# CRC SUGAR: AN EXPERIMENT IN A NOVEL APPROACH TO SUGAR R&D

By

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## Abstract

CRC Sugar was established in 1995 to undertake research and education to build the skills and technology for a competitive and environmentally responsible sugar industry. CRC Sugar was constituted as a collaborative joint venture between 13 organisations: the five major sugar milling companies (Bundaberg Sugar, CSR Sugar, Mackay Sugar, NSW Sugar and Sugar North), CANEGROWERS, BSES, SRDC, two divisions of CSIRO, the Queensland Department of Natural Resources and Mines and three universities, The University of Queensland, Central Queensland University and James Cook University, the centre host. Together, these 13 organisations conduct ~85% of sugar R&D. CRC Sugar's operational strategy has been to add value to the work, through collaborative, multi-disciplinary research, to tackle difficult or complex 'systems' issues in partnership with research end-users. CRC Sugar has leveraged an additional $3.5 million annually into sugar R&D, in the form of competitive CRC Program cash, in-kind contributions from extra-industry research providers, and conditional establishment grants from the Queensland and NSW governments. Among CRC Sugar researchers' key achievements are the pioneering 'whole-of-industry' approach to alternative options for cane supply scheduling; a science-based understanding of the industry's water quality and other environmental impacts; improved management of acid sulfate soils; a targetted approach to customising nutrient management to local needs, taking account of soil type and nutrient recycling from mill muds, effluent and green cane trash blanketing (GCTB); tools to maximise economic returns from limited water; tools and approaches for ameliorating soil sodicity and acidity; better understanding of the wet tropics low CCS issue; a range of decision support tools to assess options and explore risks and trade-offs; and an innovative education and training program. Benefit: cost analysis of selected projects indicated that the potential benefit from the cane supply options work alone exceeds the aggregate 8-year cost of the Centre. There were 'transaction' costs in operating CRC Sugar, mainly in the form of the time and effort spent on building collaborative links with other researchers and industry, and on accountability. The main gap when CRC Sugar's term ends will be in the nature and extent of environmental research, with much of the ongoing research diverting to organisations focussed on environmental protection rather than sustainable sugar production. CRC Sugar's legacies include the whole-of-industry approach to exploring options for securing operational efficiencies, a comprehensive, science-based appraisal of the industry's environmental footprint, 'best bet' options for improved environmental management, stronger industry engagement by extra-industry research providers, and a paradigm shift in favour of collaborative, participative, systems-based research.

## Introduction

The Cooperative Research Centre for Sustainable Sugar Production (CRC Sugar) is an unincorporated, collaborative joint venture between 13 organisations: the five major sugar milling companies (Bundaberg Sugar, CSR Sugar, Mackay Sugar, NSW Sugar and Sugar North), CANEGROWERS, BSES, SRDC, two divisions of CSIRO, the Queensland Department of Natural Resources and Mines and three universities, The University of Queensland, Central Queensland University, and James Cook University, the centre host. Collectively, these organisations conduct ~85% of sugar industry R&D. CRC Sugar was established in 1995 to undertake '*collaborative multi-disciplinary research and education to build the skills and technology for a competitive and environmentally responsible sugar industry*' (CRC Sugar, 1998). CRC Sugar, which operates as a cooperative research network, will formally cease operations on September 30, 2003.

At $54 million aggregate cash plus in-kind expenditure, CRC Sugar is the largest discrete research 'project' yet undertaken by the sugar industry. As the initiative nears completion, it is apposite to review the learnings from it. This paper starts that process, by sequentially addressing the questions: 'What has been done differently and how?' 'What are the main achievements?' 'What should have been done differently and why?' 'What needs to be done in the future?' and 'What are CRC Sugar's main legacies?' Given the breadth of CRC Sugar's operations, it is not possible to address these questions at other than a largely conceptual level. Tangible exemplars of the main points are presented by the CRC Sugar program leaders and colleagues in complementary papers (Bristow and Keating, 2003; Kingston and Lawn, 2003; Rayment, 2003; Wood *et al*., 2003).

## What has been done differently and how

CRC Sugar has delivered about an additional $3.5 million per annum in new resources for sugar industry R&D over its 8-year term. That is, about $28 million, or just over half CRC Sugar's aggregate cash and in-kind resources, has been additional expenditure that would not have been committed to sugar industry R&D. Of this $28 million, $18 million was competitive Commonwealth funding, which would have otherwise gone to non-sugar industry sectors. The Commonwealth cash, in turn, leveraged into sugar industry R&D an additional $10 million from extra-industry organisations like the universities, CSIRO and the Queensland government. This latter figure takes into account that these organisations would have still carried out some sugar-related R&D in CRC Sugar's absence—perhaps about $6 million given their pre-CRC Sugar expenditure patterns. The remaining $20 million came from industry organisations like SRDC, BSES and the milling companies. In CRC Sugar's absence, these resources presumably would have still been deployed on sugar R&D, although perhaps in a different manner.

The competitive Commonwealth funds were used for three main purposes: the salaries and research costs of 20 new scientists and 38 postgraduate students, fostering collaboration among the researchers, and the costs of operating the Centre. Recruitment of new staff focussed on filling gaps in expertise or capacity within the staff seconded from the parties, e.g. in modelling, operations research, agricultural and resource economics, mathematics and statistics, and spatial analysis. CRC Sugar has operated as a 'virtual' organisation, with all staff employed by and all research conducted through its joint venture parties.

Central to CRC Sugar's strategic approach has been the concept of 'adding value' and not duplicating the disciplinary research undertaken within the joint venture parties (CRC Sugar 1998). The key strategies that CRC Sugar adopted to add value to sugar industry R&D are listed in Table 1. All of its activities pursued at least one of these strategies and the best embraced all four.

**Table 1—**Four key operational strategies through which CRC Sugar has added value to the R&D of its joint venture parties.

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| 1. | Collaborative, multi-organisational activities that build on party strengths to address issues that the parties could not easily address alone because none has all the requisite skills or capacity. |
| 2. | Tackling difficult or complex research issues and being the 'honest broker' on sensitive issues. |
| 3. | Participative R&D with end-users to facilitate adoption. |
| 4. | A 'whole-of-system' view integrating biophysical with socio-economic analysis to evaluate options and examine trade-offs. |

Apart from the value-adding approach to industry sustainability issues, an important sub-theme for CRC Sugar was to strengthen sugar R&D and training capacity in the north. The Australian Science and Technology Council had recommended to government that R&D capacity in northern Australia be strengthened and better linkages be encouraged between R&D agencies and the three northern universities (ASTEC, 1993). For this reason, CRC Sugar was headquartered at JCU in Townsville, rather than Brisbane where there was greater concentration of relevant R&D capacity.

Another sub-theme for CRC Sugar, especially in the early years, was to break down the 'compartmentalisation' among R&D agencies that developed as the number of providers expanded after the formation of the SRDC in the late 1980s (Lawn, 1996). The deployment of multi-disciplinary teams to address complex issues in a systems approach has helped foster collaboration considerably. Firstly, the strategy provided a context wherein the value of different skills and perspectives from different organisations could be recognised and drawn on, and secondly, it enabled opportunities for synergies to be identified and developed.

CRC Sugar's main role is as an 'information broker', providing end-users with science-based information and assisting in its application to improve industry environmental, resource management and production practices. CRC Sugar's approach to technology transfer has taken into account that: (i) CRC Sugar has a diversity of stakeholders from the industry and the community; (ii) difficult and/or complex issues require cultural change to facilitate implementation; and (iii) where linear extension methods are relevant, the industry has in place extension networks where CRC Sugar can add value rather than duplicate.

CRC Sugar has put particular emphasis on participative R&D, or partnerships, with the end-users of the research, actively engaging them at all levels, and in all phases of operation from initial planning to evaluation and implementation of options in pilot studies. This strategy was enabled by the secondment of 5–7 fulltime staff equivalents from the milling companies, which ensured the direct involvement of industry staff in the R&D, and in turn, focussed the R&D on the priorities as seen by industry. The experience has been that, when dealing with complex issues where stakeholders may have different and even competing goals and expectations, partnerships are more effective than traditional extension.

CRC Sugar's industry stakeholders span the value chain, but primary emphasis has been on the growers and millers, and to some extent marketers and agribusiness. Community stakeholders include environmental managers (e.g. Environmental Protection Agency, Great Barrier Reef Marine Park Authority), environmental interest groups (e.g. Landcare, Integrated Catchment Management committees, environmentalists), downstream industries (e.g. fishing, tourism) and policy makers in industry, financial services, and local and State government. Emphasis was placed on CRC Sugar's role as an 'honest broker' providing objective scientific information to all end-users. Such an

approach is particularly needed with issues like cane supply scheduling/season length, management of acid sulfate soils, and natural resource management.

Examples where the participative approach has proved valuable include alternative cane supply options analysis (millers, growers and marketers), yield forecasting (cane inspectors, mill management), on-farm management of acid sulfate soils (millers and growers, community and fishing interests), natural resource management decision-making (growers, millers, councils, community, environmental interests), re-use of effluents (growers, councils), and on-farm water storage and use of limited supplemental irrigation (growers, irrigation suppliers).

An integral part of CRC Sugar's strategy for applying research and facilitating adoption has been to integrate biophysical and economic information into frameworks useful to end-users (Bristow and Keating, 2003). Biophysical models and other tools developed by CRC Sugar enable the extrapolation of experience (e.g. across regions and years) and allow complex interactions among factors (e.g. crop, soil and climate) to be understood and assessed. Coupled with economic analyses, these tools enable scenarios to be examined and options evaluated in terms of economic costs, benefits, trade-offs and risks.

CRC Sugar has fostered an active postgraduate research training and continuing education program that systematically sought to strengthen existing and/or develop new capacity to deal with sugar issues. CRC Sugar's cohort of 38 postgraduate students tackled research problems of practical or strategic industry interest, while the 'train the trainer' short courses (e.g. Bruce, 1999; Bruce *et al.*, 2000) have packaged and delivered up-to-date information on target issues to a wide range of technologists already in the workforce. These activities have been complemented with a broad-based educational program targetting the industry and wider community.

Although unincorporated, CRC Sugar has operated as a de-facto company, governed by a board representative of the joint venture parties, with an independent chair. Operational management is through a management committee comprising the chief executive officer and the program leaders. In addition to industry representation on the board, CRC Sugar has an extensive industry and community stakeholder consultative network through its advisory committee and program consultative groups. The Centre has taken a professional approach to accountability and assessment with research objectives, planned outputs and performance indicators documented in project and individual work plans. Accountability to the Commonwealth is achieved through a comprehensive published annual report, and an unpublished management data report. Scientific peer assessment is supplemented with biennial external reviews by the CRC Program, and annual review within the Centre.

## CRC Sugar's main achievements

CRC Sugar's research addressed the three central requirements for sustainability: environmental protection, maintenance of the resource base, and profitability (Standing Committee on Agriculture, 1991). The main areas where CRC Sugar's R&D outputs have already or will have substantial impact are outlined in Table 2 (and see also Lawn, 2001). The achievements reflect 'public good' as well as 'industry benefit' elements.

An external *ex ante* benefit: cost analysis of eight CRC Sugar activities (Agtrans Research and eSYS Development, 2000), based on conservative assumptions of sugar prices, adoption rates and estimates of benefits, indicated benefit:cost ratios ranging from 2:1 to 53:1 at a 5% discount rate, and internal rates of return from 12%–84%. The NPV of the cane supply options work alone exceeded the aggregate (8-year) value of CRC Sugar's R&D investment.

**Table 2—**Areas where CRC Sugar's R&D has made significant advances.

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| **Enhancing competitiveness** |
| *Whole-of-industry productivity* |
| Novel capability developed to optimise cane harvest and supply scheduling with regional efficiency gains of 7–11%. Commercial implementation underway in Mackay, Maryborough and Mossman regions. Related advances in optimising siding and harvest rosters, yield forecasting. |
| *More dollars from limited water* |
| Decision-support models to evaluate economic feasibility and to optimise design criteria for on-farm water storage (DamEa$y) and for use of municipal effluent to irrigate canelands (SUGARCO$T) in use by farmers and local councils. Related advances using APSIM sugarcane assist optimal use of limited water. |
| *Toward better productivity in the wet tropics* |
| Joint CRC-SRDC and later novel analyses of productivity data helped clarify 'low CCS problem' in wet tropics and highlighted roles of crop lodging and suckering. Related strategic work has clarified effects of lodging, identified factors promoting suckering and highlighted need to explore role of green cane trash blanketing (GCTB) in nutrient re-cycling. |
| **Sustaining soil and water resources** |
| *Better fertiliser management* |
| New paradigm promoted for tailoring fertiliser use to crop needs taking account of soil type, weather and nutrient re-cycling to optimise yield and reduce nutrient losses to environment. WWW repository of soils data (Soils of the Sugarlands) to facilitate use of soil resource data. |
| *Making better use of re-cycled nutrients* |
| Dynamics of nutrient re-cycling via GCTB, use of mill muds, biosolids and effluent recycling modelled, and complemented with economic analyses, enabling these nutrient sources to be factored into fertiliser management plans. |
| *Making difficult soils more productive* |
| Tools developed (e.g. Sodic Soils Toolkit and Gypsy) to identify sodicity and estimate how much amendment to apply to economically overcome problems in diverse soils. Liming strategies developed for overcoming acidity in lower soil profile and economics of long-term liming demonstrated. |
| **Protecting the environment** |
| *Toward better environmental management* |
| Studies on aggregate fertiliser and pesticide use, nutrient and sediment losses, nutrient leaching, pesticides, dissolved oxygen, heavy metals cycling, green house gas budget, have clarified the industry's environmental impacts. 'Best bet' management options promoted through code of practice and short courses. |
| *Acid sulfate soils* |
| Acid sulfate soils project with NSW Sugar developed industry analytical capacity, identified areas of potential acid hazard and enabled management plans to be put in place, with industry being granted self-regulation of ASS management. CRC Sugar models in use inside and outside sugar industry. |
| *Natural resource management planning* |
| WWW-based decision support for NRM planning (NRM Tools) and economic modelling (CLAM, FarmEa$y) developed and applied with industry, government and community stakeholders to assess economic, social and environmental implications in Herbert and Maroochy catchments. |
| **Education** |
| *Investing in people* |
| 38 postgraduate students trained using 'real-world' industry issues, while technical and extension staff have been equipped with better environmental know-how through 'train-the-trainer' short courses and technical workshops on key issues (>500 trainees). |

Similarly positive outcomes were evident from internal BCA of CRC Sugar's R&D on supplemental irrigation, where sensitivity analyses showed investment criteria remained positive

across a wide range of plausible scenarios (Wegener *et al.*, 2000). The external BCA analyses (Agtrans Research and eSYS Development, 2000) indicated that the return on investment was lower for environmental than production-related projects. However, this outcome owes much to the difficulties of placing 'market value' on environmental outcomes – an area where CRC Sugar made its own research progress (CRC Sugar, 2000).

On the productivity side, the main achievement has been in pioneering the 'whole-of-industry' approach in the sensitive area of cane supply scheduling/season length (Wood *et al*., 2003). CRC Sugar's operations research has turned around thinking on a previously difficult issue, to the extent that the industry in several regions is now working with CRC Sugar researchers, with SRDC support, to exploit opportunities for efficiency gains. Important advances have also been made in developing tools and capacity to evaluate options for on-farm water storage, irrigation and most economic use of limited water. At a more strategic level, CRC Sugar researchers made useful contributions in unwinding some of the complexities of the wet tropics productivity issue, opening up the way for applied research to develop solutions to issues like lodging and suckering, and identifying more robust approaches to block productivity analysis that avoid pitfalls with annual analyses of data.

On the environmental side, CRC Sugar systematically tackled the environment head on, to uniquely position the industry with robust knowledge of its environmental 'footprint', clarifying the issues and in a couple of instances, debunking myth (Rayment 2003). In particular, studies on industry aggregate fertiliser and pesticide use, on nutrient and sediment losses, on pesticide mobility, and on the oxygen-stripping role of harvest juice losses, have clarified the issues in relation to impacts on the quality of drainage waters. In NSW, the interactive farm-scale survey of acid sulfate soils helped position the industry for self-regulation of management of these soils. 'Best bet' environmental management options have been promoted through the Code of Practice for Sustainable Canegrowing and environmental short courses.

In relation to sustaining soil and water resources, CRC Sugar has systematically promoted an integrated approach to soil fertility issues, laying the basis for customised nutrient management that takes account of soil properties, crop attributes, nutrients re-cycled from green cane trash blanketing, and contributions from mill wastes and municipal effluents (Kingston and Lawn, 2003). Related research on sodicity and acidity has resulted in tools and approaches for identifying these problems and assessing commercially economic options. Improved approaches to soil amelioration and fertility management have been widely promoted through short courses, field days and industry seminars.

Throughout, CRC Sugar has emphasised a multi-disciplinary systems approach that overlays biophysical understanding with socio-economic analysis to better assess trade-offs and competing options, and sharpen decision support (Bristow and Keating, 2003). Modelling and other integrative tools (e.g. the cane supply options analyses, NRM Tools, CLAM, DamEa$y, SUGARCO$T, GREENCALC, WetUp, LUCID framework for nutritional information, FarmEa$y) have been developed and tools like the APSIM Sugarcane model substantially strengthened. Economic analyses and research have focussed on benefits of specific practices and options, regional resource use, whole-of-industry management issues and the value of research outputs (CRC Sugar, 2000).

In the education area, a coordinated approach has focussed postgraduate student research training on 'real-world' problems and brought technical advisors 'up-to-speed' on key issues in the environmental, nutrient management and irrigation debates. One indicator of the quality of the performance of CRC Sugar's postgraduate students is the relatively large number of independent accolades received for their work: collectively, CRC Sugar's 38 postgraduate students have so far

received 14 external awards. More than half the students (55%) will have graduated by the time the Centre ends, while a further 20% and perhaps as many as 30%, will finalise their theses and graduate. These completion rates compare favourably with the national average of around 52% final postgraduate completions for the agricultural sciences (Martin *et al*., 2001).

Another performance indicator is the ~300 refereed scientific papers authored/co-authored by CRC Sugar researchers during the first seven years, with more to come. An important component of this has been the sharp increase in the number (~109) and scope of papers presented at ASSCT during the period. CRC Sugar researchers have also invested considerably in delivering research outputs to end-users not directly participating in their research. During the first seven years, CRC Sugar researchers made ~980 presentations, wrote ~270 articles for industry journals, contributed to ~250 newspaper stories, and gave ~140 radio/TV interviews. They also produced an extensive array of technical reports, information sheets, extension kits and videos to deliver information to research end-users (see http://www-sugar.jcu.edu.au/ ).

CRC Sugar won very strong and explicit praise from the CRC Program during its 5th Year Review, undertaken by two external panels that evaluated the quality of its research and of its structure and management. The research was assessed as 'an excellent response to the challenges facing the industry, combining a whole-of-system approach with a research-user driven program involving the biophysical, economic and social sciences.' The Centre's 'progress against objectives', 'collaboration, technology transfer, and education and training programs' and 'overall management' were likewise all assessed as 'excellent'. Other tangible indicators of the quality of CRC Sugar's work include two *Rivercare 2000* environmental awards by the NSW Environmental Protection Agency to the project team responsible for the work on improved management of acid sulfate soils, and the 2002 Business and Higher Education Round Table award for collaborative research within a CRC, made to the CRC Sugar cane supply options team.

CRC Sugar's research outputs and contributions need to be evaluated in the context that, during the period of its operations, the resources deployed through CRC Sugar collectively represented only about 14% or one-seventh of the total industry R&D resources during the same period. Viewed in that light, the 21% ASSCT papers over the past four years, for example, add weight to the argument that research collaboration offers substantial synergies.

**What should have been done differently and why**

Without undercutting CRC Sugar's significant achievements, it is inevitable in a major and complex initiative that hindsight would suggest things that could have been done better. The more important of these are documented below, in the interests of future collaborative ventures avoiding similar pitfalls.

Professional staff, including those recruited by CRC Sugar, were often challenged to balance host organisation expectations with those of the Centre, particularly with its ethic of working in collaborative, multi-agency teams. While the 'compartmentalisation' that prevailed when CRC Sugar was established of itself demonstrated the need for a more cooperative research approach, there is no doubt that greater research progress could have been made had those institutional barriers not existed. Considerable time and effort was needed in the first few years for meetings and discussions to build trust and relationships. This is one of several examples of the additional 'transaction costs' that were encountered operating CRC Sugar. It is far easier to conduct research in isolation of industry end-users, as it is of other scientists, and there is an inevitable increase in the cost of 'doing business' associated with partnerships with end-users and with collaboration with

other scientists. It needs to be stressed, however, that the transaction costs are far outweighed by the efficiency benefits from collaboration and industry partnerships.

There is also a cost associated with the ongoing performance assessment and accountability required by the Commonwealth CRC Program. These processes are more thorough than some R&D agencies were accustomed to, but reflect the increasing requirement by government and industry that researchers are transparently accountable to those who fund them. Research assessment is an essential element of R&D 'best practice'.

These additional costs cannot be eliminated, although with goodwill, there is often scope to make sure that the synergies far outweigh the additional costs. Some organisations and/or people within them were sometimes reluctant to change their 'way of doing business' to accommodate the operational needs of their staff working within CRC Sugar. This inevitably meant that their staff shouldered greater burdens on their time than would otherwise have been necessary. In these instances, the additional burden might have been lightened had CRC Sugar been more generous in deploying cash funds to supporting seconded individuals as well as their host organisations.

Adaptation to a changing external environment is a feature of most organisations and another source of transaction cost was the organisational changes that took place in the various joint venture parties over CRC Sugar's term. Internal changes in party structure and/or strategic focus were sometimes made in isolation of the party's commitment to CRC Sugar. The most difficult to accommodate was where the strategic interests of parties changed. For example, the interest in some parties changed over seven years from a need to increase cane supply, to a view that cane supply was not an issue, and back again. It is important to retain the flexibility to adapt to changing priorities. It is not easy, however, in a collaborative research enterprise, to retain the flexibility to adapt to frequent changes in strategic emphasis, particularly when the changes in any one party are not necessarily reflected in others.

Less dramatic were internal party organisational changes that removed administrators with corporate knowledge of the party's relations with CRC Sugar, and brought in people with little or no prior knowledge. In these cases, the first sign that things had changed was when something that should have occurred did not. Again, this exemplifies that effective collaboration requires ongoing active effort on all sides.

In the early years of operation, there were some who saw CRCs as essentially another funding source, and found it difficult to accept the principle that CRC Sugar should have a say on the deployment of staff time within CRC Sugar. This applied as much to staff as to their host organisations, especially where those staff had previously been used to substantial freedom in their research. Conversely, there were some not fully familiar with research, who over-estimated the degree of 'control' that could usefully be exercised on staff activities.

Finally, the CRC Program is highly competitive, with bids competing with others from across the economy. It is critical for the success of industry-based CRC bids that all parties involved in a bid are united in purpose and strong in commitment. There is little doubt that future success in attracting support from the CRC Program and other competitive government programs demands that the sugar industry and its research providers unite to put forward strongly-supported bids, like the one that went forward for CRC Sugar in 1994.

**What needs to be done in the future**

The key gap that will be left when CRC Sugar's term concludes later this year will be in research to improve the industry's environmental management. Increasingly, the industry needs to address environmental issues in an integrated systems context that considers the economic, social and environmental aspects of operations: the 'triple-bottom-line' approach. In that way, the inevitable trade-offs between competing options can more effectively be identified and assessed.

In recent years, while CRC Sugar has accounted for only 14% of the total industry investment in R&D, it has accounted for about 65% of the industry's investment in environmental research (R&D Alliance 2001, unpublished data). While CRC Sugar has made a major contribution, it would be unrealistic to believe that there is not a major need for ongoing research to continue to improve environmental performance. In the short term, the industry can expect a 'period of grace' as it adjusts to the commercial pressures it faces. However, pressure to further improve environmental management, particularly in catchments draining to the Great Barrier Reef World Heritage Area and other sensitive ecosystems will inevitably return—probably as soon as the next environmental 'outrage' is featured in the media.

The gap in environmental research will manifest in two ways. Firstly, some of the additional funds for environmental research that were leveraged in over the past eight years will inevitably be lost. Secondly, and equally importantly, much of the future research will be undertaken outside the industry by organisations whose primary focus is more on sustainable natural resource management and environmental protection than sustainable sugar production. Thus, there is the risk of a return to the days when the industry only heard about sensitive environmental research findings through the media. While some in the industry were not always keen to hear about CRC Sugar research findings on environmental issues, CRC Sugar was committed to working constructively with the industry to identify solutions to improve environmental management.

The future is brighter for one major area pioneered by CRC Sugar: whole-of-industry approaches to securing operational efficiencies in cane production and supply. In the short term, the cane supply scheduling research and associated work aimed at efficiencies in deploying harvest and transport infrastructure will continue with support from CSIRO, SRDC, and the Mackay, Maryborough and Mossman industries. Meanwhile, the recent re-organisation of SRDC's operational plan has institutionalised a framework for addressing systems issues in a 'holistic' or whole-of-industry context. Among the areas where there remains major ongoing need for systems research is the sustainable management of water resources: rationalising use for competing purposes, improving the efficiency of water use, and minimising adverse effects of industry operations on water quality.

In the area of sustainable nutrient management, there now exists a heightened awareness of the need for fertiliser applications to take into account the inherent fertility of the soil, the likely crop demand for nutrients based on climatic constraints and availability of irrigation, the fertiliser replacement value of mill muds and biosolids, and the re-cycling of nutrients under GCTB. There is also improved understanding of the processes involved in the dynamics of nutrient cycling, much of it captured quantitatively in models. There remains a need for translating this information into simpler tools for deciding what and how much to put on, and when, in specific situations.

While CRC Sugar researchers and students played a key role in teasing out some of the key elements underlying the downward temporal trend in CCS in the wet tropics, the work has been necessarily strategic. Important advances in understanding were made in understanding the effects of lodging and suckering on productivity and in turn, on some pre-disposing factors. Likewise, the

improved understanding of the dynamics of nutrient re-cycling under green cane trash blanketing has raised the prospect that the seasonal timing of nutrient release might in some circumstances delay crop maturity, lower CCS and/or promote suckering. Considerable further agronomic and/or breeding work remains to clarify the processes and to develop practical solutions.

CRC Sugar achieved some success in its goal of strengthening research and training capacity in the north. Several CRC Sugar staff at regional centres will remain employed in the industry. However, current funding challenges militate against a net increase in R&D capacity in the north. Meanwhile, the gains in capacity in sugar production research at JCU are likely to be transitory. The challenge remains therefore to strengthen research and training capacity in the regions where the industry operates, rather than in Brisbane.

**CRC Sugar's legacies**

Among CRC Sugar's achievements are several legacies that will survive the Centre. In several regions, the industry has seen the potential opportunities of the whole-of-industry approach for securing gains in operational efficiencies and will take the work forward beyond CRC Sugar. Mackay Sugar has already seized the opportunity to build on and move beyond CRC Sugar's work on cane supply scheduling and harvest/siding rosters, putting in place online real-time monitoring of cane supply and transport operations and grower-miller interaction capability. There is potential for this type of system to deliver significant operational efficiencies and enhance grower access to benchmarking information.

The industry for the first time now has a reasonably comprehensive science-based appraisal of its environmental footprint. It provides the basis for putting in place environmental management that will help allay community concerns. The process has not always been comfortable for those involved, and how effectively this information is used to position the industry moving forward remains to be seen. However, as noted by Hildebrand (2002), the industry will be better served by taking a constructive approach that engages with the wider community on environmental issues. CRC Sugar's experience in working participatively with the NSW industry, to improve management of acid sulfate soils, provides a tangible example of how a constructive approach can change perceptions of and within the industry in relation to sensitive environmental issues.

Another legacy will be the ongoing engagement of those organisations that were drawn more fully into sugar research through CRC Sugar, most notably the CSIRO, the Department of Natural Resources and Mines, and the universities. These organisations have collectively provided a richer array of skills and capacity than previously existed. While the level of ongoing engagement of these organisations will depend on the availability of matching operational funding in place of that through CRC Sugar, they will provide a useful buffer to the current contraction in the industry's research capacity.

The capacity building through CRC Sugar's education program is an important if intangible longer-term legacy. Several of the postgraduate students already have jobs in the industry, while others work for organisations that undertake sugar research as part of a wider portfolio. Yet others are working in government agencies whose policy deliberations can influence industry operations. Because these students now have stronger understanding of the industry and its sustainability challenges, they can make better contributions. Meanwhile, the >500 trainees who have attended workshops and short courses are better placed to handle sustainability challenges than before.

CRC Sugar has also contributed to a significant shift in attitudes and perceptions on how research on difficult and complex industry issues is best conducted. Three ideas in particular will

persist beyond CRC Sugar: the whole-of-industry systems approach to dealing with complex issues, the value of research partnerships with end-users and the potential synergies from collaborative, multi-disciplinary research. As noted earlier, the integrative, systems approach pioneered through CRC Sugar has now been partly 'institutionalised' with the re-organisation of the SRDC program into a systems-based structure. Meanwhile, the collective success and achievements of the 13 organisations that comprise CRC Sugar have provided convincing evidence that they, and through them, the industry itself, have been able to achieve much more through collaborative R&D partnerships, than had they continued to operate in isolation of each other. Many of the collaborations developed through CRC Sugar will continue, albeit at perhaps a reduced level, and there is unlikely to be a return to the often-adversarial culture that prevailed before and during the early days of CRC Sugar.

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