A Decision Support System for Generating Improved Sugarcane Harvest Schedules

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Abstract: A decision support framework for the Australian sugar industry was developed to produce harvest schedules for increased profitability. Alternative cane supply arrangements, including the optimisation of on-farm harvest scheduling and geographical harvesting (harvest entitlement exchange), were implemented through pilot studies in Mossman and Mackay during the 2000 and 2001 harvest seasons. The generation of multiple on-farm harvest schedules for growers participating in the pilot studies was achieved through the development of a database system. For selected farms, and with input on paddock (block) selection by the grower, this system automatically produces a report containing guidelines and a harvest schedule towards achieving optimal cane supplies. The harvest schedules are based on results from a mathematical cane supply optimisation model and are optimal with respect to the potential gain in productivity to the sugar industry given the existing transport and milling costs and constraints within the sugar mill region. For these gains to be even partially realised in practice, complex output from the optimisation model must be presented in an uncomplicated form. This was achieved in the reports generated by the database system, which have been designed to provide ease of interpretation and implementation in the field. This paper describes the decision support capabilities of the database system, formulation of the on-farm harvest schedules, and the improvements and extensions to the system planned for future harvest seasons.

Keywords: Cane supply optimisation; Decision support system; Sugarcane harvesting schedules; Participative research

1. INTRODUCTION

The Cane Supply Options Analysis (CSOA) Project was initiated to assess the productivity and profitability of various cane supply and harvest scheduling options, that exploit geographical differences in CCS (percentage of extractable sugar from cane) and cane yield for different harvest dates across a sugar mill region. The current system enforces regulated farm and harvesting group equity to ensure that each farm harvests a similar percentage of sugarcane during specified intervals throughout the season. The three options considered for pilot studies in 2000 and 2001 were:

- Full geographical harvesting with no farm or harvesting equity (Option 1): if a harvesting group consists of farms that are considered high late in the season with regards to CCS relative to the mill then the group may benefit from harvesting more cane towards the end of the season (harvesting entitlement exchange), and vice versa;
- Geographical harvesting within harvesting groups only, so that harvesting equity is maintained without farm equity (Option 2): where harvesting entitlement exchange occurs among farms belonging to a single group and the farms are dispersed across areas in which CCS relative to the mill is considered high late in the season for some farms and high early in the season for others;
- On-farm optimal harvesting with full harvesting and farm equity (Option 3): where the on-farm harvest schedule is produced according to optimal harvest date decisions by crop class and variety.

3. FRAMEWORK FOR GENERATING HARVEST SCHEDULES

The framework for generating optimal harvest schedules consists of three main components as illustrated in Figure 1. The components are:

- the CSO model,
- the database system, and
- the decision support tools.

The support tools are accessed through the HarvSched database. The grower may observe summary graphs of historical CCS and sugar yield data with harvest date, harvesting scenarios for the three cane supply options and a colour-coded farm map displaying the automatically generated harvest schedule, all relevant to the selected farm.

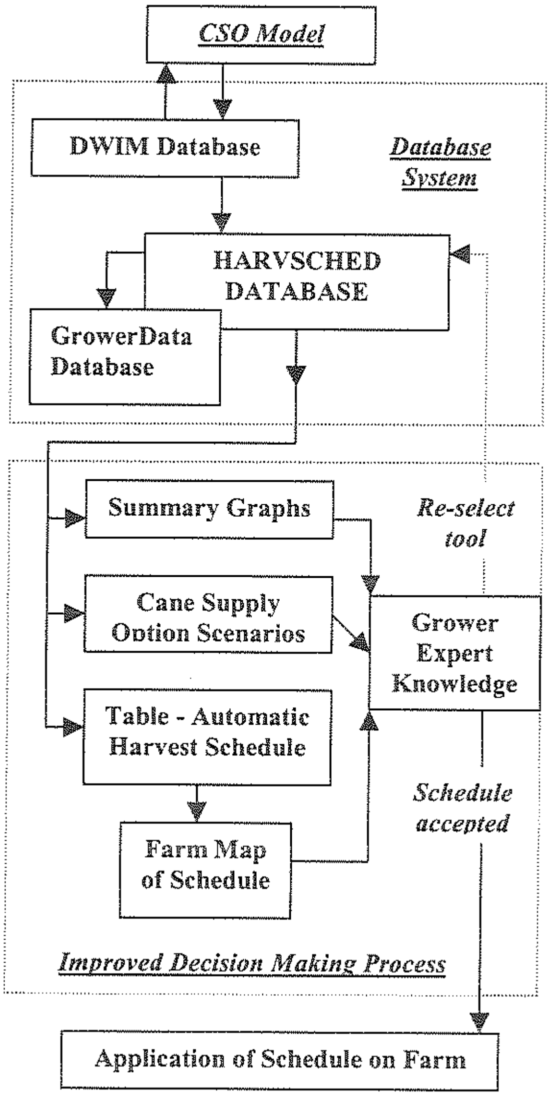

Figure 1. Decision support framework for generating optimal harvest schedules for sugarcane farms.

The summary graphs will assist the grower with deciding which cane supply scenario is most appropriate for the farm. The farm map illustrating the schedule, provides the grower with a visual display of how a harvester will be expected to move around the farm throughout the harvest season. At this point the grower may accept the generated schedule or request a re-ordering of several paddocks within the schedule due to on-farm constraints which are not able to be captured by the CSO model. Details of the complex mathematical functions and algorithms developed to generate solutions to the CSO model can be found in Higgins and Haynes [2001].

3.1 Combining Model Results and On-farm Crop Information

The variation in trends of farm relative CCS with harvest date, among farms within a sugar region, was partially captured by the derivation of farm "CCS groups" [Higgins and Haynes, 2001]. Farms were assigned to the CCS groups according to deviations in their average CCS trends from the mill trend.

For each sugar mill region, results from the CSO model are extracted and stored in three database tables (one for each cane supply option). Tables 1 and 2 give an example of how the solutions from the CSO model are presented to form the harvesting guidelines for a farm participating in Option 2. Within a harvesting group, and for each CCS group to which the farms are assigned, the CSO model generates percentages of cane (tonnage) to be harvested from a farm for six four-weekly periods across the harvest season. These percentages are generated for each harvesting group separately for Options 1 and 2 (Table 1). To produce the harvesting guidelines, HarvSched extracts the percentages associated with the harvesting group and CCS group for a farm and applies these percentages to the pre-season tonnage estimate for the farm. With Option 2, a further adjustment to the tonnages is applied to ensure that the total tonnage for the group is consistent for each harvesting period. The result is an estimated tonnage to be harvested during each four-weekly period, for every farm in the harvesting group (Table 2). For this particular harvesting group, Table 1 shows that it is not necessary to extend harvesting into the sixth period.

For on-farm paddock harvest schedules (Option 3) the CSO model generates percentages of cane tonnage for all combinations of CCS group, crop class (plant crop, 1st ratoon, 2nd ratoon, 3rd ratoon and later) and the major cane varieties for the region, for each of the six periods throughout the

Table 1. Optimal percentage of cane to be harvested from farms within Harvesting Group A with Option 2, by farm CCS group and harvesting period (1 period is equivalent to 4 weeks)

CCS Group	Number of farms	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Starts below mill – decreases relative to mill	1	27.2	21.0	28.0	19.5	4.4	0.0
Starts below mill – Follows mill	2	20.9	18.3	20.8	20.7	19.4	0.0
Starts with mill – Follows mill	1	12.6	21.2	18.5	22.3	24.6	7.9

Table 2. Optimal tonnes of cane to be harvested from farms within Harvesting Group A with Option 2, by harvesting period during the 2001 harvest season (1 period is equivalent to 4 weeks)

CCS Group	Farm	Period 1	Period 2	Period 3	Period 4	Period 5	2001 Estimate
Starts below mill – decreases relative to mill	A.1	734	552	703	472	112	2574
Starts below mill – Follows mill	A.2	3575	3015	3240	3135	3129	16093
Starts below mill – Follows mill	A.3	528	445	478	463	462	2377
Starts with mill – Follows mill	A.4	1477	2303	1893	2244	2695	10612
	Total	**6314**	**6314**	**6314**	**6314**	**6386**	**31656**

NB: Small discrepancies may sometimes occur in the sum of row and column totals due to rounding to integers for reporting.

harvest season. The task of selecting farm paddocks in an order which agrees with these percentages is not trivial, and thus, a procedure to generate an appropriate harvest schedule automatically was incorporated into HarvSched.

3.2 Framework for the Database System

The database system is essentially an intelligent decision support system which integrates optimal solutions with historical and pre-season farm block information to produce practical but intelligent guidelines [Abbass et al., 1999; O'Keefe, 1986]. The system has primarily been developed using Microsoft Access software and consists of three databases. The first database is DWIM (Database for Whole of Industry Models). DWIM was developed to store:

- data generated by the CSO model for the harvesting Options 1, 2 and 3
- information linking growers to farms, harvesting groups and mill districts
- pre-season estimates of tonnes of cane, crop class and variety for each paddock/block
- historical block productivity data.

DWIM was designed to standardise data across all mill regions to provide a generic platform from which data may be extracted for input to various other applications such as the CSO model and report generating applications such as HarvSched. Details of how the historical block productivity data, and the corresponding farm/group/mill links, are stored in DWIM is documented in Peel and Prestwidge [2000].

The second database, HarvSched (Harvest Schedules), provides access to several decision support tools as shown in Figure 1, leading to the generation of harvest schedule guidelines for the selected option. The third database, GrowerData, is filled with data records forming the harvest schedules generated and saved within HarvSched.

The database system was initially prepared for the 2000 season, to provide harvest schedule guidelines for a farm, based on selection of any of the three cane supply options. However, during the process of recruiting growers to participate, it became clear that the growers were faced with decisions relating to the feasibility of participating. In light of this, enhancements were incorporated into both the modelling process and the database system and the third component of the framework was developed to assist with decision making, in preparation for the 2001 harvest season.

3.3 Decision Support and Intervention by the Sugarcane Grower

From the front screen of HarvSched, the user selects the mill region, the start date of harvest for this mill region, and one of the three cane supply options for which schedules are to be generated. If Option 2 is selected, a list of all harvesting groups for the mill region appears so that the harvesting group guidelines can be generated for the relevant group.

If Option 3 is selected from the front screen, a list of all farms within the mill region appears. A farm or a combination of farms may be selected to generate the on-farm harvest schedules automatically. To check the accuracy of the farm information that is stored in the database, an option is available to print a report that provides details of crop characteristics and pre-season tonnage estimates for all paddocks on the farm.

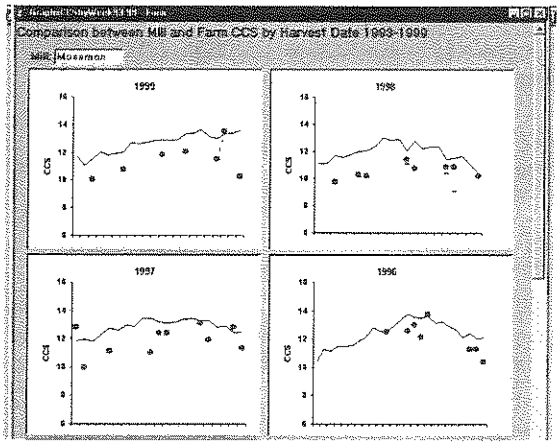

Figure 2. Summary graphs of farm average CCS (points) and mill average CCS (line) with harvest date for four different years.

To assist with the decision on choosing the best option for a farm, summary graphs specific to a farm are available in HarvSched. The graphs show historical trends in CCS (Figure 2) and sugar yield for a farm or paddock, either within a season or over several seasons. For comparative purposes these trends are also shown for the mill average. For example, if the CCS trend for a farm is consistently higher than the mill trend towards the end of a season, as compared with the start of the season, then the grower may recognise a benefit in harvesting more cane towards the end of the season which is possible through the Option 2 scenario. For the farm represented in the graphs of Figure 2, the average CCS appears to be closer to the mill average CCS later in the season for 1996, 1997 and 1998. This pattern is not so clear from the 1999 data.

When Option 3 is selected for a farm, HarvSched automatically generates schedules that are in close agreement with the solutions produced by the CSO model. The model solutions provide an order of harvest in terms of tonnage harvested by crop class, variety and time period categories. Paddocks are selected for each of these categories such that the total tonnage of the paddocks selected is reasonably close to the model tonnage.

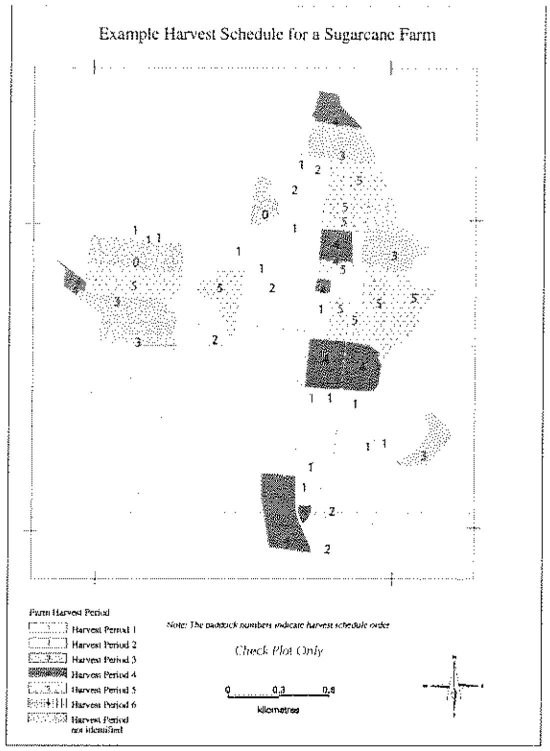

Figure 3. A farm map displaying the automatically generated harvest schedule with paddocks numbered by order of harvest.

Before accepting an on-farm harvest schedule, growers benefit by observing a map of their farm paddocks to assess whether implementation in terms of harvester movement would be practically possible. As the farm map is a crucial instrument in developing satisfactory harvest schedules, HarvSched is being extended to incorporate links with farm paddock GIS (Geographical Information Systems) data. With this new capability, a farm map is produced with paddocks reflecting a colour and number scheme which corresponds to the order of harvest generated by the automatic harvest schedule (Figure 3).

For instances in which a grower needs to alter the schedule due to on-farm contraints that are not captured by the CSO model, a facility is available to specify a priority ordering on selected paddocks, as advised by the grower. For example, in the schedule illustrated by Figure 3, the paddock in the bottom right corner of the map is scheduled to be harvested in period 3 but is some distance from the other paddocks scheduled for harvest in the same period, and this may cause some difficult with regards to harvester movement. It may be more appropriate to reschedule this paddock for harvest in period 2 or 4. This facility must be used with caution as the final schedule should still closely reflect the solutions of the CSO model.

4. CONCLUSIONS AND FUTURE EXTENSIONS

The pilot studies for implementing the alternative cane supply options during the 2000 and 2001 harvest seasons, have evolved through a participative research process [Muchow et al. 2000] involving sugar industry representatives and researchers. This process has provided improved models, new software tools and a better understanding of the requirements for the successful implementation of alternative cane supply arrangements.

An important output of the implementation phase of the CSOA Project has been the development of a decision support framework to generate harvest schedule guidelines in a form that is suitable to the grower while closely reflecting the solutions produced by the cane supply optimisation model. The framework provides decision support to the grower in the form of:

- graphs showing historical trends in CCS and sugar yield specific to a farm,
- automatically generated harvest schedules for three different cane supply options,
- the capability to re-order paddocks in the schedule to deal with on-farm constraints, and
- the capability to view a farm map showing paddocks that are colour-coded to reflect the order of harvest corresponding to the generated harvest schedule.

All of these capabilities have assisted growers with deciding on their level of participation. In particular, growers were more enthusiastic to participate in pilot studies during 2001 given the ability to re-order the paddock schedule for sound management reasons.

A further enhancement to the framework will be the capability to generate net gains and costs to a grower based on the order of farm paddocks in the harvest schedule and changes in relative CCS units by harvest date. This enhancement will be undertaken in preparation for the 2002 harvest season.

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