CANE SUPPLY OPTIONS ANALYSIS FOR MAXIMISING WHOLE INDUSTRY PROFITABILITY. A CASE STUDY FOR MACKAY

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ABSTRACT

Opportunities exist for increasing industry profitability in the Mackay region through alternative cane supply schedules that exploit differences in CCS and cane yield at harvest date, found across the Mackay region and across individual paddocks on a farm. Research within CRC-Sugar Subprogram 3.2 produced the models needed to conduct options for alternative cane supply arrangements. With Mackay as a case study, and through participatory research with the Mackay Cane Supply Options Analysis Group (MCSOAG), key on-farm input data of CCS and cane yield response to harvest date and off-farm constraints in harvesting, transport and milling were developed for the model. Options analysis showed potential gains in profitability of $13M per year were possible in Mackay, without increased expenditure on capacity. Given an agreement for pilot implementation during harvest 2000, a pathway to implementation was developed through a process of workshops using action research. Some barriers to implementation were addressed, as well as a process that would lead to a further uptake after 2000. Eighteen harvesting groups and nine growers piloted alternative cane supplies in the 2000 harvest season, and while proof of concept was not established due to adverse conditions, piloting continued in 2001. Through evaluating the pilots of the 2000 harvest season, key learnings were incorporated to improve the process for 2001.

SUMMARY

Scheduling the supply of cane to sugar mills is an important determinant of whole industry profitability and competitiveness. Opportunities exist for increasing industry profitability through alternative cane supply schedules that exploit differences in CCS and cane yield at harvest date, found across geographical zones and across individual paddocks on a farm. Developing the capability to capture this opportunity required groundbreaking research combining four key components – operations research and statistical modelling to integrate across the industry value chain, novel implementation pathways, industry cooperation and grass roots participation. In the Mackay case study, the research team worked closely with the growing and milling sectors, with the aim of developing mutually beneficial alternative methods of supplying cane to the mills. While drawing heavily on past and concurrent component research, the approach goes beyond such traditional approaches to consider whole-of-industry issues. It does this by using innovative processes that together facilitate co-learning and subsequent implementation by the various sectors of the industry.

The work required development of optimisation models (through CRC-Sugar, Subprogram 3.2) capable of examining the scope for enhancing whole-industry profitability within a mill region through better scheduling of the harvest of individual fields. The model accounted for CCS and cane yield consequences of harvest date, age, productivity zone, variety and crop class. Costs of growing, harvesting, transport and milling were also incorporated. Off-farm constraints associated with wet weather harvest disruptions, harvesting and transport capacity, and crushing capacity (including mill size and season length) were integrated into the optimisation model. These constraints were modelled using the expert knowledge within Mackay Sugar and Canegrowers. Modelling the on-farm inputs and off-farm constraints using the Mackay case study in this project has provided a blueprint for other regions. The optimisation model gave rise to an enormous number of decision variables and required the development of novel heuristic mathematical techniques capable of optimising in excess of 500,000 integer variables. This component of the work provided the capability to assess the best harvest date and crop cycle length of individual paddocks. It has also provided the capability to assess options that exploit regional or geographical variation in cane yield and CCS at different harvest dates.

With the options analysis tools on hand, the next task was to evaluate alternative cane supply arrangements for the Mackay case study. This was done in close partnership with relevant sections of the industry, since alternative cane supply options have consequences across the sugar system. Average gains in profitability of up to $158 per hectare per year were achievable through geographical harvesting that exploits the geographical differences in CCS and cane yield at harvest date. For the Mackay region (four mills) the potential gain in industry profitability was $13M per year. Through workshops, some ground-truthing was performed at mill and grower level to assess if the options could be implemented.

The next stage was pilot implementation of agreed options. These options were: geographical harvesting across groups, geographical harvesting within a group, and on-farm optimisation. Within the Mackay region, there were 18 harvesting groups (about 60 farms) who piloted geographical harvesting across groups and 9 growers who piloted on-farm optimisation in the 2000 harvest season. From the evaluation of the harvest 2000 pilots, there were considerable learnings to improve piloting in 2001, and indicative (but not conclusive) results of benefits for growers who followed the harvest schedules closely. The learnings from 2000 were incorporated into the piloting process, which is being repeated in 2001 due to the very adverse season in 2000.

BACKGROUND

Moving into the 21st Century, increasing cost/price pressure has forced the Australian Sugar Industry to seek innovative avenues for increasing profitability. In response, the milling and growing sectors are seeking ways to make more profitable use of their capital, infrastructure and land resources. Past advances have come from improvements in technical and cost efficiency of different industry sectors, but the challenge is to achieve quantum gains in competitiveness by exploiting interdependencies across the value chain. This involved modelling the key drivers and constraints across the value chain from cane growing on-farm, harvesting and transport systems to milling cane to produce raw sugar. No previous technology was available to the industry to address the complexity of value chain optimisation, nor were pathways for implementation developed that accounted for the differences in the growing, harvesting and transport and milling sectors. Whole-of-industry research has been minimal and yet it may offer scope for the delivery of even greater benefits.

One aspect of the whole-of-industry approach is concerned with cane supply management – an aspect that has implications for all three industry sectors, production, milling, and marketing. Deeply entrenched practices-such as operational cultures, use of capital and infrastructures, and equity arrangements for all cane growers, may have to be questioned if greater profitability for the whole industry in a region can be demonstrated. Research in this area required new tools and new skills for integration and analysis of information in order to evaluate alternative cane supply practices. However, it also drew heavily on the knowledge and understanding built up over the years on the individual components of the production chain through the activities of researchers in CRC-Sugar, other CRC-Sugar Programs and other organisations.

Assessing opportunities for alternative cane supply arrangements for enhancing profitability was achieved through optimising the harvest date of sugar cane, accounting for geographical differences in cane yield and CCS for different harvest dates throughout the harvesting season. In terms of complexity, a mill region contains up to 10,000 paddocks on over 450 farms and harvested by up to 100 harvesting groups cane according to a fixed rotation so all farms are harvested proportionally over time. Harvest schedules using a fixed rotation do not allow the exploitation of geographical variation in CCS and cane yield at harvest date, meaning that productivity and revenue are sacrificed. Optimisation modelling has shown that by not using a fixed rotation and by exploiting geographical differences in productivity,

significant gains in profitability are possible. Research has also required participatory action research to realise the benefits of identified and agreed cane supply options for enhanced profitability. Realising the profitability gains in the Australian sugar industry is a difficult challenge since:

- Individual farms are privately owned and farmers have for a long time been governed by regulated equity to ensure each farmer and harvester cuts a constant amount of cane throughout the harvest season.
- Profitability gains for the growers can mean losses for the milling sector and vice versa.
- There are physical constraints associated with harvesting, cane transport (road and rail) and milling which inhibit some of the potential gains. Implementation may be impossible if the constraints are not properly accounted for.
- The strategic research needs an integrated multi-disciplinary approach to address the industry issue. This includes disciplines of operations research, statistical modelling, economics, crop physiology, expert systems modelling, agronomy and change management.
- Socio-economic barriers for change from the current system in harvest management are strong in the Australian Sugar Industry, and acceptance of change varies significantly across farmers and harvesting groups.

Addressing these issues is a three-fold approach, with the ultimate aim implementing cane supply options leading to increased profitability and international competitiveness of the Australian sugar industry:

1. Strategic Research

- To develop cane supply optimisation models under CRC-Sugar Program 3 (Higgins, 1999a,b), that encapsulate on-farm productivity responses to harvest date and crop age and constraints associated with harvesting, transport and milling capacity to allow evaluation of alternative cane supply options.
- To develop implementation strategies (Muchow *et al*., 2000), pilots study schemes, software tools to assist implementation, and a process for monitoring and evaluation to realise industry benefits from changed cane supply practices.

2. Case Study Delivery

- In close participation with the MCSOAG (as an aim of this project) and the Mossman sugar industry, to refine optimisation models and develop optimal cane supplies and options analyses leading to implementation for increased profitability. A purpose of the case studies is to achieve proof of concept in practice, which may lead to a wider industry uptake.

3. Wider Industry Delivery

- To assist other Australian mill regions in evaluating different cane supply and harvest scheduling options and implementation of these, given the outputs from strategic research and case study delivery.

OBJECTIVES

The aim of the project was to gather and analyse data, and conduct options for alternative cane supply arrangements for increased profitability in the Mackay region, in partnership with key stakeholders. Through the application of systems agronomy and operations research techniques, key options analysis for exploiting geographical differences in CCS and cane yield at harvest date were delivered, as agreed by the local industry. Original project objectives were over-achieved through research for developing pathways towards implementation and large-scale piloting in the 2000 harvest season.

RESEARCH METHODOLOGY

The project required a multidisciplinary research approach. Systems agronomy was applied to gather data for time of harvest field experiments, to produce knowledge on the CCS and cane yield consequences of harvesting cane outside the traditional harvest season. Statistical analysis and database technologies were used to develop a consolidated database for historical block productivity. Data analysis techniques were required to match data from block and rakes files, assess the quality of the data including error checking, and to look at geographical, varietal and crop class trends in CCS at harvest date. These data analyses would contribute to the ground-truthing of the cane supply options analysis, as well as providing miscellaneous new knowledge such as the performance of fallow crops versus ploughout replant (Muchow *et al*., 1998a). The integration of the data from time of harvest experiments with block productivity data, would contribute towards providing the capability to assess cane supply options that go beyond the traditional season start and season length.

Analysis of whole-of-industry options for alternative cane supplies required a methodology that was able to: (i) provide a common basis for comparing options; (ii) assess potential gains in profitability for one option versus another; and (iii) simultaneously account for complex cost structures and constraints on the system within any given option. To address these requirements, operations research techniques for optimisation were used. The common basis for comparing options was through optimal harvest dates of sugarcane for each option. To do this, a large-scale integer programming model was developed to optimise the harvest date of every farm paddock within a mill region. Also optimised for each paddock was the number of ratoons before ploughing out and planting a new crop. Full mathematical details of the model are found in Higgins (1999a) and the full paper is shown in Appendix A. The resulting model, which can contain in excess of 500,000 integer variables (in the case of Marian mill), and millions of constraints, required a novel solution technique to be developed. A heuristic technique was developed to solve the sugarcane optimisation model (Higgins, 2001) and is generic enough to be applied to other industrial optimisation problems.

DETAILED RESULTS AND DISCUSSION

1. Mackay Cane Supply Options Analysis Group (MCSOAG)

The scientific research and case study delivery of options for alternative cane supplies was conducted through participatory research, driven by the MCSOAG. This group, which plays a key role in determining the direction of the research, comprised of representatives from CANEGROWERS Mackay, Mackay Sugar, Caneharvesters and CSIRO/CRC-Sugar. During the earlier stages of this project, the MCSOAG met two to three times per year to develop the tools using the Mackay case study. During the development of a pathway towards implementation during 1999/2000, the MCSOAG met four to six times per year.

2. Time of Harvest Experiments

All time of harvest field experiments have been completed for the 1998–1999 and the 1999-2000 ratoon crop cycles. Data was collected and analysed for six on-farm field experiments and the summaries for each experiment in 2000 have been included in Appendix B.

All crops were successfully ratooned in 1999 under dry conditions and the performance of these crops in 2000 (Table 1) is compared with 1999 performance (Table 2). The 2000 performance was affected by an outbreak of orange rust and by rats to some extent. The performance in 1999 was affected by wet harvesting conditions in 1998 and it is likely that this had some carry-over effect in both 1999 and 2000. Clearly 1999 and 2000 were not conducive to obtaining excellent data but some important trends are evident.

The startling trend in the 2000 data was for cane yield to be much lower with harvest date in the middle of the normal harvesting season compared to harvest dates earlier than the current

commercial harvest season (Table 1). However, CCS was always higher with later harvest date (Table 1). This meant that the effect of harvest date on sugar yield was variable with relatively small differences between harvest dates compared with differences in cane yield and CCS (Table 1). Crop age was very similar at around 12 months for each of the harvest date comparisons. Hence, these responses are primarily attributed to time of harvest independent of crop age.

Table 1. Harvest date treatments achieved in 2000 and their total crop productivity response.

Farm and Location	Start Date	Harvest Date	Cane Yield (t/ha)	CCS	Sugar Yield (t/ha)
Racecourse 150 Sunnyside	04-05-99	17-05-00	61.7	11.7	7.5
	04-08-99	24-07-00	44.1	15.1	6.7
Racecourse 155A Sunnyside	04-05-99	17-05-00	65.0	11.8	8.2
	10-08-99	06-08-00	52.4	14.8	7.9
Farleigh 172 Dumbleton	15-04-99	17-04-00	54.2	7.4	4.4
	15-10-99	20-09-00	32.7	16.6	5.5
Pleystowe 290 Palmyra	05-05-99	18-05-00	72.4	10.5	7.9
	03-06-99	13-06-00	58.5	12.8	7.6
	30-08-99	01-08-00	51.1	14.6	7.6
	11-10-99	01-09-00	42.1	14.9	6.7
	08-11-99	31-08-00	37.1	14.4	5.7
Marian 446 Finch Hatton	04-06-99	14-06-00	72.8	10.9	8.1
	11-10-99	20-09-00	47.0	16.2	7.0
Marian 268 Gargett	17-05-99	08-06-00	69.9	13.1	9.1
	20-09-99	20-09-00	54.6	17.4	9.2

Table 2. Harvest date treatments achieved in 1999 and their total crop productivity response.

Farm and Location	Start Date	Harvest Date	Cane Yield (t/ha)	CCS	Sugar Yield (t/ha)
Racecourse 150 Sunnyside	07-04-98	04-05-99	97.5	15.4	14.1
	03-08-98	04-08-99	67.5	18.6	12.7
Racecourse 155A Sunnyside	07-04-98	04-05-99	96.7	14.7	13.5
	11-08-98	10-08-99	84.2	18.5	14.5
Farleigh 172 Dumbleton	14-04-98	15-04-99	140	9.44	13.8
	28-10-98	15-10-99	74.7	18.1	13.5
Pleystowe 290 Palmyra	16-06-98	05-05-99	121	10.1	12.5
	25-06-98	03-06-99	134	12.7	18.9
	06-09-98	30-08-99	129	16.9	22.2
	06-09-98	11-10-99	79.3	19.4	15.6
	06-11-98	08-11-99	-	-	-
Marian 446 Finch Hatton	11-05-98	04-06-99	115	14.6	18.5
	30-08-98	11-10-99	61.4	17.7	10.6
Marian 268 Gargett	28-07-98	17-05-99	126	14	17.1
	27-09-98	20-09-99	66.3	15.6	10.3

The responses obtained in 2000 were very similar to those obtained in 1999 where cane yield and sugar yield were often much higher with April-May harvest dates then with August-October harvest dates (Table 2). These responses were primarily attributed to wet harvesting conditions in August to October in 1998 affecting ratooning ability whereas the early cut crops ratooned under better conditions. These effects appear to have carried forward into the 2000 season, but the 2000 season was also compounded by orange rust. These results are somewhat unexpected, but dependent on seasonal conditions, early harvest dates can be more productive. It is not possible with the type of seasons sampled in 1999 and 2000 to make comment on the wider applicability of these results.

However, CCS was always much higher with later harvest date (Tables 1 and 2). The CCS profiles with harvest date showed typical trends, but there were significant location (geographical) differences for a given harvest date (Figures 1 and 2). These geographical differences were much stronger in 1999 (Figure 2) than in 2000 (Figure 1). Also for a given harvest date CCS was generally lower in 2000 and 1999. These differences between years may be attributed to both orange rust and different climatic conditions.

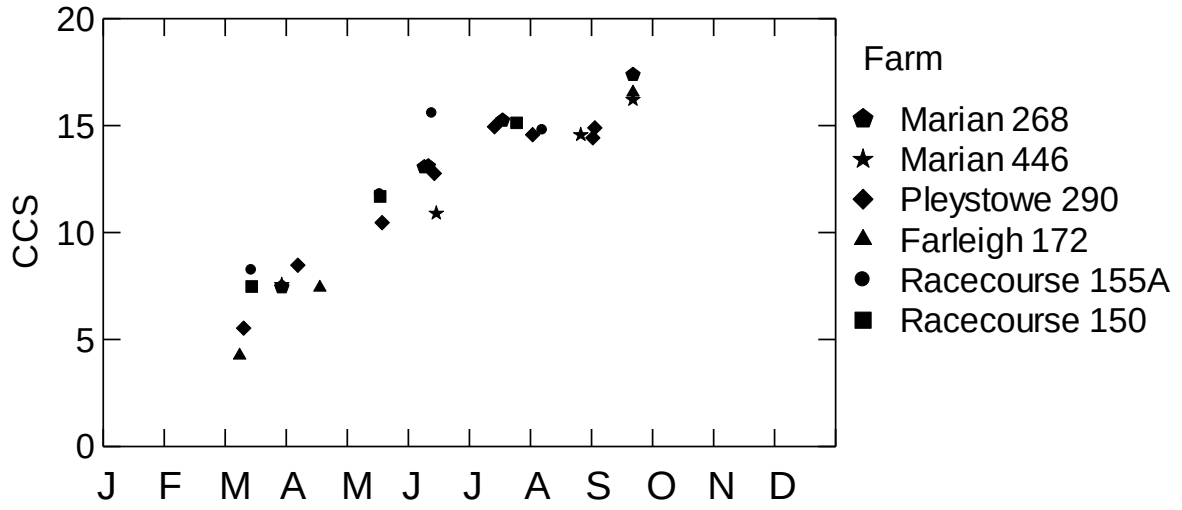

Figure 1. CCS *vs* harvest date for time of harvest experiments conducted in Mackay in 1999-00. CCS was determined on hand-sampled clean millable stalks.

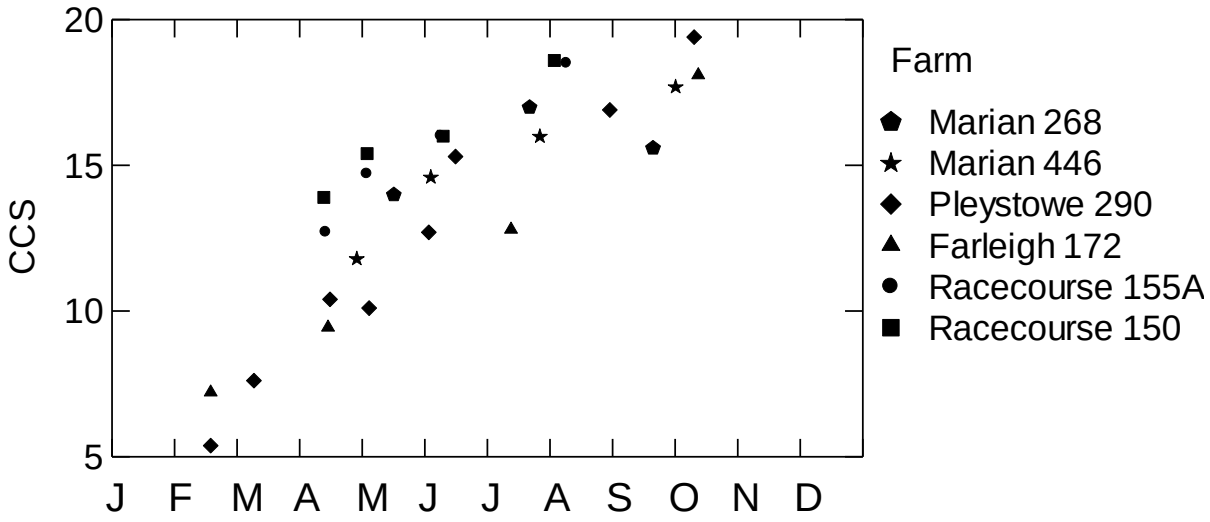

Figure 2. CCS *vs* harvest date for time of harvest experiments conducted in Mackay in 1998-99. CCS was determined on hand-sampled clean millable stalks.

3. Block Productivity Database

Block productivity data was collected and consolidated for 1992 to 2000. Consolidation required matching rakes and paddocks files to obtain the necessary data fields of: Mill, Zone, Farm, Split, Block, Paddock, Variety, Class, Area, Harvest date, TC/h, CCS, Pol and Brix. The data were extensively error checked before being used for any application. Block productivity data was used for a number of key applications as follows:

- To develop key inputs for the cane supply optimisation model of CCS and cane yield response to harvest date, given the effects of crop class, variety, harvest date in the previous year and productivity zone. Other key inputs for the optimisation models were the complete list of paddocks for a mill region for an approaching harvest season that were to be optimised to maximise industry profitability.
- Having the consolidated database allowed various data analyses to be performed. These include displaying the effects of CCS by harvest date by zone or CCS by crop class by date. Such data analyses were an integral part of this project for providing ground-truthing by showing that the options analyses are supported by historical data.
- It allowed other issues to be address such as the yield differences between a crop after fallow versus ploughout replant (Muchow *et al*., 1998a), as well as assessing the consequences of different relative CCS cane payment schemes.

4. Cane Supply Options

Through CRC-Sugar, a cane supply optimisation model was developed that is capable of examining the scope for enhancing whole-industry profitability within a mill region through better scheduling of the harvest of individual fields. Data were required to account for cane yield and CCS consequences of harvest date, age, geographical location and crop class. Data was also required to account for off-farm constraints associated with wet weather harvest disruptions, transport capacity and mill crushing capacity. Through MSA001, this information was collated for the four Mackay sugar mill regions in the form of historical block productivity data for on-farm consequences and expert knowledge for off-farm constraints.

In the case study involving the four Mackay mill regions, the key options analyses were conducted as agreed by the local sugar industry at Mackay. Each of the options led to increased profitability through the process of moving away from the current farm/harvesting equity system and harvesting cane to make best use of the geographical differences in CCS and cane yield at harvest date.

Option 0-Existing farm and harvesting equity system within the mill region.

Option 1-Removal of farm and harvesting equity:
The amount of cane that a harvesting group cuts in any one day is only restricted by road/rail transport and milling capacities. If a harvesting group contains farms that are considered high late in terms of CCS relative to the mill average, then the harvesting group can cut more cane per day during this part of the harvest season, thus increasing profitability for those farms. A possible drawback of this option is the uneven workload/workforce for the harvesting group. Early during the harvest season, the harvesting group may cut 6 hours/day and 4 days/week, while later in the season, it may be 12 hours/day and 6 days/week.

Option 1.1-All farms equal at 85%:
This is the same as Option 1, except all farms within the mill region must have 85% of their cane cut when the harvest season is 85% complete. Wet weather is considered a greater risk late in the season. Since growers do not want to be disadvantaged with this risk, they prefer to be equal with others at a certain point of the harvest season and the 85% was agreed by the MCSOAG.

Option 1.2-Removal of farm and harvesting equity for the first and last 4 weeks of the harvest season:
Some mills perceive that most of the gains of Option 1 would come from optimising harvest date of cane by considering only the first and last four weeks of a harvest season. This is because the geographical differences in CCS and cane yield are greatest during these time periods.

Option 1.3-Unlimited transport capacity:
Since transport capacity is an issue, there is key interest (for long-term planning) to know the degree to which transport restricts the profitability potential from removing farm and harvesting equity.

Option 2-Removal of farm equity:
Within a harvesting group, there are no limits on the amount of cane that can be taken from a farm at any time of the harvest season, provided it meets the harvesting equity requirements. For example, a harvesting group may have farms in a district that produces more sugar earlier in the season relative to the other farms. In this case, the harvesting group would primarily cut cane from these farms earlier, thus increasing profitability for those farms without decreasing profitability for the other farms. This option primarily benefits farms where the harvesting group contains farms in contrasting high early versus high late CCS areas.

The average profitability gains, using the optimisation model, for each option versus the current system (Option 0) are shown in Table 3 with a sugar price of A$250/t.

Table 3. Average model gains in industry profitability and productivity for each option versus current system (Option 0).

Mill	Option	Average gain in		
		Industry Prof. ($/ha)	Grower Prof. ($/ha)	Sugar Yield (t/ha)
Farleigh (22442 ha)	1	77	60	0.45
	1.1	54	43	0.29
	1.2	44	35	0.26
	1.3	86	66	0.50
	2	16	13	0.09
Marian (26076 ha)	1	53	42	0.27
	1.1	44	34	0.26
	1.2	29	24	0.16
	1.3	55	43	0.32
	2	11	9	0.06
Pleystowe (20813 ha)	1	119	101	0.66
	1.1	97	85	0.53
	1.2	81	74	0.44
	1.3	125	105	0.69
	2	45	44	0.24
Racecourse (22153 ha)	1	119	95	0.63
	1.1	77	65	0.41
	1.2	70	59	0.38
	1.3	119	95	0.63
	2	26	24	0.15

The consequences of Option 1 to sugar price are contained in Table 4 below. These options analyses along with consequences of year-to-year variability were delivered to the MCSOAG Group Meeting in November 2000 and will be submitted for publication in a scientific journal.

Table 4. Gains in profitability for Option 1 across two sugar prices.

Mill	Sugar price $350/t		Sugar price $250/t	
	Industry Prof. ($/ha)	Grower Prof. ($/ha)	Industry Prof. ($/ha)	Grower Prof. ($/ha)
Farleigh	105	77	77	60
Marian	69	49	53	42
Pleystowe	158	134	119	101
Racecourse	157	119	119	95

5. Pilot implementation

After the extensive ground-truthing process through the MCSOAG, as well as by local growers, an agreement was made for initial pilot studies in the 2000 harvest season. To achieve implementation, creative solutions workshops were held during the latter half of 1999, to develop a pathway that would allow barriers to be overcome for effective implementation in the 2000 harvest season. Answers were needed to the key question: "How would the alternative cane supplies be implemented?" As a result of the creative solutions workshops, a decision was made to implement Option 1 through a harvesting entitlement exchange scheme (HEES). If a harvesting group primarily had farms in a high early CCS region, HEES would allow the group exchange for extra bins early, and exchange out later in the season, thus overcoming the equity barrier. Appendix C contains the HEES package that was sent out to all 1,300 growers and harvester contractors in the Mackay region, inviting participation. Other achievements from the creative solutions workshops were addressing how to overcome implementation barriers and the agreement that implementation was going to be evolutionary rather than revolutionary. An ASSCT paper was presented in 2000 (Muchow *et al*., 2000) covering the participatory research leading to the development of the HEES. The paper is a major output from this project and is contained in Appendix D. Harvesting groups identified by the MCSOAG as suitable pilots were followed up with interviews. During March 2000, 60 harvesting groups were interviewed and 25 of them submitted a HEES application. The original aim was to have about a 10% uptake in the 2000 harvest season, as this would be a critical mass that would quickly lead to a further uptake. While the emphasis was on HEES, on-farm optimisation was also piloted. This only required participation from growers (not harvesters) and workshops were held late May to provide information and invite participation. As a result, 30 growers indicated that they wished to pilot. For these growers to participate, harvest schedules produced from the optimisation model needed to be presented in a format for easy interpretation. While the model can produce specific decisions on when to harvest each farm paddock, it was not flexible for on-farm practicalities, and it was not in a form that a grower or harvesting contractor could easily implement. This was overcome through the development of a database software (developed under SRDC CTA044) and an early version was used for the 2000 harvest season.

By the end of the harvest season, there were 18 harvesting group pilots for option 1 remaining, and 9 grower pilots for on-farm optimisation. This was a considerable drop from the pre-season commitments of 25 groups for HEES and 30 growers for on-farm optimisation. The attrition was due to the very adverse season caused by Q124 rust, rats, early rain and low cane yield. However, feedback from the participating pilots was positive with nearly all wishing to continue in 2001.

In terms of providing proof of concept, the option 1 pilots (geographical harvesting through entitlement exchange) for the 18 groups did not show any gain in CCS. This was due to: (a) most groups not exchanging as per the schedules to increase CCS, (b) a very short season of 15 weeks where as the model schedules represented a 20 to 22 week season, and (c) the actual tonnes cut not representing the exchange due to highly variable rising and falling estimates. With regards to (a), an argument may then be that a voluntary HEES does not produce pilots to provide proof of concept for geographical harvesting to increase profitability.

For the nine growers (16 farms) in the on-farm optimisation pilots, 5 farms had a good compliance with the optimal schedule (*i.e.* harvest more than 80% of paddocks within three weeks of model schedule), for which four of these had an improved CCS relative to the mill in 2000 compared to 1999 and 1998. While this is promising, it is not conclusive due to the low numbers with a good compliance. It is now extremely important that participating farms in the pilot study during 2001 to follow the optimal harvest schedule closely throughout the entire season so that the benefits of on-farm optimisation can be estimated accurately with a reasonable degree of confidence. Full details of the piloting process (Higgins *et al*., 2000b) are contained in Appendix E.

Several advancements for 2001 arose from the pilots, including an improved piloting process and better tools to meet the information needs of the growers and harvesters. This was further motivated by the wish for nearly all existing pilots of the 2000 harvest season to continue in 2001.

As proof of concept was not achieved in 2000, due to the very adverse season, the MCSOAG agreed to repeat the pilots in 2001. Given the learnings from 2000 harvest season pilots, the group agreed that:

(1) The focus needed to be on a smaller number of pilots. However, a great deal of attention would be given to these growers to ensure that compliance with model schedules was achievable and that gains to the growers would be substantial. This meant that harvesting groups and growers would be invited to participate in the pilot study, according to their potential gains and likelihood of compliance.

(2) From experiences with the harvesting and transport logistical complexity in implementing option 1 through HEES during the 2000 harvest season, the focus needed to be on establishing option 2 pilots for geographical harvesting. These pilots included whole harvesting groups or growers who owned farms in contrasting high early versus high late areas. It was expected that harvesting groups would eventually re-form to take full advantage of option 2. If groups did form this way, the gains in profitability for option 2 would be close to option 1, since harvesting equity would no longer be a barrier for exploiting geographical differences in CCS and cane yield at harvest date.

(3) Significant enhancements were needed to the optimisation modelling and end-user tools, to enhance use and likelihood of achieving the potential gains in profitability. As a result of major research in CRC-Sugar Subprogram 3.2 and SRDC CTA044, the key input of CCS response to harvest date was improved through statistical modelling techniques. This provided more relevant harvest schedules at grower level, which was acknowledged by stakeholders in Mackay, Mossman and Maryborough. The user-friendly tools developed in CTA044 were enhanced to: 1) automatically develop harvest schedules for growers according to the optimisation model; 2) allow the grower to fine tune these given on-farm practicalities; 3) provide schedules in a GIS farm map format for easier interpretation by growers and harvester contractors; and 4) provide summary graphs of historical CCS trends at grower level to assist the grower on the decision to implement alternative cane supplies. This has gone a long way towards increasing grower confidence in all mill

regions where pilot implementation is taking place during 2001, which is reflected in the large number of pilot farms participating, given the difficulties from 2000.

Through the project officer (Mr Gerry Turner) based in Mackay and funded by this project, the pilot recruitment process took place through the first half of 2001. During the earlier part of 2001, the emphasis was on identifying harvesting groups and growers that were most likely to benefit under option 2. This was achieved using (a) statistical methods to assess if the farm is high early CCS versus high late, and (b) tonnes of cane that would be exchanged within the group. This selection procedure was integrated with a ranking of the likelihood that the harvester contractor would co-operate, which was assessed using expert knowledge of the chief field officers. It is anticipated that putting a major effort into selecting suitable harvesting groups and growers for pilot participation will help maximise the probability of establishing proof of concept, leading to wider uptake.

Through the piloting process pre-harvest season 2001, twenty pilots were confirmed for option 2. Most of these pilots were individual growers who wish to conduct geographical harvesting across their own farms. Of these option 2 pilots, most will attempt an option 3 as well. There are two option 1 pilots through the harvesting entitlement exchange scheme. The grower validation workshop, for those who participate in the pilot scheme, will be held on 27 November 2001.

ANALYSIS OF OUTPUTS AND OUTCOMES COMPARED TO OBJECTIVES

Project Objectives

This section lists project objectives, along with key outputs and outcomes associated with each.

Objective 1. Develop a partnership approach to the prioritisation of research needs, discussion and interpretation of research results and analysis of cane supply options by establishing a consultative process involving industry representatives and research staff, with a case study in the Mackay district.

Output
A MCSOAG that met at least twice per year and drove the research in the Mackay region, ensuring the delivery on the projective objectives and milestones.

Outcome
An acceptance within the Mackay region for a whole of system research approach and that alternative cane supplies has the potential to substantially increase profitability.

Objective 2. To obtain data on seasonal and within district variation in productivity in relation to time of harvest using on-farm field experimentation in the Mackay district as a case study to validate models and options analysis being developed in CRC-Sugar.

Output
Time of harvest field experiments completed for 1998 to 2000 showing the CCS and TC/h for six experiments at various harvest date by age combinations, which will provide key inputs for cane supply options outside the current harvest start and finish times.

Objective 3. Develop databases on crop productivity to facilitate effective use of tools and models being developed in CRC-Sugar to evaluate different crop scheduling options to assist industry decision-making.

Output
A consolidated and validated database for historical block productivity data (1992 to 2000), which is available for cane supply optimisation and other research.

Outcome
A common understanding to the degree of geographical variation in CCS and TC/h that exists within the Mackay region.

Objective 4**.** Develop options using operations research methodology to take advantage of the spatial and temporal variation in productivity to improve industry profitability and competitiveness using the Mackay district as a case study.

Outputs
A Mackay cane optimisation model, incorporating the local constraints on harvesting, transport and milling, and able to deliver options for alternative cane supply arrangements.

Alternative cane supply options, as specified in partnership with the Mackay industry, showing the potential gains in profitability (grower and industry) from mill level down to grower level.

Outcome
A common understanding throughout the industry of the average potential gains in profitability for different options exploiting geographical, crop class and harvest age differences at harvest date that occur in CCS and cane yield.

Objective 5. Specify data requirements for extension of operations research methodology developed on cane supply options analysis to other cane growing districts in the Australian Sugar Industry.

Output
A document specifying the data requirements necessary to extend the cane supply options capability to other mill regions.

Outcomes
Efficient adaptation of the tools to the Maryborough and Burdekin regions, resulting in the delivery of preliminary options ahead of schedule.

Timeframe from start-up to implementation reduced from 4 years to one year, for other mill regions.

Additional Outputs

A draft process that would allow a progressive uptake of alternative cane supplies in the Mackay region, by overcoming barriers for implementation.

Pilot implementation of alternative cane supply options in the 2000 harvest season, along with a documented evaluation showing gains in profitability and key learnings to improve the process in 2001.

Provision of knowledge on how to implement different options for alternative cane supply arrangements, thus overcoming key implementation barriers in risk, equity and harvesting/transport logistics.

Provision of knowledge on a range of potential barriers for implementation that need to be addressed through further research, for which the outputs from this research would lead to a wider and faster uptake of alternative cane supplies.

Additional Outcome

An increase in average CCS to most growers who followed the on-farm harvest schedules closely during the pilots of harvest 2000.

POTENTIAL BENEFITS AND LIKELY IMPACT TO THE AUSTRALIAN SUGAR INDUSTRY

The potential gains in profitability of Table 3 have also been assessed for Mossman, Maryborough and the Burdekin. Considering option 1 only, the average potential gains in profitability per year for Mackay, Mossman, Maryborough and the Burdekin are $119/ha (81000 ha of harvested cane), $79/ha (13000 ha), $77/ha (11000 ha) and $235/ha (67000 ha) respectively. This gives a total of $27M for these mills, over a total harvested land of 172000 hectares. Given the Australian sugar industry has 400000 hectares, the potential from option 1 could be approximated as $27M*400000/172000=$63M per year. Further gains are possible from optimising the harvest date of farm paddocks at farm level, exploiting the differences in varieties and crop classes at harvest date.

In the 2001 harvest season, pilot implementation of alternative cane supplies is taking place in Mackay, Mossman and Maryborough. In Mossman and Maryborough, the uptake is about 5 and 15% respectively. The impact in other mills has been the delivery of advanced preliminary options in the Burdekin, with the decision for pilot implementation in Maryborough, and interest from the Tableland, Mulgrave, Tully and the Herbert to explore options for alternative cane supplies. This further interest was partially a result of this project, since the Mackay case study showed the potential benefits and how it could be achieved in other mill areas. The capacity to deliver and implement options for alternative cane supplies to other mill regions is being made available primarily through the development of end-user versions of the tool under SRDC CTA044.

The overall likely impact to Australian sugar industry depends on the level of uptake in each mill region and the time it will take to achieve maximum uptake. Through the evaluation of the pilots of the 2000 harvest season and the process of setting up pilots for 2001, issues were raised that need to be addressed to allow a full mill region uptake. These are listed in the recommendations.

PROJECT TECHNOLOGY

The database software HarvSched, which was developed under SRDC CTA044, was applied to produce harvest schedules for the piloting growers in 2000 and 2001. Issues of licensing, security and patenting are currently being addressed within CSIRO, particularly as the software will be used across the industry. The software does use commercially sensitive block productivity data, which cannot be made available to those who do not have authorised access to the data.

RECOMMENDATIONS

This project, and its linkages with CRC-Sugar, has provided major groundbreaking outputs in the development of optimisation models and delivery of whole-of-industry options for alternative cane supply arrangements. Through the participatory research, the project had major achievements in developing a process for implementation, and piloting the cane supply options with several harvesting groups and growers during the 2000 harvest season. These achievements, which are beyond the objectives of the project, have not been done previously on a whole-of industry project within the Australian sugar industry.

Despite the tremendous progress made with this project, a number of issues arose that need to be addressed for the industry to realise the full benefits from alternative cane supply arrangements. Issues relating to the presentation of schedules, recruitment of pilots and model inputs of CCS and cane yield response to harvest date, are being addressed through SRDC CTA044 and CRC-Sugar. Issues recommended for further research or development are:

- Alternative cane supply arrangements have co-dependencies with decisions made on irrigation, pest management, ripeners, variety selection, best practice harvesting and trash management etc. Concerns raised by growers in the cane supply options pilots of harvest 2000 included the increased cost or difficulty to irrigate a farm if most of the cane is to be harvested in a short time frame (eg 1 month) due to high relative CCS.
- Implementing and realising the full potential benefits of alternative cane supply arrangements may increase the costs and complexity of harvesting and transport. As a consequence, many growers, including those who had significant potential benefits, decided not to pilot alternative cane supply arrangements in the 2000 harvest season. There are two potential avenues to address this issue. Firstly, develop institutions and incentives for harvesters and the mill to uptake alternative cane supply arrangements, despite potential increased costs and complexity. Secondly, to deliver options for integrated cane supply, harvest and transport systems, providing maximum net benefit for the combined system, and potentially leading to a win-win situation across all sectors. An example would be integrating tools for cane supply options, harvester rostering, siding rostering, TO tools (SRI) and so on.
- As an incentive for participating, some growers need to know the overall net benefit from any alternative cane supply schedule, accounting for all socio-economic consequences.
- Historical productivity data limitations in many mill regions currently prevents the ability to extend the tools to all mill regions or to deliver reliable options analysis.

In terms of implementation in other mill regions in the Australian sugar industry, the tools developed for alternative cane supply arrangements are not Plug-and-Play, even given the user-friendly versions developed in SRDC CTA044. A partnership is firstly recommended to (a) formulate the local cane supply issues, (b) assess data quality, and (c) promote the value-adding capability within the local mill region. Given the experiences with the extension of the technology of this project to the Maryborough region, the time form start-up to implementation can be as short as one year.

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PUBLICATIONS RESULTING FROM THE PROJECT

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2. HIGGINS, A.J. (1999b). Solving an extension of the generalised assignment problem found in sugar cane harvest scheduling: A dynamic tabu search approach. *Proceedings Australian Society of Operations Research Conference* **15**: 560-570.
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LIST OF APPENDICES

APPENDIX A. HIGGINS, A.J. (1999). Optimising cane supply decisions within a sugar mill region. *Journal of Scheduling* **2**: 229-244

APPENDIX B. Time of harvest experiments

APPENDIX C. Information Package: Mackay Harvesting Entitlement Exchange Scheme (HEES)

APPENDIX D. MUCHOW, R.C., HIGGINS, A.J., ANDREW, W.J. and HAYNES, M.A. (2000). Towards improved harvest management using a whole industry systems approach. *Proceedings Australian Society of Sugar Cane Technologists* **22**: 30-37.

APPENDIX E. Pilot study evaluation of alternative cane supply options in Mackay sugar region