BRIA to correct the groundwater problem. • The key recommendation was to address the disparate responsibilities and activities of the multiple stakeholders and forge a strategic partnership in which all stakeholders collaborate to develop solutions. • The project supported the formation of a Regional Land and Water Management Plan working group that developed a five year plan for the BRIA. • The aim of the plan is to reduce groundwater and salt levels in BRIA below December 2008 levels by 2014. • The plan was agreed to in March 2009 by all key stakeholders including BRIA Irrigators, Canegrowers, Sunwater, Dept of Environment and Resource Management and North Queensland Dry Tropics NRM. • The plan outlines strategies and actions in the areas of irrigation efficiency, groundwater pumping, channel and weir losses, export of salt water, and communication and monitoring.
BBF001 Groundwater management in Upper Haughton	• The project was led by a group of growers in the Upper Haughton region and managed by the Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC). • A steering committee was formed which involved three growers from the Upper Haughton area as well as the BBIFMAC project manager. • The growers on the steering committee were provided with groundwater monitoring kits and trained in monitoring groundwater height and quality. • BSES Ltd and CSIRO assisted growers to develop on-farm irrigation improvement programs using SIRMOD to reduce infield deep drainage. • Twenty shallow piezometers were installed in the Upper Haughton area to gain a better understanding of the groundwater behaviour. • One of the growers measured the piezometers approximately each fortnight for height and salinity. • In addition to the manual readings, several of the piezometers had automatic loggers installed to allow closer evaluation of the groundwater behaviour. • Results have shown groundwater levels rising quickly and consistently, averaging 0.36 m per year for the past two years. In some areas groundwater came to within 0.5 m of the surface during the 2009 wet season. • Presentations on the project were given regularly at Cane Productivity Initiative (CPI) meetings and BBIFMAC general meetings. • Additional presentations on the project were given at the BRIA Groundwater Forum (organised by BBIFMAC), to the Lower Burdekin Water Futures group, and at the field day of the Mulgrave Area Farm Integrated Action grower group’s project (MAF002- Evaluating Alternative Irrigation for a Greener Future). • Project updates and results were posted on the BBIFMAC website including groundwater heights at each piezometer. • Grower involvement in the project diminished over time. • Australasian Groundwater and Environmental (AGE) consultants were contracted to analyse the data and develop a model running scenarios on the effect of possible groundwater management practices. However, the

	scenarios were considered impractical by the grower group. • It was recommended that the project be continued and expanded to include a larger area of the BRIA.
BSS297 Web-based irrigation management	• Working groups of irrigators were established in Burdekin, Bundaberg, Maryborough and Atherton Tablelands, to introduce WaterSense to growers and compare it to other irrigation scheduling tools. • Group facilitators and participants received training in the use of the Cane Optimiser and WaterSense programs. • The use of WaterSense highlighted knowledge gaps. Information such as water holding capacity of soils, amount of irrigation water applied per irrigation and depth of water extraction by the plant at differing crop stages was not understood by many irrigators. • WaterSense was promoted through Cane Productivity Initiative (CPI) meetings at Burdekin and CaneTalk discussion group meetings at Bundaberg. • Information was also on show at field days at Maryborough, Isis, Bundaberg, Mackay, Burdekin and the Atherton Tablelands. • Regular scheduling advisory notes were published in the Bundaberg CANEGROWERS newsletter. • Scheduling advisory notes were prepared for Maryborough and faxed to irrigators. • Regular scheduling advice was texted to local irrigators at Atherton. • Regular scheduling advice was emailed and faxed to growers in the Burdekin, including the Millaroo-Dalbeg and McDesme areas. • A water-use-efficiency pamphlet was produced incorporating the use of WaterSense for Bundaberg irrigators. • An Operator's Manual was produced for use in all centres. • An introductory article was published in a BSES Bulletin. • Promotion took place in irrigation advisory articles such as Australian Canegrower and via radio interviews. • A published paper, 'Enhancing irrigation management planning with EnviroSCAN and WaterSense', was presented at the Irrigation Australia (IA) 2008 conference. • The project completed a commercial assessment of WaterSense as well as nine case studies.

SRD021
Water management R&D workshop
	• The workshop was held on 4 December 2007.
	• 45 participants attended the workshop.
	• Short-term and long-term research priorities were identified and ranked in order of importance by the participants.
	• The highest short-term priority identified was:
	    o Relationship between best management practice and water quality (both on-farm and regional).
	• The highest long-term priorities identified were:
	    o Development of extension capacity, for example training and conferences.
	    o Coordinated monitoring at catchment/area/regional scale.
	• Participant feedback on the workshop was collected and was, in general, positive.

CG020 Water quality	• The workshop was held in Ingham in early April 2008. • About 50 people participated in the workshop and came from as far north as

monitoring workshop	Babinda and as far south as the Burdekin. They included canegrowers, BSES, Productivity Board, sugar mill and CANEGROWERS staff, NRM representatives and people from state government departments.
	• The workshop consisted of four main activities:
	  o Four grower presentations representing different grower water quality monitoring groups from the Herbert, Burdekin, Innisfail and Babinda.
	  o A discussion session covering what growers had learnt from their water quality monitoring, how important they regarded this activity, any improvements that have been or could be made, and the key steps involved in achieving a larger program involving many more growers.
	  o The launch of the Field Guide (developed in project CG013) aimed at assisting growers in measuring their water quality using simple techniques and low cost equipment. The cost of printing this guide was covered by this project.
	  o A field tour to inspect water quality monitoring sites on different farms, a water analysis laboratory that was established to support project CG013 and an environmentally sustainable aquaculture venture (prawn farm) which is highly dependent on the use of uncontaminated water supplies.
	• There were also two speakers from Terrain NRM covering District Water Quality Improvement Plans, Reef Rescue Package, NRM Plan review and the Water Quality Incentive Scheme.
	• The feedback from people at the workshop appeared to be generally very positive. Expectations of the workshop by participants was mostly exceeded (>65% of respondents). People most valued the presentations by farmers and also valued seeing the on-farm monitoring by the growers on the bus trip.
	• Following the workshop, the Field Guide has been widely distributed amongst growers, BSES, Cane Productivity Boards and regional NRM bodies. In total, 1,000 copies have been distributed. It is also available as a downloadable PDF file from CANEGROWERS and other websites.
	• Articles on the workshop were published in the Australian Canegrower and the Herbert River Express.
	• The recommendations arising from the workshop include the following:
	  o Continued support for grower-led monitoring of water quality coming from cane farms. The low-cost monitoring procedures are relatively simple and readily accepted by farmers. Costs per site for materials are estimated at around $150 per annum and it is believed that a part-time coordinator is important to keep local grower-led monitoring programs going.
	  o Three levels of sample analysis are recommended: ongoing monitoring of water quality by growers; periodic checks of the accuracy of grower-collected data by the local laboratory; and very occasional samples sent to a NATA accredited laboratory for herbicide residue analysis.
	  o The different farmer-led water quality monitoring programs in the Herbert, Burdekin, Mackay, Isis, Babinda and NSW should be compared and evaluated for their impacts.
	  o Test strips are now available for the detection of atrazine residues (and possibly other herbicides) and these should be trialled in grower-led programs.

Outcomes

A brief summary of outcomes by project is provided in Table 7.

Table 7: Summary of Project Outcomes

Project	Outcomes
CG013 Water quality monitoring in Herbert	• The project has improved the knowledge and skills of the participating growers in the following areas: o Techniques for measuring nutrients, pH, dissolved oxygen and turbidity of farm drainage water. o Accuracy and reliability of the different tools used to measure water quality. o Relationship between rainfall and discharge characteristics of farm drains. o Relationship between on-farm management practices and water quality. o What constitutes high, medium and low levels of different water quality parameters. o Taking water samples correctly and avoiding contamination. o Interpretation of water analyses. o Maintaining a comprehensive set of records of farm activities, rainfall and water quality parameters. • The level of consultation and collaboration between Herbert canegrowers and other groups with an interest in sustainable land management has increased considerably since the project began. • The Field Guide for Water Quality Monitoring was launched at a water quality monitoring workshop (see project CG020). • The success of the project has inspired other grower groups to obtain funds and initiate grower-led water quality projects in Babinda, Innisfail, Burdekin and the Mackay/Whitsunday regions.
CG018 Groundwater management in Burdekin	• Since the project has finished, Canegrowers has managed to secure other funding that is being used to implement the five year plan. As at August 2011, $4 million has been secured to address 2 of the 4 key areas outlined in the plan. • Despite being in the early stages of implementation, the plan appears to be on track to achieving its aim of reducing groundwater and salt levels below December 2008 levels by 2014 (Eric Danzi, pers. comm., 2011).
BBF001 Groundwater management in Upper Haughton	• The project has helped to raise awareness of the seriousness and urgency of the rising groundwater issue within the local farming, industry and science community. • Improved management of groundwater levels so reducing production losses from waterlogging and reducing secondary salinisation in areas of poor water quality. • Potential slowing down of the long-term trend of an increasing area of cane land being affected by rising groundwater levels. • The project has led to the development of the Lower Burdekin Groundwater Science Plan, which may lead to implementing actions to address the rising groundwater issue in the BRIA.

BSS297 Web-based irrigation management	• The working groups indicated that the number of individuals wanting to use WaterSense directly is limited, but all areas are keen to have district irrigation advice, produced from WaterSense, made available. • Customers who have indicated they would want direct access are mostly larger corporate farms. • Participation in the working groups has helped to further growers' and extension officers' knowledge of the chief factors influencing crop water use and soil water holding capacity.
SRD021 Water management R&D workshop	• It is expected that SRDC took these priorities into account when allocating resources to R&D projects relating to water management.
CG020 Water quality monitoring workshop	• The workshop successfully highlighted the value of grower-led water quality monitoring programs and has potentially encouraged growers to initiate similar programs in their regions. • It is expected that the Field Guide has prepared growers to monitor and analyse water quality.

Benefits

A brief summary of benefits by project is provided in Table 8.

Table 8: Summary of Project Benefits

Project	Benefits
CG013 Water quality monitoring in Herbert	• The project has enabled participating growers to develop skills in water quality monitoring and analysis. • In particular, growers now have a better understanding of the relationship between farm practices and water quality. This may lead to changes in management practices in order to improve the quality of water leaving their farms. • Improved water quality will potentially improve coral health and biodiversity in downstream ecosystems, particularly in the Great Barrier Reef. • The industry's reputation and the relationship between the Herbert sugar industry and regulatory and environmental groups are also likely to improve as a result of improved water quality leaving cane farms. • Changes to management practices may provide economic benefits to the growers that change. For example, growers that apply less pesticide may reduce their input costs.
CG018 Groundwater management in Burdekin	• The implementation of the strategies and actions outlined in the five year plan is expected to significantly reduce groundwater levels in the BRIA. • Reduction in loss of cane yield due to water logging and secondary salinisation. • Reduction in permanent losses of cane land in the next 10 years (Danzi, 2009). • This may displace a number of growers in the BRIA and potentially cause negative social and economic ramifications. Avoiding such a scenario is another benefit of reducing groundwater levels.
BBF001	• The project has potentially raised awareness within the farming community

Groundwater management in Upper Haughton	of the extent and seriousness of the rising groundwater levels in the BRIA. • This may encourage growers to adopt best management practices in order to improve their water use efficiency and reduce the rate at which the groundwater levels are rising. • High groundwater levels pose a number of issues including lost production due to water logging and secondary salinisation. • Therefore, the key benefit of reducing groundwater levels is the avoided yield loss. • Unproductive caneland may displace a number of growers and cause negative social and economic ramifications. Avoiding such a scenario is another benefit of reducing groundwater levels.
BSS297 Web-based irrigation management	• The project has built on the knowledge of participating growers and extension officers with regards to irrigation scheduling and planning. • Growers may apply this knowledge to their irrigation practices which may deliver benefits to the grower. • Likewise, extension officers are likely to share this knowledge with growers who may also benefit from applying it to their irrigation practices. • The project may have also increased the number of growers using WaterSense directly. • The direct and indirect use of WaterSense has potentially improved the water use efficiency of farms. The principal benefit is likely to be increased cane yield then followed by water savings. • Improved water use efficiency may also lead to reduced run-off. This would have environmental benefits particularly in downstream ecosystems. • Another benefit may be reduced deep drainage. This would assist in curtailing the rising groundwater levels.
SRD021 Water management R&D workshop	• It is expected that the workshop has achieved efficiency gains with regards to resource allocation of water management related R&D.
CG020 Water quality monitoring workshop	• This project has potentially led to an increase in the number of growers that are involved in water quality monitoring programs. • The benefits of monitoring water quality are described above for project CG013.

Table 9 summarises the major benefit types, and the contribution of each project to that benefit.

Table 9: Summary of Contribution of Each Project to Major Benefit Types

Project	**Major Benefit Types**			
	Improved water quality	Avoided yield loss	Increased cane yield	Efficiency gains in R&D resource allocation
CG013	√			
CG018		√		
BBF001		√		
BSS297			√	
SRD021				√
CG020	√			

Summary of Benefits
A summary of the principal types of benefits associated with the outcomes of investment in the cluster of projects is shown in Table 10.

Table 10: Categories of Principal Benefits from the Investment

Levy Paying Industry	**Spillovers**	
	Other Industries	**Public**
<u>Economic Benefits</u>		
Avoided yield loss due to reduced groundwater levels Increased cane yield due to WaterSense Efficiency gains in R&D resource allocation		Efficiency gains in R&D resource allocation
<u>Environmental Benefits</u>		
		Improved water quality in downstream ecosystems
<u>Social Benefits</u>		
		Avoided displacement of growers due to reduced groundwater levels

Public versus Private Benefits
The benefits are both private and public in nature. The private benefits relate to avoided yield loss, increased cane yield and efficiency gains in R&D resource allocation. The public benefits relate to efficiency gains in R&D resource allocation and improved water quality in downstream ecosystems.

Distribution of Benefits along the Sugar Supply Chain
The benefits from the projects in this cluster will be shared along the cane supply chain with farmers, harvesters, transporters, and mills all benefiting.

Benefits to other Primary Industries
There will be limited benefits to other primary industries from the cluster investment.

Benefits Overseas
There will be no benefits to overseas consumers or producers of sugar.

Additionality and Marginality
Supporting these projects was a medium-to-high level priority for SRDC. If public funding of SRDC were reduced, it is likely that the projects would still have been funded but to a lesser extent or over a longer period of time.

Further detail is provided in Table 11.

Table 11: Potential Response to Reduced Public Funding to SRDC

1. What priority were the projects in this cluster when funded?	Medium-to-high (for the majority of the projects)
2. Would SRDC have funded this cluster if only half of public funding of SRDC had been available?	Yes, but possibly to a lesser extent (75%-100%) or over a longer time period
3. Would the cluster have been funded if no public funding for SRDC had been available?	Yes, but possibly to a lesser extent (50%-75%) or over a longer time period

Match with National Priorities
The Australian Government's National and Rural R&D Priorities are reproduced in Table 12.

Table 12: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The projects in the cluster contribute to National Research Priority 1 and Rural Research Priorities 1 and 3.

Quantification of Benefits

Of the four major benefits identified in Table 9, three are quantified in this analysis. These are:
- Improved water quality in the Great Barrier Reef
- Avoided yield loss in the BRIA
- Increased cane yield due to WaterSense

The benefit not quantified is:
- Efficiency gains in R&D resource allocation

Improved water quality entering the Great Barrier Reef
This benefit was valued based on a recent study that applied choice modelling to assess community values for reduced agricultural emissions that would improve water quality and therefore improve coral health in the Great Barrier Reef (GBR) (Windle and Rolfe, 2010). Changes in agricultural emissions were presented in the survey as 'water quality units' where one unit was equivalent to the

reduction of 100,000 tonnes of sediment, 200 tonnes of nitrogen and 46 tonnes of phosphorus. The survey was completed by households from coastal GBR communities, Brisbane, Melbourne and Perth. The results indicate that households were willing to pay $2.40 (in Brisbane), $4.09 (in Perth), $4.35 (in Melbourne) and $5.55 (in coastal GBR communities), every year for five years to generate an annual improvement of one water quality unit in the GBR catchment area for 25 years. These values aggregate to a national benefit of $23.6 million per annum.

For the purposes of this analysis, it is assumed that a 1% improvement of one water quality unit will be achieved as a result of the projects in this cluster. That is, an annual reduction of 1,000 tonnes of sediment, 2,000 kg of nitrogen and 460 kg of phosphorus. The benefit of a 1% improvement of one water quality unit is therefore $236,000 per annum for five years (1% of $23.6 million). Another recent study was used to estimate the cost of reducing agricultural emissions on a cane farm in the GBR catchment area (Rolfe and Windle, 2011). It is assumed that it costs a cane farm $2.36, $0.77 and $5.72 to reduce 1 tonne of sediment, 1 kg of nitrogen and 1 kg of phosphorus, respectively. This was derived by taking the median of the minimum and average cost reported in Rolfe and Windle (2011). The total annual cost of achieving a 1% improvement of one water quality unit is therefore $6,531 (1,000 t x $2.36 + 2000 kg x $0.77 + 460 kg x $5.72).

The benefits and costs were assumed to begin in the year ending June 2011, the year after the last year of investment.

Avoided yield loss in the BRIA

If the trend in groundwater levels continues to rise over the next 10 years, it is assumed that 10% of the BRIA (around 4,000 ha) will be taken permanently out of cane production (Danzi, 2009). This would amount to the loss of 460,000 tonnes of cane per annum, assuming an average production of 115 tonnes of cane per ha. Using a commercial cane sugar (CCS) of 13%, the annual amount of lost sugar production is 59,800 tonnes. This loss is valued at $23.92 million per annum based on a sugar price of $400 per tonne.

The costs associated with the production of cane and consequently sugar is avoided due to the inability to produce cane on 4,000 ha in the BRIA. The cost of harvesting cane and transporting it to the mill is assumed to be $6.15 and $1.72 per tonne of cane, respectively. The mill costs of processing cane is assumed to be $10.50 per tonne of cane and the cost of transporting the sugar to the point of sale is assumed to be $6 per tonne of sugar. When applied to the amount of cane and sugar that is not produced, the avoided costs total $8,809,000 per annum.
Therefore, the value of losing 10% of the BRIA is estimated to be just over $15.11 million per annum. It is assumed that the maximum area at risk (4,000 ha) will be completely lost in 2019/20 (10 years from the last year of investment). However it is reasonable to expect that prior to this, parts of the 4,000 ha will be lost leading up to 2019/20. Therefore, it is assumed that 20% of the maximum area at risk will be lost in 2015/16 and this will accumulate by 20% every year until the maximum is reached in 2019/20.

The scenario described above is also known as the counterfactual scenario (without the investment). However, it is assumed that due to the implementation of the five year plan (developed in project CG018), the impact of the losses estimated will be reduced by 50%. The investment's attribution to this benefit is assumed to be 5% since the implementation of the five year plan will require a significant amount of funding and effort by other people and organisations to achieve the assumed benefit.

Increased cane yield due to WaterSense

One of the key features of WaterSense is the advice that is given with regards to the timing of water application. In general, it advocates the application of water earlier in the season than is currently practiced. It is assumed that this would result in a yield increase of 10 tonnes of cane per ha for each ML of water that is applied earlier in the season (Agtrans Research, 2006).

This benefit is assumed to be applicable to irrigators in the sugarcane producing regions of Bundaberg, Burdekin, Maryborough and Atherton Tablelands. It is limited to these regions due to the activities and outputs of project BSS297, the driver of this benefit. In 2009, these regions harvested 102,938 ha in total (Canegrowers Annual Report 2009/2010).

It is assumed that 1% of the total area harvested is using WaterSense due to the project BSS297. Since farms may not irrigate in wet years, a probability of 80% that a farm irrigates in any given year is assumed. Given these assumptions, the total amount of additional cane harvested is 8,235 tonnes per annum. Assuming a CCS of 13%, the total amount of additional sugar produced is 1,071 tonnes. This translates to an additional $428,222 per annum at $400 per tonne of sugar.

Additional costs are incurred due to the increase in cane production and should be deducted from the total benefit of a yield increase. These additional costs are assumed to be the same as the costs described in the avoided yield loss benefit above. When applied to the total amount of additional cane harvested, the additional costs add up to $157,701 per annum.

The net benefit is therefore $270,521 per annum and is assumed to begin in the year ending June 2011, the year after the last year of investment.

Summary of Assumptions
A summary of the key assumptions made is shown in Table 13.

Table 13: Summary of Assumptions

Variable	Assumption	Source
Improved water quality entering the Great Barrier Reef		
1 water quality unit	100,000 tonnes of sediment 200 tonnes of nitrogen 46 tonnes of phosphorus	Windle and Rolfe (2010)
Annual benefit for the improvement of 1 water quality unit in the GBR	$23.6 million	Windle and Rolfe (2010)
Improvement in water quality achieved by this investment	1% of 1 water quality unit	Agtrans Research
Annual benefit for a 1% improvement of 1 water quality unit	$236,000	1% of $23.6 m
Reduced emissions due to a 1% improvement of 1 water quality unit	1,000 tonnes of sediment 2 tonnes of nitrogen 0.46 tonnes of phosphorus	1% of 100,000 t 1% of 200 t 1% of 46 t
Cost of reducing emissions	$2.36 per tonne of sediment $0.77 per kg of nitrogen $5.72 per kg of phosphorus	Median of the minimum and average cost reported in Rolfe and Windle (2011)
Total cost of improving 1 water quality unit by 1%	$6,531 per annum	(1,000 t x $2.36) + (2000 kg x $0.77) +

		(460 kg x $5.72)
First year of benefits	2010/11	1 year after last year of investment
First year of costs	2010/11	1 year after last year of investment
Final year of benefits	2014/15	Benefits were assessed as annual payments for 5 years to generate improvements for 25 years (Windle and Rolfe, 2010)
Final year of costs	2034/35	Costs were assessed as the annual cost of making changes over a 25 year period (Windle and Rolfe, 2010)
Avoided yield loss in the BRIA		
% of BRIA at risk	10% (which is around 4,000 ha)	Danzi (2009)
Average cane yield	115 tonnes of cane per ha	Danzi (2009)
Amount of cane lost if 10% of the BRIA was unproductive	460,000 tonnes of cane per annum	4,000 ha x 115 t
Commercial cane sugar (CCS)	13%	Agtrans Research
Amount of sugar lost due to cane lost	59,800 tonnes of sugar per annum	460,000 t x 13%
Price of sugar	$400 per tonne of sugar	Agtrans Research
Value of lost production	$23.92 million	59,800 t x $400
Cost of harvesting cane	$6.15 per tonne of cane	Agtrans Research
Cost of transporting cane	$1.72 per tonne of cane	Agtrans Research
Cost of processing cane	$10.50 per tonne of cane	Agtrans Research
Cost of transporting sugar	$6 per tonne of sugar	Agtrans Research
Total avoided costs	$8,809,000 per annum	(460,000 t x $6.15) + (460,000 t x $1.72) + (460,000 t x $10.50) + (59,800 t x $6)
Value of lost production less avoided costs	$15.11 million	$23.92 m - $8.81 m
Year the maximum area at risk (4,000 ha) is lost	2019/20	10 years from the last year of investment
% of 4,000 ha that is lost every year for 5 years leading up to the year the maximum is lost	20%	Agtrans Research
Year the first 20% is lost	2015/16	5 years leading up to 2019/20
Extent of counterfactual scenario reduced due to the implementation of the five year plan	50%	Agtrans Research

Investment's attribution to this benefit	5%	Agtrans Research

Increased cane yield due to WaterSense		
Increase in cane yield	10 tonnes of cane per ha	Agtrans Research (2006)
Total area harvested in 2009 (includes Bundaberg, Burdekin, Maryborough and Atherton Tablelands)	102,938 ha	Canegrowers Annual Report 2009/2010
Adoption rate	1% of total area harvested	Agtrans Research
Area subject to yield increase	1029.38 ha	1% of 102,938 ha
Probability that a farm will irrigate in any given year	80%	Agtrans Research
Additional cane harvested	8,235 tonnes per annum	1029.38 ha x 10 t x 80%
Commercial cane sugar (CCS)	13%	Agtrans Research
Additional sugar produced	1,071 tonnes per annum	13% of 8,235 t
Price of sugar	$400 per tonne of sugar	Agtrans Research
Gross benefit	$428,222 per annum	1,071 t x $400
Cost of harvesting additional cane	$6.15 per tonne of cane	Agtrans Research
Cost of transporting additional cane	$1.72 per tonne of cane	Agtrans Research
Cost of processing additional cane	$10.50 per tonne of cane	Agtrans Research
Cost of transporting additional sugar	$6 per tonne of sugar	Agtrans Research
Total additional costs	$157,701 per annum	(8,235 t x $6.15) + (8,235 t x $1.72) + (8,235 t x $10.50) + (1,071 t x $6)
Net benefit	$270,521 per annum	$428,222 - $157,701
First year of benefits	2010/11	1 year after the last year of investment

Results
All past costs and benefits were expressed in 2010/11 dollar terms using the CPI. All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high 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 (2009/10) to the final year of benefits assumed.

Investment criteria were estimated for both total investment and for the SRDC investment alone, as reported in Tables 14 and 15 respectively. Each set of investment criteria were estimated for different periods of benefits.

Table 14: Investment Criteria for Total Investment and Total Benefits for Each Benefit Period (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	2.27	3.99	5.79	7.19	8.29	9.16
Present value of costs ($m)	3.69	3.69	3.69	3.69	3.69	3.69	3.69
Net present value ($m)	-3.69	-1.42	0.31	2.10	3.50	4.60	5.47
Benefit-cost ratio	0.00	0.62	1.08	1.57	1.95	2.25	2.48
Internal rate of return (%)	Negative	Negative	6.1	10.1	11.6	12.2	12.5

Table 15: Investment Criteria for SRDC Investment and Benefits to SRDC for Each Benefit Period (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years	30 years
Present value of benefits ($m)	0.00	0.85	1.50	2.17	2.70	3.12	3.44
Present value of costs ($m)	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Net present value ($m)	-1.38	-0.53	0.12	0.79	1.32	1.73	2.06
Benefit-cost ratio	0.00	0.62	1.09	1.57	1.96	2.25	2.49
Internal rate of return (%)	Negative	Negative	6.2	10.2	11.6	12.3	12.6

There are three benefits valued in the analysis. Table 16 shows the estimates of the relative contribution from each source.

Table 16: Contribution of Source of Benefits to Present Value of Benefits

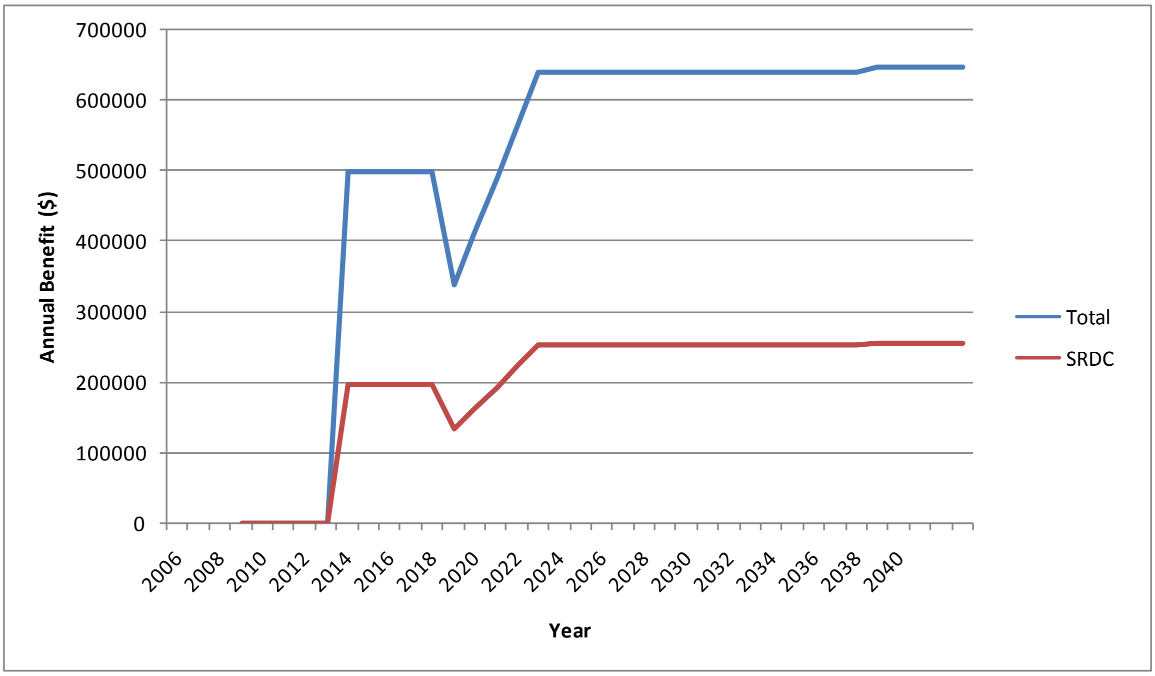
Source of Benefit	PVB Contribution ($m)	PVB Contribution (%)
Improved water quality entering the Great Barrier Reef	0.98	10.66
Avoided yield loss in the BRIA	3.82	41.66
Increased cane yield due to WaterSense	4.37	47.68
Total	9.16	100

The benefit of increased cane yield alone would have covered the costs of the total investment in the cluster. The benefit of avoided yield loss would have also covered the total investment costs on its own.

The quantified benefits address Rural Research Priorities 1 (productivity and adding value) and 3 (natural resource management).

The annual net benefit undiscounted cash flows for both total investment and SRDC investment for the 30 year period from the year of first investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Benefits



Sensitivity Analyses
Sensitivity analyses were carried out on a range of variables and results are reported in Tables 17 and 18. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 17) 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 17 shows that the investment criteria are somewhat sensitive to the discount rate.

Table 17: Sensitivity to Discount Rate
(Total investment, 30 years)

Criterion	**Discount rate**		
	0%	5% (base)	10%
Present value of benefits ($m)	17.82	9.16	5.64
Present value of costs ($m)	3.14	3.69	4.32
Net present value ($m)	14.69	5.47	1.32
Benefit-cost ratio	5.68	2.48	1.31

Table 18 presents the sensitivity of the results to the sugar price. The sugar price was used to value the benefits of avoided yield loss and increased cane yield. The benefit of improved water quality and all other assumptions were held at their base values. The results indicate that if the sugar price falls to $300 per tonne, the investment is still profitable with a benefit-cost ratio of 1.61 to 1. The break-even sugar price was calculated to be $231 per tonne.

Table 18: Sensitivity to Sugar Price
(Total investment, 30 years)

Criterion	Sugar price		
	$200	$300	$400 (base)
Present value of benefits ($m)	2.68	5.92	9.16
Present value of costs ($m)	3.69	3.69	3.69
Net present value ($m)	-1.01	2.23	5.47
Benefit-cost ratio	0.73	1.61	2.48
Internal rate of return (%)	2.5	8.8	12.5

Confidence Rating
The results produced are highly dependent on the assumptions made, many 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 19). 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 19: Confidence in Analysis of Managing Water More Sustainably Cluster

Coverage of Benefits	Confidence in Assumptions
High	Medium

Conclusions

The SRDC investment in the Managing Water More Sustainably cluster includes a mixture of six projects: two projects on groundwater, two projects on water quality, one project on irrigation scheduling and one R&D workshop.

The benefits identified are both private and public in nature. The private benefits relate to avoided yield loss, increased cane yield and efficiency gains in R&D resource allocation. The public benefits relate to efficiency gains in R&D resource allocation and improved water quality in downstream ecosystems, namely the Great Barrier Reef.

The majority of the identified benefits have also been quantified. These include improved water quality entering the Great Barrier Reef, avoided yield loss in the BRIA and increased cane yield due to WaterSense.

The total investment of $3.69 million (present value terms) has been estimated to produce total benefits of $9.16 million (present value terms) providing a net present value of $5.47 million, a benefit-cost ratio of 2.48 to 1, and an internal rate of return of 12.5% (over 30 years, using a 5% discount rate).

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Eric Danzi, Canegrowers

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