ASSESSMENT OF INVESTMENT BY SRDC IN SELECTED PROJECTS

Final Report

To
Sugar Research and Development Corporation

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SRDC Internal Project Number - SRD007

by

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Executive Summary

The Sugar Research & Development Corporation (SRDC) required benefit-cost analyses (BCAs) to be undertaken on six of their recently completed investments.

Information from the original project proposal, milestone reports, final reports and relevant correspondence was extracted from the appropriate SRDC files and relevant published papers and reports and other material were assembled. Principal Investigators for each project were also consulted.

Each of the six case studies provides a description of the project background, objectives, activities, costs, outputs, outcomes, benefits, quantification of benefits and results.

Investment criteria of Net Present Value (NPV), Benefit-Cost Ratio (B/C Ratio) and Internal Rate of Return (IRR) were estimated at discount rates of both 5% and 10%. The NPV is the difference between the Present Value of Benefits (PVB) and the Present Value of Costs (PVC). Present values are the sum of discounted streams of benefits and/or costs. The B/C Ratio is the ratio of the PVB to the PVC. The IRR is the discount rate that would equate the PVB and the PVC, thus making the NPV zero and the B/C ratio 1:1.

All dollar costs and benefits were expressed in 2004/05 dollar terms and discounted to the year 2004/05. A 30 year time frame was used in all analyses, with the first year being the initial year of investment in the R&D project. Costs for the initial R&D project included those for SRDC as well as contributions (dollar and in-kind) from other funding organisations and the participating R&D group.

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. The sensitivity analyses were conducted only for the 5% discount rate, except for the sensitivity around the price of sugar which was effected for both the 5% and 10% discount rates.

Table 1 presents the investment criteria for each of the 6 projects analysed at a 5% discount rate and a sugar price of $285/ts.

Table 1: Investment Criteria for 6 Projects
(discount rate = 5%; sugar price = $285/ts)

Project No.	**Project Title**	**PVB ($m)**	**PVC ($m)**	**NPV ($m)**	**B/C ratio**	**IRR (%)**
SRI097	CBA boiling scheme	3.6	0.075	3.5	48.2 to 1	41.2
MSA003	Cooperative systems model	5.4	0.5	5.0	10.5 to 1	29.9
BSS261	Harvesting market signals	8.0	1.2	6.8	6.6 to 1	27.0
CSE001	Supplementary irrigation	3.2	1.9	1.3	1.7 to 1	8.7
CTA028	Regional selection programs	8.3	1.5	6.9	5.7 to 1	23.6
YDJV	Yield Decline Joint Venture	286.9	32.6	254.3	8.8 to 1	22.4

Table 2 presents the investment criteria for each of the 6 projects analysed at a 10% discount rate and a sugar price of $285/ts.

Table 2: Investment Criteria for 6 Projects
(discount rate = 10%; sugar price = $285/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	2.1	0.092	2.0	23.1 to 1	41.2
MSA003	Cooperative systems model	3.0	0.5	2.5	5.5 to 1	29.9
BSS261	Harvesting market signals	4.5	1.2	3.3	3.7 to 1	27.0
CSE001	Supplementary irrigation	1.7	2.0	-0.3	0.8 to 1	8.7
CTA028	Regional selection programs	6.2	1.7	4.5	3.7 to 1	23.6
YDJV	Yield Decline Joint Venture	194.9	44.8	150.1	4.3 to 1	22.4

Table 3 presents the investment criteria for each of the 6 projects analysed at a 5% discount rate and a sugar price of $350/ts.

Table 3: Investment Criteria for 6 Projects
(discount rate = 5%; sugar price = $350/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	4.0	0.075	4.0	54.0 to 1	42.5
MSA003	Cooperative systems model	8.2	0.5	7.7	15.6 to 1	36.4
BSS261	Harvesting market signals	8.0	1.2	6.8	6.6 to 1	27.0
CSE001	Supplementary irrigation	4.8	1.9	2.9	2.5 to 1	11.7
CTA028	Regional selection programs	11.8	1.5	10.4	8.1 to 1	27.4
YDJV	Yield Decline Joint Venture	295.6	32.6	263.0	9.1 to 1	22.5

Table 4 presents the investment criteria for each of the 6 projects analysed at a 10% discount rate and a sugar price of $350/ts.

Table 4: Investment Criteria for 6 Projects
(discount rate = 10%; sugar price = $350/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	2.4	0.092	2.3	25.9 to 1	42.5
MSA003	Cooperative systems model	4.5	0.5	3.9	8.2 to 1	36.4
BSS261	Harvesting market signals	4.5	1.2	3.3	3.7 to 1	27.0
CSE001	Supplementary irrigation	2.5	2.0	0.5	1.2 to 1	11.7
CTA028	Regional selection programs	8.8	1.7	7.1	5.2 to 1	27.4
YDJV	Yield Decline Joint Venture	200.1	44.8	155.2	4.5 to 1	22.5

Table 5 presents the average and aggregate investment criteria for the six selected case studies at discount rates of 5% and 10% and sugar prices of $285/t and $350/t. The simple averages of the investment criteria (NPV, B/C ratio and IRR) for the six selected case studies are presented. Please note that because the sample was selected, it can not be assumed that these averages apply to all SRDC funded projects. The aggregate B/C ratio for the six selected case studies has been calculated as the sum of the PVBs divided by the sum of the PVCs. This essentially provides a 'weighted average' B/C ratio. Once again, this aggregate B/C ratio can not be extrapolated outside of the six selected case studies. The total NPV for the six selected case studies is also presented.

Table 5: Simple Average and Aggregate Investment Criteria Across Six Selected Projects (at 5% and 10% discount rate and $285/ts and $350/ts)

Discount rate	5%		10%	
Sugar Price	$285/ts	$350/ts	$285/ts	$350/ts
NPV (total)	$277.8m	$294.7m	$162.1m	$172.3m
NPV (simple average)	$46.3m	$49.1m	$27.0m	$28.7m
B/C ratio (simple average	13.6 to 1	16.0 to 1	6.8 to 1	8.1 to 1
IRR (simple average)	25.5%	27.9%	25.5%	27.9%
B/C ratio (aggregate)	8.4 to 1	8.8 to 1	4.2 to 1	4.4 to 1

1. Introduction

The Sugar Research & Development Corporation (SRDC) required benefit-cost analyses (BCAs) to be undertaken on a number of its recently completed investments. Six investments were selected for analysis:

1. SRI097 – Costs and benefits of the CBA boiling scheme for high pol sugar production
2. MSA003 – A cooperative systems model for the Mackay regional sugar industry
3. BSS261 – Measurement and feedback systems for improving market signals for harvesting
4. CSE001 – Increased profitability and water use efficiency through best use of limited water under supplementary irrigation in sugarcane
5. CTA028 – Evaluation and re-structuring of regional selection programs to maximise efficiency and speed of cultivar release
6. YDV001 & YDV002 - Sugar Yield Decline Joint Venture

A BCA on the Sugar Yield Decline Joint Venture had recently been completed for the Queensland Department of Primary Industries and Fisheries, and this analysis was revised to be consistent with the other five analyses.

Section 2 of the report provides a brief summary of the methods used. Section 3 reports a summary of the investment criteria of the six assessments. The individual BCAs for the six investments are presented in Sections 4 to 9.

2. Methods

Each selected project was evaluated through the following steps:

1. Information from the original project proposal, milestone reports, final reports and relevant correspondence was extracted from the appropriate SRDC files. Relevant published papers and reports and other material was assembled with assistance from SRDC personnel, Principal Investigators and others.
2. An initial description of the project background, objectives, activities, costs, outputs, and outcomes and benefits was drafted. Additional information needs were identified.
3. Telephone contact was made with the Principal Investigator (an alternative researcher in some cases) and the draft sent to that person for perusal and comment, together with specific information requests.
4. Further information was assembled from statistical and industry sources, where appropriate.
5. Some analyses proceeded through several drafts, both internally within the project team as well as externally via Principal Investigators and industry representatives.
6. Final drafts were passed by Principal Investigators for comment.

Investment criteria of Net Present Value (NPV), Benefit-Cost Ratio (B/C Ratio) and Internal Rate of Return (IRR) were estimated at discount rates of both 5% and 10%. All dollar costs and benefits were expressed in 2004/05 dollar terms and discounted to the year 2004/05. A 30 year time frame was used in all analyses, with the first year being the initial year of investment in the R&D project. Costs for the initial R&D project included those for SRDC as well as contributions (dollar and in-kind) from other funding organisations and the participating R&D group.

Assumptions were made in a consistently conservative manner when valuing benefits. Analyses were undertaken for total benefits that included future expected benefits.

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. The sensitivity analyses were conducted only for the 5% discount rate, except for the sensitivity around the price of sugar which was effected for both the 5% and 10% discount rates.

In two out of the six cases another actual R&D project had to be included in the analysis.

The principal base assumptions that were used in the quantitative analyses are provided in Table 2.1.

Table 2.1: Base Assumptions Used in the Analyses

Item	Value
Value of sugar (a)	$285/ tonne
Cost of sugar transport to port	$6 per tonne of sugar
Cost of cane harvesting	$6 per tonne of cane
Cost of cane transport	$2 per tonne of cane
Cost of sugar milling	$90 per tonne of sugar
Average sugar content of cane (b)	13.68%
Average cane area (c)	429,000 ha
Average cane yield (c)	79.6 tonnes per ha
Cane production in Australia (c)	34,203 m tonnes

(a) Average of five years from 2000/01 to 2004/05 expressed in 2004/05 $ terms (Source: Average gross returns to millers, Australian Commodity Statistics, ABARE).

(b) Average sugar per tonne of cane over five years 2000/01 to 2004/05 (Source: Australian Commodity Statistics, ABARE).

(c) Average cane production, area and yield over five years 2000/01 to 2004/05 (Source: Australian Commodity Statistics, ABARE).

3. Summary of Results

The investment criteria calculated for each project were the NPV, the B/C Ratio and the IRR. The NPV is the difference between the Present Value of Benefits (PVB) and the Present Value of Costs (PVC). Present values are the sum of discounted streams of benefits and/or costs. The B/C Ratio is the ratio of the PVB to the PVC. The IRR is the discount rate that would equate the PVB and the PVC, thus making the NPV zero and the B/C ratio 1:1.

Table 3.1 presents the investment criteria for each of the 6 projects analysed at a 5% discount rate and a sugar price of $285/ts.

Table 3.1: Investment Criteria for 6 Projects
(discount rate = 5%; sugar price = $285/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	3.6	0.075	3.5	48.2 to 1	41.2
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YDJV	Yield Decline Joint Venture	286.9	32.6	254.3	8.8 to 1	22.4

Table 3.2 presents the investment criteria for each of the 6 projects analysed at a 10% discount rate and a sugar price of $285/ts.

Table 3.2: Investment Criteria for 6 Projects
(discount rate = 10%; sugar price = $285/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
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YDJV	Yield Decline Joint Venture	194.9	44.8	150.1	4.3 to 1	22.4

Table 3.3 presents the investment criteria for each of the 6 projects analysed at a 5% discount rate and a sugar price of $350/ts.

Table 3.3: Investment Criteria for 6 Projects
(discount rate = 5%; sugar price = $350/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	4.0	0.075	4.0	54.0 to 1	42.5
MSA003	Cooperative systems model	8.2	0.5	7.7	15.6 to 1	36.4
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YDJV	Yield Decline Joint Venture	295.6	32.6	263.0	9.1 to 1	22.5

Table 3.4 presents the investment criteria for each of the 6 projects analysed at a 10% discount rate and a sugar price of $350/ts.

Table 3.4: Investment Criteria for 6 Projects
(discount rate = 10%; sugar price = $350/ts)

Project No.	Project Title	PVB ($m)	PVC ($m)	NPV ($m)	B/C ratio	IRR (%)
SRI097	CBA boiling scheme	2.4	0.092	2.3	25.9 to 1	42.5
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YDJV	Yield Decline Joint Venture	200.1	44.8	155.2	4.5 to 1	22.5

Table 3.5 presents the average and aggregate investment criteria for the six selected case studies at discount rates of 5% and 10% and sugar prices of $285/t and $350/t. The simple averages of the investment criteria (NPV, B/C ratio and IRR) for the six selected case studies are presented. Please note that because the sample was selected, it can not be assumed that these averages apply to all SRDC funded projects. The aggregate B/C ratio for the six selected case studies has been calculated as the sum of the PVBs divided by the sum of the PVCs. This essentially provides a ‘weighted average’ B/C ratio. Once again, this aggregate B/C ratio can not be extrapolated outside of the six selected case studies. The total NPV for the six selected case studies is also presented.

Table 3.5: Simple Average and Aggregate Investment Criteria Across Six Selected Projects (at 5% and 10% discount rate and $285/ts and $350/ts)

Discount rate	5%		10%	
Sugar Price	$285/ts	$350/ts	$285/ts	$350/ts
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IRR (simple average)	25.5%	27.9%	25.5%	27.9%
B/C ratio (aggregate)	8.4 to 1	8.8 to 1	4.2 to 1	4.4 to 1

Confidence in Analyses

The investment criteria produced are highly dependent on the assumptions made in each analyses. There are usually two areas of concern. The first 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 involves the assumptions relating to the difference that the investment has made. Some of these assumptions can be contentious and many made in the analyses are a matter of judgement. To account for the uncertain assumptions, a series of sensitivity analyses has been conducted, where the investment criteria are recalculated with variations of some of the uncertain assumptions.

A rating has been given to the confidence in the results of the investment analyses. The confidence is made up of two factors including the coverage of benefits and the degree of certainty in the assumptions. 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 significant uncertainties in assumptions

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

Table 3.6 presents an estimate of the confidence in analyses for each of the quantified projects, expressed via the factors defined above.

Table 3.6: Confidence in Analysis for Quantified Projects

Project No.	Project	Coverage of Benefits	Confidence in Assumptions
SRI097	CBA boiling scheme	High	Medium
MSA003	Cooperative systems model	Low	Medium
BSS261	Harvesting market signals	High	Medium
CSE001	Supplementary irrigation	Medium	Low
CTA028	Regional selection programs	High	High
YDJV	Yield Decline Joint Venture	High	High

4. SRI097: Costs and Benefits of the CBA Boiling Scheme for High Pol Sugar Production

Organisation: Sugar Research Institute
Start Date: 1 July 1999
Completion Date: 30 June 2000 (subsequently extended with final report submitted in June 2004).
Principal Investigator: Dr Ross Broadfoot

Background

When this project was proposed in 1999, increases in the demand for high pol Australian sugar were expected, largely due to the need to compete with increasing exports of high pol and low colour sugar from Brazil. This was starting to threaten the Australian position as preferred supplier in some traditional premium markets.

The Australian sugar industry processes cane with a relatively high purity and generally produces, in comparison with many other countries, a lower pol sugar. This allows the Australian industry to use the three massecuite crystallisation scheme whereby two sugars (A and B) are produced as shipment sugar. While the system is capital efficient (less pans, receivers, fugals, etc) and energy efficient (less steam due to minimal dissolution of crystalline sugar) it is less suited to high pol sugar production. When high pol sugars are produced through the system the efficiencies decrease and costs increase. Additional washing at the A and B fugals causes increased dissolution of sugar and increased recirculation of sugar to the pan stage for reprocessing, resulting in increased quantities of massecuite to be processed at the pan and fugal stations. Use of a double purging process is made in some Australian factories but adds costs in that extra high grade massecuite is boiled requiring additional pan stage and fugal capacity. A small increase in steam consumption is also required for the double purge process.

Australia produces export sugar from both A and B sugars but major competitors such as Brazil, Thailand and South Africa use only A sugar. Australian sugar factories thought they may have to revert to just using A sugars and so adopt alternative boiling schemes for producing high pol sugars. There was a tradeoff perceived in considering the various options regarding the risk of not consistently meeting specifications and overall factory costs.

This project was aimed at assessing the cost savings and economics of producing high pol sugar through various equipment combinations using alternative boiling schemes.

The Project

Project Objectives

The project objective was to reduce the cost of production and increase the reliability in meeting sugar industry quality compliance in making high pol sugar by:

(i) determining equipment and processing arrangements for the economical production of high pol sugar based on the CBA (and other) boiling schemes.

(ii) quantifying cost savings that can be achieved in the CBA boiling scheme through the implementation of technologies such as continuous pans, continuous fugals, double purging schemes and the SRI magma preparation system.

These objectives were to be achieved through modelling simulations to determine the technical requirements for various process flowscheme options, coupled with costing analyses.

Project Description

The researchers used the SRI models for pan stage and fugal station operations to simulate Intermediate High Pol (IHP) and Queensland High Pol (QHP) sugar production using different flowschemes. The flowschemes simulated were:

- the three massecuite boiling system (conventional Australian system)
- the three massecuite boiling system with double purging of the B sugars to produce QHP sugar
- the CBA system (excess C and B sugar is remelted and sent to the liquor tank)
- the CB system (all B sugar and surplus C sugar is remelted and sent to the liquor tank)
- full remelt system (all B and C sugar is remelted and sent to the liquor tank)
- the BA system (all C sugar and surplus B sugar is remelted and sent to the liquor tank)

In addition, the colour of the shipment sugar was estimated by taking into account the transfer of coloured impurities into the crystal and the development of colour in the boiling process. Also, steam consumption in the pan boiling operations was estimated.

A range of assumptions were used including:

- Cane input conditions including those for early season cane with low CCS and low liquor purity and mid season cane with high CCS and high liquor purity
- Pan stage and fugal station operational parameters
- Mean size for the sugar product and crystal numbers in the different strikes

For each system the different massecuite production quantities of different compositions were estimated. From this, appropriate equipment needs were specified for a 600 t/hour factory, taking into account the different equipment needs during early season and mid-season operations.

The above equipment specifications for each system allowed an economic analysis to be performed on a range of options for producing high pol sugar. A series of cost assumptions was made for all capital equipment required, maintenance costs, cost of steam, revenue from sugar and molasses sales, and transport costs from factory to port. No additional labour costs were assumed. The discount rate assumed was 12%.

Associated Projects
An earlier study by Wright in 1995 assessed different flow schemes for production of Brand 1 sugar: Wright P G (1995) "Cost/Benefits of Modified Crystallisation Schemes", SRI Technical Report 4/95

Costs
Estimates of the total investment costs of the project are provided in Table 1 for each of the years specified.

Table 1: Estimate of Investment in High Pol Sugar Project (nominal $)

Year	SRDC	SRI	Total
1999/2000	26,842	17,310	44,152
2000/2001	0	0	0
2001/2002	0	0	0
2002/2003	0	0	0
2003/2004	0	0	0
2004/2005	5,239	3,378	8,617
Total	32,081	20,688	52,769

Outputs

The principal output from running the simulation models was a series of simulation results for each flowscheme for each of early and mid season cane inputs. The results showed that the different flowschemes required different massecuite production quantities of different compositions. This meant that different pan stage equipment, massecuite receivers, tanks and fugal station equipment needed to be installed. Several alternative specifications were used in each flowscheme. These specifications were used in the economic analyses carried out in the project for a range of alternative production systems for high pol sugar.

The principal results of the economic analysis for the different production systems were expressed as the additional revenue per tonne of IHP or QHP sugar that must be obtained for a zero Net Present Value of the investment in any production system. Costs and benefits for each producing system are expressed in relation to producing Brand 1 sugar based on the three massecuite boiling flowscheme.

Thus the most economically attractive production system for high pol sugar will be that production system that requires the least additional revenue per tonne of sugar to produce a 12% rate of return on capital. Other assumptions are a crushing period of 3500 hours, 40% is early season cane and 60% mid season cane and the factory produces at the rate of 600 tonnes of cane per hour. Further it is assumed that no existing equipment is utilised.

The economic analysis was undertaken for the base revenue from Brand 1 sugar being $200 per tonne and final molasses being $50 per tonne. A sensitivity analysis for the sugar price assumed $250 and $300 per tonne and for the molasses price $30 and $80 per tonne.

The key results emanating from the simulation modelling are summarised in Table 2.

Table 2: Summary of Key Results from Simulation Modelling of the Different Flowschemes

1. The additional cost of production of the IHP sugar by the CBA flowscheme ($1.66/ts) is substantially lower than that for the three massecuite scheme ($3.90/ts). These costs are based on the use of batch pans for the A and B strikes.
2. Using the three massecuite scheme the cost of producing QHP sugar with double purging of the B sugar is lower than producing IHP sugar by washing up the A and B sugars.
3. Using the three massecuite scheme the additional cost of producing QHP sugar is lower than producing QHP sugar by the CBA flowscheme ($2.94/ts versus $4.12/ts).
4. The double purging of the C sugar shows an economic benefit for the manufacture of QHP sugar for both the CBA and the three massecuite flow schemes with savings of the order of $0.30 to $0.50 per tonne of sugar.
5. The additional costs of producing both IHP and QHP sugar by the CB flowscheme are significantly higher than for the CBA flowscheme.
6. The flowscheme employing full remelt of the C and B sugars is the most expensive sugar to produce.
7. A sensitivity analysis showed that when the sugar price for Brand 1 sugar is higher a larger premium is required for high pol sugar in order to provide a return on the extra capital and operating costs.
8. The low grade massecuite station (pans, crystallisers, fugals) is about 30 to 35% of the total pan stage, crystallisers and fugal station investment.
9. Continuous pans rather than batch pans can provide substantial savings in the capital costs of installed pans and receiver capacity for the three massecuite boiling scheme, and for the CBA scheme and variations. Savings range from $0.67/ts to $2.00/ts with the largest saving being when the total B sugar in the CBA scheme is remelted.
10. The production of IHP sugar by the three massecuite scheme costs an additional $3.90 per tonne using batch pans compared with the cost of making Brand 1 sugar.
11. The three massecuite boiling scheme is the most energy efficient of all the schemes.
12. There is a strong incentive to reduce steam consumption on the pan stage if there are significant opportunities for sale of steam, bagasse or congenerated electricity. The cost of steam consumption on the pan stage is substantial and amounts to $8.50/ts Brand 1.
13. The SRI magma preparation system is effective and economically beneficial in preparing magma from C sugar. Other schemes are likely to be more suited to preparing magma from B sugar in the CBA scheme.
14. The CBA flowscheme is able to produce lower colour shipment sugar than the three massecuite scheme, with the differences estimated at about 50 to 80 units of colour.

The lowest cost flowschemes for producing IHP and QHP sugar are shown in Table 3.

Table 3: Lowest Cost Flowschemes for Producing IHP and QHP Sugar

Sugar	Flowscheme	A and B Strike Pans	Cost per tonne of sugar (a)
IHP	CBA	Batch	1.66
		Continuous	0.87
QHP	Three massecuite with double purging of the B sugar	Batch	2.94
		Continuous	2.19

(a) Cost is relative to Brand 1 sugar production using batch pans

In addition to these results information on the predicted steam usage and colour of the shipment sugar has been produced for the different flowschemes and sugar specifications. Overall the project has produced information that will benefit future studies by the industry into operating integrated factory sites with multiple plants such as cogeneration plants and distilleries. The study also has highlighted the cost reducing attributes of continuous pans and fugal stations and the SRI magma preparation system, as well as the variations in mass flow, steam usage and equipment requirements for the different flowschemes.

Outcomes

The key outcome will be changes in the methods of producing high pol sugar by the Australian industry that will lead to lower costs and increased competitiveness in international markets.

Other key potential outcomes are:

(a) Improved knowledge of the CBA scheme which is likely to be adopted by Australian sugar factories which supply a high purity molasses stream as feedstock to a distillery.

(b) Increased focus by mills on reducing the cost of production of crystal sugar. In this regard the study has highlighted:
   - the high cost of steam consumption on the pan stage;
   - the large investment in C massecuite processing equipment; and
   - the magnitude of savings through the use of continuous pans, continuous fugals, and the SRI magma preparation system for C sugar magma.

(c) The potential benefits of double purging C sugar for factories producing high pol sugar.

While these outcomes are likely to occur at some stage, changes in the systems for producing high pol sugar have not yet eventuated. However, it is only 12 months since sugar factories received the report for SRI097. Factories are maintaining their current producing methods due to their overriding strategies of avoiding any new capital investment due to the recent depressed sugar prices. Factories are likely to avoid the capital investment required in changing their sugar production systems unless another major change is planned such as investment in cogeneration or distillation. In the short term, the most promising application of the information on the CBA scheme will be on factories intending to supply a high purity molasses to a distillery for ethanol production.

As the study reinforces the existing double purging scheme for producing QHP sugar, adoption of more QHP production systems may be brought forward from when they would otherwise occur in future. Some factories may need to commence producing QHP sugar in the future, but the timing of this will depend on the future demand for QHP sugar and the associated threat to existing markets.

It is also likely that more attention will be given in future to steam savings as a result of the study, now that the cost of steam per tonne of sugar has been highlighted.

There are also worthwhile savings through the use of continuous pans that have been highlighted in the study. Even for continuous pans on A and B massecuites in the three massecuite formula making Brand 1 sugar the savings are estimated at $0.67 per tonne sugar. While the calculations have not been done, this may still not justify the replacement of batch pans. However, where another pan has to be installed (e.g. through a batch pan reaching the end of its service life), then the continuous pan would be more economical.

The overall benefit from SRI097 will be a strong base on which to plan future changes to the pan stage operations of sugar factories. A summary of key benefits includes:

- Increased knowledge of how to operate the CBA scheme effectively
- Relative costs of production of high pol sugar (IHP, QHP) for the different schemes
- Knowledge of the high cost of steam consumption in the pan stage
- The magnitude of the cost/benefit of continuous pans, continuous fugals and the SRI magma preparation system

Quantification of Benefits

Three benefits drawn from the above outcomes are quantified in this analysis.

Cost Savings from Use of the CBA Scheme

There is a chance that the use of the CBA boiling scheme to produce IHP sugar may occur in the next few years, but this will rely on other investments being made. The project shows that the cost of producing IHP sugar with the three massecuite scheme using batch pans (the usual scenario for Australia) is $3.90 per tonne of sugar. Using the CBA scheme with 10% remelt of B sugar using continuous pans for the A and B massecuites the cost is $1.30. The saving is $2.60 per tonne of sugar.

If a sugar factory implements distilleries for fuel alcohol production, then there is a strong likelihood that these mills will simplify their boiling scheme, use the CBA scheme to produce a high pol sugar from the A sugar, and produce a higher purity molasses from the second boiling (viz a BA scheme). It is feasible that up to three factories could implement such a scheme by 2010 to meet the government's biofuels target. If one factory crushes at 600 t/h for 3,500 hours per year, the likely sugar output (of high pol sugar) will be 280,000t per year. This assumes sugar production from 7.5 tonnes of cane is 1 tonne of high pol sugar when high purity molasses is sent to a distillery. For purposes of this evaluation it is assumed that only one factory implements the scheme with a probability of implementation of 80%. The change to introduce ethanol production will be the key driver and this will take advantage of the potential for this 'shelf technology' for producing high pol sugar.

However, as the CBA system is well proven overseas this change may have occurred anyway; the attribution to SRI097 of the benefits from adopting the system is estimated at 20%.

Cost Savings for QHP Production

It is assumed that there will be an increase in demand for QHP sugar from Australian factories in order to remain competitive. However, factories need certainty of markets before making a major capital investment for high pol sugar production. QSL would need to have a market established and may need to contract a factory to make high pol sugar in order to encourage factories to make the investment in pans etc.

The study has demonstrated that the existing QHP process is quite competitive. This information in itself is helpful to factories planning for changes to high pol sugar production, when and if the need arises. The adoption rate of QHP production systems therefore may be enhanced due to SRI097 but these benefits from any increase in uptake have not been incorporated into the analysis.

For QHP sugar the savings are not very significant as the recommended current method of production is very economical. The cost is estimated at $2.94 per tonne (with batch pans). The savings here are only through the use of continuous pans. The cost of production is then $2.19 per tonne – a saving of $0.75 per tonne.

The average pol and tonnage for IHP and QHP sugar for Queensland for the past six years are shown in Table 4.

Table 4: Tonnages for IHP and QHP Sugar Produced in Queensland from 2000-2005

Season	IHP sugar (tonnes)	QHP sugar (tonnes)	Total IHP and QHP sugar (tonnes)	Total sugar produced in Queensland (tonnes)	% sugar that is IHP or QHP
2000	490,856	173,902	664,758	3,797,000	17.5
2001	419,817	275,371	695,188	4,212,000	16.5
2002	370,755	225,580	596,335	4,953,000	12.0
2003	409,805	348,195	758,000	4,667,000	16.2
2004	242,331	476,296	718,627	4,871,000	14.8
2005	234,770	415,195	649,965	4,782,000	13.6

Source: Queensland Sugar Limited

Table 4 shows that high pol sugar production has remained fairly constant over the past six years. IHP sugar production in Queensland has decreased somewhat over this period while QHP production has increased.

Standard Brazilian raw sugar is now 99.2 pol and is exported into eastern Europe, Africa and the Middle East. In the last year however, Brazilian raw sugar has been sold into the traditional Queensland market of Malaysia. For the Queensland industry to maintain its competitive position in East Asian markets, high pol sugar needs to be produced by Australian sugar factories and sold in to East Asian markets. If a lower cost high pol sugar could be produced then up to an additional one million tonnes per annum of high pol sugar could be sold into East Asian markets (Hywell Cook, pers. comm., December 2005).

It is assumed that one additional factory producing 300,000 t per year of sugar changes to QHP production and commences production in the 2008/09 year. It is conservatively estimated that the probability of this happening is 80%. The idea of continuous pans may have been utilised without SRI097 and therefore an attribution factor to SRI097 of 50% has been applied.

Value of Steam Savings

Highlighting the cost of steam in sugar production could stimulate adoption of systems that lead to steam savings. SRI has been carrying out work on other technologies which will allow this change to be implemented.

It would be feasible to target 10% reduction in steam consumption on the pan stage (Broadfoot, pers comm, 2005). For purposes of the analysis, it is conservatively assumed that 5% steam savings are made. A 5% reduction in steam usage equates to a reduction in the cost of Brand 1 sugar of $0.425 per tonne of sugar. Highlighting the costs of steam is assumed to result in one additional factory making steam savings (probability of 50%) with savings commencing in 2007/08.

Sugar Price Adjustment
The base sugar price used in the SRI097 cost analyses was $200 per tonne of sugar (Table 6.4 on Page 78 of final report). The added cost relative to Brand 1 sugar moves from 3.15 to 4.05 when the sugar price moves from $200 to $300 per tonne. Hence the additional cost moves upwards 29%.

The current SRDC investment analyses uses a base sugar price for all analyses of an average for the last five years ($285 per tonne sugar in 2004/05 $ terms). Hence using 85/100 times 29% give an uplift in the added cost gap of a factor of 24.6%. A corresponding percentage uplift factor can be estimated for any other sugar price increase. This uplift factor has been applied to the cost saving for QHP and IHP sugars but not to the steam saving which should be independent of the sugar price.

Table 5 summarises the assumptions made in the quantitative analysis.

Table 5: Summary of Assumptions

Variable	Assumption	Source
Implementation of the CBA scheme		
Number of factories investing in ethanol production	1	Agtrans
Probability of investment occurring	0.8	Agtrans
Year of investment	2007/08	Agtrans
Year of first production of IHP sugar	2008/09	Agtrans
Attribution of change to SRI097	0.2	Agtrans
Cost of producing high pol sugar by three massecuite scheme (batch pans)	$3.90 per t sugar	SRI097
Cost of producing high pol sugar through CBA scheme (continuous pans)	$1.30 per t sugar	SRI097
Factory sugar production of IHP	280,000 t per annum	Agtrans
Cost savings from QHP production		
Number of factories converting to QHL	1	Agtrans
Probability of investment occurring	0.8	Agtrans
Year of investment	2007/08	Agtrans
Year of first production of QHP sugar	2008/09	Agtrans
Cost of producing QHL sugar with batch pans	$2.94 per t sugar	SRI097
Cost of producing QHL sugar with continuous pans	$2.19 per t sugar	SRI097
Factory sugar production of QHP	300,000 t per annum	Agtrans
Attribution of savings to SRI097	50%	Agtrans
Steam Savings		
Number of factories making steam savings as a result of SRI097	1	Agtrans

Probability of one factory making savings	0.5	Agtrans
Year savings commence	2007/08	Agtrans
Percentage savings made	5%	Agtrans
Cost of steam	$8 per tonne of steam	SRI097
Cost of steam	$8.50 per tonne of sugar	SRI097
Magnitude of savings	$0.425 per tonne of sugar	$8.50 times 5%
Factory sugar production	300,000 t per annum	Agtrans
Sugar Price		
Base sugar price used in SRDC analyses	$285 per tonne	Past five year average sugar price in 2004/05 dollar terms
Base sugar price used in SRI097 analyses	$200 per tonne	SRI097
Impact of raising sugar price from $200 to $300 per tonne	+29% to cost difference	Derived from SRI 097
Impact of raising sugar price from $200 to $285 per tonne	+24.6% cost difference	Derived from 85% of 29%
Impact of raising sugar price from $200 to $350 per tonne	+43.5% cost difference	Derived from 150% of 29%

Results

All past costs and benefits were expressed in 2004/05 dollar terms using the Consumer Price Index. All benefits after 2004/05 were expressed in 2004/05 dollar terms. All costs and benefits were discounted to 2004/05 using a discount rate of 5% and 10%. 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 30 years from the first year of investment (1999/00) to the final year of benefits assumed (2028/29).

The investment criteria were all expected values but were positive as reported in Table 6.

Table 6: Investment criteria for total investment and total benefits

Criterion	**Discount Rate**	
	5%	**10%**
Present value of benefits (m$)	3.61	2.13
Present value of costs (m$)	0.075	0.092
Net present value (m$)	3.54	2.04
Benefit-cost ratio	48.2 to 1	23.1 to 1
Internal rate of return (%)	41.2	

The impact of the very small investment costs given the assumptions made is a very high rate of return with a moderately sized NPV. Approximately 45% of the total benefits can be attributed to the use of the CBA scheme, 34% due to the QHP production system, and 21% due to steam savings.

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 7 and 8. All sensitivity analyses were performed using a 5% discount rate, except for those for the sugar price, where both 5% and 10% were used. All other parameters were held at their base values.

Table 7 shows the investment criteria if only one of the three benefits was included in the analysis.

Table 7: Sensitivity if only One Benefit Included

Criterion	**Benefit included**		
	Cost savings from CBA only	**Cost savings from QHP only**	**Steam savings only**
Present value of benefits (m$)	1.61	1.24	0.76
Present value of costs (m$)	0.075	0.075	0.075
Net present value (m$)	1.53	1.17	0.69
Benefit cost ratio	21.5 to 1	16.6 to 1	10.2 to 1

Table 8 shows the sensitivity to the probabilities of each factory saving occurring. Even at 10% of the base assumption regarding probabilities, the investment criteria are still positive at a 5% discount rate.

Table 8: Sensitivity to Probabilities of each Benefit Occurring

Criterion	**Probability**		
	Probabilities 10% of Base	**Probabilities 25% of Base**	**Base**
Present value of benefits (m$)	0.36	0.90	3.61
Present value of costs (m$)	0.075	0.075	0.075
Net present value (m$)	0.29	0.83	3.54
Benefit cost ratio	4.8 to 1	12.1 to 1	48.2 to 1

Tables 9 and 10 show the sensitivity of the investment criteria to sugar prices of $200, $285 (the base price used) and $350 per tonne.

Table 9: Sensitivity to Sugar Price at 5% Discount Rate

Criterion	Sugar Price of $200 per tonne	Sugar Price of $285 per tonne (Base)	Sugar Price of $350 per tonne
Present value of benefits (m$)	3.05	3.61	4.04
Present value of costs (m$)	0.075	0.075	0.075
Net present value (m$)	2.97	3.54	3.97
Benefit cost ratio	40.7 to 1	48.2 to 1	54.0 to 1
Internal rate of return (%)	39.2	41.2	42.5

Table 10: Sensitivity to Sugar Price at 10% Discount Rate

Criterion	Sugar Price of $200 per tonne	Sugar Price of $285 per tonne (Base)	Sugar Price of $350 per tonne
Present value of benefits (m$)	1.80	2.13	2.39
Present value of costs (m$)	0.092	0.092	0.092
Net present value (m$)	1.71	2.04	2.30
Benefit cost ratio	19.6 to 1	23.1 to 1	25.9 to 1
Internal rate of return (%)	39.2	41.2	42.5

Table 11 shows the sensitivity of investment criteria to the assumed cost of steam. Since the report for SRI097 was written the cost of coal has increased substantially, with an estimate of the cost of steam now around $12 per tonne of steam. This increases the benefits from steam savings quite considerably.

Table 11: Sensitivity to Cost of Steam (Only Steam Benefits Included)

Criterion	Cost of Steam at $8 per Tonne of Steam (Base)	Cost of Steam at $12 per Tonne of Steam
Present value of benefits (m$)	0.76	1.14
Present value of costs (m$)	0.075	0.075
Net present value (m$)	0.69	1.07
Benefit cost ratio	10.2 to 1	15.2 to 1

Discussion

As no use to date has been made of the findings in SRI097 by Australian factories, it has been necessary to make a set of conservative assumptions regarding future uptake of the findings. There is a high level of uncertainty regarding how many factories may change systems in the future, when this may occur and how influential SRI097 findings may have been in influencing system changes.

There are opportunities for benefits to be captured from the knowledge produced in SRI097 through lowered costs in producing IHP or QHP sugars, and also from steam savings whose magnitudes have been identified in the study.

Conclusions

The investment in SRI097 has been relatively small. However, the magnitude of the expected investment criteria could have been greater if the project had not taken so long to complete, although the past few years have not been conducive to new investment.

Opportunities for producing high pol sugar in Australia at lower cost in the future have been identified in the project. However, this production will require new investment by sugar factories and such investment is currently scarce. There is also the potential for steam savings in some sugar factories as a result of the investment in SRI097.

The quantitative analysis has suggested the investment is likely to provide a modest NPV and a very high B/C Ratio and internal rate of return. However, the investment criteria estimates rely on a set of assumptions concerning how many factories are likely to change their production system or make steam savings as a result of this investment.

Acknowledgments

Much of the information presented on this project has been based on the final report for SRI097. Ross Broadfoot of SRI has assisted with comments on the analysis as well as a number of the assumptions made. Hywell Cook and Warren Males of Queensland Sugar Limited assisted with information about the market for high pol sugar and this assistance is gratefully acknowledged.

References

Broadfoot R and Pennisi S N (2004) "Costs and Benefits of the CBA Boiling Scheme for High Pol Sugar Production" Final Report Submitted to SRDC for Project SRI097.

5. MSA003: A Cooperative Systems Model for the Mackay Regional Sugar Industry

Organisation: Mackay Sugar Cooperative Association Limited
Start Date: 1 July 2003
Completion Date: 30 June 2005 (extension to 1 November 2005)
Principal Investigator: Mr Geoffrey Fleming, Mackay Sugar Cooperative Association Limited

Background

Since 1999, Mackay Sugar had been applying computer and communication technologies to streamline the grower-miller and harvester-miller interfaces. Up until 2003, they had invested over half a million dollars establishing a web portal and communications infrastructure and building the technical capability of end users through training, technical support and negotiation with technology providers.

A communications centre provided a single point of contact for field and transport-related issues and automated the manual/paper processes used previously. A vertical web portal provided on-line access to:

- Harvesting reports and siding availability
- Cane delivery information and crushing statistics
- Productivity and yield estimate information via an on-line farm map interface incorporating satellite imagery

The change to such a web portal and database system was initially directed purely at cost reduction through reducing staff numbers and streamlining grower-harvester-miller interfaces.

In 2003, approximately 80% of growers and harvest contractors were using the web portal regularly. Some cost savings and efficiencies had already been achieved by reducing the labour required to communicate between sectors.

In 2003 funding was sought from SRDC to further develop the system. The importance of a regional, whole of value chain systems approach to operations across all industry sectors was highlighted in the Hildebrand report, and is one of SRDC's priorities for R&D investment.

The Cooperative Systems project was initiated to develop value chain management strategies for the region underpinned by technology. The existing web portal provided the preliminary physical infrastructure.

The Project

Project Objectives

The objective of this project was to develop a whole value chain management model to underpin reduction of costs and improved profitability and sustainability for all sectors of the Mackay sugar industry.

The management strategy uses a participative action learning approach to:

- Develop a "cooperative systems" model that integrates the links of the value chain in order to add value to its component parts (cooperative systems are computer-based systems used by individual businesses in a value chain that integrate and work together to support management decision making across the chain)
- Demonstrate the performance and benefits of the cooperative systems model on a pilot scale
- Develop an implementation strategy for adoption by the Mackay sugar industry based on the learning gained from the pilot process
- Document project outcomes and lessons for wider industry benefit

Project Description

An advisory committee was established to work with the project management committee to coordinate and evaluate the overall project using participatory evaluation methodologies. Reference groups of growers and harvester operators were formed to work with sub-groups of the project team on individual components of the model. Workshops were held with these reference groups to introduce them to the management concepts underlying the project.

These workshops produced a priority list of systems for further investigation:

- Mill Systems
    - On-line Analysis (NIR)
    - New cane payment schemes
    - Electronic Consignment
- Harvesting Systems
    - Harvester monitoring
    - Cane quality
    - Harvesting costs (Harvest Haul Model)
- Farming Systems
    - Paddock inputs and yield recording
    - Variety selector
    - Pest and disease management
    - Harvest scheduling
    - Financial benchmarking

For individual components, systems were designed employing an iterative development methodology, wherein rapid development techniques are used to generate prototypes which can be evaluated against requirements and specifications, revised, modified and reviewed again. The reference groups formed a key part of this process.

The individual components were then integrated into an overall model for value chain management. The integrated system was trialled, trial results were evaluated, and the model was revised in line with the findings from the evaluation.

The outputs of the trials and revised model were then communicated to stakeholders and a detailed plan was developed to implement the cooperative systems model across the Mackay sugar industry value chain.

While it was originally intended that the cooperative systems model would be implemented as a pilot program, the success of the project has meant that broadscale implementation of some components of the system has occurred within the timeframe of the project.

Associated Projects
The project has included some interaction with BSS261 “Measurement and feedback systems for improving market signals for harvesting”.

Costs
Table 1 presents the annual investment costs for MSA003 contributed by both SRDC and the Mackay Sugar Cooperative.

Table 1: Annual Investment Costs for MSA003 (nominal $)

Year	SRDC	In-kind Contribution[1]	Total
2003/04	155,450	161,815	317,265
2004/05	90,000	93,685	183,685
Total	245,450	255,500	500,950

[1] Mackay Sugar Cooperative Association Limited

Outputs

The major output of the project is a tested value chain management cooperative systems model, incorporating computer-based management systems for farmers and harvester operators integrated with mill systems for consignment, transport, receival and analysis of cane.

The model provides a database of shared information which serves as a comprehensive and accurate record of regional information. Third party systems can utilise and contribute to the database and this has the potential to provide services that add further value for stakeholders and contribute to productivity initiatives for the region.

Also as part of the process, the industry value chain has been documented and analysed, initially to establish baseline costs, and progressively to identify and overcome inefficiencies.

Electronic consignment trials have been completed. These trials used mobile data units with touch screens in harvesters. It was determined that further work was needed to improve the reliability of the technology, but that it shows promise and was well received.

The harvester monitoring trials were successful and Mackay Sugar is deploying 40 tracking/data units on harvesters in 2005. GPS tracking and data monitoring units were installed for trials and results were captured on the web portal. The data was used to provide weekly updates of area harvested and yield versus estimate during the season. Results were displayed spatially on the web portal. Programs are being finalised to display the operating data obtained such as ground speed, operating versus cutting hours, etc on farm maps via the web portal's map interface. The objective was to collect and analyse data as a basis for harvesting contracts based on market signals that will encourage harvesting best practice (links to project BSS261 "Measurement and Feedback Systems for Improving Market Signals for Harvesting").

NIR rake data for cane quality (extraneous matter, dirt etc) can be reported at a paddock and sub-paddock level by relating it to harvester tracking data and the data can be used in models such as BSES Harvest Haul to quantify operating costs of harvesters. Mackay Sugar is also considering installing tracking/data units on its locomotive fleet for collision avoidance and also to improve communication and integration between the harvesting and transport sectors (streamline scheduling).

Contract programmers are continuing to work on the farm management system components of the model. These components have not yet been deployed in trials, however prototypes for most of the farm management systems components have been or are almost completed.

A new cane payment system was developed during the project which replaces CCS with Percent Recoverable Sugar (PRS) based on NIR analysis of cane and historical losses during processing.

Confidentiality of data is assured, as growers are allocated a user name and password that give them access to all information relevant to their farm. The grower can then authorise other users to have various levels of access to their data. For example their harvesting contractor can be restricted to viewing the tonnage and bin information relevant to their operations, and not financial data.

In addition to the actual model and its components, other outputs of the project include:

- Development of capability of stakeholders to understand and apply management systems and technologies
- Workshops, training, discussions and involvement by stakeholders, improving stakeholder capacity for understanding and adoption
- A strategy for implementation of the pilot model across the broader industry

Outcomes

The model has been adopted by Mackay Sugar throughout its mill regions. By implementing the model, cost savings will be realised through the elimination of paper-based and labour intensive interfaces, and on-line access to the information required for timely decision making. In addition, comprehensive and accurate records will result in improved business management and will also build a database of shared information that will be invaluable for research and regional management purposes, including environmental monitoring and management. It should be recognised that the efficiency benefits from moving from a paper-based to an automated system are largely due to the work undertaken by Mackay Sugar prior to the commencement of MSA003.

As at April 2005 the web portal components were fully functional and the on-line near infra-red (NIR) analysis was operational at all mills. It was used for payment analysis as well as cane quality measurement in 2005. Data was collected for sugar analysis (brix, pol and fibre) and cane quality (ash, yielding dirt and extraneous matter).

A key outcome is the adoption of the new cane payment system developed during the project. It was developed and endorsed by Canegrowers for incorporation in supply agreements in 2005. CCS is replaced by a new "sugar from cane" figure (PRS). Payment is based on a new cane price formula that covers not only the sugar in cane, but also molasses (from impurities) and electricity (from fibre). It can be extended to include any other product and the new formula has been included in cane supply agreements for the 2005 and 2006 seasons. In 2005, the price difference compared to the old scheme has been in the growers' favour due to the high price of molasses and a relatively low PRS. However this will differ between seasons. The major desired outcome of the new cane payment system is to focus growers on the impact and contribution of the components and quality of their cane on the whole value chain. This is done by paying them for the revenue contributions of their fibre and non-sugar constituents; through sharing in the sugar quality premium payments; and through sharing in the improved sugar recovery from a regular, clean cane supply.

In summary, the primary source of benefits from this investment is the application of value chain management principles. The web portal/systems are the vehicle for implementing the management strategies and the payment scheme is the vehicle for putting the right commercial/market signals in place for them. The main tangible benefits are:

- Increased crop productivity
- Best practice harvesting resulting in improved cane quality and reduced in-field losses
- Payment systems that facilitate industry diversification and equitable distribution of costs and rewards between sectors
- Reduced administrative and communication costs

Other outcomes include:

- Increased awareness and knowledge of the principles, benefits and application of value chain management in the regional sugar industry
- Cooperation between industry sectors to share information and manage the industry across the whole value chain

Some elements of the cooperative systems approach have been taken up by Proserpine Sugar and CSR Burdekin mills (Geoff Fleming, pers comm., 2006). The model is adaptable to any sugar company.

Quantification of Benefits

Some components of the Cooperative System have already been adopted in Mackay, and other components are continuing to be developed, including the farm management component. The key features that have been adopted include the web portal and harvesting data collection systems; as well as the use of NIS for quality data; and the revised cane payment system.

Together, these systems seek to improve the overall efficiency of the Mackay sugar industry and to increase the quality of cane being delivered to its mills.

Only one benefit has been quantified that is assumed to flow from the MSA003 project as part of this analysis. This relates to a general cane productivity increase. Other benefits associated with milling and harvesting practices etc. have not been valued. This is partially due to the difficult nature of assessing relationships between outputs and benefits with respect to systems based projects, and therefore the sources of system improvement. These other benefits may be more easily valued in the future as further information becomes available.

It is assumed that due to the increased availability of data and the emphasis on the value chain implications, that growers are better able to manage their crop. This is a result of increased paddock scale data which can link practices on-farm and other attributes of the paddock to harvesting and quality data made available, also on a paddock scale. It is assumed that through a variety of changed practices (for example variety choice, fertilizer management, pest management), the average cane productivity in the Mackay region increases by 1%. The Cooperative System has already been adopted in Mackay, however the farm management aspects have not yet been released. It is assumed therefore that the benefits do not start to accrue until 2007/08. It is further assumed that the maximum benefit is reached within 5 years. It is assumed that there is a 90% probability that the farm management aspects of the Cooperative Systems model will be successfully completed and applied.

While it is recognised that the assumed benefit would most likely not have been achieved without MSA003, the prior work by Mackay Sugar in establishing the database and web portal should be considered as part of the investment to achieve these benefits. The initial development costs (prior to MSA003) are assumed to be at least $0.5 million, a similar amount to that invested in MSA003. Therefore an attribution factor for MSA003 of 50% is applied to the benefits.

Table 2: Summary of Assumptions

Variable	Assumption	Source
Area of cane harvested for four Mackay mills	77,906 ha	Mackay Sugar (average of last 5 seasons, 2001 to 2005)
Cane productivity for four Mackay mills	73.4 tonnes of cane per ha	Mackay Sugar (average of last 5 seasons, 2001 to 2005)
Sugar content for four Mackay mills	14.145%	Mackay Sugar (average of last 5 seasons, 2001 to 2005)
Assumed increase in cane yield due to MSA003	1%	Agtrans assumption, after discussion with Geoff Fleming
First year of benefits	2007/08	Agtrans assumption
No. of years until maximum benefits are reached	5 years	Agtrans assumption
Attribution of benefits to MSA003	50%	Agtrans assumption
Probability of assumed benefit being achieved	90%	Agtrans assumption

Results

All past costs and benefits were expressed in 2004/05 dollar terms using the Consumer Price Index. All benefits after 2004/05 were expressed in 2004/05 dollar terms. All costs and benefits were discounted to 2004/05 using discount rates of 5% and 10%. 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 30 years from the first year of investment (2003/04) to the final year of benefits assumed (2032/33).

The investment criteria are reported in Table 3. At a 5% discount rate, the results demonstrate a modest NPV ($5.0m), and a high B/C ratio (10.5 to 1) and IRR (30%). The rates of return are influenced by the relatively small value of the PVC and the reasonably rapid rate of change.

Table 3: Investment Criteria for Total Investment and Total Benefits

Criterion	**Discount Rate**	
	5%	**10%**
Present value of benefits ($m)	5.49	2.99
Present value of costs ($m)	0.52	0.54
Net present value ($m)	4.97	2.45
Benefit-cost ratio	10.5 to 1	5.5 to 1
Internal rate of return (%)	29.9%	

Sensitivity Analysis
Sensitivity analyses were carried out for several variables and results are reported in Tables 4 and 5. All sensitivity analyses were performed using a 5% discount rate, except for those for the sugar price, where both 5% and 10% were used. All other parameters were held at their base values.

Table 4 shows the sensitivity of the investment criteria to the increase in cane productivity. It shows that if the increase is halved to 0.5%, then the return to the investment is still reasonably high, with a B/C ratio of 5 to 1. If the assumption is increased to 3%, the B/C ratio increases to 31 to 1.

Table 4: Sensitivity to Increase in Cane Productivity

Criterion	**Increase in Cane Productivity**		
	0.5%	**1% (base case)**	**3%**
Present value of benefits (m$)	2.7	5.5	16.5
Present value of costs (m$)	0.5	0.5	0.5
Net present value (m$)	2.2	5.0	15.9
Benefit-cost ratio	5.2 to 1	10.5 to 1	31.4 to 1

Tables 4 and 5 show a strong sensitivity of the investment criteria to the sugar price. It shows that at a 5% discount rate and a sugar price of only $235 per tonne, the investment still yields a positive return, with a B/C ratio of 6.5 to 1.

Table 5: Sensitivity to Sugar Price at Discount Rate of 5%

Criterion	**Level of Sugar Price ($/t)**			
	235	**285 (base case)**	**335**	**350**
Present value of benefits (m$)	3.4	5.5	7.6	8.2
Present value of costs (m$)	0.5	0.5	0.5	0.5
Net present value (m$)	2.9	5.0	7.0	7.7
Benefit-cost ratio	6.5 to 1	10.5 to 1	14.4 to 1	15.6 to 1
Internal Rate of Return (%)	23.2	29.9	35.0	36.4

Table 6: Sensitivity to Sugar Price at Discount Rate of 10%

Criterion	**Level of Sugar Price ($/t)**			
	235	**285 (base case)**	**335**	**350**
Present value of benefits (m$)	1.9	3.0	4.1	4.5
Present value of costs (m$)	0.5	0.5	0.5	0.5
Net present value (m$)	1.3	2.4	3.6	3.9
Benefit-cost ratio	3.4 to 1	5.5 to 1	7.6 to 1	8.2 to 1
Internal Rate of Return (%)	23.2	29.9	35.0	36.4

Conclusions

The investment in MSA003 has built on and added significant value to a basic web portal and database system which had previously been developed by Mackay Sugar. It developed the value chain approach within the region, and further integrated data collection and provision of data between all sectors of the industry (including farm, harvesting, transport and milling).

The benefits from the implementation of the Cooperative Systems approach will eventually feed through to all sectors of the industry, including harvesting and milling. However, for the purposes of this analysis, only the cane productivity benefits from on-farm management changes have been quantified. Therefore it should be recognised that this analysis is likely to provide an under-estimate of the benefits of this investment.

However, even with only valuing the single benefit, the project yields a significant return on its investment, with a B/C ratio of 10.5 to 1.

Acknowledgments

Geoff Fleming, Mackay Sugar
Jim Crane, Mackay Sugar

6. BSS261: Measurement and Feedback Systems for Improving Market Signals for Harvesting

Organisation: BSES Ltd (also Mackay Sugar, Maryborough Sugar Factory, CSR Ltd)
Start Date: 1 July 2003
Completion Date: 30 June 2005
Principal Investigator: Mr Trevor Willcox

Background

The harvesting payment system in the sugar industry has previously been a simple one-price system based on the tonnage of sugar cane harvested. This has led to a situation where there is little or no incentive to improve farm layout or presentation of sugar cane for harvest. In addition, harvesters have no incentive to reduce extraneous matter and soil in sugar cane. This is because commercial cane sugar (CCS) levels, higher fibre and reduced sugar quality are not reflected in payments to either harvesters or growers. The Hildebrand report (2002) viewed the existing contract harvesting system as unsustainable.

This was reinforced with the development by BSES (with funding from SRDC) of the Harvesting Best Practice Manual for Chopper-Extractor Harvesters. This manual was published in 2002. Industry feedback received during development and extension of the manual indicated that while the Harvesting Best Practice (HBP) principles were sound, there were barriers such as the harvester payment system which were hampering total adoption of all facets of HBP (Cam Whiteing, pers comm., 2005).

In 2003, SRDC contracted a review on harvesting practices/payment arrangements culminating with a workshop in Mackay in May 2003. The outcomes of that workshop and review were used in developing objectives of the BSS261 project.

This project was funded by SRDC in 2003 and sought to remove some of the barriers to adoption in the uptake of improved harvesting technology in the industry.

The Project

Project Objectives
The key objective of the project was determination of optimal structures and policies that increase whole-of-industry profitability through requiring buyers and sellers of harvesting services to establish meaningful pricing structures to reflect quality of work and output, and to improve efficiency and market satisfaction.

The project was to improve understanding of market signals and facilitate changes in industry performance, through:

- Determining the critical success factors for valuing harvesting services using three locations, Burdekin, Mackay and Maryborough, as models.
- Determining and evaluating payment systems that address these critical success factors and maximise new payment methods beyond the pilot areas to other industry locations.

Project Description

A number of harvesting groups at each pilot location were given assistance to develop and trial new payment systems. There were three harvest groups at Maryborough, five at Mackay and four from the Burdekin.

The first step in the project was to undertake a survey of farming practices on farms in the participating harvesting groups in order to obtain baseline data on practices that influence harvest efficiency. This survey also sought to obtain an indication of the current understanding, knowledge, attitudes, skills and aspirations of the growers and harvester operators as a baseline against which to measure progress towards acceptance of improved practices.

A baseline survey of harvester operators was also undertaken in order to evaluate alternative payment systems that reflect both output and quality of the harvesting operation. Focus groups were held at each of the three locations to determine what market signals are important to growers, contractors and millers. It was found that at Racecourse and Pioneer mills in the Mackay area, most contractors were paid per tonne of cane, with the only variations being for long haulage distances. At Maryborough, most contracts used a base rate (per tonne of cane) plus an additional payment for fuel (base rate + fuel system).

The groups collected logbook data to evaluate and compare payment systems. Harvesters were fitted with recording equipment such as hour or fuel meters. In the second year of the project, GPS/web-based data-logger units were fitted to most harvesters to provide additional information. Data collected included fuel use, engine hours and elevator hours. Cane quality information was collected by near infra-red (NIR) technology located at the mills. Logbook data from the groups was run through the BSES Harvest-Transport Model to estimate actual harvesting costs and compare payment systems. The data for blocks and farms was compared and suggestions offered on farming practices or farm layouts to reduce costs. The analysis of the data produced information on relationships between parameters such as crop size, row length, haul distance, fuel use and field efficiency.

The alternative cane harvesting payment systems were evaluated and modified to ensure they promoted equitable, simple and effective measures to increase returns across the value chain. The payment systems were introduced to additional innovative groups in years 2 and 3 for further development, implementation and review.

The alternative payment methods considered were:

- An hourly rate

- A base rate (e.g. $5.80/t) plus grower supplies fuel
- A base rate plus fuel priced above normal to allow for labour and machinery
- A sliding scale, variable rate per tonne based on crop yield (e.g. $7.00/t @ 40 t cane/ha to $6.40/t @ 100 t cane/ha)
- A sliding scale based on crop yield plus fuel
- Hourly rate plus a base rate. This, for example, may be $150/h plus a flat rate of $3.00/t

The final report includes results and learnings from participative groups and pilot evaluations of alternative harvesting and harvest payment arrangements. It makes recommendations for widespread delivery of the findings and suggested pathways for adoption across the Australian sugar industry.

Associated Projects
The project utilised the findings of BS227, which developed "The Harvesting Best Practice Manual for Chopper-Extractor Harvesters". BSS227 included data gathered during project BSS189.

Projects BSS189 and BSS227 created industry awareness of and the desire to implement HBP principles, while BSS261 (the project being evaluated here) sought to identify financial drivers which might break down barriers to adoption.

Costs
Table 1 provides the investment costs for project BSS261.

Table 1: Investment Costs for BSS261 by Year for SRDC and Others (nominal $)

Year	SRDC	In-kind Contribution[1]	Total
2003/04	172,437	396,076	568,513
2004/05	180,207	413,924	594,131
Total	352,644	810,000	1,162,644

[1] Includes contributions from BSES, Mackay Sugar, CSR Ltd and Maryborough Sugar

Outputs

The conclusions reached about the various methods with respect to how equitable they are, and how they will encourage the adoption of harvesting best practice (HBP) are as follows.

Current System - $/t
- Encourages minimal loss of cane.
- Easy to monitor and understand.
- Sends a market signal that quality is a minor focus.

Base rate plus Fuel (BR+F)

- Easy to monitor and validate
- Reduces the level of cross subsidisation,
- Cost of bad blocks still borne by the harvester
- Sends some market signals for high pour rates to maintain viability
- Commercially proven in Maryborough

Base Rate plus Fuel + $

- Fuel is priced to allow for labour
- Used by some groups in NSW
- Intention is to recognise that paying for fuel alone does not compensate for machinery and labour costs

Hourly rate

- Rate negotiated between grower and contractor.
- Monitoring equipment needed for growers to know that the machine was working as contracted.
- Sends best market signals as it creates the greatest variation in price per tonne and reflects true costs, as most variable costs are accumulated on an hourly basis.
- Encourages best-practice farming, as the more efficient a farm is to harvest and the better the crop size and yield, the lower the cost per tonne to harvest.
- Allow the grower to prescribe the mode of harvester operation for each block.
- If a grower does not understand the financial benefits of HBP, this could lead to unwise decision-making focused on minimum time and, hence, minimum cost at the expense of high cane loss, low cane quality and damaged ratoons.
- Hourly rate should be linked to a cane-quality measurement system at the mill to provide targets for cane quality.
- There is no incentive for the harvester to reduce cane loss, so settings of the harvester such as extractor fan speed and forward speed need to be monitored.
- There is no incentive for the harvester to perform efficiently time-wise.

Sliding-Scale Base Rate plus Fuel

- A simple system with good market signals.
- Transparent and easy to apply.
- Base rate covers cane loss issues and true fuel costs are covered.
- The sliding scale covers some labour and machinery costs associated with crop size.
- As it is still a tonnage rate it encourages maximising pour rates and delivery rates.

The final report recommended that the major components of an ‘ideal’ package would be:

- Farm layouts and cultural operations that enable efficient harvesting.
- Harvesters set up and operating at best practice monitoring position, forward speed, delivery rate, extractor fan speed and other parameters through a GPS based data logging unit linked to a central web site.
- Payment for harvesting based on a system that mirrors harvesting costs and provides incentives for best practice farming and harvesting. Options include:

    - Hourly rate
    - Base rate plus fuel (BR+F)
    - Base rate plus fuel plus $
    - Sliding scale on yield plus fuel
- Payment for cane based on a Cane Quality Index that varies with parameters that influence sugar quality measured automatically using a system such as NIR
- A data-feedback system that returns data on cane quality immediately to harvester operators and cane growers so that adjustments may be made when quality falls.

It was concluded that the payment methods that provide the best market signals are those based on an hourly rate. Methods where the fuel is charged to the grower send weaker market signals, but still link to best practice and provide incentive to change. The methods most likely to be adopted in the short term are the BR+F methods.

The study found that the new system should be successful in changing attitudes and accelerating the adoption of HBP. It found that the aspect of HBP that is most difficult for operators to adopt is a reduction in pour rate to improve cane quality. This is because reduced pour rate increases harvesting costs. Pour rate can be increased without increasing costs if farm layout is improved to avoid time spent turning on headlands or waiting for haulouts to traverse rough headlands.

The study was also useful in demonstrating the value of using NIR technology for cane quality aspects. At Maryborough and Mackay project officers worked with the mills to establish cane-quality indices using NIR. At Mackay this was done through links to the MSA003 project "A cooperative systems model for the Mackay regional sugar industry in developing a cane quality system".

The project revealed some contrasting attitudes and practices between Maryborough and the Central district. Maryborough has operated under a base rate plus fuel system for over ten years, while the Central district has been predominantly a flat rate per tonne system.

In Maryborough, growers were more acutely aware of on-farm factors which impacted on harvesting costs/efficiency and were more likely to allow operators to harvest two blocks simultaneously which can significantly improve efficiency. Assessment of farm layouts, headland conditions and turning efficiency at Maryborough indicated significant investments by farmers in developing farms which were efficient for harvesting and this was evidenced by the high average field efficiencies of the participating harvesting groups (Cam Whiteing, pers comm., 2005).

Outcomes

Adoption of the recommendations from the project is expected to result in improved efficiency and profitability for all sectors of the industry. For example:

- Growers will have methods of determining the quality of contracted harvesting and better feedback systems.

- Harvester owners will benefit as harvesting charges and incentives will reflect true costs and job quality.
- Millers will have better cane quality and more assured supply.

The outputs of the report can act as a resource to guide the industry though the rationalisation of harvesting structures and operation.

The final report for the project identified the following indicators that change was occurring:

- Widespread interest and purchase of NIR Cane Assessment Systems (CAS)
- Widespread interest and purchase of GPS based data-logging units to monitor harvesting
- Harvest groups moving to new payment methods, principally base rate plus fuel throughout the industry
- Results of surveys showing that growers and harvest operators are adopting best practice farming and harvesting techniques to reduce harvesting costs and gain incentives for cane quality

Statistics on how many operators have changed and what system they are using would involve an extensive survey that was not possible within the scope of the project (Cam Whiteing, pers comm., 2005).

The Maryborough groups have stayed with their plus fuel system, and one of the Mackay groups has moved to a plus fuel system. Two of the Mackay groups stayed with a flat rate, but varied the rate between farms or varied the rate for long hauls. This sends a market signal to the farms charged the higher rates that they could improve layouts and reduce harvest costs.

Anecdotal evidence from harvester operators throughout Queensland has indicated that there is generally a perceived need to change harvesting payment to more accurately reflect the true costs. In the far north, a number of groups have moved to a plus fuel system as this region has a firm understanding of HBP (Cam Whiteing, pers comm., 2005).

The potential adoption of alternative payment systems is expected to vary considerably across different regions and will be influenced by factors such as the existing distribution and financial positions of harvesting businesses or the level of miller and grower support for change (Cam Whiteing, pers comm., 2005).

Another impediment to adoption is that all Queensland sugar regions are not necessarily aware of HBP and the associated financial benefits. BSS189 was based in north Queensland and BSS227 was focused on the Central and Northern districts. Therefore these districts are more aware of HBP and its benefits than other regions. For example in Mulgrave where BSS189 was based there has already been a number of harvesting businesses move to base rate plus fuel due to a high level of HBP awareness.

In regions where promotion of HBP has been less concentrated or there are high numbers of harvesting businesses competing for cane the uptake of alternative payment systems will be much slower (Cam Whiteing, pers comm., 2005).

"Financial pressures, variable fuel prices and natural attrition will facilitate a move to alternative payment systems but accelerated adoption profiles will depend to a great extent on ongoing support for HBP work" (Cam Whiteing, pers comm., 2005).

Adoption of HBP will mirror the adoption of improved market signals, however there will be significant time lags for several reasons. Firstly, growers must become aware of factors which impact on their own harvesting costs, and secondly, changes to farm and block layouts can only occur between the end of one crop cycle and the next planting which can be five years.

There is the potential for almost total adoption of HBP in areas where it has been well promoted and an improved payment system is introduced. However there will be some farms or blocks on which it may never be viable to adopt HBP due to physical and financial constraints.

Quantification of Benefits

The adoption of a changed harvester payment system that includes market signals is assumed to result in the increased adoption of HBP. There are several main benefits from adoption of HBP:

1. Less extraneous matter, resulting in improved sugar quality less sucrose lost and reduced cost to mills caused by dirt.
2. Reduced overall harvesting costs for industry due to improved planting designs/layouts.
3. Reduced cane loss and therefore increased sugar production, through optimal extractor speeds and pour rates.

Each of the above benefits can also have associated costs. For example, reducing the fan extractor speed reduces sugar loss by increasing the total cane yield and therefore sugar production by up to 15%. It is estimated that an average potential benefit to the industry of say 5% is achievable. However, reducing the extractor speed can also result in an increase in extraneous matter levels by 1% to 3% which reduces bin weights and increases transport costs to the milling and harvesting sectors. Generally, the benefit of the reduced sugar loss outweighs the increased transport costs. However in cases where bin weights are already at a critical level in terms of maintaining mill crushing rate this can present a problem. Another example is feedtrain optimisation, which might cost the harvester operator $5,000, but can increase sugar yields by 2% to 4% (Cam Whiteing, pers comm., 2005).

As the examples above show, the benefits of adopting HBP are difficult to determine, due to the large number of variables which may be influenced. The examples also show that the implementation of alternative cane payment systems will be crucial to the adoption of HBP, as the benefits of adopting these practices do not always accrue to those who bear the costs of adopting those practices.

It has been estimated that adopting HBP has the potential to provide an extra $100/ha or more to the industry (Agnew et al 2002, cited in Willcox et al 2004). This is assumed to be a net benefit due to the combination of reduced cane loss, harvesting efficiency and improved sugar quality.

For the purposes of this analysis it is conservatively assumed that the average benefit where HBP is adopted is $50/ha. It is recognised that this assumption is made up of a combination of factors, including benefits from improved sugar quality, reduced cane loss, and improved harvester efficiency. It is assumed to be net of any costs of implementing HBP, and of any additional harvesting, transport and milling costs. It is further recognised that the increased benefit is an average benefit, and that different adopters will adopt different components of HBP, with not all cane growers and harvester operators adopting the total HBP package.

It is assumed that adoption of HBP in the Queensland sugar regions will increase in a linear fashion over 10 years from the completion of the project until maximum adoption is reached. The maximum adoption level is assumed to be 12.5% of the cane area. It is further assumed that 25% of the adoption is attributable to BSS261 and the adoption of changed payment systems, with the remainder attributable to earlier projects including the development of the HBP manual. This attribution factor also accounts for some future extension which will be required to achieve the level of adoption assumed.

Table 2: Summary of Assumptions

Variable	Assumption	Source
Total area of cane harvested in Queensland	429,000 ha	Past five year average
Maximum adoption of HBP	12.5% of total cane area (53,625 ha)	Agtrans assumption
Average benefit per hectare from HBP	$50 per ha	Agtrans assumption (following discussion with Cam Whiteing)
Attribution of adoption to BSS261	25%	Agtrans assumption
Year of first adoption	2004/05	Agtrans assumption
Year of maximum adoption	2013/14	Agtrans assumption

Results

All past costs and benefits were expressed in 2004/05 dollar terms using the Consumer Price Index. All benefits after 2004/05 were expressed in 2004/05 dollar terms. All costs and benefits were discounted to 2004/05 using discount rates of 5% and 10%. 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 30 years from the first year of investment (2003/04) to the final year of benefits assumed (2032/33).

The investment criteria were all expected values as reported in Table 3.

Table 3: Investment Criteria for Total Investment and Total Benefits

Criterion	**Discount Rate**	
	5%	**10%**
Present value of benefits ($m)	7.99	4.52
Present value of costs ($m)	1.21	1.23
Net present value ($m)	6.79	3.28
Benefit-cost ratio	6.6 to1	3.7 to 1
Internal rate of return (%)	27	

Sensitivity Analysis
Sensitivity analyses were carried out on a range of variables and results are reported in Tables 4 and 5. All sensitivity analyses were performed using a 5% discount rate. All other parameters were held at their base values.

Table 4 shows the investment criteria if the maximum adoption level is reduced to 5% and increased to 30% or 75%. It shows that the investment criteria are highly sensitive to this parameter, but that even at 5% adoption level, a positive B/C ratio of 2.7 to 1 is still achieved.

Table 4: Sensitivity to Maximum Adoption Level

Criterion	**Maximum Adoption Level**			
	5%	**12.5% (base)**	**30%**	**75%**
Present value of benefits ($m)	3.20	7.99	19.18	47.96
Present value of costs ($m)	1.21	1.21	1.21	1.21
Net present value ($m)	1.99	6.79	17.98	46.75
Benefit-cost ratio	2.7 to 1	6.6 to1	15.9 to 1	39.8 to 1

Table 5 shows the investment criteria of the benefit per hectare of adopting HBP is decreased to $10 per ha, $25 per ha or increased to $100 per ha. The analysis shows that if the value of the benefit per hectare is reduced to only $10, then the return on the investment is negative, with a benefit to cost ratio of 0.3 to 1.

Table 5: Sensitivity to Value of Benefit

Criterion	Value of Benefit ($/ha)			
	10	25	50 (base)	100
Present value of benefits ($m)	0.32	2.00	7.99	31.97
Present value of costs ($m)	1.21	1.21	1.21	1.21
Net present value ($m)	-0.89	0.79	6.79	30.77
Benefit-cost ratio	0.3 to 1	1.7 to 1	6.6 to 1	26.5 to 1

Discussion
The adoption of payment systems that provide incentives for adopting HBP have not yet been widely implemented, and therefore adoption of HBP itself has been slow. For this reason a low maximum adoption level for HBP has been assumed. However the sensitivity analysis has shown that even at low maximum adoption levels, the return on the research investment is still positive. More important is the net benefit from the adoption of HBP. If the assumed benefit of $50 per hectare is halved, the return on investment becomes very small (1.7 to 1).

Conclusions

The investment in BSS261 builds on earlier SRDC-funded work aimed at identifying Harvesting Best Practices. If alternative cane harvesting payment systems are introduced, it is expected they will result in the increased adoption of HBP, and the benefits to the industry may be significant.

Acknowledgments

Cam Whiteing, BSES Ltd

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7. CSE001: Increased Profitability and Water Use Efficiency through Best Use of Limited Water Under Supplementary Irrigation in Sugarcane

Organisations: CSIRO Sustainable Ecosystems, Rural Water Use Efficiency Initiative, and CRC for Sustainable Sugar Production
Start Date: 1 September 2001
Completion Date: 1 September 2005 (final report to be submitted March 2006)
Principal Investigator: Dr Geoff Inman-Bamber

Background

Well over half of Australian sugarcane is produced with the use of irrigation, to increase yield and to reduce risks associated with seasonal climatic variability. Requirements for irrigation vary from year to year in many sugarcane production regions. Hence questions are often posed such as:

- Is investment in irrigation worthwhile and what investment is optimal?
- Is it worthwhile storing water on farm?
- How can irrigation water be used more efficiently?

This project followed another SRDC supported project CTA018 that was completed in 1999. This former project was entitled "Efficient Use of Water Resources in Sugar Production: Optimising the Use of Limited Water Under Supplementary Irrigation". CTA018 demonstrated that the use of supplementary irrigation could result in high sugarcane production increases in the Herbert region. Yield increases of greater then 25 tonnes of cane per Megalitre (ML) were observed, such gains being higher than previously accepted benchmarks. Information about crop response to supplementary irrigation was developed as part of the project and the APSIM model was used to help define key crop production and water use relationships. The research results also were used to develop a decision support tool called "DAMEA$Y" that assisted with determining optimum storage capacity and irrigation system investment guidance.

Another SRDC project CTA038 that was completed in 2003 also addressed sugar yield and water stress, used APSIM extensively, and developed irrigation scheduling improvements.

CSE001 was to build on the modelling capability developed in these former projects and was developed to play a major role in the Program on Rural Water Use Efficiency supported by the Queensland Government through the Department of Natural Resources and Mines.

The Project

Project Objectives

The broad objective of project CSE001 was to increase profitability of sugarcane production via improved water use efficiency. The specific objectives were:

(i) Build on past research to develop guidelines to support tactical and strategic decisions regarding timing of limited water applications, water allocations to each paddock, extending ratoon life, making use of water upflow from water tables and withholding irrigation to reduce risks of waterlogging;
(ii) Further enhance sugarcane systems modelling capability;
(iii) Customise tools for industry; and
(iv) Work with extension officers in applying these tools in an action research context with industry.

Project Description

In general, the project focused on experiments for determining sugar yield response to irrigation, in conjunction with the cropping system model APSIM.

A series of modelling experiments was conducted using APSIM with the aim of defining the best time to irrigate sugarcane given climatic variability. The APSIM model and an optimising procedure (now called WaterSense) were used to schedule irrigation in replicated field experiments on ratoon crops on sites near Bundaberg and Childers. Treatments included no irrigation, current grower practice, and two model determined "best-bet" strategy treatments. The skill of WaterSense was compared with that of the grower in terms of achieving high soil moisture and yield. Optional water use was linked to seasonal forecasting indicators.

One of the main concerns of growers in the drier Bundaberg region is when to use the limited irrigation water available to them during the water year of July to June, as these availabilities are set at the beginning of the water year. Allocations generally vary from 1 to 4 ML per hectare. Growers may also have access to 'out of allocation water' and 'water harvesting' water, bore water or water stored in on-farm dams. Strategies for optimising limited water need to consider all these options in conjunction with soil and climate conditions. The APSIM model had not been tested in the Bundaberg region and there was a need to validate the model as well as develop optimum strategies for use of limited water. This would then lead to development of strategies for a range of soil types, regions, water resources and climates not only in Bundaberg but in all regions where water for irrigation is limited.

Another experiment in the Burdekin region focused on producing a water production curve. This trial dealt with the issue of diminishing returns from an increase in water allocations and optimising water use over the whole farm. The project was used as well to test the capability of APSIM to simulate the production curves produced in each of two crops, a plant and first ratoon. Also, the residual effects of limited water application on subsequent ratoon establishment were studied in the same experiment.

The trials were designed jointly by extension officers, grower committees and researchers and were integrated closely with the District Rural Water Use Efficiency (RWUE) Committees.

A variation made to the project in 2002 was to develop a user friendly software program to predict optimum timing for use of limited irrigation water.

A review of the project in 2003 was highly positive but directed the project to increase the focus on extension outputs as the extension support given by the RWUE Initiative ceased at the end of June 2003.

Associated Projects
As previously mentioned this project built on at least two previous SRDC supported projects carried out by CSIRO (CTA018 and CTA038):

- CTA018 "Efficient Use of Water Resources in Sugar Production: Optimising the Use of Limited Water Under Supplementary Irrigation". A major output from CTA018 was DAMEA$Y which has not been valued in the current analysis. However, without CTA018, the model and supporting research in CSE001 would not have gained the respect evident from BSES and Bundaberg Sugar flowing on to many other industry stakeholders (e.g. Mackay Sugar, Proserpine Canegrowers).

- CTA038 "Irrigation risk management strategies to reduce water use and maximise profitability: a paradigm shift in performance to $ per unit of water". This was a fairly basic study with benefits flowing mainly to full irrigation schemes in the Ord and Burdekin (Inman-Bamber, pers. comm., December 2005).

Adoption of the findings of CSE001 is being enhanced through CSE009:

- CSE 009 "Moving from case studies to whole of industry adoption: Implementing methods for wider industry adoption". This is a current SRDC project and will encourage wider industry adoption of a range of technologies including crop model decision support systems.

Costs
The investment in the project CSE001 is given by year in Table 1. The project was supported financially by SRDC and was a part of the RWUE Initiative administered by the Queensland Department of Natural Resources and Mines (QDNRM).

Table 1: Total Investment in Project CSE001
(nominal $)

Year	SRDC	QDNRM	CSIRO	Total
2000/2001	14,775	85,609	140,965	241,349
2001/2002	18,192	97,080	161,871	277,143
2002/2003	21,885	95,969	165,497	283,351
2003/2004	105,138	0	147,641	252,779
2004/2005	92,660	0	134,161	226,821
2005/2006	10,000	0	10,000	20,000
Total	262,650	278,658	760,135	1,301,443

The investment in the project CSE009 is given by year in Table 2.

Table 2: Total Investment in Project CSE009
(nominal $)

Year	SRDC	CSIRO	Total
2003/2004	158,899	221,320	380,219
2004/2005	201,238	280,265	481,503
2005/2006	214,866	299,283	514,149
2006/2007	223,528	311,294	534,822
Total	798,531	1,112,162	1,910,693

It is assumed that CSE009 will produce benefits in three categories:

- enhanced adoption of climate forecasting information,
- enhanced adoption of irrigation management, and
- adoption generally of enhanced technologies.

It is assumed that 20% of the costs of CSE009 presented in Table 2 could be attributed to the combined irrigation management benefits. The Chief Investigator of CSE001 is also a Chief Investigator for CSE009.

As discussed earlier, CTA018 made some contribution to the benefits from CSE001. Hence, only 90% of the benefits from CSE001 have been attributed directly to the investment, with the other 10% being assigned to CTA018.

Outputs

Understanding of crop physiology
The project has produced new knowledge concerning crop physiology and crop modelling. Areas of sugarcane physiology that have been refined as a result of the project include sugar accumulation responses to moisture stress and the effect of crop lodging on water use and sugar yields. The APSIM model has been improved due to the investment in this project. For example, the ability of APSIM to simulate high water stress and

rainfed conditions has been improved. The project has resulted in a number of publications in the international literature.

Irrigation Scheduling

The experiments in Bundaberg and Childers showed that computerised scheduling techniques tend to do as well as or somewhat better than what good growers can achieve, particularly in unusual seasons. The results support the use of the computerised technique for planning ahead for the water year. One of the main implications of this research is that it helps growers to assess the value of water allocations used earlier than current practice since in many situations allocations were not fully used by the end of the water year. Growers tend to keep water in reserve in case of severe dry periods. This research assesses and balances the risks of water stress throughout the crop growth cycle such that growers can benefit from large responses to early irrigation without undue risk of running out of water.

The technique termed “WaterSense” is available on the web and is being trialled by Bundaberg Sugar. This web based program allows growers to access four automatic weather stations in the Childers/Bundaberg region and set up simulations to optimise decisions regarding use of available irrigation water. The program has been tested and refined with the assistance of growers and industry extension personnel. Early prototypes have been presented at workshops throughout the project.

Water Production Functions

Marginal responses to irrigation under different circumstances of crop stage and time of year have been quantified. Marginal returns were better in some soil types than others and in districts with lower annual rainfall rather than in wetter districts during dry years. The implication for growers is that they should use limited water on specific blocks, based on time of harvest, soil types and predicted rainfall.

The results may have important implications for investment in water infrastructure including on-farm storage. Current estimates of yield response and hence profit from irrigation may be too high when considering increased investments in or allocations from storages. The finding is that the lack of response to extra water due to lodging increases the downside risks in investment in supplementary irrigation.

Modelling capability has also been enhanced by this project to take into account the influence of watertables on the optimum use of restricted irrigation water. One output of the project was to provide a simple way of monitoring water tables. Also simulation of the effect of waterlogging during germination indicated that the risk from irrigation was small. However, the waterlogging risk from rainfall alone in some regions is very high in certain months and this information can be used by growers to reduce risk.

Lodging

While irrigation can exacerbate lodging, a major output of the project was that lodging of sugarcane can limit the response to irrigation. It was found that sugar yield is limited by lodging with no added sugar yield response above 4 ML per ha at the Burdekin trial site.

This suggests that in these circumstances water can be saved with associated benefits of less labour use and lowered offsite impacts. This also has implications for decisions on purchasing additional water allocations where lodging does occur and also for investment in on-farm storage capacity, that is, additional investment may not be required.

Impact of irrigation on ratoon health
Many growers believed that dry conditions prior to harvest reduced the vigour of the subsequent ratoon. The experiments in the Burdekin did not support this hypothesis as yield of the new ratoon was not affected by drying off between 2 to 7 months in a dry year. If anything, the dry conditions that developed before harvest from reduced irrigation could have benefited the crop provided the young ratoons were irrigated soon after harvesting. It should be noted that these experiments were carried out where the seasonal conditions did not cause stalk death in the previous crop and impacts may be different in that situation.

Outcomes

A key outcome planned for the project by the RWUE extension program was that at the conclusion of the project 70% of irrigators will have adopted best practice as contained in the improved Code of Practice for the industry. Certainly the project will have produced applied knowledge that can be incorporated into best practice. Whether 70% will have adopted best practice by the end of the project is highly unlikely, although some adoption of best practice by a limited numbers of irrigators may be apparent.

Implications for improved practices
The decisions addressed by the scheduling aid are complex and need to be made in an environment of uncertainty of sugar prices and climate. For example, despite the general relationships, growers may be risk averse about letting the crop get too dry before harvest in case the subsequent ratoon is affected.

The main constraint to adoption of the scheduling technology is the speed of delivery (slow speed of the APSIM model) and how it can be delivered simply to irrigators. There will need to be an extensive educational and extension effort to encourage adoption. Irrigators will then decide whether the benefits from using the scheduling aid are worthwhile resulting in use or non-use of the aid. Alternatively, regional guidelines may be produced and made available to irrigators. These guidelines may be easier to use than the individually used aids, but may be less effective as they will not be available in real time.

When the implications of the water production functions are extended to irrigators they may potentially reallocate water use for specific cane blocks, based on time of harvest, soil types and predicted rainfall. This could enhance the return to water for some irrigators especially in the Bundaberg and Childers region. The functions could also raise the returns to investment in water infrastructure including on-farm storage, considering the lack of response to additional irrigation due to lodging. John Eden (Mackay

Canegrowers) has used the production functions to provide indications of profit margins of low pressure and high pressure systems with varying allocations of water.

On some soils over-irrigation may be contributing to deep drainage losses and leaching of nutrients. If this is accepted, responses may not only save water but also reduce nutrient export to rivers and consequently decrease the probability of coral reef damage, at least in North Queensland regions.

Adoption
Workshopping the interface with growers with respect to scheduling aids is expected in early calendar 2006 and this is intended to refine the decision support system and extend it according to user needs. Project personnel are aware that widespread adoption of the web based system may take some time and that a significant extension program may be necessary to follow on from CSE001.

Quantification of Benefits

Benefits Quantified
The key benefit expected from this investment is improved profitability from irrigated sugarcane due to more efficient timing of use of water. An estimate of the magnitude of this benefit is made in this quantitative analysis. Profitability is affected by when, how and where water is applied. A second benefit could be more efficient investment in water storages on farm or in securing water allocations from off-farm sources due to the improved water production functions produced by the project. However, this benefit is not quantified since the flatter water production curves have not been incorporated into the DAMEA$Y decision aid, and in some areas water allocations are not available.

A third benefit in some environments will be less drainage losses and leaching of nutrients. However, this benefit also is not valued due to the difficulty in estimating the extent of drainage losses that are likely, as well as their impact.

Timing of Water Application
With regard to the principal benefit quantified (timing of water application), it would be desirable if the implications of the findings of the project could be analysed for profitability improvements with different assumptions for regions, soil types, and by attitude to risk and propensity to change. However, this is not possible given the evaluation resources available, so aggregate assumptions have been necessary.

The benefits are assumed to apply to irrigators in the sugarcane producing regions of Maryborough, Childers, Bundaberg, Sarina, Mackay and Proserpine. The principal benefit assumed is an increased average cane yield from real time scheduling aids that will generally advocate using water earlier in the season than is currently practiced.

In many cases as much as 2 ML per hectare of irrigation water is not used by the end of the season (Geoff Inman-Bamber, pers. comm., 2005). It is assumed that adoption of

“WaterSense” directly or indirectly could lead to this water actually being used in the water year and at the best time resulting in a further 10 tonnes of cane per ha for each ML of water if used generally earlier in the season. If up to 2 ML of currently saved water is assumed to be used earlier, this could provide an additional 20 tonnes of cane per ha. This potentially could arise from the guidelines or decision aids developed in this project. This additional yield could be generated with only a small time input by the canegrower and with no additional capital investment.

For the purposes of the analysis, it is conservatively estimated that the additional yield of cane generated is only 10 tonnes per ha for those adopting the decision aids, equivalent to using about one ML of water per hectare earlier than currently practiced.

Adoption

It is assumed that in the Bundaberg and Isis areas some 95% of growers have access to some water and that the improved scheduling aids will be available and relevant to them. For the second area (Maryborough, Sarina, Mackay, and Proserpine) the percentage assumed is 80%.

Despite the magnitude of the potential benefits, it is believed that a number of factors will limit the adoption of the improvement including:

- the risk-averse nature of many growers
- lack of water to be allocated in some regions in some years
- the labour demanding nature of irrigation when other competing activities also require labour early in the growing season (e.g. spraying, fertilising).

On the other hand, at least in the Bundaberg region, the number of cane farms is contracting which should make the encouragement of adoption of change easier.

Attribution of irrigation practice change to CSE001 is another factor to be considered in association with adoption as similar principles had been established earlier through other projects. Bundaberg Sugar for example has more or less changed practices to earlier irrigation (although constrained by labour shortages). While these changes had been made before CSE001 findings were available, the findings did confirm the practice change (Mike Smith, pers. comm., December 2005).

Notwithstanding the contribution to adoption of irrigation practice change by CSE009, CSE001 will be completed in early 2006 with only a start made in direct extension effort of the findings and end user involvement in the final decision aid that is delivered. The following assumptions on adoption are therefore made without considering any input into further development of the decision aid and any further investment into its extension.

A maximum of 2% of the area with access to water in the Bundaberg and Isis areas is assumed to adopt whatever guidance products emanate from CSE009 and CSE001. This maximum is assumed to be reached in the year 2016/2017. A maximum of 1% of the area with access to water is assumed to adopt in other relevant areas. A linear rate of adoption is assumed in both cases, commencing in the 2007/08 year for 10 years.

Summary of Assumptions

Table 4 summarises the assumptions made in the quantitative analysis.

Table 4: Summary of Assumptions

Variable	Assumption	Source
Increase in cane yield	10 t cane per ha	Discussions with Geoff Inman-Bamber
Areas to which yield increase could apply	(i) Bundaberg and Isis (ii) Maryborough, Sarina, Mackay and Proserpine	Discussions with Geoff Inman Bamber
Total area of cane in	Area(i) 50,000 ha Area (ii)149,000 ha	Hildebrand (2002)
Proportion of area to which potential increase could apply	Area (i) 95% has access to water Area (ii) 80% has access to water	Discussions with Geoff Inman Bamber and others
Maximum adoption	Area (i) 2% of area Area (ii) 1% of area	Agtrans, after discussions with Craig Baillie, Tony Linedale, Geoff Inman- Bamber, and Mike Smith
Year of first adoption	2007/08	Agtrans
Year of maximum adoption	2016/17	Agtrans
Sugar Price	$285 per tonne sugar	Average for the five years to 2004/05 (Australian Commodity Statistics)
Cost of harvesting additional cane	$6 per tonne of cane	Agtrans
Cost of transporting additional cane	$2 per tonne of cane	Agtrans
Cost of factory processing additional cane	$90 per tonne of sugar	Agtrans
Cost of transporting additional sugar	$6 per tonne of sugar	Agtrans
Proportion of benefits defined that have been attributed to CSE001	90%	Agtrans
Proportion of costs of CSE009 that is relevant to generating the assumed adoption rate	20%	Agtrans after discussion with Robert Troedson

Results

All costs and benefits were expressed in 2004/05 dollar terms using the CPI. All costs and benefits were discounted to 2004/05 using discount rates of 5% and 10%. All analyses ran for 30 years from the first year of investment (2000/01) to the final year of benefits assumed (2029/30).

The investment criteria were all positive at a 5% discount rate as reported in Table 5. However, at a 10% discount rate the NPV is negative.

Table 5: Investment Criteria for Total Investment and Total Benefits

Criterion	**Discount rate**	
	5%	**10%**
Present value of benefits (m$)	3.22	1.71
Present value of costs (m$)	1.89	2.04
Net present value (m$)	1.33	-0.34
Benefit cost ratio	1.7 to 1	0.8 to 1
Internal rate of return (%)	8.7	

It is apparent that while the productivity gain is quite large, the estimate of benefits is considerably reduced by the low adoption rate assumed.

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 6, 7, and 8. All sensitivity analyses were performed using a 5% discount rate, except for those for the sugar price, where both 5% and 10% were used. All other parameters were held at their base values.

Table 6 shows that halving or doubling the average yield improvement provides a significant impact on the investment criteria.

Table 6: Sensitivity to Cane Yield Improvement

Criterion	**Level of cane yield improvement (tonnes of cane per ha)**		
	5	**10 (Base)**	**20**
Present value of benefits (m$)	1.61	3.22	6.45
Present value of costs (m$)	1.89	1.89	1.89
Net present value (m$)	-0.28	1.33	4.56
Benefit cost ratio	0.85 to 1	1.7 to 1	3.4 to 1

Table 7 shows that the sensitivity of investment criteria to the level of maximum adoption. Obtaining a maximum adoption rate of 20% for Area 1 and 10% for Area 2 could deliver very high levels of benefits.

Table 7: Sensitivity to Maximum Adoption Level

Criterion	**Maximum Adoption Level (% of those who have access to water)**		
	2% Area 1 and 1 % Area 2 (Base)	**Adoption Rate x 2**	**Adoption Rate x10**
Present value of benefits (m$)	3.22	6.45	32.2
Present value of costs (m$)	1.89	1.89	1.89
Net present value (m$)	1.33	4.56	30.35
Benefit cost ratio	1.7 to 1	3.4 to 1	17.1 to 1

Tables 8 and 9 show that the investment criteria are quite sensitive to the sugar price. The break even price for sugar for the project to have returned a 5% rate of return was $230 per tonne.

Table 8: Sensitivity to Sugar Price at Discount Rate of 5%

	Level of sugar price ($/t)			
Criterion	**235**	**285 (Base)**	**335**	**350**
Present value of benefits (m$)	2.01	3.22	4.44	4.80
Present value of costs (m$)	1.89	1.89	1.89	1.89
Net present value (m$)	0.12	1.33	2.55	2.91
Benefit cost ratio	1.1 to 1	1.7 to 1	2.3 to 1	2.5 to 1
Internal rate of return (%)	5.4	8.7	11.1	11.7

Table 9: Sensitivity to Sugar Price at Discount Rate of 10%

	Level of sugar price ($/t)			
Criterion	**235**	**285 (Base)**	**335**	**350**
Present value of benefits (m$)	1.07	1.71	2.35	2.54
Present value of costs (m$)	2.04	2.04	2.04	2.04
Net present value (m$)	-0.98	-0.34	0.30	0.50
Benefit cost ratio	0.5 to 1	0.8 to 1	1.1 to 1	1.2 to 1
Internal rate of return (%)	5.4	8.7	11.1	11.7

Conclusions

CSE001 builds on earlier irrigation practice projects. The findings of CSE001 provide important quantitative data that will make a stronger case for individual farmers to make changes to irrigation practices on when and where to apply scarce water resources. The project has enabled a real time decision aid to be developed that has the potential to assist cane farmers optimise irrigation scheduling from a profitability viewpoint.

Apart from scheduling, there may be other benefits derived from this project in terms of:

- improvements to APSIM,
- potential improvements to the DAMEA$Y model,
- reduced deep drainage
- improved efficiency of investment (quantity and type) in irrigation infrastructure

These other benefits have been difficult to quantify but there are likely to be some benefits accruing from these areas in the future. In this regard the investment criteria are likely to be an underestimate of the true performance of the project.

The investment appears to have been extremely sound. Given the assumptions made for low adoption, the investment in project CSE001 and part of CSE009 still shows for a 5% discount rate an expected net present value of $ 1.3 m, a benefit-cost ratio of nearly 2 to 1, and an internal rate of return of nearly 9%.

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Tony Linedale, BSES Limited, Bundaberg
Mike Smith, Bundaberg Sugar
Robert Troedson, SRDC

References

ABARE “Australian Commodity Statistics”, 2005 and earlier

Hildebrand C (2002) “Independent Assessment of the Sugar Industry”

8. CTA028: Evaluation and Re-Structuring of Regional Selection Programs to Maximise Efficiency and Speed of Cultivar Release

Organisations: CSIRO Plant Industry, BSES Ltd, CSR Ltd
Start Date: 1 July 1997
Completion Date: June 2005
Principal Investigators: Scott Chapman, Alan Rattey, Phil Jackson

Background

Sugarcane yields vary greatly as a result of different combinations of soil type, growing environment (temperature, radiation and rainfall) and crop management. In the Australian sugar industry, breeding of new cultivars is required to maintain resistance to existing and prospective pests and diseases, and to provide constant improvement in crop productivity, quality and profitability. BSES Ltd, as well as CSR Ltd in some regions, operate the sugar breeding programs in Australia.

The best clones for release are selected through a multi-stage selection process that involves progressively more intensive testing of fewer clones over several years in multiple sites. In Australia there are six cultivar crossing and selection programs, each targeting different regions (North, Herbert, Burdekin, Central, South and northern NSW). In the past, detailed information on clone by environment interactions was not available to compare interactions across regions. Varieties have been developed for specific adaptation within the six geographically diverse regions with exchange of clones among regions occurring later in the breeding process.

This project was first funded by SRDC in 1997 and was aimed at determining whether clones generated directly from crosses generally perform consistently relative to each other between regions, or whether many clones exhibit specific adaptation to regional environments at early stages of evaluation before selection has taken place. This does not discount the existence of regional differences later in the selection process, when clones have been selected for 'local adaptation'.

The Project

Project Objectives

The central objective of the project was to obtain the basic data required to rationalise and improve the overall cost effectiveness of BSES and CSR breeding programs in Australia. Specifically the project aimed to:

- Assess the importance of clone by region interaction and determine the number of regions required to adequately sample the Australian production environments;

- Identify opportunities to link selection sites within and between regions by determining whether similar selections are made at different sites;
- Attempt to maximise the cost effectiveness of servicing new regions by identifying sites in current production regions that adequately predict performance in the Atherton Tableland and in the Ord.
- Characterise environments to identify factors driving clone by environment interactions and the incidence of specific challenges (e.g. water stress) that might be addressed by direct breeding; and
- Establish a basis to utilise specifically managed environments to improve the efficiency of core selection.

Project Description

Data on past analyses of genotype and genotype by environment interactions were collated in order to begin the characterisation of the production environments of sugar-growing regions and the specific environments of testing sites.

Trials were undertaken on experiment stations and grower properties at 24 sites with 59 harvests (including plant and ratoon crops) between 2000 and 2004. This consisted of 24 plant harvests, 24 1st ratoon harvests and 11 2nd ratoon harvests.

A common set of between 36 and 48 (average 45) ‘unselected’ clones from a range of random crosses in the BSES and CSR Herbert breeding programs were grown, along with 4 to 6 commercial cultivars. Some problems with propagation and correct identification of germplasm required additional DNA fingerprinting work. The trials were multi-row plot trials and were managed using conventional commercial practices within each region.

Diaries of agronomic management were kept; soil samples were collected for chemical and pathological analysis; and weather data were logged and/or retrieved from the nearest Bureau of Meteorology recording sites. Data were collected at harvest on cane yield and commercial cane sugar (CCS). Other traits measured were visual percentage scores for lodging, suckering, arrowing, stool-tipping, stalk breakage, rat damage and existence of gaps in plots. Measurements of the average length, diameter and single stalk fresh weight of the stalks were taken for CCS determination.

The results were analysed and interpreted using a quantitative genetics framework and multi-variate methods used to explain relationships between trials (and regions). The results were used to develop recommendations for breeding programs.

The environmental characterisation of the trials aimed to identify factors that can be related to observed relationships. The historic and current field trials were analysed to determine genetic parameters characteristic of later stages of selection.

Associated Projects

A current SRDC-funded project, BSS267, was proposed on the basis of early results of CTA028. BSS267 involves developing and implementing a data analysis methodology that integrates data collected across all regions appropriately, using genetic parameters obtained from CTA028. The benefits of CTA028 quantified in this analysis are independent of BSS267 and therefore no investment costs for BSS267 are included in this analysis.

Costs
Table 1 presents the investment costs for CTA028 by year.

Table 1: Investment Costs for CTA028 by Year for SRDC and Others (nominal $)

Year	SRDC	In-kind Contribution[1]	Total
1997/98	51,345	21,255	72,600
1998/99	91,168	37,740	128,908
1999/2000	0	0	0
2000/01	154,410	73,921	228,331
2001/02	217,302	89,956	307,258
2002/03	0	30,000	30,000
2003/04	137,504	56,922	194,426
2004/05	128,256	53,094	181,350
Total	779,985	362,888	1,142,873

[1] CSIRO Plant Industry, BSES Ltd, CSR Ltd

Outputs

The major physical outputs of the project are the collated datasets and interpreted results, including workshop reports and research papers. These reports and papers include recommendations for changes in the breeding programs. The trial datasets themselves are a valuable resource and can be utilised by breeders for additional analyses in future. They are currently being utilised in SRDC project BSS267.

Propagation errors were identified in the Burdekin and this experience demonstrated the value of analysing data soon after collection. It allowed a major problem to be corrected in order to compare the Burdekin with other regions. The propagation process was under greater scrutiny than normal due to the planting of the same trials in every region. This led to a review of the standard propagation process and introduction of new check systems to reduce this problem in any inter-region propagation. The new procedures were distributed and discussed among technical staff in the project.

The projects major findings were

1. Genotype by region effects were only a relatively small proportion of total genotype by environment effects.
2. Genetic correlations among environments were similar within and between regions.
3. Prior analysis of variance components were not consistent or conclusive with respect to the importance of interaction with environments and/or regions.

4. In this study, the ratio of genotype to genotype by environment interaction was 1.8 for CCS and 1.3 for tonnes of cane per hectare (TCH).
5. Genotypic variance was significant for TCH and CCS in almost all environments with trial precision maximised at moderate levels of TCH and moderate to high CCS.
6. Mean trial TCH and CCS were negatively correlated across the dataset, but within trials, locations or regions there was no genetic correlation between TCH and CCS for unselected clones.
7. Compared to commercial clones, unselected clones yielded 80 to 85% of the TCH and 90% of the CCS with the best unselected clones matching the commercial clones.
8. Early season CCS of unselected clones was correlated with harvest CCS.
9. Averaged over trials, most secondary agronomic trait scores were unrelated to clonal rankings for TCH or CCS.
10. Several sets of environmental variables were found that could capture a significant amount of the variation for environmental variables among trials.
11. No combination of soil, location, weather or pathology variables that were tested had a significant impact on genotype by environment interaction variances.
12. Across the whole dataset, genotype by location effects for TCH and CCS were greater than interactions associated with crop class (i.e. plant, ratoon etc.).
13. There was no opportunity to select indirectly for CCS in the Ord, as the Ord does not correlate well with other regions with respect to CCS.
14. Adaptation to lower temperatures may be important in the broad adaptation of successful commercial germplasm.

Overall, the results indicate that selection trial data within any particular region is relevant and important to selection programs targeting any of the sugarcane growing regions.

The major recommendations of the project were:

- Routine data analysis of all trials (i.e. including prior trials) should be used to predict commercial and breeding value of potential clones across all regions, not just the data from the region in which the clone is currently evaluated (being implemented in SRDC BSS267)
- Superior clones in regional trials should be transferred earlier to other regions and be promoted directly into regional final assessment trials (FATs) rather than re-tested in the less precise small-plot early stage trials (already implemented)
- That the economic values of secondary agronomic traits should be considered for each region to determine whether their use is justified in predicting commercial or breeding value of clones (being implemented in BSS267)

The report also provides recommendations for the overall re-structuring of the Australian sugarcane breeding effort.

Outcomes

The major recommendation of the project has already been implemented and a greater number of superior clones (identified within any region) are now exchanged between regional programs, and the best of these are now included in FATs rather than in earlier stage trials. This is expected to lead directly to:

- Faster release of broadly adapted clones across multiple regions (3 to 4 years earlier)
- Better quality clones in FATs with an associated increase in selection gain and the release of improved clones within each region.

The major long-term outcome will be earlier releases of superior varieties and greater genetic gains in the Australian sugarcane breeding program. Protocol alterations (as recommended) should reduce the time from identification of superior varieties outside a particular region of origin from > 5 years to 2 years. In addition, faster rates of genetic gain should increase the value of new varieties over time.

Generally, the investment in a new variety commences about 12 years before the variety is released. This is because a new sugarcane clone takes approximately 12 years to cross, select and release. Prior to this project, clones with potential for adaptation outside their original region of selection, would be taken from the local trials in year 10 of that 12 years, and be sent to breeding programs in other regions. There, they would be entered into early stage trials, and it would take another 8 years before breeding and testing was complete in other regions, leading to a total breeding period of 18 years. Following CTA028, at year 10 in trials, clones are selected and moved into Final Assessment Trials (FATs) in other regions, and there is only then an additional 4 years of breeding and testing of that variety. This results in a total breeding period of 14 years, a reduction of 4 years compared with the existing system.

The benefits of being able to release varieties earlier vary by region. This is because as a general rule, varieties travel better south, but not north beyond about Townsville. This general rule applied before CTA028, and continues to apply following the outputs of the research. Therefore, in the Northern/Herbert region 100% of cane grown is from varieties released from the Northern/Herbert program. Approximately 70% of cane grown in the Burdekin is from varieties released from the Burdekin program. The other 30% is from Northern/Herbert and Central varieties. Approximately 30% of the cane grown in the Central region is from the Central program. The remainder of the cane is from varieties developed in Northern, Burdekin and Southern programs. Approximately 60% of cane grown in the Southern region is varieties developed from the Southern program. The remainder is from all three other regions (Northern, Burdekin and Central).

The second major benefit is the reduced error associated with assessing clones. There is now a reduced risk of losing elite clones that have been transferred from one region to another. This is expected to result in an overall average increase in productivity gain from new clones, over what would have been achieved without the change to the new system.

Quantification of Benefits

While the project's outputs have been applied to both the BSES and CSR breeding programs, this analysis is only undertaken on the benefits to the BSES breeding program. In 2000, at least 98.5% of all sugarcane grown was derived from BSES breeding and selection activities (Agtrans Research, 2005). Also, the analysis refers to Queensland regions only.

In March 2005, a benefit-cost analysis of the BSES breeding program was undertaken by Agtrans (Agtrans Research, 2005). This analysis was based on the productivity gains that can be attributed to variety improvement, as measured using the Best Linear Unbiased Programming (BLUP) technique. Using the BLUP technique it was found that the annual average productivity improvement for all Queensland regions over the period 1983 to 2002 has been 0.19 tonnes of sugar per hectare (TSH). The BLUP productivity gains estimated refer to the improvement over time of the new varieties released in each year over the release period, as estimated by the regression coefficient with time as the independent variable and the BLUP productivity score as the dependent variable.

For the purposes of this analysis, it is assumed that the benefits of CTA028 accrue to the BSES breeding program, through an increase in the average annual productivity improvement, as well as through the earlier release of some clones. Therefore the benefit-cost analyses undertaken on the BSES breeding program using the BLUP outputs is used as a basis for this analysis. The benefit of CTA028 is assumed to be the difference in the net return to the BSES breeding program with, and without, CTA028.

The investment in a new variety generally commences about 12 years before a variety is released. At year 10 in this 12 year cycle, clones are taken across to breeding programs in other regions. Previously, it would take another 8 years for selection and testing to be completed for those clones to be recommended in those other regions. That is, adoption of those varieties would start to occur in year 18 of the cycle. Following the adoption of the recommendations from CTA028, this time is reduced by 4 years, and therefore adoption in those other regions commences in year 14 of the cycle.

Costs of the BSES Breeding and Selection Program

The costs of the BSES breeding and selection program depend on the release period selected for the analysis. Given that the investment in new varieties commences about 12 years before the first variety is released, allowance for some cost of the program needs to commence 12 years before the initial release period commences (and 18 years before the release of clones in 'other regions' under the old system).

However the expenditure on the program in the twelfth year before release also contributes to varieties released in the eleven years before the release period commences and therefore part of these expenditures will not correspond to the benefits assumed from the variety releases examined.

Likewise the investment costs in the final year of the release period will be associated with benefits produced from varieties released outside of the release period. Only one twelfth will correspond to the benefits produced from the period of releases. Investment costs in intermediate years will either be all of the investment in that year or some proportion of total costs in each year.

Investment costs in the program have not changed significantly over time. The total budget for running the crossing and the core selection program in 2002/03 totalled $2.75 million (in 2002/03 dollar terms). These costs exclude research and external grants. For the purposes of the current analysis it is assumed that the annual cost of the program over the investment period of interest is $2.89 m per annum, expressed in 2004/05 dollar terms.

Without Scenario

It is assumed that without CTA028, the BSES breeding program would have continued as previously, and would have continued to achieve an average 0.19 TSH productivity improvement. A 10 year period from July 2012 to June 2022 is specified as the release period considered.

Given an average variety life of 10 years, it is assumed that the proportion of area to which the productivity gain would apply would be 10% in 20012/13, with 20% in the second year etc until 100% of the area of sugarcane grown is of new release varieties in 2021/22. Since some of the varieties released in the first ten years after the release period has ended will be used for the next ten years, further benefits are assumed to accrue based on a declining proportion of expected production (90% in the first year after the release period declining to 0% in the tenth year after the end of the release period).

With Scenario

It is assumed that with CTA028, clones from the breeding program can be released in ‘non-local regions’ four years earlier. It is also assumed that the average annual productivity increase due to the breeding program increases by 5% due to not rejecting some elite clones. It is assumed that this increase starts from 2008/09.

The benefit of CTA028 relating to the reduced time for release clones are assumed to only relate to that area of the Queensland sugar regions which are planted to ‘non-local varieties’. This is 0% for Northern, 30% for the Burdekin, 70% for Central and 40% for Southern. The general increase in the annual productivity improvement is assumed to apply to the entire Queensland sugar industry.

General assumptions

The value of additional production has been estimated by multiplying the additional production of sugar each year by the average price for the five years 2000/01 to 2004/05 and converted to 2004/05 dollar terms using the Consumer Price Index (CPI).

An allowance was made for the costs of harvesting, transporting and processing the additional cane and sugar produced. All costs were expressed in 2004/05 terms. In order to estimate additional costs of harvesting, transport and milling, it is assumed that approximately 85% of the additional sugar due to the breeding program emanates from sugarcane yield improvements and the other 15% from CCS gains.

Table 2: Summary of Assumptions

Variable	**Assumption**	**Source**
BSES Breeding and Selection Costs		
Investment period for BSES breeding program	1995/96 to 2006/07	Investment commences 12 years before the release period commences.
Annual cost of breeding and selection program	$2.89 m expressed in 2004/05 $ terms	BSES
Time to produce a new variety	12 years	Cox, pers. comm., 2005
Time to release a new variety in 'other regions'	18 years	Chapman and Rattey, pers. comm., 2006
Proportion of annual costs attributed in each year of investment period	8.3% (one twelfth) in 1995/96 increasing linearly with steps of 8.3% to 91.7% in 2005/06; then 91.7% in year 2006/07; then declining 8.3% each year from 2007/08 to 2015/16; and thereafter 0%.	Assumption is that costs are distributed evenly over the 12 years taken to breed and select a new variety
Productivity gains		
Increased annual sugar yield due to new releases from the breeding and selection program	0.19 TS per ha average	From Cox et al (2005) estimate of average productivity gain over the period 1980-2002
Maximum improvement to average annual sugar yield increase due to CTA028	5% (improvement from 2008/09)	Assumption (Chapman and Rattey, pers comm., 2005)
No. of years by which release of clones to 'other regions' is 'sped up' due to CTA028	4 years	Assumption (Chapman and Rattey, pers comm., 2005)
Areas harvested		
Total area of cane harvested		
Northern/Herbert	148,641 hectares	Australian Sugar Milling Council Annual Review 2004 (average for period
Burdekin	74,333 hectares	
Central	121,421 hectares	

Southern	68,515 hectares	1999/2000 to 2003/04)
Proportion of cane planted to 'non-local varieties'		
Northern/Herbert	0%	Assumption; Chapman and Rattey pers comm. 2006
Burdekin	30%	
Central	70%	
Southern	40%	
Proportion of area harvested with new releases over the period	Varies from 10% in first year of release to 100% in 10th year of release; declines by 10% per year from 10th year until 0% is reached	Assumed each new variety has a life of ten years.
Prices and costs		
Price of sugar	$285 per tonne of sugar	Average for the five years to 2004/05 (Australian Commodity Statistics)
Cost of additional harvesting	$6 per tonne of cane	Agtrans
Cost of additional cane transport	$2 per tonne of cane	Agtrans
Cost of additional sugar factory processing	$90 per tonne of sugar	Agtrans
Cost of additional transport from factory	$6 per tonne of sugar	Agtrans

Results

All past costs and benefits were expressed in 2004/05 dollar terms using the CPI. All benefits after 2004/05 were expressed in 2004/05 dollar terms. All costs and benefits were discounted to 2004/05 using discount rates of 5% and 10%. The base run used the best estimate of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for 30 years from the first year of investment (1997/98) to the final year of benefits assumed (2026/27).

The investment criteria are reported in Table 3. The investment criteria show that at a 5% discount rate, the investments has a B/C ratio of almost 6 to 1, and an NPV of $6.9 million. At a 10% discount rate the B/C ratio decreases to 3.7 to 1.

Table 3: Investment Criteria for Total Investment and Total Benefits

Criterion	Discount Rate	
	5%	10%
Present value of benefits ($m)	8.32	6.22
Present value of costs ($m)	1.45	1.70
Net present value ($m)	6.87	4.52
Benefit-cost ratio	5.7 to 1	3.7 to 1
Internal rate of return (%)	23.6%	

Sensitivity Analysis
Sensitivity analyses were carried out on the assumed increase to the annual yield improvement, as well as to the sugar price. Results are reported in Tables 4 and 5. All sensitivity analyses were performed using a 5% discount rate, except for those for the sugar price, where both 5% and 10% are used. All other parameters were held at their base values.

Table 4 shows that the investment criteria are not very sensitive to the increase in annual productivity improvement. Even if this improvement is decreased from 5% to 1%, the B/C ratio only falls from 5.7:1 to 3.9:1. This demonstrates that the majority of the benefits are attributable to the ‘speeding up’ benefit as opposed to the ‘annual improvement’ benefit.

Table 4: Sensitivity to Increase in Annual Productivity Improvement

Criterion	Increase to Annual Productivity Improvement		
	1%	5% (Base)	10%
Present value of benefits (m$)	5.69	8.32	11.60
Present value of costs (m$)	1.45	1.45	1.45
Net present value (m$)	4.24	6.87	10.15
Benefit cost ratio	3.9 to 1	5.7 to 1	8.0 to 1

Tables 5 and 6 demonstrate the sensitivity of the investment criteria to the sugar price. At a discount rate of 5% and a sugar price of $235, the investment yields a positive NPV of $4.18 million.

Table 5: Sensitivity to Sugar Price at Discount Rate of 5%

Criterion	Level of sugar price ($/t)			
	235	285 (Base)	335	350
Present value of benefits (m$)	5.63	8.32	11.00	11.81
Present value of costs (m$)	1.45	1.45	1.45	1.45
Net present value (m$)	4.18	6.87	9.55	10.36
Benefit cost ratio	3.8 to 1	5.7 to 1	7.6 to 1	8.1 to 1
Internal Rate of Return (%)	19.5	23.6	26.6	27.4

Table 6: Sensitivity to Sugar Price at Discount Rate of 10%

Criterion	Level of sugar price ($/t)			
	235	285 (Base)	335	350
Present value of benefits (m$)	4.21	6.22	8.23	8.83
Present value of costs (m$)	1.70	1.70	1.70	1.70
Net present value (m$)	2.51	4.52	6.53	7.13
Benefit cost ratio	2.5 to 1	3.7 to 1	4.8 to 1	5.2 to 1
Internal Rate of Return (%)	19.5	23.6	26.6	27.4

Conclusions

The research investment in CTA028 has resulted in recommended changes to the sugar breeding programs. These changes have been adopted within those programs. In addition, valuable data and processes have been produced which are being incorporated into other research projects and will contribute to future realisation of productivity gains.

The economic evaluation showed that the investment has yielded a positive return at discount rates of both 5% and 10%. The majority of the benefits are due to the earlier release of clones in regions for which they were not originally bred. In addition, there is expected to be an overall increase in the average annual sugar yield improvement due to the reduced risk of dismissing elite clones.

Acknowledgments

Scott Chapman, CSIRO Plant Industry
Alan Rattey, CSIRO Plant Industry (formerly BSES)

References

Agtrans Research, 2005, “Assessment of Investment in BSES Ltd Cane Breeding and Selection Program Using BLUP Productivity Measures”. Report to BSES.

Cox, M., Stinger, J, and Cervellin R., 2005, “An Analysis of Productivity Increases from New Varieties in the Queensland Sugar Industry”, Proceedings of ASSCT Conference 2005.

9. YDV001 and YDV002: Sugar Yield Decline Joint Venture

Organisation: BSES Limited
Start Date: 1 July 1993
Completion Date: 30 June 2005
Principal Investigator: Dr Alan Garside

Background

Yield decline and yield plateaus had been a concern to the industry for a number of years before the joint venture was initiated. The first phase of the joint venture was established in 1993 and ran for six years to June 1999. The second phase followed from July 1999 and has run to June 2005, after a mid term review in 2002. The venture comprised a number of funding and provider R&D organisations including BSES Ltd, the Sugar Research and Development Corporation, CSIRO Land and Water and two Queensland Government Departments (Department of Primary Industries and Fisheries and the Department of Natural Resources and Mines).

A previous quantitative analysis of the venture (December 2002) carried out for SRDC consisted of three parts. The first part covered the investment period from 1993 up to and including June 2003. This referred to a situation where the venture might have been curtailed in June 2003, and covers the benefits (past and expected future benefits) from the investment made up to June 2003. That first part of the analysis set a baseline for expected benefits in relation to costs already committed, and provided some accountability for the past investment.

The second 2002 analysis excluded past investment and focused on any additional benefits that would have accrued from new investment from June 2003 to July 2005. This was to assist decision making regarding continuing investment, but required the assumptions and analysis made in the first part in order to quantify benefits from the additional two years of investment. The third part of the 2002 analysis included estimating all benefits (past and future) arising from the entire 13 year period (1992/93 to 2004/05) of investment in the venture.

This 2005 analysis updates the third part of the 2002 analysis, namely all benefits accruing to the investment made over the 13 year period (1992/93 to 2004/05). This updating therefore takes into account what has happened between December 2002 and June 2005 and the translation of these events into the revised assumptions that underpin the analysis.

The Project

Project Objectives

The objectives of the two phases of the venture were:

Phase 1

(i) To identify causal factors and their contribution to yield decline in sugarcane

(ii) To develop solutions to minimise or alleviate the impact of such causal factors on productivity in sugarcane

(iii) To promote the use of appropriate technologies developed by the venture

Phase 2

(i) To quantify the factors that have been identified as important in the yield decline syndrome through the rotation and rundown experiments

(ii) To identify if, and understand how soil chemical, physical and biological factors interact to produce the yield decline syndrome

(iii) To utilise organic matter, reduced tillage and acidity ameliorants as soil amendments, and research tools to further understand and counter the causes of yield decline

(iv) To develop, demonstrate and extend changes to the farming system that will result in more sustainable sugarcane production

(v) To substantially increase the extension component of the Joint Venture to promote the early adoption of the outcomes of Phase 1 and the emerging outcomes of Phase 2

Costs and Associated Projects

Estimates of the total investment costs of the venture are provided in Table 1 for each of the years specified. Included in Table 1 is the cost of investment in associated projects that need to be included, given the benefits assumed in the analysis. Appendices 1, 2 and 3 provide further detail of the associated projects including their costs.

Table 1: Estimate of Investment in Sugar Yield Decline Joint Venture (1993 to 2005) (nominal $)

Year	**Investment Source**								
	SRDC	**SRDC-CP2002**	**SIRP**	**BSES**	**CSIRO**	**QDPI**	**QDNR**	**Associated Projects**	**TOTAL**
1992/93	110,000	0	0	1,000	0	0	0	0	111,000
1993/94	280,000	0	0	314,720	413,436	0	0	150,000	1,158,156
1994/95	305,000	0	0	314,720	413,436	0	0	618,284	1,651,440
1995/96	313,000	0	412,000	499,350	429,403	0	0	845,424	2,499,177
1996/97	305,000	0	427,320	363,990	364,576	250,323	0	740,004	2,451,213
1997/98	370,501	0	370,320	278,306	301,058	196,875	0	579,940	2,097,000
1998/99	370,499	0	366,910	205,846	309,012	214,274	0	318,210	1,784,751
1999/00	530,485	322,154	0	206,450	129,493	135,040	45,240	267,384	1,636,246
2000/01	174,356	113,537	0	206,450	129,493	135,040	45,240	127,320	931,436
2001/02	360,911	237,666	0	206,450	129,493	135,040	45,240	0	1,114,800
2002/03	599,865	0	0	206,450	129,493	135,040	45,240	0	1,116,088
2003/04	601,256	0	0	254,060	64,746	480,000	45,240	0	1,445,302
2004/05	609,143	0	0	20,000	0	802,782	45,240	883,626	2,360,791
TOTAL	4,930,016	673,357	1,576,550	3,077,792	2,813,639	2,484,414	271,440	4,530,192	20,357,400

SRDC: Figures for 1992/93 to 2001/02 from actual payment made by SRDC (accounts records); figures for 2002/03 to 2004/05 from page 4 of Schedule 3 of phase two agreement. The SRDC-CP2002 column consists of actual payments made by SRDC (accounts records).
SIRP: Figure for 1995/96 from Report of Mid-term Review; figures for 1996/97 to 1998/99 from summary of contributions in proposal for phase two (September 1998).
BSES: Figures for 1992/93 to 1994/95 from phase one agreement; figures from 1995/96 to 1998/99 from budget summary (Table 7) in phase two proposal (September 1998); figures from 1999/00 to 2002/03 from contributions sought in phase two proposal; figures for 2003/04 and 2004/05 from QDPI outcome partitioning budgets.
CSIRO: Figures for 1992/93 to 1994/95 from phase one agreement; figures from 1995/96 to 1998/99 from budget summary (Table 7) in phase 2 proposal (September 1998); figures from 1999/00 to 2002/03 from contributions sought in phase two proposal; assumes no contribution in last year of phase two and only 50% of the original budget for 2003/04.
QDPI: Figures from 1995/96 to 1998/99 from budget summary (Table 7) in phase two proposal (September 1998); figures from 1999/00 to 2002/03 from contributions sought in phase two proposal; figures for 2003/04 to 2004/05 QDPI outcomes partitioning budget.
QDNR: Figures from 1999/00 to 2004/05 from contributions sought in phase two proposal.
ASSOCIATED PROJECTS: SRDC funding obtained from SRDC Annual Reports and Alan Garside; assumed that equal contribution made by R&D organisation.

Outputs

The principal outputs for the investment include:

(a) There is now a more specific definition of "yield decline", which is now viewed separately from the "yield plateau". There is now greater recognition of the complexity of yield decline compared to earlier thinking. There is now a central focus on the likely involvement of early root development after planting that involves soil biology, including pathogenic fungi and nematodes, soil tillage and compaction, the type and level of soil organic carbon, and silicon availability. There is an improved understanding of yield decline by cane farmers including the message that there is no single recipe for halting yield decline.

(b) A rotation with pasture or non-sugar crops has been shown to provide improved cane establishment, improved soil health, and higher yields in the next cane planting compared with the common industry practice of ploughing out and replanting quickly to avoid missing a cane harvest.

(c) The higher yields after the cane break continue for all subsequent ratoon crops compared to the plough out/replant practice.

(d) Improved agronomic practices for legume crops have been developed including reduced tillage, development of planters and improved management of weeds including volunteer cane.

(e) The nitrogen contribution from the legume crop and its availability to the next cane crop has been quantified.

(f) There is no loss in cane yield when minimum tillage for the plant crop is used. It has been shown that minimum tillage allows savings in labour, fuel and chemicals, reductions in tractor sizes, and enhanced timeliness of operations since cultivation of wetter and drier soils can be undertaken compared to conventional tillage.

(g) There has been confirmation of the persistency of the yield effect from rotations and improved packaging and communication of technical information.

(h) Improved knowledge has been produced on the interaction between break crops, minimum tillage and controlled traffic, planting density, and yield improvements.

(i) Improved planting designs have been developed that allow maximum advantage to be taken of the benefits from the legume rotation including minimum tillage for the plant crop, direct planting into the legume residue, and improved weed control, all of which can lead to higher cane yields and reduced costs from the legume rotation.

(j) Improved knowledge has been developed of the long-term impact of organic matter build up from cane and legume trash on cane yields via soil structure and the associated effect on cane yields.

Outcomes

The principal outcomes of the investment have been:

(a) Legume crops are now being more effectively used in rotations since their contribution is significantly enhanced through improved weed control.

(b) Yields of cane are being improved by appropriate breaks in cane cropping through use of legume crops, either used as manure crops or harvested for grain.

(c) The nitrogen contribution from the legume crop is sufficient to avoid having to use fertiliser nitrogen in the plant crop and 50% less in the first ratoon crop.

(d) Costs of tillage for the plant cane crop (eg. fuel and oil, repairs and maintenance, labour and capital requirements) are being reduced through the use of minimum tillage, whether using a break crop or not. Chemical savings are also apparent and ‘softer’ chemicals are being used.

(e) The outputs have been packaged into improved farming systems applicable to particular regions. The planting of legume break crops, particularly soybeans and peanuts, in rotation with cane are now being observed in most cane growing regions.

(f) Further improvement in cane yields and possibly lowered costs are starting to be captured from improved planting designs, direct planting, and controlled traffic (compaction is reduced from controlled traffic, so improving water use efficiency, less stool damage and improved timeliness of operations). However, most of these savings have not been included in the current analysis.

(g) Further long-term improvement in cane yields may occur from improved soil structure and soil health due to higher levels of organic matter.

(h) A higher level of uptake by cane farmers of project outputs than otherwise would have occurred has occurred due to the project from packaging and communicating knowledge that has provided a higher level of understanding and the need for different individual and regional approaches.

(i) Adoption of legume rotations, minimum tillage and controlled traffic is occurring due to greater confidence in the persistency of benefits being realised in all ratoon crops, as well as in subsequent rotation cycles when legume crops are used.

A summary of the principal types of benefits and related costs expected to be associated with the outcomes of the project are shown in Table 2. These costs are implementation costs and exclude the costs of the R&D investment.

Table 2: Categories of Benefits and Costs from the Investment to June 2005

Benefits	Costs
• Cane yield increase after the legume crop in the cane plant crop and subsequent ratoon crops, due to improved soil health • Cane yield increase due to minimum tillage • Sale of legume grain crop if harvested • Avoidance of growing and harvesting the lost cane crop • Savings of nitrogen fertiliser and its application in cane plant crop and (in part) the first ratoon crop • Reduced level of nitrogen export from farms due to reduced nitrogen fertiliser use • Reduced cultivation and chemical costs for the plant cane crop • Labour savings and improved timeliness and flexibility of operations • Reduced level of sediment export from farms and use of softer chemicals so potentially benefiting water quality and biodiversity • Capital savings due to lowered requirements for high powered tractors and tillage equipment • Increased adoption of legume break crop and minimum tillage by cane farmers, due to technology packaging, extension, and greater confidence of cane farmers	• Loss of sale of cane crop for one year • Cost of establishing and managing the legume crop (eg. cultivation, planting weed control) • Cost of harvesting and marketing the legume crop (if harvested) • Cost of harvesting the additional cane yield • Additional machinery costs due to need for double disc opener direct cane planter

Other benefits emanating from the investment, but not discussed further, include:

- Improved scientific understanding and contribution to knowledge
- Improved integration of effort between disciplines and inter-institutional cooperation

Quantification of Benefits

Introduction and qualifications

Most but not all of the benefits listed in Table 2 are quantified for the purpose of the investment analysis. Those quantified are largely those with the most significant industry benefits. Conservative assumptions have been used in general and are presented as clearly as possible. The environmental benefits are difficult to value and hence are not quantified, contributing to a possible underestimate of total societal benefits, along with the other conservative assumptions made.

The “without project” situation assumes that little “effective” use of break crops would have occurred without this investment, the emphasis being on the word “effective”. The assumption is that the usual “dirty” legume crops used in the past would not have contributed to improved soil health due to cane plants in the legume crop maintaining detrimental soil biota and the “dirty” legume crops contributing much less nitrogen.

Also, a decision had to be made as to whether the existing farming systems to which the R&D outputs would be applied should, for purposes of the analysis, be divided up into regional, irrigation versus dryland, good versus poor soil types, etc. This would allow regional specific assumptions to be made about impacts and/or differing adoption rates. For example,

- in irrigated areas yield improvements after the legume crop may not be as great as in non-irrigated areas
- soils with good structures, drainage and fertility may provide lowered impacts
- some regions are more climatically suited than others to the harvest of a legume crop such as soybeans

Due to time constraints, the decision was made to model the yield and cost impacts in aggregate for the Australian industry as a whole, rather than regionally.

Some of the important assumptions for the analysis are presented below.

The break crop
The break crop assumed in all cases is soybeans grown during the summer period, although it is recognised that other crops (including winter crops) may also be suited and are being grown (e.g. peanuts, navy beans). It is assumed that some of the soybean crops will be harvested for grain, but, due to harvesting difficulties, many areas will be left to decay on the surface before cane is replanted, especially in North Queensland.

Cane yield assumptions
Experimental cane yield increases after the legume crop have been reported as 50-60% in Tully, Ingham and Mackay, with 20-25% in Bundaberg and Burdekin (irrigated), and generally have been sustained through the plant and following ratoon crops. An overall average for the yield increase is 21% across all regions and all plant and ratoon crops. It is assumed that commercial crop yield improvements will be lower than for experimental conditions by a recognised 70%, so that a base yield improvement of 15% has been assumed for the plant crop and the following four ratoon crops, at least up to the 2004/05 year.

The major benefit from controlled traffic and other refinements to the sustainable system is an improvement of yield through the plant crop and subsequent ratoons. Controlled traffic includes the development of permanent wheel tracks and machines including tractors, harvesters and trailers not travelling along the crop row. Other sources of yield improvements from the latter stages of the investment include further development of plant density and planting designs, use of raised beds with further tillage cost savings, and less herbicide use in the long term. Further, avoiding burning or incorporating trash into the soil from both soybeans and cane is likely to improve soil health via more effective organic matter buildup, also contributing to further increases in yields in the long term. There may be a need for some additional equipment in the form of a double disc-opener planter, although this would be offset by the savings in the reduced capacity required in other machinery. The yield increase that is likely from these and other refinements has not yet been formally substantiated so an assumption has been made.

of a cane yield increase of 22.5% compared to the traditional system from 2004/05 onwards.

The number of ratoon crops has been set at four, whether a legume crop break is used or not. The plant crop plus 4 ratoon crops and a legume crop break, means that the cycle is now extended to six years instead of five years.

It is assumed there is no depression in ccs with the use of a break legume crop. Also, while ccs may fall with ratoon age, since the number of ratoons has been maintained at four with and without the legume crop, average ccs has been assumed to remain constant throughout the analysis.

The major cost of the break crop system is the loss of one cane harvest in the 6 year rotation. The insertion of the legume crop means that on average there is less cane area overall, so consequently there will be some savings in cane planting and growing costs on an annual basis. Also, harvesting costs will change with the additional yields per ha and the reduced area of cane.

If use is made of the legume crop, minimum tillage, and controlled traffic, the ease and cost of replanting can be reduced substantially.

Nitrogen savings

The nitrogen contribution from the legume crop is assumed to be sufficient to avoid application of any N fertiliser in the plant crop of cane, and to save 50% of that normally applied in the first ratoon crop. Fertiliser is also saved due to there being less cane area each year.

When soybeans are harvested, it is assumed that the nitrogen contribution is less due to some nitrogen being removed in the grain, but the quantity is still sufficient to avoid nitrogen fertiliser use in the plant crop eg. if 240 kg nitrogen is available from the tops, then there is still 80 kg left if the grain is taken off (assumes two thirds of that in the tops is in the grain). Also, there is another 80 kg available from decaying roots and nodules (Alan Garside, pers comm, 2002 and 2005). So it is assumed that there is still 160 kg nitrogen available from the legume crop. However, in this case there will be a need to fertilise normally in the first ratoon crop (Alan Garside, pers comm, 2002 and 2005).

Growing and harvesting soybeans

It is assumed that 40% of the total area of legume break crop that is planted is harvested for grain and 60% not harvested.

The cost of establishing and growing soybeans is a cost against the legume rotation system. It is assumed that no additional equipment is required for land preparation for soybeans and that minimal cultivation is required if the cane stool is sprayed out. The total cost of planting and growing soybeans not for harvest is about $172 per ha (Neil Sing, pers comm, 2005). If the soybeans are harvested, additional input costs and harvesting and transport are assumed. Table 3 provides the costs and revenues assumed for the soybean break crop with and without grain being harvested.

It is possible that yield improvements for soybeans can be made over time. Already potential new varieties are available that will improve yield and weather resistance. The market for edible soybeans is expected to increase and some price increase may be expected in future but is not accounted for here.

Table 3: Costs and revenue assumed for soybean break crop

Soybeans not harvested for grain	
	$/ha
Spray out cane	43.36
Seed	68.18
Planting	26.46
Herbicide	13.01
Spray out soybeans	20.60
Total	171.61
Crop harvested for grain	
Revenue	
Price ($ per tonne)	350.00
Yield (t per ha)	3.50
Total revenue ($ per ha)	1225.00
Costs	$ per ha
Land preparation	212.46
Planting	133.70
Fertiliser	62.50
Weed control	59.72
Insect control	21.22
Irrigation	144.85
Harvesting	100.65
Freight ($37 per tonne)	129.50
Levy (1%)	12.25
Drying ($14 per tonne)	49.00
Total costs	925.85
Net revenue ($ per ha)	299.15
Sources: Not harvested for grain assumptions from Neil Sing (pers. comm., 2005); Harvested for grain assumptions from Trish Cameron (pers. comm., 2005)	

Minimum tillage
Minimum tillage has been largely developed and driven by the project and is relevant for plant cane whether a break crop is grown or not. Minimum tillage for the plant cane crop can provide substantial cost savings, and it has been shown that there are no negative yield impacts. Cost savings are in the form of reduced tractor size and hence capital, fuel costs, and labour, and improved timeliness due to the ability to perform both wet and dry working. There are some difficulties in quantifying this impact as there are various definitions used in the industry for "minimum tillage". The estimate

used here is a saving of $455 per ha (Neil Sing, 2005) for those using the legume package as opposed to conventional planting.

Minimum tillage savings can also be captured when a break crop is not grown. The use of reduced tillage and zonal tillage in these circumstances can also be largely attributed to the venture. Zonal tillage is where permanent wheel tracks/inter-rows are used and only the crop growth area is cultivated. Reduced tillage is when cultivations are reduced in number.

An estimate of savings from one case study of zonal tillage is $120 per ha and $147 per ha if timeliness benefits are included (Neil Sing, pers comm, 2005). If benefits from reduced tillage are assumed to be represented by four less cultivations, the cost savings would be about $116 per hectare (Neil Sing, pers comm, 2005). The final assumption made for both reduced and zonal tillage is $120 per ha.

Other cane growing costs
There will be savings from other cane growing costs due to the reduced cane area caused by the introduction of the legume crop.

Adoption
It is assumed that the first year of adoption of the "clean soybean" crop was in 1999/00 with an estimated area of 500 ha. The area in the next two years was taken from Table 4 that shows the actual area actually planted by region. It is estimated that the area planted to legumes serving as a break crop in 2004/05 was about 10,000 ha. Interpolation was used to estimate the areas planted in the years between 2001/02 and 2004/05. The area after 2004/05 is assumed to increase by 1,000 ha each year until the last year of the analysis (2021/22). The latter part of the investment in the project has focused to a greater extent on extension, resulting in a high level of adoption of the legume package

This last assumption means that the assumed area in 2021/22 will be 27,000 ha. Given that there is currently about 70,000 ha of new cane planted each year, the 27,000 ha does not seem unreasonable given the magnitude of the benefits that can be captured. If there is further extension investment the level of adoption could prove higher.

The adoption rate for minimum tillage external to the legume break is assumed to commence in the 1999/00 year and increase by 2% each year of the area of plant cane that is not subject to the legume package.

Table 4: Area of soybeans planted as break crop in 2001 and 2002 seasons

Region	Soybeans 2000/01 summer (ha)	Soybeans 2001/02 summer (ha)	Legumes 2002/03 (ha)	Legumes 2003/04 (ha)	Legumes 2004/05 (ha)
North Qld	202	602			
Herbert	11	230			
Burdekin	160	1100			
Mackay	800	1400			
Bundaberg	300	500			
Rocky Point	-	350			
NSW	(a)	(a)			
Total	1473	4182	6,000	8,000	10,000

(a) 500-600 ha per year have been grown as a cash crop in NSW for the past ten years or so, but systems can be improved from principles developed by the joint venture (Beattie, pers comm, 2002). Hence, while some benefits will be expected for the NSW industry in future, these benefits have not been quantified in the analysis.

Attribution
It is assumed that a high proportion of the benefits specified can be attributed to the investment in the yield decline joint venture and associated investment included in this analysis. However, there may be other factors contributing to the past impact and expected uptake. For the purposes of the analysis it is assumed that 100% of the benefits assumed from the legume break crop system, and 90% of the reduced and zonal tillage benefits external to the legume break system can be attributed to the investment.

Summary of Assumptions
A summary of the key assumptions made is shown in Table 5.

Table 5: Summary of assumptions

Variable	Assumption	Source
Price of sugar	$285 per tonne	Average for the five years to 2004/05 (Australian Commodity Statistics)
CCS	13.7	Average for the five years to 2004/05 (Australian Commodity Statistics)
Existing cane yield	85 tonnes per ha	Agtrans after discussion with Alan Garside (2002,2005)
Harvesting cost	$6 per tonne of cane	Agtrans
Cane yield increase after	15%	Alan Garside

legume break (1999/00 to 2004/05)		(2002,2005), Agtrans
Cane yield increase after legume break (after 2004/05)	22.5%	Agtrans after discussions with Alan Garside (2005)
Cost of establishing and growing soybeans without harvesting	$171 per ha	Neil Sing (2005)
Proportion of soybean area harvested	40%	Agtrans after discussions with Alan Garside and Judy Skilton (2005)
Price of soybeans	$350 per tonne	Neil Sing, Judy Skilton (2005)
Yield of soybeans	3.5 tonnes per ha	Alan Garside, Judy Skilton, Trish Cameron (2005)
Gross margin for soybeans with grain crop	$299 per ha	Trish Cameron (2005)
Number of ratoon crops	4	Agtrans
First year of benefits from the legume break system	1999/00	Agtrans
First year of benefits from reduced and zonal tillage external to the legume break system	1999/00	Agtrans
Attribution of benefits from legume break to venture investment	100%	Agtrans after discussion with Alan Garside (2005)
Attribution of benefits from reduced and zonal tillage external to the legume break system	90%	Agtrans after discussion with Alan Garside (2005)
Fertiliser savings in plant year whether soybeans harvested or not	160 kg per ha	Alan Garside (2002.2005)
Fertilizer savings in first ratoon crop (only if soybeans not harvested)	80 kg per ha	Alan Garside (2002.2005)
Cost of plant crop of cane excluding fertiliser	$953 per ha	Neil Sing (2005)
Minimum tillage savings in plant crop of cane	$455 per ha ($953-$498)	Neil Sing (2005)
Reduced and zonal tillage savings in cane plant crop (undertaken outside the legume package)	$120 per ha excluding timeliness benefits	Agtrans after discussions and data from Neil Sing (2005)
Non-plant year cane growing costs excluding fertiliser	$335 per ha including lime	Neil Sing (2005)

Legume area	1999/00 500 ha 2000/01 1,473 ha 2001/02 4,182 ha 2002/03 6,000 ha 2003/04 8,000 ha 2004/05 10,000 ha Increase of 1,000 ha per year thereafter to 27,000 ha in 2021/22	Alan Garside, Neil Sing (2005), Agtrans
Growth of reduced and zonal tillage external to the legume package	2% per annum	Agtrans after discussions with Alan Garside (2005)

Results

The spreadsheet model constructed in 2002 was updated to accommodate the revised assumptions described earlier and summarised in Table 5. All past costs and benefits were expressed in 2004/05 dollar terms using the CPI. All benefits after 2004/05 were expressed in 2004/05 dollar terms. All costs and benefits were discounted to 2004/05 using a discount rate of 5% and 10%. 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 30 years from the first year of investment (1992/93) to the final year of benefits assumed (2021/22).

The investment criteria were all positive as reported in Table 6.

Table 6: Investment Criteria for Total Investment and Total Benefits

Criterion	**Discount rate**	
	5%	**10%**
Present value of benefits (m$)	286.9	194.9
Present value of costs (m$)	32.6	44.8
Net present value (m$)	254.3	150.1
Benefit cost ratio	8.8 to 1	4.3 to 1
Internal rate of return (%)	22.4	

The impact of the relatively high investment costs and the lag between the investment and the accrual of benefits is demonstrated by the relatively modest benefit-cost ratios (compared with the relatively high net present values) and the impact on results of the higher discount rate. Approximately 93% of the total benefits can be attributed to the legume package (including minimum tillage) with only about 7% of benefits to the zonal and reduced tillage outside the legume package.

The proportion of benefits from each source within the legume package is not easily disentangled due to the interactions caused by the rotational changes (less cane area planted and harvested overall, the yield increases for cane that is planted). It is apparent that a large part of the benefits are derived from the cane yield/rotation complex with a significant contribution from the minimum tillage savings due to the package. The contribution from nitrogen savings and sale of legume crops make up together about 20% of the total benefits.

If the above results are compared with those produced in 2002 for the equivalent analysis, the estimate of Present Value of Benefits has increased using the same discount rate and length of period. A part of this increase is due to the dollars being expressed in 2004/05 terms and the discounting made to 2004/05 instead of 2001/02. If these factors had remained the same, there still would have been an increase. The benefit cost ratio is currently estimated at 8.9 to 1 whereas in 2002 it was estimated at 5.5 to 1 at a discount rate of 5%. The reason for this increase is that a number of assumptions have changed, the major ones being the assumption of a higher increase in cane yields after the legume crop, a higher level of cost savings from minimum tillage, and an increase in the projected area of legume crops. On the other hand the minimum tillage cost savings outside the legume package have decreased but the area subjected to this cost reduction has increased. Another major change has been to introduce two budgets for soybeans, one for a green manure crop and another for a grain crop. This has decreased benefits from the soybean grain crop.

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 7 to 11. All sensitivity analyses were performed using a 5% discount rate, except for those for the sugar price, where both 5% and 10% were used. All other parameters were held at their base values.

Table 7 shows that at a 15% cane yield improvement post 2004/05, the investment would still be quite positive at a 5% discount rate. However, the results in Table 7 indicate that the investment criteria are quite sensitive to the assumption about yield improvement due to the legume break.

Table 7: Sensitivity to cane yield improvement after 2004/05

Criterion	**Level of cane yield improvement after 2004/05 (%)**		
	15	**22.5 (Base)**	**30**
Present value of benefits (m$)	181.5	286.9	392.2
Present value of costs (m$)	32.6	32.6	32.6
Net present value (m$)	148.9	254.3	359.6
Benefit cost ratio	5.6 to 1	8.8 to 1	12.0 to 1

Table 8 shows that the sensitivity to the level of minimum/zonal/reduced tillage savings (both within and outside the legume package) is somewhat significant. Most of this effect comes from changes in the minimum tillage assumptions.

Table 8: Sensitivity to minimum/zonal/reduced tillage savings

Criterion	**Level of tillage savings ($ per ha)**		
	50% less	**$455 per ha (minimum tillage and $120 per ha (zonal/reduced)**	**50% more**
Present value of benefits (m$)	235.3	286.9	338.4
Present value of costs (m$)	32.6	32.6	32.6
Net present value (m$)	202.7	254.3	305.8
Benefit cost ratio	7.2 to 1	8.8 to 1	10.4 to 1

Table 9 shows that the rate at which the legume break crop increases in area is reasonably important to the investment criteria. Results for changing the current assumption of an increase of 1,000 ha per year after 2004/05 to 500 ha per year or 2,000 ha per year are presented.

Table 9: Sensitivity to growth in legume area

Criterion	**Growth in soybean area post 2004/05**		
	Low growth of 500 ha per year	**Base of 1,000 ha per year**	**High growth of 2,000 ha per year**
Present value of benefits (m$)	240.8	286.9	378.9
Present value of costs (m$)	32.6	32.6	32.6
Net present value (m$)	208.2	254.3	346.3
Benefit cost ratio	7.4	8.8 to 1	11.6 to 1

Table 10 shows the investment criteria are not overly sensitive to the proportion of soybean area harvested.

Table 10: Sensitivity to proportion of soybean area harvested

Criterion	**Proportion of soybean area harvested (%)**		
	20	**40 (Base)**	**60**
Present value of benefits (m$)	272.6	286.9	301.1
Present value of costs (m$)	32.6	32.6	32.6
Net present value (m$)	240.0	254.3	268.5
Benefit cost ratio	8.4 to 1	8.8 to 1	9.2 to 1

Tables 11 and 12 show that the investment criteria are also not particularly sensitive to the sugar price. This is due to the large part of the benefits that are derived from cost savings. In fact increasing the sugar price can actually lower the investment criteria due to overall lower total sugar production from the legume break if only low yield increases are obtained. If the yield improvement increases above about 20% in the case of 4 ratoon crops, an increasing sugar price will then improve rather than reduce the investment criteria.

Table 11: Sensitivity to sugar price at 5% discount rate

	Level of sugar price ($/t)			
Criterion	**235**	**285 (Base)**	**335**	**350**
Present value of benefits (m$)	280.1	286.9	293.6	295.6
Present value of costs (m$)	32.6	32.6	32.6	32.6
Net present value (m$)	247.5	254.3	261.0	263.0
Benefit cost ratio	8.6 to 1	8.8 to 1	9.0 to 1	9.1 to 1
Internal rate of return (%)	22.1	22.4	22.5	22.5

Table 12: Sensitivity to sugar price at 10% discount rate

	Level of sugar price ($/t)			
Criterion	**235**	**285 (Base)**	**335**	**350**
Present value of benefits (m$)	190.9	194.9	198.9	200.1
Present value of costs (m$)	44.8	44.8	44.8	44.8
Net present value (m$)	146.1	150.1	154.0	155.2
Benefit cost ratio	4.3 to 1	4.3 to 1	4.4 to 1	4.5 to 1
Internal rate of return (%)	22.1	22.4	22.5	22.5

Conclusions

Now that phase two is completed the investment will have spanned 13 years and totalled over $20m in nominal dollar terms, when the associated projects are included. Despite the long time period of the investment and its overall magnitude, and given the assumptions made, the investment appears to have been extremely sound.

Given the assumptions made the investment up to 2004/05 shows an expected net present value of $254 m for a 5% discount rate, a benefit-cost ratio of 8.8 to 1 and an internal rate of return of 22%. The legume package provides the major source of benefits with zonal and reduced tillage independent of the legume package contributing only about 7% of the total benefits. Benefits are derived from various sources within the legume package itself.

There are a number of factors that will lead to some underestimation of benefits. These include:

(a) benefits to the environment and long term resource health have not been included due to the difficulty in their quantification; for example, possible benefits (both cost and environmental) from lowered chemical requirements have not been included

(b) no account has been made for labour savings and benefits from more timeliness of operations, the former due to the difficulty of valuing labour savings on small to medium farms

(c) no account has been made to value capital savings due to the need for less tractor power

(d) there has been no allowance for the possibility that without system change, yield decline as defined by the venture would have worsened or occurred more commonly in the industry in the future

(e) potential benefits from improved legume break systems in NSW have not been included

(f) no assumptions have been made about likely future increases in soybean yields and prices due to new varieties and new markets

The impact of assuming more or less ratoon numbers (different cycle lengths with and without a legume break) can not be assessed without further model development.

There are likely to be only minor impacts for sugar factories as the throughputs of cane are not likely to change markedly. Harvesters may have a reduced area of cane to harvest but yields per ha may be higher.

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Appendix 1: Estimates of Investment in Associated Projects that were not Funded from Joint Venture Budgets ($)

Year	BS106	BSS121	CS2	BSS143	CS4	BSS142	BS170 &CS6	BSS211	BSS266	BSS269	TOTAL
1993/94	75,000										75,000
1994/95	74,350	140,670	94,122								309,142
1995/96	69,450	124,440	77,522	70,720	35,100	45,480					422,712
1996/97	41,250	127,340	77,522	54,580	25,500	28,860	14,950				370,002
1997/98	37,400	132,940	33,100	61,030	25,500						289,970
1998/99	23,895	120,710						14,500			159,105
1999/00				133,692							133,692
2000/01				63,660							63,660
2001/02											0
2002/03											0
2003/04											0
2004/05									149,925	150,000	299,925
TOTAL	321,345	646,100	282,266	383,682	86,100	74,340	14,950	14,500	149,925	150,000	2,123,208

Note: Figures in table above are for SRDC funding only. Other funding (eg. in-kind) is approximately equal to the SRDC funding for each project for each year and has been incorporated into the total investment costs in Table 1. An exception to this was BSS269 where the in-kind leverage ratio against SRDC funds was 2.89 to 1.

Appendix 2: Associated projects - funded or part funded outside Joint Venture but where budgets need to be included in Joint Venture analysis

No	Years	Title
BS106	July 1993 to Dec 1998	Assessing linkages between machine traffic, soil conditions and productivity
BSS121	July 1994 to June 2000	Cane Based farming systems for the amelioration of yield decline
CSS2S-CS2-CLW002	July 1994 to June 1998	The role of root growth and activity in determining sugarcane productivity (*evaluated qualitatively in 1998*)
BSS 143	July 1995 to June 2002	Strategic tillage to reduce soil structural degradation and improve productivity
CS4-CLW004 (BSES2024)	July 1995 to June 2001	Breakdown in soil productive capacity under sugar cane monoculture *(evaluated qualitatively 1998-called BSES 2024 and went to 2002)*
BSS142	1997/98	Economic cost of soil compaction
BS170	July 1996 to June 1997	Study tour of yield decline research in South Africa, Mauritius and Swaziland
CS6	July 1996 to August 1996	Travel to attend the International Root Research Symposium and visit root research labs
BSS211	July 1998 to June 2001	Increasing farmer participation in the Yield Decline Joint Venture
BSS266	July 2004 to June 2005	Cane Grubs
BSS269	July 2004 to June 2005	Adoption

Appendix 3: Associated projects where budgets not to be included in Joint Venture analysis

No	Years	Title
BSS 155	July 1996 to June 2001	Factors affecting the residual value of lime
CLW009	July 1999 to May 2002	Improving yield and ccs in sugarcane through the application of silicon based amendments
CSR024	July1996 to June 2001	Improving the environment for sugarcane growth through the amelioration of soil acidity
BSS145	July 1995 to March 1999	Improving sett/soil contact to enhance sugarcane establishment
NSWA1S-NA1	July 1992 to June 1997	Increasing sugar cane yields by improvements in soil structure
DQ8	July 1995 to June 1996	National controlled traffic conference
BS98	July 1993 to June 1996	Factors affecting the residual value of lime
BS79	July 1993 to June 1996	Identification of resistance mechanisms in sugarcane to infection by *Pachymetra*
BS80	July 1992 to Dec 1995	The role of *Pythium* species in yield decline in southern canegrowing districts (*qualitatively evaluated in 1993 plus then monitored for two years).*
UQ13	July 1993 to June 1996	Development of DNA probes for identification of rhizosphere fungi responsible for yield decline in sugarcane (*linked to monitoring of BS80)*
BS73S	July 1991 to June 1995	Identification of unknown root pathogens responsible for sugar cane yield decline
DAQ4S	July 1992 to June 1995	Effect of sugarcane farming systems on specifications of soil conservation structures
BSES 2009	1994-1999	Rotations and Green Farming Systems for southern Cane lands Implications for Yield Decline (*evaluated quantitatively in 1998 for SRDC/BSES/SRI*). Assumed to be included in SIRP funding of YDJV
BS27S	July 89?	Inheritance of resistance to pachymetra root rot (*evaluated qualitatively in 1993 for SRDC)*
BS33S	July 89 for 2 years	Pachymetra chaunorhiza as a factor involved in stool tipping in NQ (*evaluated qualitatively in 1993 for SRDC)*
BSES 2005	Jan 95 to Dec 1999	Nematode Pests of sugarcane and associated crops: Understanding their role in yield decline and developing suitable management strategies (*evaluated qualitatively in 1998 for SRDC/BSES/SRI).* Assumed to be included in SIRP funding of YDJV