

ASSESSING THE POTENTIAL FOR IMPROVING MILL AREA PROFITABILITY BY MODIFYING CANE SUPPLY AND HARVEST SCHEDULING: A SOUTH AFRICAN STUDY

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Abstract

In South Africa, cane is delivered to the mill uniformly over the milling season and across all supply areas. This delivery schedule does not exploit the cane quality patterns, represented by the 'recoverable value' (RV) of sugar, which show distinct regional trends, primarily due to climate differences and the resulting differences in agronomic practices. This study, which focused on the Sezela mill supply area, investigated the potential for improving mill area profitability by modifying cane supply and harvest scheduling to account for sub-region cane quality trends. Production and delivery data from mill weighbridge and cane quality databases was analysed for 2000 and 2001, to determine cane quality trends as well as the capacity and variability of cane deliveries through the season. Sub-areas likely to have similar patterns in cane quality throughout the year were delimited using weather data, and new curves for RV distribution were developed for these areas using the cane quality database. Various cane supply scenarios from these sub-areas were evaluated using a spreadsheet model developed during the project. Each scenario represented different start and end dates for cane delivery in each sub-area, and different rates of delivery during the harvest window. The results showed that, by breaking the mill supply area into homogenous zones and adapting allocation according to cane quality variations, total RV production could be increased by 1-5%. Furthermore, results showed that all growers (inland, hinterland and coastal) would improve their revenues under the scenarios tested. The implications of this new organisation for delivery allocation between growers within a sub-area, harvest operations at farm level and the cane payment system, are discussed.

Keywords: sugarcane, cane quality, mill supply, supply chain management, delivery allocation, simulation

Introduction

While the South African sugar industry is recognised as a low cost, efficient sugar producer, ongoing efficiency improvements are imperative for it to remain globally competitive.

Profitability gains can be sought at different stages (crop growing, milling and marketing), and is the aim of most research programmes in the industry. However, there is also potential to improve profitability at the mill area level by looking at cane supply management, a process that involves interaction between numerous stakeholders.

There are the farmers who manage the harvest, the harvesting contractors, the hauliers who transport the cane to the mill, and the millers who organise supplies to regulate the mill operation. Improving cane supply management requires an analysis of the system, and the application of specific methodology to provide useful information to both growers and millers (Muchow *et al.*, 2000).

Various improvements can be considered, ranging from changes in harvest and transport techniques to new rules for delivery allocation (Gaucher *et al.*, 1997). Based on a study conducted from April to August 2002 in the Sezela mill area (Guilleman *et al.*, 2002), this paper investigates methods of maximising sugar production by changing the structure of cane deliveries from the fields to the mill, bearing in mind the existing harvest and transport systems as well as mill capacity. As required by Sezela stakeholders, alternative scenarios focus on variations in cane quality within the supply area.

Problem Statement

In 2000/2001 the Sezela mill crushed 2.38 million tons of cane, produced by its miller-cum-planter estate (22%), 180 large scale farmers (65%) and 5000 small scale farmers (13%). Its supply management involves up to four operators: growers who often cut and transport their own cane, harvest-contractors, hauliers and the mill. The Mill Group Board (MGB) is responsible for planning and co-ordination between these operators.

From the miller's point of view, cane quality refers to the sucrose content of the cane and the amount of sucrose that can be extracted. The higher the fibre and non-sucrose contents, the more difficult sucrose extraction is. The sugar industry has defined an indicator to assess the amount of sucrose extracted from cane, and to link payment to the quality of cane delivered. The Recoverable Value rate (% RV) includes the sucrose, non-sucrose and fibre contents of the cane (Murray, 2002; Moor, 2002).

The % RV in cane consignments, as measured by the Cane Testing Service (CTS) of the South African Sugar Association, depends on factors such as climate, production techniques and harvest/transport conditions. Variations in these factors within a mill supply area might result in sub-regional patterns in sugarcane production and RV distribution. As the current system is based on rateable (uniform) delivery allocation across all regions and throughout the milling season, it may be profitable to investigate alternative supply systems based on variations in quality.

The Sezela mill was chosen for this study because of (i) the potential diversity in cane quality within the supply area, (ii) interest in the potential of the approach and (iii) the availability of data on production and cane quality, captured at the weighbridge since 2000.

Methods

Conceptual background

Supply chain management is mainly a matter of co-ordination between stakeholders to regulate the quantity and quality of flow of raw material from the farmer to the miller. This regulation process involves interaction between several sets of constraints (Gaucher *et al.*, 1998; Gaucher *et al.*, 2003). Millers aim at controlling supplies in order to fully utilise their industrial capacities while adjusting to market demands. Farmers have to adapt to the miller's requirements according to their own constraints of land, labour and equipment. Contractors and hauliers face equipment and financial constraints when fulfilling their commitments to the farmers and millers (Le Gal and Requis, 2002).

Co-ordination processes cause frequent conflicts between stakeholders regarding the observance of contracts, payment for individual efforts and the day-to-day management of cane supply. Solving these conflicts requires the stakeholders to switch from individual points of view to the search for collective growth strategies. Simulation models can be particularly useful in assisting stakeholders involved in this process. Designing the model enables one to highlight disagreement points and critical interfaces between stakeholders within the chain. Simulation provides a quick and reliable way to assess and compare alternative scenarios for chain circumstances and supply organisation. Manipulating these components and results enhances the knowledge common to all stakeholders, and the capacity to find solutions (Hatchuel and Molet, 1986).

Two approaches to modelling can be used (Gaucher, 2002; Gaucher *et al.*, 2003). The first focuses on strategy, and takes into account the entire supply area on a daily or weekly basis. The second addresses logistic issues such as operation scheduling and equipment selection on a daily or hourly basis (Barnes *et al.*, 1998).

Most of the simulation tools used for strategic issues are based on optimisation, and aim at finding a 'one best way' solution. For example, an Australian team has developed a model that maximises the sugar yield and net revenue of the chain by defining suitable harvest dates and crop cycle lengths for a range of production units (Higgins, 1999; Higgins *et al.*, 1998). The model provides an optimal solution for harvest scheduling, given the structure and capacity of the supply chain at the mill area level.

Optimisation models may be relevant when the stakeholders are closely integrated and information can be easily accessed. An alternative simulation approach has been investigated in La Réunion to address cases with numerous independent stakeholders (see Gaucher *et al.*, 2003 for details). The approach aims at assessing and comparing alternative supply scenarios referring to changes in capacities or planning/operational rules. The model is based on a simplified representation of the various operators in the supply chain, and their constraints and relationships. Changes in structure, capacities and planning/operation rules are simulated, and their consequences in terms of sugar production are quantified at the mill area level.

The model is made up of two sub-modules, the first for supply planning and operation and the second for cane processing (Figure 1). It is underlined by a three-level representation of the supply area, consisting of mill, transloading zones and production units (PUs), and simulates a crushing season on a weekly step basis, according to the cane flow paths between these three levels, their given characteristics and some planning and operating rules.

The PUs are defined as individual elements treated as homogeneous from a capacity and cane quality point of view as well as for the rules that the mill applies to them for planning and operating delivery. PUs are thus characterised by cane quantity (cane area and yield), a quality curve and a maximum flow rate that includes limitations for harvest and transport to a given transloading zone.

Transloading zones collect the cane coming from the PUs, and are characterised by a maximum transfer flow rate that includes cane handling capacity, storage capacity and limitation for final transport to the mill. The mill is characterised by its hourly crushing capacity, weekly working hours, maintenance time and frequency of breakdowns.

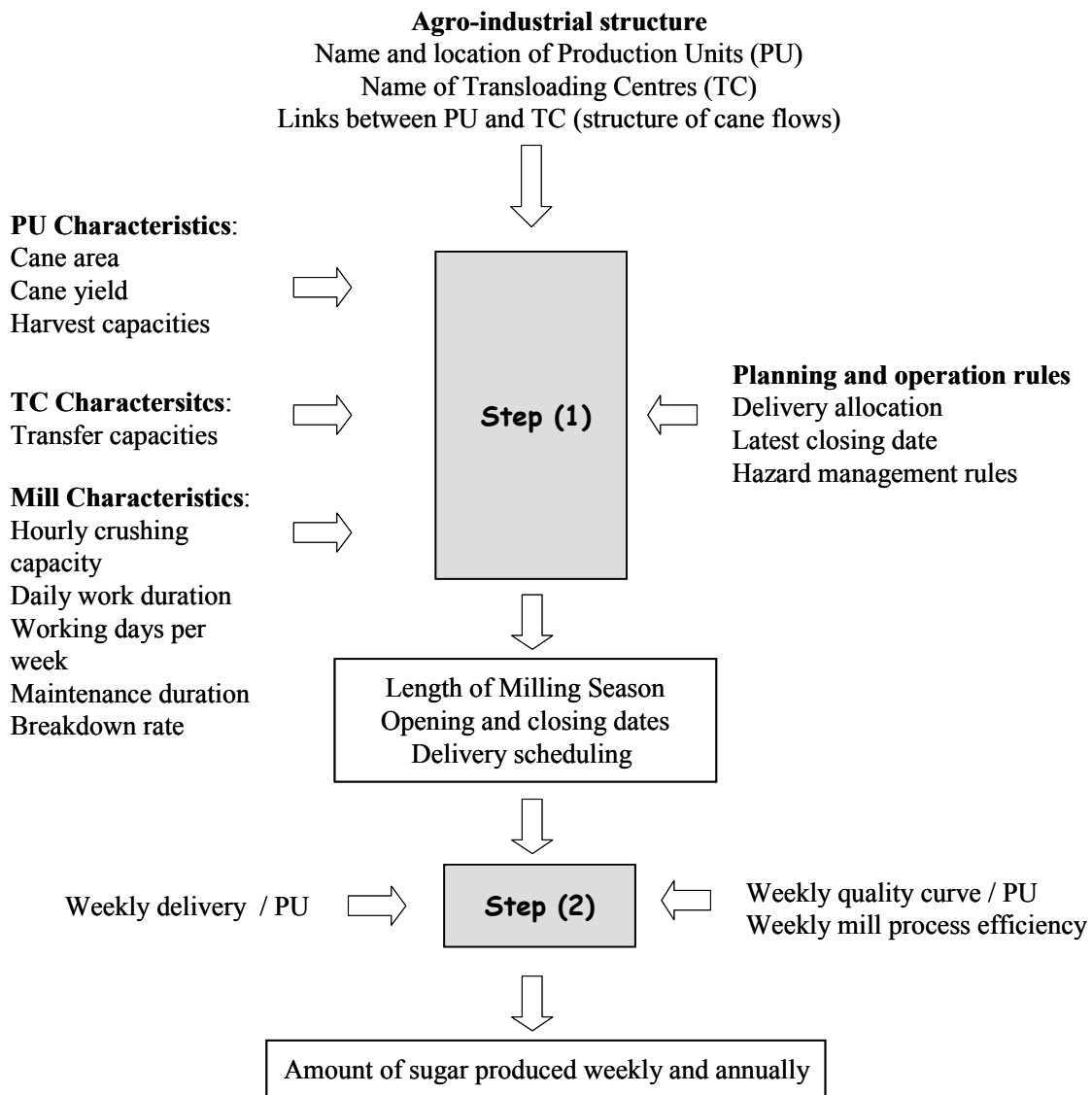


Figure 1. Conceptual framework of mill supply modelling (adapted from Gaucher, 2002).

The planning and operation module includes an estimation of cane tonnages to be delivered by the production units, calculation of the mill crushing capacity, determination of the length and dates of the milling season and allocation of delivery rights to the PUs. Simulation of this module provides the weekly delivery scheduling for the entire mill supply area, as well as for each PU. The cane deliveries are then transformed into sugar production through the process module according to individual quality and mill process efficiency. The amount of sugar produced weekly and annually is calculated and used to evaluate and compare scenarios.

This model was selected to address the issues raised by the Sezela stakeholders, as it differentiates the roles played by each stakeholder along the supply chain, and it takes into account the characteristics and management of cane quality at the mill supply area level. Its computing transcription into a simulation tool called MAGI (Le Gal *et al.*, 2003) was not adapted to the South African case at the time of the study. A specific Excel[®] program based on this conceptual framework was therefore developed to simulate various scenarios of supply management.

Data collection and analysis

Analysis and modelling of the current context in Sezela were addressed through bibliographic work and numerous interviews with different operators in the supply chain. This step enabled us to define the structure of the mill area, to understand the relationships and co-ordination rules between the different levels of the supply chain during the season and to highlight problems and potential improvements.

Variability in cane quality within the supply area was analysed by using the data captured in 2000 and 2001 at the Sezela weighbridge. These data include cane origin (farmer, field, harvest technique), cane delivery (date, time and payload), cane quality for 60% of all consignments (sucrose, fibre, non-sucrose and RV), and cane haulage (haulier and truck identification, truck traffic in the millyard). Some data were not systematically available, such as varieties and burn-to-crush delays, but the database was informative enough for designing a zoning of the supply area based on variability in cane quality.

An assessment of the capacities along the chain was carried out by (i) analysing the data collected in 2000 and 2001, (ii) conducting interviews with hauliers and mill representatives, and (iii) sending a questionnaire to the growers. The values used in the simulations and the benchmark scenario configuration were discussed with grower and miller representatives. New scenarios were compared against the benchmark scenario. Results were presented to and discussed with miller and grower representatives at the end of the study.

Results

Current supply chain

The Sezela mill supply is managed as follows. Harvesting is done by the growers themselves or by harvest contractors (especially for small scale growers). Harvesting includes cutting and transporting the cane to a loading zone (LZ), and transfer into large lorries called 'hilos'. At this stage the cane bundles may be weighed so that the cutters can be paid. Cutting is done by hand, and many different modes of transport are used to haul cane from the fields to the LZ.

Hauliers are in charge of the final transport from LZs to the mill. A haulier may be an independent, a member of a company or a private grower who owns a truck. The same haulier will generally transport the entire season's cane for a grower, as contracts exist that cannot be broken during the course of the season. The relationship between growers and hauliers is thus part of the supply chain structure.

Eventually, the mill receives the cane and transforms it into sugar. On arrival at the millyard, payloads are weighed and offloaded onto one of the two tables that feed the mill, or are deposited on the stockpile. Consignments are sampled for analysis while the cane is on the conveyor belt that takes it from the shredder to the diffuser.

The length of the milling season (LOMS) is decided by the MGB and has to account for the total crop of the mill area and the mill capacity ($LOMS \sim \text{total crop size} / \text{weekly crush capacity}$). The Local Grower Council determines the size of the crop from estimates sent in by the large scale growers and the small scale grower sectors. The MGB refines the estimates through comparison with the previous four seasons.

The mill estimates its target crushing rate by taking into account (i) the size of the crop in order to calculate an indicative LOMS, (ii) an opening season date set according to the Easter holidays, (iii) maintenance, breakdown and holiday stops in order to deduct the weekly non-crushing time (168 hours minus scheduled stops for each week) and (iv) a quality-dependent crushing rate, computed according to the mill performances (namely brix, fibre and non-sucrose handling capacities, in tons per hour) and forecast cane quality figures (historical data from preceding seasons). The weekly crush capacity is then calculated by multiplying the crush time by the crush rate, and the average is used for planning purposes.

When the LOMS has been determined, the opening and closing dates are set for the mill, and are usually such that the season ends before Christmas (unless the crop is too large). The cutters are usually seasonal workers that come from far away, and particular attention is thus given to avoid crushing over Easter and Christmas.

Daily Rateable Deliveries (DRDs) are calculated from estimations of cane production and the LOMS, and are allocated by the MGB to individual growers. For operational purposes, these individual DRDs are aggregated and allocated to 20 or so hauliers responsible for transporting the cane from the farm LZs to the mill. The hauliers have to make regular deliveries to the mill, and conduct their own arrangements with their growers.

A relative payment system is used to compensate the cane revenue of growers who do not deliver rateably. Growers are thus paid according to the relative % RV of their cane for each week, according to the following formula:

$$\text{Grower's relative \% RV} = \text{grower's \% RV} - \text{mill week average \% RV} + \text{mill season average \% RV}$$

Modelling of the supply chain

The modelling of this supply chain is based on its three levels of management, i.e. growers (PUs), hauliers and the mill. Simulating the crushing season requires a set of data describing each level (Table 1).

Table 1. Simulation parameters and variables per management level.

	Production units	Hauliers	Mill
Parameters	Total crop Harvest capacity RV curves	Transport capacity: <ul style="list-style-type: none"> • number of trucks per day • number of trips per day • working days per week • average payload 	Crush capacity: <ul style="list-style-type: none"> • scheduled stops • breakdown rate • cane handling capacity • fibre handling capacity • non-sucrose handling capacity • brix handling capacity
Variables	Weekly DRD		Opening or closing date

Two types of crush capacity have been calculated. The first is based on cane handling capacity ('crush capacity'), and does not take into account cane quality variations over time. The other is based on fibre, non-sucrose and brix handling capacities and is called 'QD crush capacity', as it is quality-dependent.

The definition of PUs depends on both the level of accuracy required by the model users according to their objectives and on the data available for the supply area.

For example, each commercial farm and each small scale grower sector can be considered an individual PU, or they can be aggregated into larger units. In this study PUs are defined as homogeneous areas according to cane quality, in order to simulate alternative supply organisations based on variability in cane quality.

Supply area zones based on cane quality variations

Computing the % RV of cane consignments for the 2000 and 2001 seasons shows that the average % RV follows a bell-shaped curve, with a quality peak of around 13% RV in both cases. Nevertheless, these results are sensitive to the weather conditions that prevailed during the season, e.g. in 2001 RV peaked three weeks earlier than in 2000, and then dropped dramatically towards the end of the season (Figure 2).

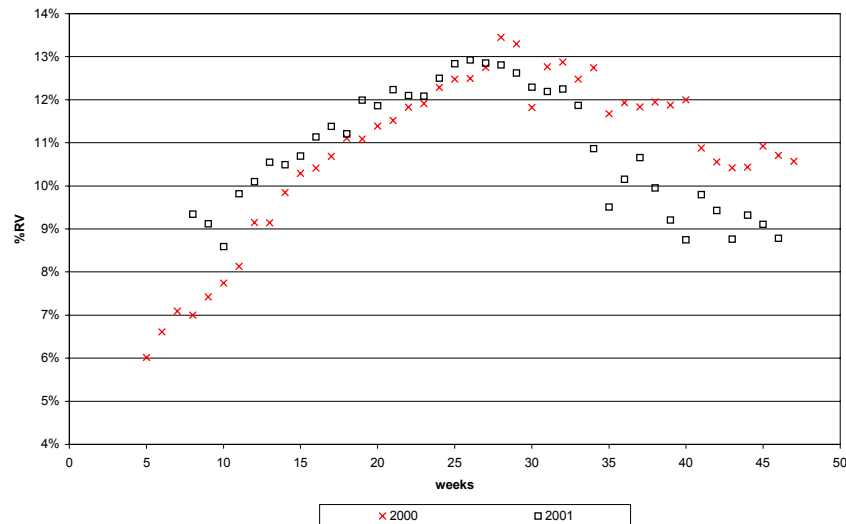


Figure 2. Weekly weighed average % RV of cane consignments delivered to Sezela mill in the 2000 and 2001 seasons.

Factors such as soil and climate, agronomic practices and harvest and transport conditions account for variability in cane quality. Soil and climate depend on the natural environment, whereas the other factors are the results of decisions made by growers. As detailed and comprehensive information was not available for these grower decisions, zoning was based on climatic factors and assumed that growers follow an economic rationality aimed at maximising their RV yield at any time of the season. Nevertheless, this assumption did not account for small scale growers who seek for trade-off between financial constraints and once-off harvest.

Considering that temperature and water balance are the main climatic factors driving cane quality (Fauconnier, 1991; Singels and Bezuidenhout, 2002), the authors selected altitude (to account for temperature), date representing the end of the moisture growing season¹ and mean annual precipitation as zoning criteria from among the variables available at the mill area level in the South African Atlas of Agrohydrology and Climatology (Schulze, 1997).

Crossing those criteria enabled the three zones shown in Figure 3 to be defined. These were a coastal area, characterised by high rainfall and warm temperatures, an inland area, cooler and dryer, and an intermediate area (hinterland).

¹ The moisture growing season is that period of the year when growth is not limited by rainfall and soil moisture (precipitation greater than 0.3 times the A-pan evaporation in South Africa). This period ends when active growth cannot be sustained and the cane is supposed to start ripening.

This zoning was linked to the mill database and RV curves were extracted for the three zones (Figure 4). The curves show significant differences, with inland and hinterland areas enjoying a better RV at the beginning of the season. Two other zones were added to take into account diversion (cane coming from another mill belonging to the same milling company) and small scale grower cane.

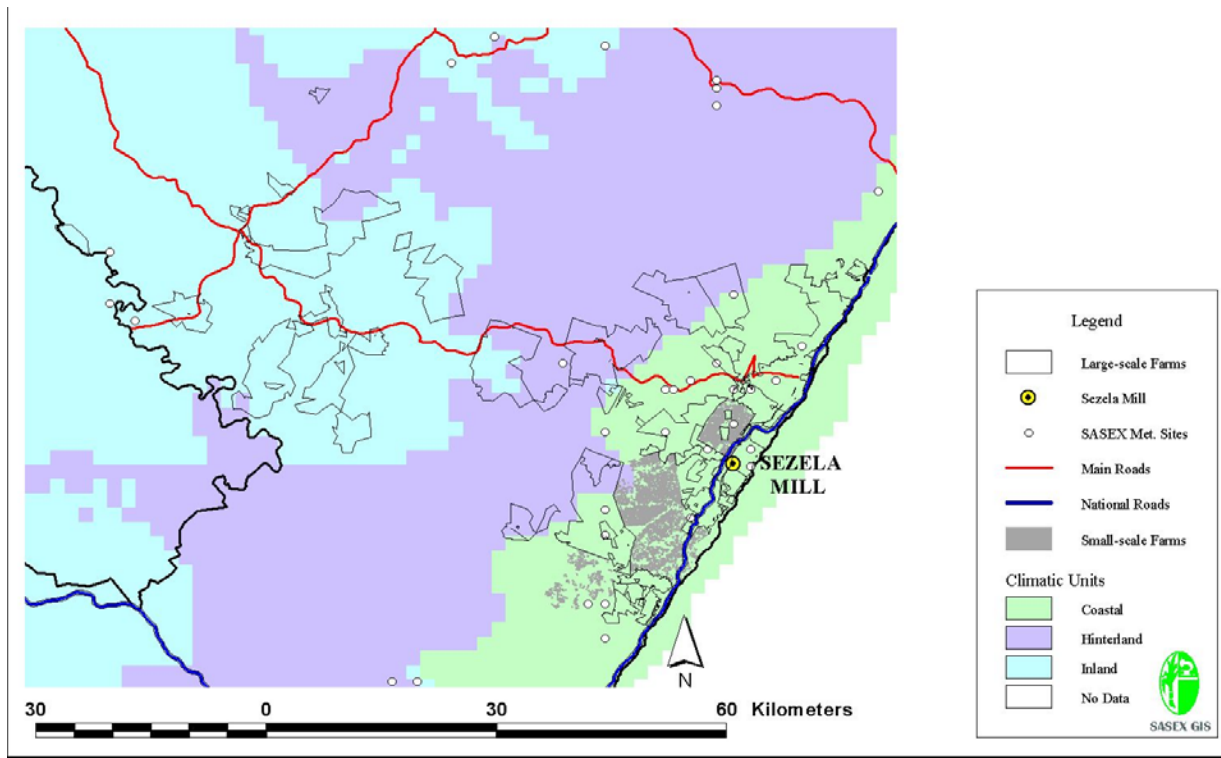


Figure 3. Map of the Sezela mill supply area, showing the coastal, hinterland and inland zones.

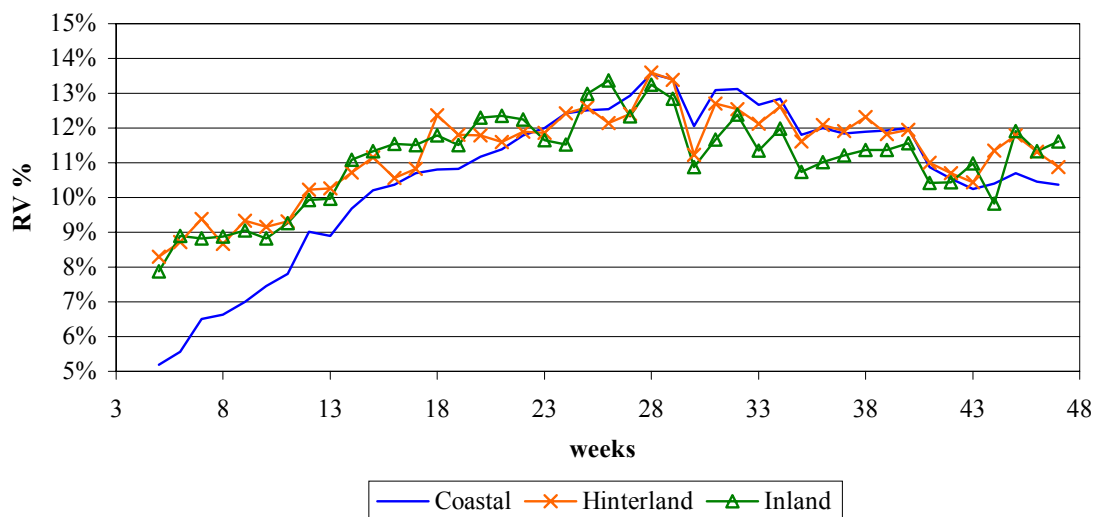


Figure 4. % RV curves for three climatic zones for the 2000 season.

Simulating alternative supply scenarios

There are two options to explore for alternative scenarios that would make use of the variability in cane quality within the supply area and during the season: (i) to postpone the beginning of the season, and (ii) to adapt harvest windows for mill area sub-regions. Both options involve different rules of delivery allocation to PUs.

Five alternative scenarios were simulated and compared with a benchmark scenario. They differ in allocation rules, length of season and opening date (Table 2). In all cases PU tonnages and harvest capacities were assessed by summing the farm values for each of the five zones from the 2000 and 2001 databases. Maximum individual harvest capacities were considered by taking into account the best performances recorded during the season, plus 25% due to over-capacity in the large scale growers' case. This value was adopted after discussion with grower representatives.

Table 2. Characteristics of simulated scenarios.

	Benchmark	A	B	C	D	E
Week No	5-42	8-45	8-44	5-42	5-42	8-43
LOMS (weeks)	38	38	37	38	38	36
Harvest windows	Uniform		Adjusted*			
DRD**	Rateable**				Variable	

* Harvest windows are *adjusted* when they differ from one zone to another; otherwise they are *uniform*.

**DRD is *rateable* when the tonnage to be delivered by a zone remains the same throughout the harvest window; otherwise the DRD is *variable*.

Comments:

Benchmark: rateable delivery allocation to each zone during the entire season.

A: the opening date is postponed in order to profit from the asymmetric RV curve.

B: similar to A, plus priority to inland and hinterland cane at the beginning of the season.

C: similar to B, but the season starts on week 5.

D: gives priority to inland and hinterland cane at the beginning of the season and both zones deliver at their maximum capacity from week 5. Coastal growers deliver more cane at the end of the season than in the beginning.

E: ranks zones according to their % RV and gives priority to the zones with the highest cane quality. The first zone is assigned a DRD equal to its maximum capacity, and so are the following zones until the mill is running at full capacity.

Transport parameters were used to calculate the number of trucks that would have been sufficient to haul the cane in the different scenarios. This result was compared with the current number of trucks available and being used (± 120 vehicles) to account for transport capacity limitations.

$$\text{number of trucks} = \sum_i \frac{\text{tonnes cane from zone } i \text{ per week} / \text{average payload}}{\text{number of trips to zone } i \text{ per day} \times \text{working days per week}}$$

All simulated scenarios showed 1-5% more RV gain than the benchmark scenario (Figure 5), with various impacts on the supply organisation:

- The later the opening date, the higher the gain (compare B with C and E with D).

- Scenarios B and C imply that there should be a slight increase in mill capacity, for example by reducing maintenance stops.
- Scenarios D and E imply that growers should modify their harvest organisation to cope with higher DRDs.
- No gainful trade-off could be found to reconcile the mill crush capacity and adjusted harvest windows with rateable DRDs.
- In all cases transport requirements did not exceed the current fleet capacity of 120, while truck usage was shown to vary during the season, depending on the scenario.

The stability of these gains from one year to another still needs to be addressed. Nevertheless, these results were discussed with grower and miller representatives to investigate both the potential value of such organisational changes and their practical feasibility.

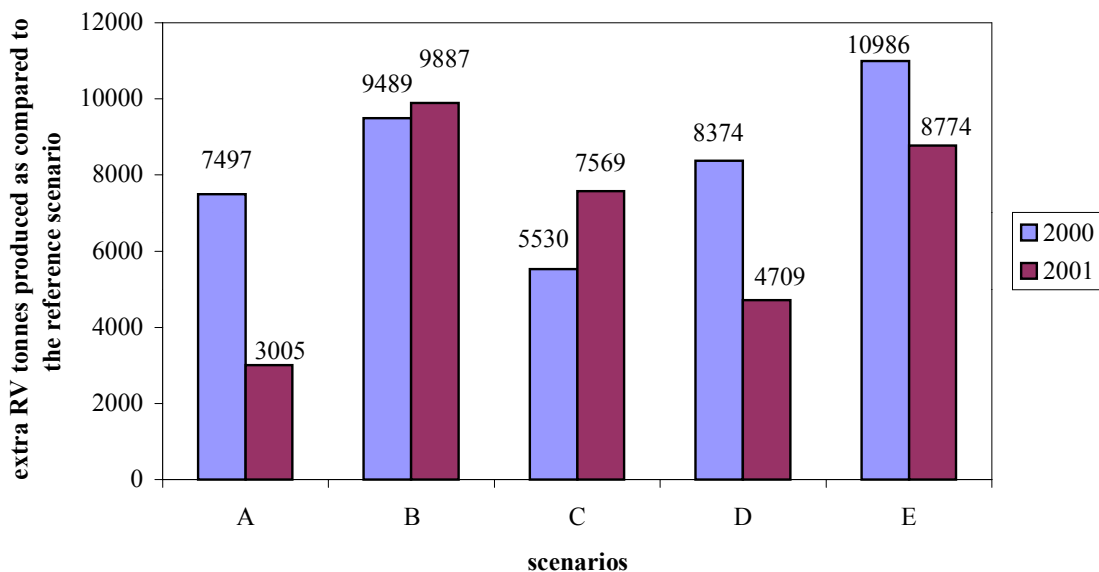


Figure 5. Differences in RV tonnage between alternative and benchmark scenarios.

Discussion

The potential gains expected from delivery allocations, based on zones of homogenous RV, represents for Sezela growers and millers an increase of between 3 000 and 11 000 tons RV per annum, with a value of between R4,05 and R14,85 million (based on R1 350/ton RV). Furthermore, results showed that all growers (inland, hinterland and coastal) would improve their revenues under the scenarios tested (Figure 6). Coastal growers, however, would still earn less than inland growers, due to their lower cane quality. This suggests the need to adjust payment to account for % RV deviation from the sub-area average and not the mill average, as is presently done. The impact of establishing cane payment systems linked to each sub-supply zone will be analysed during 2003, with regard to grower revenues and total milling costs.

To exploit the regional patterns of RV distribution, different sub-areas, for example inland, would have to deliver cane over a shorter period at the beginning of the season when RV is significantly higher than in other sub-areas. This will require new rules of distribution among growers of a given sub-area, for example sharing the zone DRD according to the relative total crop of each grower or group of growers.

This would also have operational implications, since growers harvesting over a shorter period would have machinery standing idle over longer periods and would require additional labour over the shorter period of harvest. This would provide scope for some sort of partnership with farms of another sub-area to facilitate better utilisation of harvest and transport equipment and labour through the season.

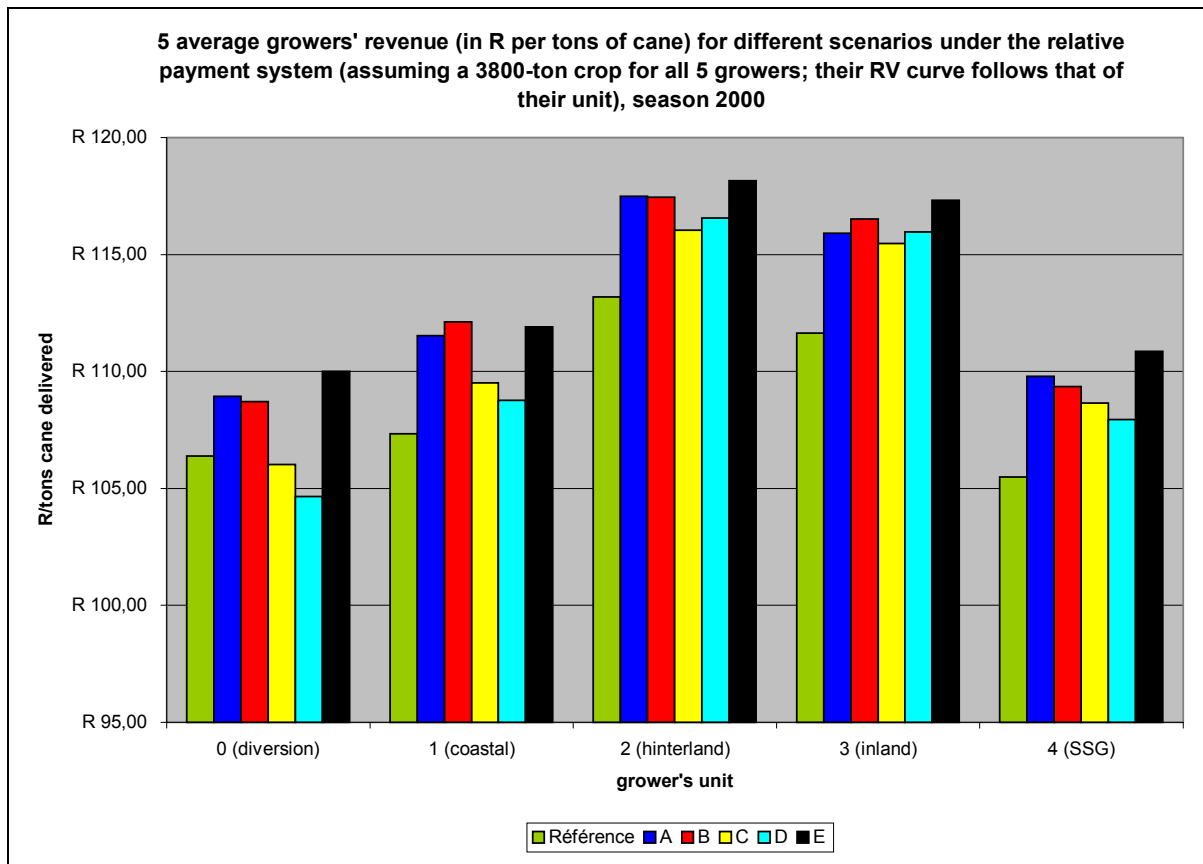


Figure 6. Virtual growers' revenue with the relative value (RV) cane payment system.

Millers might have to adjust their processing capacities as well. For example, Scenarios D and E imply crushing a little in excess of the quality-dependent capacity at some stages (Figure 7). This could be achieved through reduction of maintenance stops, provided such high activity periods are not too long. In Scenarios B and C mill capacities are exceeded for unacceptably long periods. A decrease in maintenance stops might not be sufficient to crush all the cane and it would considerably increase the risk of breakdowns. In that case, the costs of the required capacity increment would have to be balanced with expected gains.

The net result of both these organisational and structural changes would be increased revenue and profits for the mill supply area as a whole, which would need to be distributed equitably to all stakeholders.

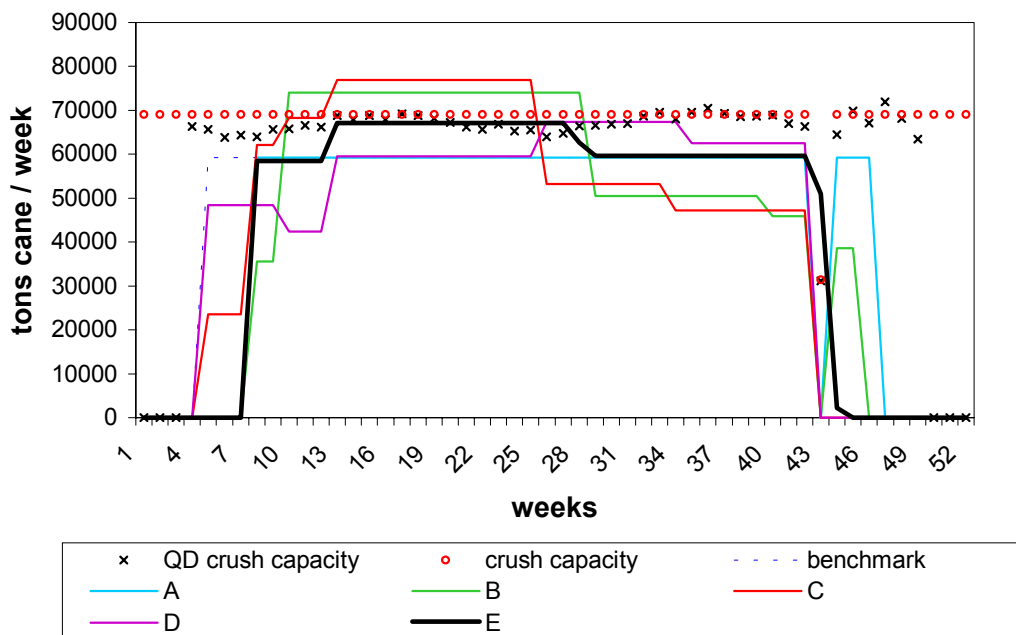


Figure 7. Comparison of delivery profile and mill capacities according to scenarios.

Conclusion

Through implementation of a modelling approach for the Sezela mill, this study proved that zoning the supply area and adapting DRD allocation according to variations in cane quality could increase total RV production, for the profit of both growers and millers. The research identified the need to further investigate the impact that changes to harvest schedules (e.g. a shorter, earlier harvest season for inland growers) would have on farm agronomic and operational practices. There is also a need to evaluate the costs attached to changing harvesting schedules. This could best be achieved using the LOMS model developed to optimize harvest season length.

Availability of accurate information is crucial in this type of investigation. This includes (i) characterisation of infield cane quality and agricultural practices as well as delivery flows from the fields to the mill, and (ii) accounting for economic and logistic considerations. Improving the information system along the chain according to the users' requirements would be a valuable action to take in the future.

Improved information systems will help 'fine-tune' the proposed scenarios by providing better knowledge in terms of spatial and temporal trends in cane quality. Meanwhile, research programs being undertaken at SASEX on dry matter partitioning will assist in modelling cane quality. This information will allow simulation of RV curves over a range of years and weather patterns for input to the modelling approach developed in this study, which was limited to observed data for the years 2000 and 2001.

This pioneering case study has stressed the potential of this modelling and simulation approach in addressing supply organisation issues at the mill supply area level. Focusing on cane flows between farmers, contractors, hauliers and miller, and taking into account their interactions along the chain, would complement daily logistic tools and economic evaluation tools such as LOMS. Simulating scenarios provides a powerful and quick way to assess the impact of proposed changes on the profitability of the chain. Stakeholders can use this information to support their negotiation and decision-making processes.

Other mill areas could be interested in undertaking similar investigations. Development of a cane supply simulation program adapted to the South African context will help address specific issues concerning supply chain management. The ongoing collaborative research project between CIRAD and SASEX will investigate the value of a new version of MAGI suitable for both La Réunion and South Africa (Le Gal *et al.*, 2003).

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