SUGAR RESEARCH AND DEVELOPMENT CORPORATION

An Economic Analysis of Investment in the Sugar Yield Decline Joint Venture: Phases One and Two

Study conducted for SRDC by Agtrans Research Ltd

Background

Cane yield decline and yield plateaus had been a concern to the sugar industry for a number of years. A new investment, called the Yield Decline Joint Venture was established in 1993 and its first phase ran for six years to June 1999. The second phase followed from July 1999 and ran to June 2005, after a mid-term review in 2002. A third phase is currently operating until December 2009. The joint venture comprised a number of funding and provider R&D organisations. The Sugar Research and Development Corporation (SRDC) was the largest investor in the venture. Other investors and researchers included BSES Ltd, CSIRO Land and Water and two Queensland Government Departments (Department of Primary Industries and Fisheries and the Department of Natural Resources and Water).

This current analysis includes identifying all benefits (past and future) arising from the 13 year (1992/93 to 2004/05) investment in the first two phases. A number of these benefits are valued allowing the economic return to the total investment, as well as the return to the SRDC investment, to be estimated.

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 by SRDC and others are provided in Table 1 for each of the years specified. Table 2 provides further detail of the funding sources, both cash and in kind.

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

Year ending June	SRDC	Other investors	Total
1993	110,000	1,000	111,000
1994	355,000	803,156	1,158,156
1995	614,142	1,037,298	1,651,440
1996	1,147,712	1,351,465	2,499,177
1997	1,102,322	1,348,891	2,451,213
1998	1,030,791	1,066,209	2,097,000
1999	896,514	888,237	1,784,751
2000	986,331	649,915	1,636,246
2001	351,553	579,883	931,436
2002	598,577	516,223	1,114,800
2003	599,865	516,223	1,116,088
2004	601,256	844,046	1,445,302
2005	909,068	1,451,723	2,360,791
Total	9,303,131	11,054,269	20,357,400

Table 2: Specific Contributions to Investment in Sugar Yield Decline Joint Venture (1993 to 2005)
(nominal $)

Year ending June	SRDC (direct projects)	Associated SRDC Projects	SRDC (CP2002)	SRDC (SIRP)	BSES	CSIRO	QDPI	QDNRW	TO
1993	110,000	0	0	0	1,000	0	0	0	
1994	280,000	150,000	0	0	314,720	413,436	0	0	1
1995	305,000	618,284	0	0	314,720	413,436	0	0	1
1996	313,000	845,424	0	412,000	499,350	429,403	0	0	2
1997	305,000	740,004	0	427,320	363,990	364,576	250,323	0	2
1998	370,501	579,940	0	370,320	278,306	301,058	196,875	0	2
1999	370,499	318,210	0	366,910	205,846	309,012	214,274	0	1
2000	530,485	267,384	322,154	0	206,450	129,493	135,040	45,240	1
2001	174,356	127,320	113,537	0	206,450	129,493	135,040	45,240	
2002	360,911	0	237,666	0	206,450	129,493	135,040	45,240	1
2003	599,865	0	0	0	206,450	129,493	135,040	45,240	1
2004	601,256	0	0	0	254,060	64,746	480,000	45,240	1
2005	609,143	883,626	0	0	20,000	0	802,782	45,240	2
TOTAL	4,930,016	4,530,192	673,357	1,576,550	3,077,792	2,813,639	2,484,414	271,440	20

SRDC (direct projects): 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.
SRDC (Associated Projects)**:** SRDC funding obtained from SRDC Annual Reports and Alan Garside; assumed that equal contribution made by R&D organisation. Appendices 1, 2 and 3 provide further details of the associated projects including the breakdown of their costs.
SRDC (CP2002): Consists of actual payments made by SRDC (accounts records).
SRDC (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.
QDNRW: Figures from 1999/00 to 2004/05 from contributions sought in phase two proposal.

Outputs

The principal outputs for the investment include:

(a) There is a more specific definition of "yield decline", which is now viewed separately from the "yield plateau" recognised before the investment was made. 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 earlier 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 for ratoon crops 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 concerning 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 soybeans or other legumes.

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

(d) Costs of tillage for the plant cane crop (e.g. 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. Herbicide savings are also apparent and chemicals that are more environmentally friendly 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, in rotation with cane is 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 high level of uptake by cane farmers of project outputs 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 persistence of benefits being realised in all ratoon crops, as well as in subsequent rotation cycles when legume crops are used.

(j) A series of positive environmental outcomes is also likely. These include improvements to water quality through less export of sediment, nutrients and hard chemicals. While limited quantification of these benefits has been made, Project BSS269 (commenced 2004) is comparing runoff volumes and sediments and nutrients in conventional and the new farming systems in Central Queensland (Les Robertson, pers comm., 2007).

(k) Reduced fuel consumption and tractor sizes have been observed, leading to lowered carbon emissions.

(l) There have been contributions to restoring natural resource sustainability through improvements to soil structure, organic matter and overall soil health.

(m) With widespread and successful adoption of the new farming systems, this investment has built the capacity for change across all regions of Australia in which sugarcane is grown.

(n) Other social outcomes emanating from the investment include:
- Improved scientific understanding and contribution to knowledge
- Improved integration of effort between disciplines and inter-institutional cooperation

Benefits
A summary of the principal types of benefits and related costs associated with the outcomes of the project is shown in Table 3. The costs are implementation costs and exclude the costs of the R&D investment.

Table 3: Categories of Benefits and Costs from the Investment to June 2005

Economic	Environmental	Social
Benefits • 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 costs for the foregone cane crop • Savings of nitrogen fertiliser and its application in the cane plant crop and (in part) the first ratoon crop • Reduced cultivation and chemical costs for the plant cane crop • Labour savings and improved timeliness and flexibility of operations • 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,	• Reduced level of nitrogen export from farms due to reduced nitrogen fertiliser use • Reduced level of sediment export from farms due to less tillage • Overall likely reduction in any impact the cane industry could have been having on the water quality and biodiversity of proximate coastal waters and possibly on the Great Barrier Reef. • Use of less and softer chemicals so potentially benefiting water quality and biodiversity • Lowered non-renewable energy use and carbon emissions	• Reduced tractor requirements has resulted in growers having more time for family and other activities • Higher level of capacity for change in the sugar industry • Improved scientific understanding and contribution to knowledge • Improved integration of effort between disciplines and inter-institutional cooperation

extension, and greater confidence of cane farmers *Costs* • Loss of sale of cane crop for one year • Cost of establishing and managing the legume crop (e.g. 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		

Public versus Private Benefits

Most of the benefits identified will be of a private nature and will be captured by the sugar industry. However, there will be some spinoff benefits to the wider public from the outputs of the research investment. The magnitude of both adoption and the resulting private benefits are significant and will have an impact on maintaining a viable sugar industry on the north east coast of Australia. A number of communities, particularly in Queensland rely on the industry for employment and income. The next best land uses for much cane land is horticulture and beef where markets (horticulture) and relative profitability per hectare (beef) considerations can constrain changes.

The environmental benefits listed in Table 3 are also public benefits. The potential water quality improvements (whose magnitudes have not been valued) could have significant implications for the sustainability of the Great Barrier Reef as well as other biodiversity implications in streams and rivers downstream from cane farms.

Without the Australian Government financial contribution to SRDC it is likely that Phase One of the investment would still have been made as the issue was of considerable concern to the industry in the early to mid 1990s. However, when the second phase was proposed, the Corporation was struggling to find resources to continue the investment. Further, the outputs from Phase 1 were more associated with scientific understanding rather than providing actionable solutions so that its continuation was under threat.

From 1999 the sugar industry entered a period of low production and low prices. Extreme weather conditions, disease and pest incursions reduced industry cane production significantly. Also, world sugar markets collapsed in 1999 and 2000. Revenues in the year 2000 were reduced to 55% of those earned in 1997. Levy income for SRDC was reduced substantially.

The pending commitment to Phase Two represented a large amount of resources. The investment would probably not have been made (or made at lower levels) if the special

CP2002 resources had not been provided by the Australian Government. The CP2002 program was a special assistance grant to the sugar industry for productivity and profitability research. The investment most likely would not have been made at all if the continuing government matching contribution had been reduced and the CP2002 resources not been made available.

Distribution of Benefits Along the Sugar Supply Chain
The new farming systems that utilise the legume break in the cane cycle will effectively reduce the area of cane that is harvested, suggesting that sugar mills could lose throughput to their disadvantage. However, the increased yield per ha for the reduced area of cane harvested will at least compensate for the fall in cane area. Mills should receive at least the same cane tonnage as what had been delivered with the traditional rotation system. The lowered cost of production of cane could eventually result in cane producers sharing some of the benefits with sugar mills, depending on the supply contract arrangements within each region. However, currently there is no mechanism in agreements for cost reductions to cane growers being shared by mills (Les Robertson, pers.comm., 2007). Sugar mills may also benefit from the improved economic viability of cane producers in that supply to some mills may be enhanced reducing their overhead costs compared to a situation of land being lost to cane and hence a smaller mill throughput. Input suppliers may also benefit from being able to maintain markets due to the enhanced cane grower viability.

Benefits to other Primary Industries
Indirect benefits could accrue to the soybean processing and peanut industries in terms of maintaining or increasing throughputs of their processing and/or marketing.

Match with National Priorities
The Australian Government's national and rural R&D priorities are listed in Table 4.

Table 4: National and Rural R&D Research Priorities 2007-08

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

The major focus of the investment has been on the first Rural Research Priority (productivity improvements). Also, the venture is strongly associated with the first National Research Priority (environmentally sustainable Australia) and the aligned rural research priority of natural resource management. The investment has also been prominent in servicing the third National Research Priority (frontier technologies) as well as its support for rural research priorities through the building of innovative skills and technologies in the form of the development of new farming systems and the stimulation of an innovative culture.

Quantification of Benefits

Introduction and qualifications

Most but not all of the productivity and profitability benefits listed in Table 3 are quantified for the purpose of the investment analysis. Conservative assumptions have been used in general and are presented as clearly as possible. The environmental benefits (e.g. improved water quality off farm from reduced nutrient, chemical and sediment exports) are difficult to value and hence are not quantified, contributing to a likely underestimate of total benefits.

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 some areas of poorly managed low input ("dirty") legume crops used in the past would have continued, but 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 have allowed regionally 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 lower impacts than less favourable soils
- 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 legumes (including winter crops) are also suited and are being or have been grown (e.g. peanuts, lab lab, cowpea). While soybeans dominate the legume break, it is assumed that only 15% of the soybean crops will be grown and harvested for grain due to harvesting difficulties and other factors. In many areas, the crop 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.

Other sources of yield improvements from the latter stages of the investment include further development of plant density and planting designs. 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% from 2004/05 onwards compared to the 15% increase assumed before 2004/05.

Use of raised beds provides tillage cost savings and less herbicide use in the long term. The major benefit from controlled traffic and other refinements to the sustainable system is also a reduction in costs of growing cane. Controlled traffic includes the development of permanent wheel tracks and machines including tractors, harvesters and trailers not travelling along the crop row. Recent results demonstrated better water infiltration after 3-4 years of controlled traffic but it has not yet been confirmed that this has translated to yield increases (Les Robertson, pers. comm., 2007).

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 for this evaluation the cycle for the new system is now extended to six years instead of five years.

It is assumed there is no depression in commercial cane sugar (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 nitrogen fertiliser in the plant crop of cane, and to avoid 50% of that normally applied in the first ratoon crop. Fertiliser is also saved due to there being less cane area each year on a whole farm basis.

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 e.g. 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 15% of the total area of soybean that is planted is harvested for grain and 85% not harvested. This percentage varies according to the cane growing region with most harvested soybeans grown in south Queensland around Bundaberg, Isis and Maryborough.

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 as reported in Table 5 (Neil Sing, pers comm., 2005). However, in some cases full cultivation is used to prepare land for soybeans (Les Robertson, pers.comm., 2007). It is assumed that this could increase the total cost of planting and growing soybeans not for harvest to around $300 per ha. The average cost of planting and growing soybeans not for harvest is assumed to be a simple average of $172 and $300 or $236 per ha.

If the soybeans are harvested, additional input costs and harvesting and transport are assumed. Table 5 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. It is also quite possible that the proportion of the soybean crop planted for grain may increase in the future.

Table 5: Costs and Revenue Assumed for Soybean Break Crop

Soybeans not harvested for grain	
	$/ha
Spray out cane	43.36
Seed	68.18
Planting	26.46
Herbicide	13.01
Spray out soybeans	20.60
Total	171.61
Soybeans harvested for grain	
Revenue	
Price ($ per tonne)	450.00
Yield (t per ha)	3.50
Total revenue ($ per ha)	1575.00
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%)	15.75
Drying ($14 per tonne)	49.00
Total costs ($ per ha)	929.35
Net revenue ($ per ha)	645.65

Sources: Not harvested for grain assumptions from Neil Sing (pers comm., 2005); Harvested for grain assumptions from Trish Cameron (pers comm., 2005); Revised price of soybeans Andrew Dougall (pers.comm., 2007).

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

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 6 and shows the actual area actually planted by region. It is estimated that the area planted to legumes serving as a break crop in 2002/03 was 4,300 ha, 5,000 ha in 2004/05, 6,700 ha in 2005/06 and 8,300 ha in 2006/07. Interpolation was used to estimate the area planted in 2003/04. The area after 2006/07 is assumed to increase by 1,000 ha each year until the last year of the analysis. The latter part of the investment in the venture 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 2029/30 will be 31,300 ha. Given that there is currently about 70,000 ha of new cane planted each year, the 31,000 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 even higher.

The adoption rate for minimum tillage external to the legume break is assumed to commence also 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 6: Area of Legumes Planted as a Break Crop

Region	Soybeans 2000/01 summer (ha) (a)	Soybeans 2001/02 summer (ha) (a)	Legume fallow 2002/03 (ha) (b)	Legume fallow 2004/05 (ha) (c)	Legume fallow 2006 (ha) (b)	Legume fallow 2007 (ha) (b)
North Qld	202	602				
Herbert	11	230				
Burdekin	160	1,100				
Mackay	800	1,400				
Bundaberg	300	500				
Rocky Point	-	350				
NSW	(d)	(d)				
Total	1,473	4,182	4,300	5,000	6,700	8,300

(a) Source: Alan Garside, pers comm., 2005
(b) Source: Les Robertson, pers comm., 2007
(c) Source: SRDC Update, April 2005
(d) Some areas of legume have been grown as a cash crop in NSW before the joint venture, but systems have been improved from principles developed by the joint venture (Beattie, pers comm., 2002). Hence, while some benefits will be expected for the NSW industry, 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 7.

Table 7: Summary of Assumptions

Variable	Assumption	Source
Price of sugar	$270 per tonne	Average for the five years to 2004/05 (Australian Commodity Statistics, 2006)
CCS	13.8	Average for the five years to 2005/06 (Australian Commodity Statistics, 2006)
Existing cane yield	84 tonnes per ha	Average for five years to 2005/06 is 84 tonnes per ha (Australian Commodity

		Statistics, 2006)
Cane area	415,000 ha in 2005/06	Australian Commodity Statistics, 2006
Harvesting cost	$6 per tonne of cane	Agtrans
Cane yield increase after legume break (1999/00 to 2004/05)	15%	Alan Garside (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	$236 per ha	Agtrans after discussion with Neil Sing (2005) and Les Robertson (2007)
Proportion of soybean area harvested	15%	Agtrans after discussions with Neil Sing (2007) and Les Robertson (2007)
Price of soybeans	$450 per tonne	$350 per tonne after input from Neil Sing and Judy Skilton in 2005; revised to current assumption after input from Andrew Dougall in 2007
Yield of soybeans	3.5 tonnes per ha	3.5 tonnes per ha after input from Alan Garside, Judy Skilton, and Trish Cameron in 2005 and Andrew Dougall in 2007
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) and Les Robertson (2007)
Fertiliser savings in plant year whether soybeans harvested or not	160 kg per ha	Alan Garside (2002, 2005)
Fertiliser 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	Alan Garside, Neil Sing (2005), Les Robertson

	2001/02 4,182 ha 2002/03 4,300 ha 2003/04 4,650 ha 2004/05 5,000 ha 2005/06 6,700 ha 2006/07 8,300 ha Increase of 1,000 ha per year thereafter to 31,300 ha in 2029/30	2007), some interpolation by Agtrans
Growth of reduced and zonal tillage external to the legume package	Linear increase of 2 per cent of plant area where a legume break in not used. Consistent with about 10,000 ha in 2006/07 (Les Robertson, 2007). Equivalent to 23,000 ha in 2029/30.	Agtrans after discussions with Alan Garside (2005); Les Robertson (2007).

Results

All past costs and benefits were expressed in 2006/07 dollar terms using the CPI. All benefits after 2006/07 were expressed in 2006/07 dollar terms. All costs and benefits were discounted to 2006/07 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 25 years from the last year of investment (2004/05) to the final year of benefits assumed (2029/30).

Investment criteria were estimated for both total investment and for the SRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria were all positive as reported in Tables 8 and 9. The exception to this was when benefits are only summed to the last year of investment.

Table 8: Investment Criteria for Total Investment and Total Benefits (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	12.32	59.84	126.76	200.81	275.44	346.74
Present value of costs (m$)	38.13	38.13	38.13	38.13	38.13	38.13
Net present value (m$)	-25.81	21.71	88.63	162.68	237.31	308.61
Benefit cost ratio	0.32 to 1	1.57 to 1	3.32 to 1	5.27 to 1	7.22 to 1	9.09 to 1
Internal rate of return (%)	Negative	10.4	16.3	18.2	19.10	19.4

Table 9: Investment Criteria for SRDC Investment and Benefits to SRDC (discount rate 5%)

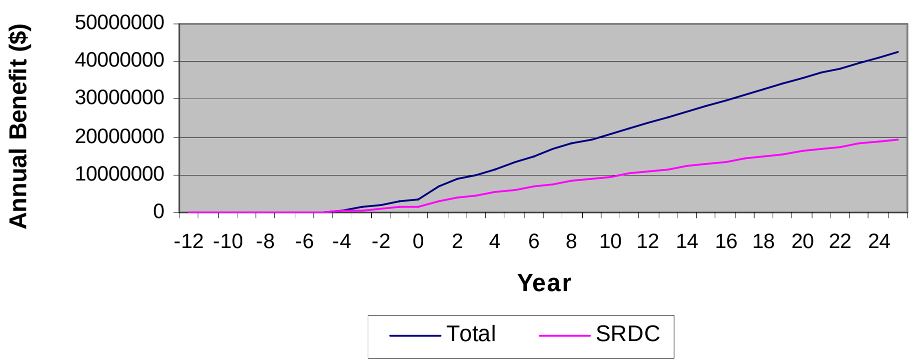
Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits (m$)	5.63	27.33	57.90	91.72	125.81	158.37
Present value of costs (m$)	17.33	17.33	17.33	17.33	17.33	17.33
Net present value (m$)	-11.71	10.00	40.56	74.38	108.47	141.04
Benefit cost ratio	0.32 to 1	1.58 to 1	3.34 to 1	5.29 to 1	7.26 to 1	9.14 to 1
Internal rate of return (%)	Negative	10.6	16.5	18.5	19.3	19.6

The proportion of benefits from each source within the new farming systems are 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). However, it is apparent that a large part of the benefits are derived from the minimum tillage savings for plant cane derived from the package. The contribution from nitrogen savings and sale of legume crops together make up about 25% of the total benefits.

In terms of the quantified benefits, 100% could be attributed to the productivity and adding value component of the rural research priorities.

The cash flow of benefits is shown in Figure 1 for both the total investment and for the SRDC investment.

Figure 1: Benefit Cash Flow



Sensitivity Analyses
Sensitivity analyses were carried out on a range of variables and results are reported in Tables 10 to 14. All sensitivity analyses were performed using a 5% discount rate for the SRDC investment only. Benefits were estimated over the life of the investment plus 20 years from the year of last investment. All other parameters were held at their base values.

Table 10 shows that at a 15% cane yield improvement post 2004/05 (rather than the 22.5% assumed as the base assumption), the investment would still be quite positive at a 5% discount rate. If there were no yield increase per ha due to the legume break, the investment would just break even at a 5% discount rate.

Table 10: Sensitivity to Cane Yield Improvement after 2004/05
(SRDC investment, 5% discount rate; 20 years)

	Level of cane yield improvement per ha after 2004/05 (%)		
Criterion	15	22.5 (Base)	30
Present value of benefits (m$)	80.11	125.81	171.50
Present value of costs (m$)	17.33	17.33	17.33
Net present value (m$)	62.78	108.47	154.16
Benefit cost ratio	4.62 to 1	7.26 to 1	9.89
Internal rate of return (%)	16.0	19.3	21.6

Table 11 shows that the sensitivity to the level of minimum tillage within the legume package and zonal/reduced tillage savings outside the legume package is moderately significant. Most of the effect comes from changes in the minimum tillage within the legume package.

Table 11: Sensitivity to Minimum/zonal/reduced Tillage Savings
(SRDC investment, 5% discount rate; 20 years)

	Level of tillage savings ($ per ha)		
Criterion	50% less	$455 per ha (minimum tillage and $120 per ha (zonal/reduced)	50% more
Present value of benefits (m$)	100.67	125.81	150.94
Present value of costs (m$)	17.33	17.33	17.33
Net present value (m$)	83.34	108.47	133.60
Benefit cost ratio	5.81 to 1	7.26 to 1	8.71
Internal rate of return (%)	17.2	19.3	21.0

Table 12 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 12: Sensitivity to Growth in Legume Area
(SRDC investment, 5% discount rate; 20 years)

	Growth in legume area post 2004/05		
Criterion	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$)	104.57	125.81	168.28
Present value of costs (m$)	17.33	17.33	17.33
Net present value (m$)	87.24	108.47	150.94
Benefit cost ratio	6.03 to 1	7.26 to 1	9.71 to 1
Internal rate of return (%)	18.4	19.3	20.7

Table 13 shows the investment criteria are not overly sensitive to the proportion of soybean area harvested.

Table 13: Sensitivity to Proportion of Soybean Area Harvested
(SRDC investment, 5% discount rate; 20 years)

	Proportion of soybean area harvested (%)		
Criterion	5	15 (Base)	60
Present value of benefits (m$)	120.38	125.81	150.23
Present value of costs (m$)	17.33	17.33	17.33
Net present value (m$)	103.05	108.47	132.89
Benefit cost ratio	6.94 to 1	7.26 to 1	8.67 to 1
Internal rate of return (%)	19.0	19.3	20.3

Table 14 shows that the investment criteria are not particularly sensitive to the sugar price. This is due to the large part of the benefits that are derived from cost savings.

Table 14: Sensitivity to Sugar Price
(SRDC investment, 5% discount rate; 20 years)

	Level of sugar price ($/t)		
Criterion	230	270 (Base)	330
Present value of benefits (m$)	123.24	125.81	129.65
Present value of costs (m$)	17.33	17.33	17.33
Net present value (m$)	105.91	108.47	112.32
Benefit cost ratio	7.11 to 1	7.26 to 1	7.48 to 1
Internal rate of return	19.2	19.3	19.4

An additional table is presented below (Table 15) that shows the sensitivity of the Net Present Value to the area of adoption of the legume break post 2006/07 at low (500 ha per annum), expected (1,000 ha per annum) and high (2,000 ha per annum) levels of adoption and for different analysis periods.

Table 15: Sensitivity of Net Present Value ($m) to Adoption of the Legume Break post 2006/07
(Total Benefits and Costs; Discount Rate of 5%)

Period	0 years	5 years	10 years	15 years	20 years	25 years
Low	-25.81	20.74	79.06	136.64	190.82	240.27
Medium	-25.81	21.71	88.63	162.68	237.31	308.61
High	-25.81	23.65	107.78	214.76	330.29	445.29

Conclusions

The investment has spanned 13 years and totalled over $20 m 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 total investment up to 2004/05 shows an expected net present value of $237 m with a 20 year benefit period, a benefit-cost ratio of 7 to 1 and an internal rate of return of 19%. The legume package including minimal tillage provides the major source of benefits with zonal and reduced tillage independent of the legume package contributing a smaller part 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 from lowered export of nutrients, chemicals and sediment and the ensuing impact on water quality in waterways 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

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 mills 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.

Acknowledgments

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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 Tables 1 and 2. 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