DEVELOPING CANE SUPPLY AND HARVESTING SCHEDULES THAT ENHANCE WHOLE INDUSTRY PROFITABILITY

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Abstract

An important question for sugar industries worldwide is, "What opportunities exist for modified cane supply and harvest scheduling arrangements to enhance whole industry profitability and competitiveness?" This is a complex issue, especially with vertical and horizontal expansion in production where consideration of crushing capacity and harvest season length are necessary. Given this complexity and the need to consider on-farm consequences on productivity and off-farm constraints related to transport, milling and storage capacity, this paper outlines a research approach to assess the consequences of different harvest scheduling options that integrate across the industry value chain.

The approach has two key features: (i) multidisciplinary research integrating database technology, field experimentation, crop growth simulation modelling and operations research; and (ii) strong participation from industry (growers and millers) at all stages of the research process from initiation to delivery. Through case studies for several locations in the Australian sugar industry, it is shown that manipulation of cane supply scheduling offers the potential to substantially increase mill region net revenue by taking into account spatial and temporal variation in cane yield parameters.

Introduction

The profitability of sugar industries world-wide is testimony to the good management decisions made by cane growers, sugar millers and marketers. Research, development and extension have contributed to this success with improved varieties (Berding *et al.*, 1997), better production systems (nutrient management, Keating *et al.*, (1997); Wood *et al.*, (1997), improved irrigation (Robertson *et al.*, 1997), improved harvesting procedures (Brennan *et al.*, 1997), better milling technology (Allen *et al.*, 1997), and market awareness (Fry, 1997; Males and Clive, 1996)). Despite these improvements to the different components of the industry value chain, sugar industries face increasing cost/price pressure and international competition. Given that the rate of increase in productivity has slowed in some countries (e.g. Australia) (Garside *et al.*, 1997), there is a need to examine novel options for further efficiency gains across the entire sugar industry value chain. Modified cane supply and harvest scheduling arrangements can potentially enhance whole industry profitability and competitiveness.

When considering industry expansion the options are either vertical expansion (increase in yield) or horizontal expansion (increase in grown area). The profitability of these options depends on the return from investment in land, and transport, milling and sugar storage infrastructure. The vertically integrated nature of the industry demands the consideration of the complex issues of mill crushing capacity, harvest season length and equity issues (fixed proportion of cane supplied by each farm to the mill in each time period) as well. Crush start time and harvest season length are sensitive issues with growers as they influence seasonal cane quality, commercial cane sugar (CCS) and the growth duration and yield of subsequent ratoons. These factors impact directly on milling profitability by influencing the use of capital assets, manpower planning, factory maintenance schedules, crushing rates, sugar recovery and financial planning. The timing and availability of sugar are also important considerations in marketing to maximise export earnings. Alteration to equity arrangements by using cane supply schedules that exploit district variation in CCS and yield profiles throughout the harvesting season offer the opportunity to maximise mill region net income.

Harvest date influences cane yield and quality and hence sugar yield. Within a sugar mill region, the yields obtained for a given harvest date and crop age vary with geographical location, variety and crop class (i.e. plant and ratoon crops) and these yields vary with seasonal climatic conditions from year to year (Rostron, 1972; May and Middleton, 1972; Chapman and Leverington, 1976; Leverington *et al.*, 1978; Inman-Bamber, 1994). The achievement of profitability on an industry basis, which is influenced by the high capital costs associated with milling, harvesting, transport and storage, dictates that harvest and milling of cane occur over a prolonged period. This means that all fields of cane are not necessarily harvested at the time of maximum cane yield and quality. Hence, an important question is, "What opportunities are there to maximise productivity and profitability at an industry level by better scheduling the harvest date and crop cycle length of cane fields in a mill region?"

Given the complexity of cane supply arrangements and their impact on on-farm productivity and off-farm constraints related to transport and milling capacity, this paper outlines a research approach to assess the consequences of different cane supply and harvest scheduling options that integrate across the growing and milling sectors. This approach is currently being used in the Cooperative Research Centre (CRC) for Sustainable Sugar Production in Australia. In reporting progress to date, case studies for several locations in the Australian sugar industry are presented to show the scope for improving profitability by modified cane supply and harvest scheduling arrangements.

Research approach

The research approach involves (i) industry consultation and partnership from project initiation to implementation and delivery of findings; (ii) database development to account for temporal and spatial variation in climate, cane yield and quality of individual farm blocks; (iii) knowledge generation on the effect of time of harvest on seasonal and district variation in productivity, using field experimentation and crop growth simulation analysis; (iv) assessment of the risk of wet weather disrupting harvesting using climatic analyses; and (v) cane supply options analysis at mill district and industry level using operations research methodology to optimise block harvest schedules with the industry objectives of increased profitability and competitiveness.

Industry consultation and partnership

Given the sensitivity of the issues and the commercial implications to growers and millers, it is essential that industry is a partner in the research process to ensure the shared ownership of both the approach and the findings. At the industry level, representatives from the CANEGROWERS organisation and the Australian Sugar Milling Council have formed a Consultative Group with research leaders to ensure that knowledge generated from this research is equally available to all parties (growers and millers) in the industry to assist in decision making. The role of this group is: (i) to develop information management protocols to ensure common access to research results within the Australian Sugar Industry; (ii) to facilitate the understanding and application of the research information to optimise the potential of industry resources; (iii) to provide feedback on focus, methodology and interpretation of research to support its adaptability to industry needs; and (iv) to transfer strategic management tools to industry participants which enhance profitability and sustain economic competitiveness. At the mill region level, frequent consultation with growers and millers has occurred from the project initiation stage. It is essential that the partnership be developed at this stage to set research direction and facilitate data collection and that it be maintained throughout the project so that results can be interpreted with local knowledge. Growers have an important role to play in this project in assisting with on-farm experimentation, as well as ensuring accuracy of block productivity databases that record the consignment of cane to the mill. Similarly, millers have an important role to play in providing data on transport constraints and milling capacity. Financial data are required from all industry participants to assess the consequences of cane supply options in terms of net industry revenue.

Climatic and block productivity databases

In sugarcane production, climate has a major impact on the productivity of individual fields in terms of cane yield and quality, but climate, and rainfall in particular, also has a major influence on harvesting operations. Given the wide geographical spread of the Australian sugar industry (latitude 15 to 30° S) there is considerable temporal and spatial variability in climate. Hence, it is not possible to extrapolate findings and options developed in one location to other locations without taking account of this variability. Databases containing daily rainfall and solar radiation are required for assessing the impact of climate on harvesting operations, and daily solar radiation, temperature and rainfall for productivity analyses.

In Australia, the RAINRISK database system has been developed by CSIRO Tropical Agriculture, which contains up to 100 years of daily rainfall data for 88 locations in the Australian sugar industry. The database system allows assessment of the probability of different amounts of rain occurring over specified time periods. Use of this database system is outlined later to assess the risk of wet weather disrupting harvesting.

Records of daily solar radiation and temperature are much more limited than records of daily rainfall (Muchow *et al.*, 1997). As will be discussed later, crop growth simulation models are a valuable tool to assess productivity responses due to climatic variability, both across seasons and across locations. Solar radiation and temperature are key input data for these models. Regular calibration and maintenance of sensors is a prerequisite to obtaining quality climatic databases. The authors feel that the issue of obtaining high quality climatic data is a high priority issue to be addressed by the Australian Sugar Industry, and that sugar industries worldwide should consider assessing the availability of such data.

Block productivity databases are used in various sugar industries to benchmark productivity trends and to identify opportunities for yield improvement (e.g. in Australia, Lee-Lovick *et al.* (1992); in South Africa, the Field Records System (FRS), Hellman (1988) and Inman-Bamber *et al.* (1993); and in Colombia, Cock and Luna (1996)). In Australia, cane is consigned to the mill based on block (paddock or field) number and data are available for each block on variety, crop class, area and yield attributes. The accuracy of the area measurement of individual fields and the accuracy of consignment to the mill are important determinants of the value of these databases. The practice of cutting through several fields where cane is cut green with mechanical harvesters, is of particular concern. Given this valuable resource, as outlined later, we advocate the collection of quality block productivity data to assist implementation of improved cane supply and harvest schedules. In contrast to field experimentation and crop growth simulation, block productivity data account for quantifiable climatic, harvest date and crop age effects, but also unquantifiable effects due to variations in farmer management and other abiotic and biotic influences.

Knowledge generation using field experimentation and crop growth simulation

Field experimentation is required to gain physiological knowledge on the effect of harvesting sugarcane crops at different times of the year. Early experimentation in South Africa (Rostron, 1972) showed that time of harvest and crop age had significant effects on crop productivity. However, currently in Australia the only reliable information is from crops which have been harvested within the existing harvest season, that is between mid-June and mid-to-late-November. Previous research in Australia has examined the performance of crops harvested before and after the existing season (Leverington *et al.,* 1978; Chapman and Leverington, 1976). However, this research cannot provide reliable information to assess the consequences of modified cane supply and harvest scheduling arrangements, for a number of reasons as outlined below.

Previous research in South Africa has shown that harvest date affects initial stalk production and elongation. Rostron (1972) observed that differing patterns of stalk growth may affect lodging of crops. He suggested that the time of year when lodging occurs influences subsequent crop growth and the maximum cane yield attained. Rostron (1972) found that although sugar yield generally increased with age, there were large differences in sugar yield at 72 weeks in crops harvested and ratooned at different times, with a November harvested crop yielding 15,6 ters/ha and a crop ratooned in February yielding 23,3 ters/ha. At 56 weeks, crops harvested in June and July had the highest sugar yields, although differences between different harvest times were not as great as observed at 72 weeks of age. The main conclusions from Rostron's work were that the yield of crops which lodged at the beginning of summer, was not improved by carrying them over to the next season, and that varying the time of harvest of crops involves varying the age to which crops should be grown in order to maximise production for the cropping cycle.

Rostron (1972) conducted his experiment under conditions of high fertility and adequate water supply, so that the main factors effecting crop growth were the prevailing temperature and solar radiation. It is important that the effect of harvest time on crop production is not confounded by other management factors. In Australia, most of the previous experimentation on the effect of harvest time has been confounded by factors in addition to the prevailing climatic conditions. Leverington *et al.* (1978) imposed five time of harvest treatments to a crop planted in May. However, they harvested the first subsequent ratoon crops at times of the year different to when the plant crops were harvested. Accordingly, the authors were comparing the yields of crops of different ages and attributing differences to the effect of time of harvest. In addition, it appears waterlogging of the late harvested crops occurred in their experiments, and this further confounded any effects due to harvest time. The confounding of crop age and harvest time, combined with management differences between treatments, renders the findings of this experiment inconclusive.

The wet season in Queensland extends between December and March, and crops harvested late in a season have a higher risk of being affected by factors such as waterlogging, stool damage, and soil compaction, particularly those grown in poorly drained fields. Chapman and Leverington (1976) reported poor yields in crops harvested late in the season at Mackay. However, these crops were grown in fields 'in which imperfect drainage conditions prevail', and were harvested in wet conditions, and experienced prolonged periods of waterlogging. The comparatively low yields of late harvested crops, which were attributed to the effects of harvest time by the authors, were in fact also affected by stool damage, soil compaction and waterlogging. These factors, whilst real under some circumstances in commercial production, were not present in crops harvested earlier in the season. Hence it is difficult in this study to clearly attribute yield responses solely to time of harvest.

Given the limitations of past research and the need to know the productivity consequences of a wide range of harvest dates and crop ages, there is a need for further experimentation using current commercial varieties. These experiments need to be conducted under well controlled conditions, so that the effects of harvest time and other factors such as waterlogging, water stress, stool damage and soil compaction, can be clearly separated and quantified. Field experimentation recently initiated within the CRC for Sustainable Sugar Production is aimed at gaining the required data, to be better able to predict the effects of harvesting outside the currently accepted milling season. Here, experiments are conducted adjacent to calibrated automatic weather stations, with initial soil, water and nutrient conditions characterised and good records of crop management and husbandry kept. The collection of a minimum dataset of crop, climatic, soil and management information is essential, both to allow interpretation of the productivity responses to harvest time and crop age, but also to allow the data to be used in the testing and enhancement of crop growth simulation modelling capability. The SUGARBAG database system has been developed to allow the electronic storage of these minimum datasets which have been clearly specified by Robertson *et al.* (1996).

Conducting field experimentation is expensive, and it is not possible with experimental treatments to sample the infinite number of combinations of factors that impact on productivity. For example, yield responses would vary for different locations and for the different climatic conditions that occur from season to season. Crop growth simulation models, that quantify the importance of different physiological processes, soil type and climatic elements in their contribution to yield variation, are an important tool to enhance research efficiency in examining the effects of harvest time and crop age on the productivity of different varieties and crop classes. When used with historical climatic data for different locations, crop sugarcane simulation models can be used to assess indicative impacts of different management factors on block productivity.

In Australia, the APSIM sugarcane model has been used to quantify climatic and management impacts on productivity (Muchow *et al.*, 1997; Robertson *et al.*, 1997; Keating *et al.*, 1997). As the capability for predicting yield consequences of current and subsequent ratoon crops harvested at different times of the year (particularly outside the current season) is enhanced, this model will be used with historical climatic data for different production systems to generate harvest date by crop age matrices on cane yield and quality. However, the matrices will not be able to be used directly in the cane supply options analysis outlined below. Block productivity databases currently allow such matrices to be constructed for harvest within the conventional harvest season and reflect actual production in farmers' fields (i.e. with unquantifiable constraints). The actual block productivity data obtained during the conventional harvest season can be used to validate and scale the simulated matrices, both within the conventional harvest season and outside. These scaled matrices (reflecting commercial field production) can then be used as input into the cane supply options analysis to examine the consequences of modified cane supply and scheduling arrangements as outlined below.

Assessment of wet weather harvesting tasks

Since crush start date and season length are crucial determinants of industry profitability, knowledge of the risk of rainfall disrupting operations can assist in decision making on optimising the scheduling of harvest. Muchow and Wood (1996) used the CSIRO RAINRISK database system to assess wet weather risk to harvesting operations within and outside the normal harvest period for three regions (Ord, Burdekin and Herbert) in the Australian Sugar Industry. That analysis is extended for the geographical range of the Australian sugar industry in Figure 1. Rather than using average rainfall data, Figure 1 presents a more risk-averse assessment by using the minimum amount of rainfall likely in the wettest 20% of years. The data shown for 'early' and 'late' represent the likely start and finish dates of the harvest season with current arrangements in north Queensland with an earlier start occurring in the Ord (Kununurra) and a later start occurring in southern regions. The data for 'very early' and 'very late' represent a change to crush start and finish times.

Considerable temporal and spatial differences exist in rainfall risk. The risk of rainfall occurring is far greater at the end of the harvest season than at the beginning at Kununurra, Ingham, Ayr, Mackay and Bundaberg, but the opposite is the case in the wet tropics (Innisfail) and in NSW (Murwillumbah). There is also observed geographical variation in rainfall risk within a region. For example in the Herbert region, based around Ingham, it is wetter earlier in the season and drier later in the season in Halifax, compared to the opposite response at Bambaroo (Figure 1). This indicates that there is scope for minimising wet weather harvesting risk by exploiting temporal and spatial variation.

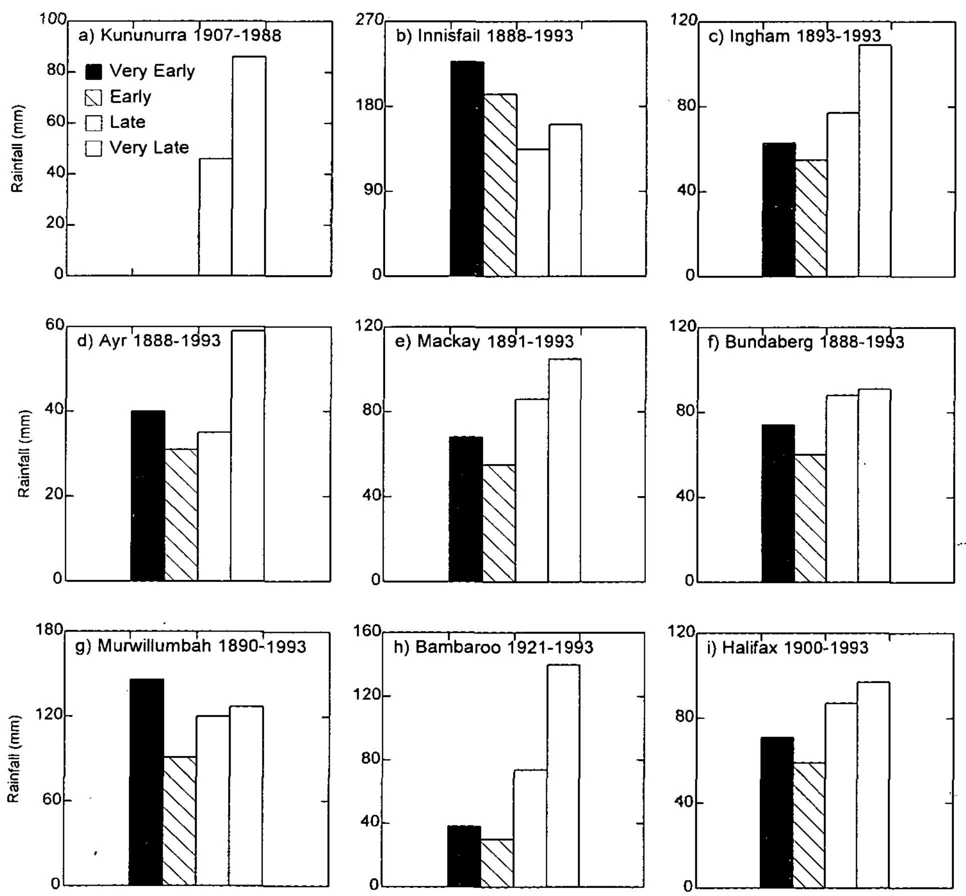

Figure 1. Minimum amount of rainfall (mm) likely to be received in 20% of the wettest years at different harvest times in selected locations in the Australian sugar industry. Harvest times are: very early (May 28 to June 17); early (June 18 to July 8); late (October 23 to November 12); very late (November 13 to December 3). Data from all years in the historical record were sorted in ascending order, and the 80% cumulative probability value (i.e. 80% chance of receiving less than that amount in each period) was calculated.

This work is being extended through industry participation in defining the consequences for different amounts of rainfall in terms of wet days, taking account of time of season and geographical differences. Since soils differ in the time that they take to dry out after wet weather, this will affect the resumption of mechanical harvesting and cane haulage operations. Research is planned to investigate the use of soil attributes that relate to drainage and trafficability so that the concept of a wet day can be more accurately specified for different districts and soil types. Historical rainfall occurrence is also being related to mill stoppages to develop models for forecasting likely disruption to harvest. The role of seasonal climate forecasting in managing the conduct of harvest is also being assessed.

Cane supply options analysis

Operations research methodology, namely linear and integer programming, can be used to optimise harvest date of all farm paddocks within a mill region according to specified criteria (e.g. maximising sugar yield and maximising net revenue). The methodology accounts for yield and sugar content variation during the harvest season and specified constraints associated with transport and crushing capacity. Operations research is a set of mathematical tools, which when applied to cane supply optimisation, seeks to find efficiently the best harvest date combinations (for an entire mill region) that meets the operational constraints from a large number of possible solutions. This approach has been applied extensively to processes in other industries, particularly assembly line manufacturing, transport scheduling, and traffic light timing. It has also been applied in the sugar industry, to optimise rail transport (Pinkney and Everitt, 1997) and to optimise harvest and transport operations combined (Grimley and Horton, 1997).

For consideration of cane supply and scheduling arrangements within the existing harvest season length and with existing milling capacity, block productivity data are a valuable data resource. For a given block, data are required on geographical location, area, harvest date, harvest date the previous year or crop age, variety, crop class and yield attributes. For ratoon crops, crop age can be calculated by matching blocks from the previous year, given the harvest date in that year. For plant crops, additional information is required on whether planting was after fallow or immediately after plough-out and also the planting date. Information is also required on planting costs, growing costs and harvesting costs. To assess the consequences of varying crush start time and harvest season length, additional productivity data are required on the effect of harvest date outside the conventional harvest season, and use of block productivity data and scaled crop growth simulation data to achieve this purpose was outlined above. Additional data are also required on the likely wet weather risks for harvesting outside current historical experience.

Off-farm data requirements include those associated with mill crushing capacities throughout the harvest season, geographical transport and harvesting limitations, as well as financial data at an industry level. Mill crushing capacity, at any harvest date, is defined as the mill rated capacity minus the expected capacity lost due to wet weather, mill breakdowns, as well as scheduled maintenance. For applications within the current harvest season, crushing capacity can be estimated using historical mill data. Assessing the consequences of different seasons start/finish times requires knowledge of the consequences of wet weather on the amount of cane which is able to be supplied to the mill and crushed. Financial data requirements include sugar price, costs associated with milling throughout the season, and geographical transport costs. Whilst financial data are easily obtained for analyses given the current harvest season, there are many confounding factors (e.g. asset cost, utilisation and depreciation) which make these data difficult to predict when assessing the consequences of different season start/finish times. Research is currently being carried out by the CRC for Sustainable Sugar Production to better estimate these financial data.

Initial optimisation models have been developed to determine the optimal area of land to be harvested at each stage, given variation associated with crop age, crop class as well as district (or productivity zone) (Higgins *et al.*, 1998). Applications, as discussed below, have been conducted given current cane supply arrangements (Higgins and Muchow, 1998) and research is continuing on model development and applications to assess the consequences of modified cane supply and harvest scheduling arrangements for different season lengths and milling capacity.

Research applications

Potential applications to assess the consequences of modified cane supply and harvest scheduling arrangements are summarised in Table 1. The first of these is for the case where there are no changes to harvest season length, crushing capacity or supply restrictions (e.g. equity). That is, the potential gain over current practice for optimal cane supply is achieved with no extra expense to the miller or grower. The second application assesses potential gains to the industry when grower supply restrictions are relaxed. This allows geographical differences in high early and high late CCS to be exploited. In the case of minor changes to supply restrictions, such a model provides knowledge on better farm rotation strategies within a harvesting group. The third application, which provides optimal cane supply decisions outside the current harvest season, requires a significant amount of additional information. While block productivity data provide, within the current season, the required information of yield and CCS responses to different harvest date by harvest age responses, field experimentation and crop growth simulation models are required to generate data outside the current harvest season. Additional information is also required on wet weather impacts on harvesting outside the current season. This application is particularly relevant where horizontal and vertical expansion is occurring as it allows profitability impacts of increased season length verses increased mill crushing capacity to be assessed. This third application also requires an economic and socioeconomic analysis due to possible large impacts on all industry participants. Finally, the fourth application considers the case where a region contains more than one mill and cane is able to be transported physically (e.g. flexible transport capacity) to an alternative mill.

Table 1. Applications to assess the consequences of modified cane supply and harvest scheduling arrangements.

Application 1

Given current harvesting arrangements, scope for modifying the scheduling of harvest of individual blocks and modifying crop cycle length to increase profitability.

Possible sensitivity and options analysis:

- Different crop cycle lengths
- Fraction of replant to fallow
- Sugar price
- Spatial arrangement of districts/ productivity zones

Outputs and benefits:

- Potential for gain over current system
- Best decisions on harvest date and crop cycle length for individual blocks
- Best decisions on whether fallow or replant after ploughing out

Application 2

Assess consequences of changing equity in a given mill region

Possible sensitivity and options analysis:

- Geographical harvesting
- Harvester rotation for farms

Outputs and benefits:

- Potential for gain over current equity restrictions and best utilisation of high early and high late CCS variation across districts/ productivity zones
- Improved strategies for rotating farms within a harvesting group

Application 3

For a given mill region, assess consequences of changing mill start and finish dates, as well as crushing capacity at different regional production levels.

Possible sensitivity and options analysis:

- Availability of Early Season sugar
- Trade off between season length and crushing capacity

Outputs and benefits:

- Profitability and productivity consequences at mill and farmer level for different season start and finish times
- Most appropriate cane supply arrangements for an extended season or increased mill crushing capacity. This may be different to current arrangements.

Application 4

In the situation of more than one mill within a region, assess the consequences of cane supplied from farms to alternative mills. This is an extension from applications 1 to 3 above.

Possible sensitivity and options analysis:

- Opening one mill early for high early CCS districts/ productivity zones

Outputs and benefits:

- Consequences of extending or upgrading transport infrastructure.
- Potential for supplying cane to alternative mills within the same region which contain different season start/ finish times.

In terms of applications carried out to date (Higgins and Muchow, 1998), Table 2 illustrates the potential profitability gains of optimising cane supply given the current industry arrangements (application 1 of Table 1). Three mills were selected, Mossman which is the northern most in Queensland, Invicta which is located in the Burdekin region, and Marian which is located in the Mackay region. Optimal cane supplies achieved the greatest benefits for Marian mill with a 12,5% increase in net revenue over current practice. Mossman and Invicta were slightly less with 8,3% and 6,9% respectively (Table 2). These gains were obtained by selecting the best time to harvest individual paddocks and the most appropriate crop cycle length (i.e. number of ratoons before plough-out). The optimal cane supplies for Mossman and Marian resulted in a slightly longer average crop cycle length than in current practice (about one ratoon), while the crop cycle length for Invicta was shorter. The shorter crop cycle length for Invicta was due to the large decrease in sugar yield per hectare from plant crop to first ratoon. These estimates of potential gains are being refined as additional information and enhanced models become available.

Conclusions

Initial analyses for specific mills in the Australian sugar industry have shown that there is considerable potential for modified cane supply and harvest scheduling arrangements to improve industry profitability. To realise this potential, a multidisciplinary research approach involving database development, field experimentation, simulation and mathematical optimisation modelling, and appropriate economic analysis is required. Given the regulated nature of the current Australian sugar industry, strong industry participation at all levels (growers, millers, marketers) is required to develop appropriate strategies from the technically efficient options.

Field experimentation alone cannot address this complex issue, although it is an essential component to provide fundamental physiological knowledge on the sugarcane crop response to harvest date and crop age leading to enhancement of simulation modelling capability. Simulation modelling is required to account for variability associated with climatic conditions from one season to the next and across locations and for different production systems. Central to the use of simulation modelling is quality historical climatic databases including solar radiation, temperature and rainfall for locations of interest.

Whilst field experimentation and crop growth simulation modelling are important tools to assess the production risk associated with different management options (e.g. harvest date and crop ages), these technologies alone cannot take account of industry constraints such as transport and milling capacity and harvest season length in determining best cane supply options. Advanced mathematical optimisation and scheduling modelling is required to take account of harvest date and crop age influences on production and quality through the harvest season as well as transport and milling capacity constraints. Important input data to this approach are (i) temporal and spatial variation in productivity data from individual field productivity records, field experimentation and crop growth simulation modelling, (ii) climatic data and models to assess wet weather harvesting risks; (iii) transport configuration and milling capacity; (iv) financial data on growing, transport and milling costs, as well as on assets; and (v) sugar storage capacity before sale and market premiums.

Perhaps the most important ingredient to achieving success in this approach is the partnership between industry and researchers. Industry must be involved from the project inception stage to assist in setting research direction and to highlight opportunities and constraints. Furthermore, industry has a vital role to play in data collection and the assessment of its reliability and relevance as the output from the research technologies (e.g. optimisation modelling) is very much dependent on the quality of input data and the assumptions that underpin the models. Industry also has an important role to play in data interpretation and ensuring that the information generated is of real value in assisting industry decision making. In many sugar industries worldwide, there is too much segregation among growers, millers, marketers and researchers – the research approach outlined here aims to integrate all these areas to benefit whole industry profitability.

Table 2. Results of optimising cane supply.

Mill	Net revenue ($/ha)		Sugar yield (t/ha)		CCS	
	CP	Optimal	CP	Optimal	CP	Optimal
Mossman+	1 385	1 500	11,95	12,24	12,75	12,86
Invicta++	2 388	2 553	17,53	17,94	14,84	14,85
Marian+++	1 775	1 997	13,59	13,80	13,95	14,14

\+ Averages for 1992 to 1996 ++ Averages for 1993 to 1997 +++ Averages for 1994 to 1996 CP = Observed in current practice

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