

BUILDING AND ASSESSING SUPPLY MANAGEMENT SCENARIOS BASED ON CANE QUALITY VARIATIONS: EXAMPLE OF LA REUNION ISLAND

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Abstract

Cane and sugar yields within a sugar mill area vary with geographical location and climatic conditions. Delivery allocations policy and sugarcane supply management may take into account these variations of quality in order to improve sugar production and mill area profitability. In La Réunion Island, alternative supply scenarios based on quality variations were designed and simulated for Le Gol mill area. An analysis of sugarcane quality variations within the mill area was necessary to design new supply scenarios. The mill area was split into homogeneous quality zones by carrying out a statistical cluster analysis. A simulation tool, called MAGI, was then used to evaluate the impact on sugar production of supply scenarios based on two zoning levels. Different harvest windows were tested for each zone to increase sugar production. Delivery allocation took into account the mill crushing capacity and the storage and transport capacity between mill and transloading zone. Results show a gain of 2-5% sugar, depending on the zoning accuracy.

Keywords: sugarcane, mill supply, simulation tool, sugar production, cane quality

Introduction

About 5 000 smallholder farmers cultivate 26 500 hectares of sugarcane in La Réunion Island. They produce almost two millions tons of cane, equally processed by two mills for a roughly annually output of 200 000 tons of sugar. The millers decide the weekly delivery allocation for each grower, according their estimated tonnage and the mill capacity. These allocations remain constant throughout the season, regardless of cane quality variations.

Sugarcane quality varies within a sugar mill area according to the location of the field and climatic conditions, and the sugar content of the cane depends mainly on soil moisture conditions and the temperatures that prevailed before harvest. Water stress and low temperatures increase sucrose content, whereas fibre and non-sucrose contents decrease (Clements, 1980; Fauconnier, 1991).

In La Réunion, the diverse climatic conditions lead to large variations in cane quality. Sugarcane is grown from sea level to an altitude of 1 000 m. The average annual rainfall varies from 500 mm on the west coast to 5 000 mm on the east coast. Significant differences can thus be seen in the quality curve from the northern to the southern parts of the island (Figure 1a) and from the lowlands to the highlands (Figure 1b). In addition, most of the drought zones are cropped under irrigation.

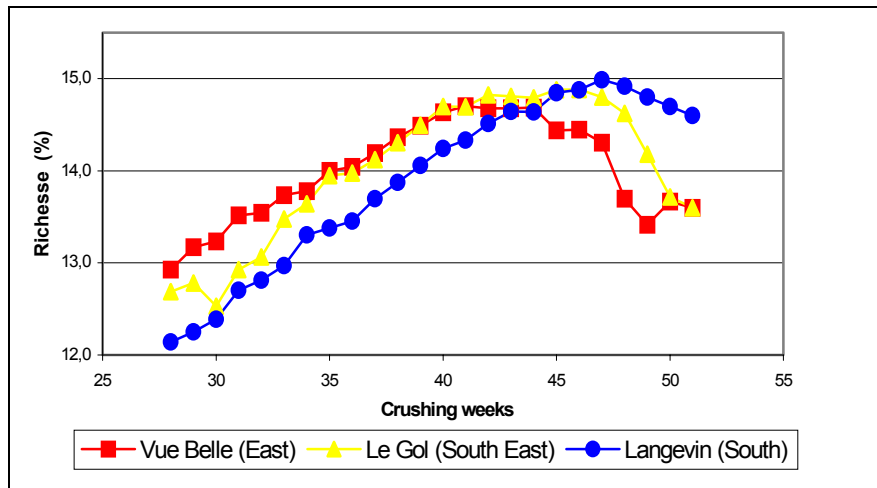


Figure 1a. Quality curve observed from the northern to the southern part of La Réunion Island.

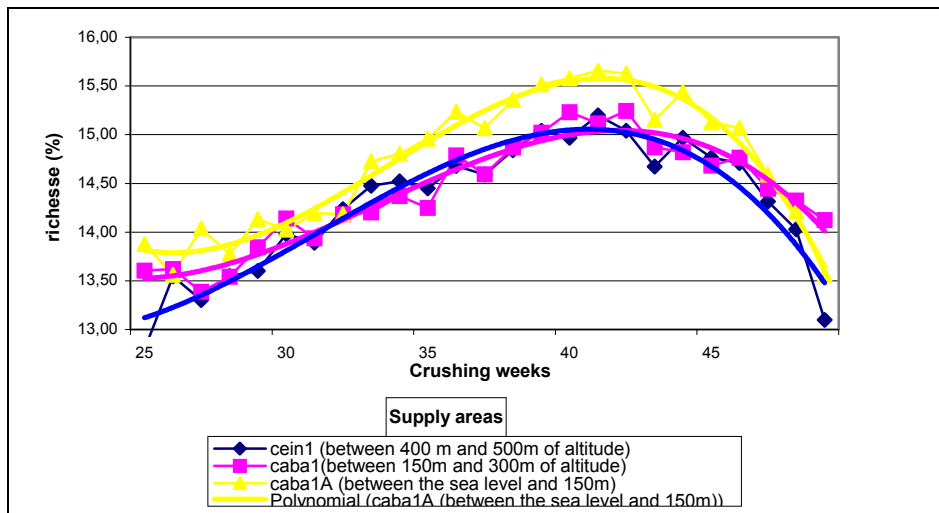


Figure 1b. Quality curve observed from lowlands to highlands on La Réunion Island.

As the current supply system is based on uniform delivery allocation in all regions throughout the milling season, it might be profitable to investigate alternative supply systems based on variations in sugarcane quality at different times of the year and at different locations. It may be possible to improve sugar production and mill area profitability by modifying the delivery allocation rules to benefit from cane quality variations within a supply area.

This paper presents different supply scenarios based on quality variations in different geographical sectors within the supply area of Le Gol mill (west coast of the island). Cane quality variations were statistically analysed to split the mill area into homogeneous quality zones. New supply scenarios based on two zoning levels were then designed and compared, using a simulation tool called MAGI (Lejars *et al.*, 2002; Le Gal *et al.*, 2003).

Splitting the Supply Area into Homogeneous Quality Zones

Quality definition

An indicator, called ‘richesse’ is used in La Réunion to estimate the amount of sugar that would be extracted from cane, and to link payment to the quality of the cane delivered by growers.

‘Richesse’ is measured at the delivery zone. It includes both sucrose and fibre content, but not sugar lost during transport from the delivery zones to the mill, or from the milling process.

Available dataset

The Réunion mill supply areas are divided into delivery zones. There are seven for Le Gol mill. Each zone has a transloading station where growers deliver their cane and where cane quality is measured. Deliveries are sampled and processed by a specialised body, independent from growers and millers. The grower’s name and number are recorded for each delivery, along with the quality characteristics of his cane.

Each delivery is linked to the grower’s physical address, but not to the plot harvested. Plots of one farm may be spread across the mill supply area, and could fall into different climate zones because of La Réunion’s climatic diversity. The analysis was therefore limited to growers cultivating closed or grouped plots, in order to link geographic location and quality data (i.e. ‘richesse’).

An existing zoning of the island, called ‘ARMES’ zoning, was used to define homogeneous quality zones. In 1996, an inter-professional body stratified the island’s cane production area into 250 ARMES sub-regions, each covering 500 to 1000 hectares. Expert knowledge was used to delimit these homogeneous sub-regions based on agricultural properties such as soil type, potential for mechanisation and transport constraints.

This study was conducted at the ARMES sub-region level. Growers cultivating all their plots in one ARMES sub-region were selected, and the average quality of each sub-region was calculated using the weekly delivery data from these growers. Of 3000 growers, 1645 were selected from 117 sub-regions of Le Gol supply area (Figure 2). A consistent dataset was then built up by selecting from the records, years and weeks that were common to the grower sample. The statistical analysis was carried out using data from the years 2000, 2001 and 2002, 19 weeks out of the 23 of the crushing season (week 31 to week 48) and 68 ARMES sub-regions.

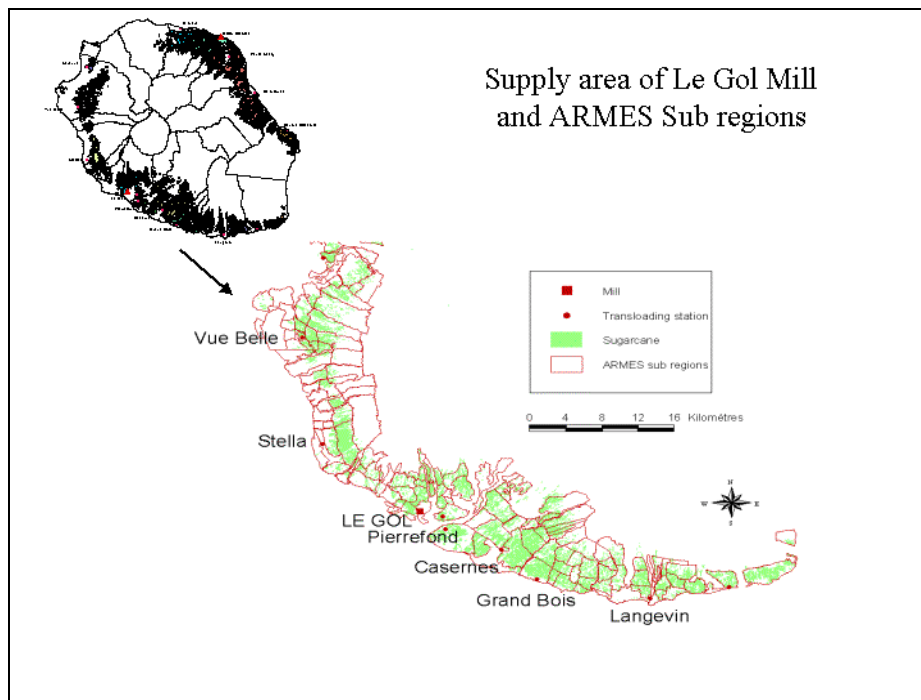


Figure 2. Le Gol mill supply area and ARMES sub-areas.

Statistical analysis

The statistical analysis aimed at (i) grouping ARMES areas with similar profiles of quality evolution, and (ii) testing quality evolution stability between years. The three methods used were a correlation study, a principal component analysis (PCA) (Ihaka and Gentleman, 1996; Lebart *et al.*, 1979) and a hierarchical cluster analysis.

The stability of cane quality in the ARMES sub-regions between years was tested using correlation analysis. Correlations between the years studied (2000 and 2001, 2001 and 2002, 2000 and 2002) were calculated for each ARMES sub-region. The data table used was composed of 19 lines (one for each week) and 204 columns that corresponded to the 68 ARMES sub-regions over the three years (GTAM00, GTAM01, GTAM02 ... with 4 letters for ARMES ID and 2 figures for the year). Figure 3 shows the result of the correlation study for the TAMA sub-regions for year 2000 and year 2002. The graphs were similar for most of the sub-regions, and showed that the quality curves have a similar profile for each sub-region, regardless of the year. Quality evolution was stable between years, although differences of about one week were found.

Correlation of TAMA00 and TAMA02																								
Variance of input = 0.357525																								
Number of Observations 19																								
Crosscorrelations																								
Lag	Covariance	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	
-4	0.054633	0.13401												***										
-3	0.138296	0.33922												*****										
-2	0.194880	0.47802												*****										
-1	0.281505	0.69050												*****										
0	0.359078	0.88078												*****										
1	0.327715	0.80385												*****										
2	0.263275	0.64579												*****										
3	0.221698	0.54380												*****										
4	0.147852	0.36266												*****										

Figure 3. Results of the correlation study for the TAMA sub-regions (2000 and 2002).

A PCA was then carried out to determine the occurrence of similar quality evolution profiles between sub-regions. The data table had 68 lines (one for each selected ARMES sub-region) and 69 columns corresponding to the 19 weeks per year throughout the three years (week3100, week3200 ... week4801, week4802). PCA showed that some sub-regions could be grouped (Figure 4), because they had similar quality curve profiles. However, these groups could not be easily determined with this method.

A hierarchical cluster analysis was thus used to classify and group ARMES sub-regions with similar quality evolution profiles. Many methods can be used to apply the hclust function (Ihaka and Gentleman, 1996). Figure 5 was obtained by using a complete method with Euclidean distance. Similar clusters were found, whatever the method used.

Six main groups were defined, based on the cluster dendrogram. Groups 2, 3 and 6 were further divided into two sub-groups. These nine groups were considered as homogeneous in terms of their quality profiles from one year to another.

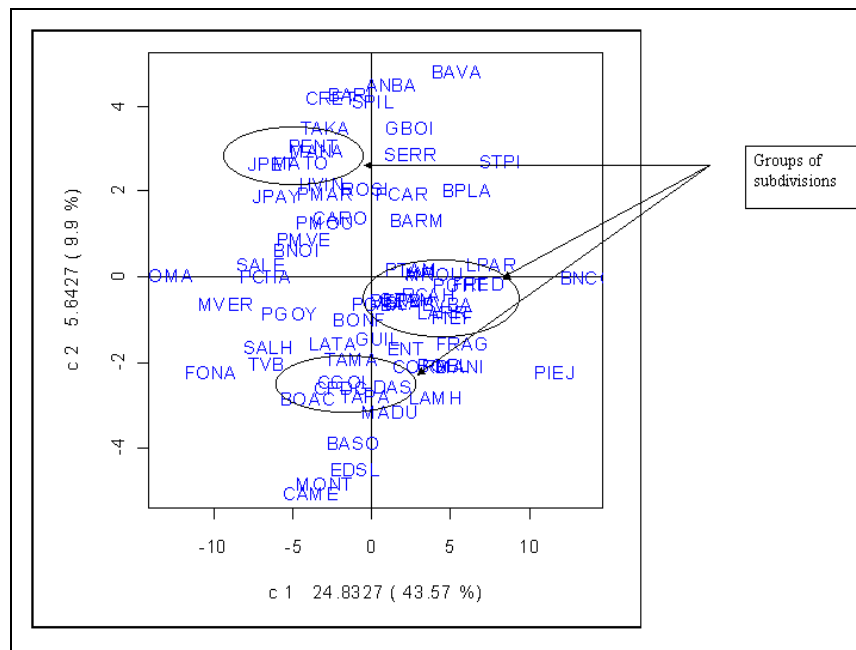


Figure 4. Results of Principal Component Analysis: Representation of 68 subdivisions.

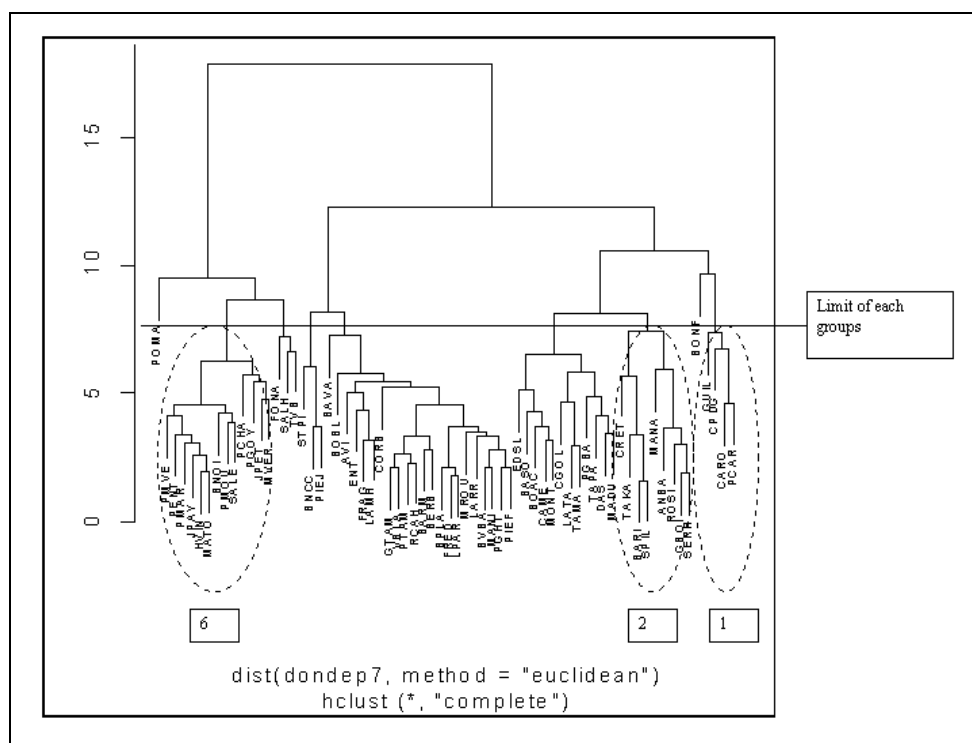


Figure 5. Hierarchical cluster analysis dendrogram.

Homogeneous quality areas

The nine groups of ARMES sub-regions resulting from hierarchical cluster analysis were mapped (Figure 6). Analysing the map showed that the main quality differences (i) occur from the north to the south of Le Gol supply area, and (ii) depend on the altitude of the sub-regions.

The existing delivery areas matched by the nine groups were:

- Groups 2a, 2b, 6a and 6b are located on Grand Bois and Langevin

- Groups 1 and 3b match exactly the delivery areas of Stella and Vue Belle
- Groups 3a, 4 and 5 are located on Le Gol, Casernes and Pierrefonds.

The nine matching zones were used to design supply scenarios, taking into account the various quality profiles encountered within the entire supply area.

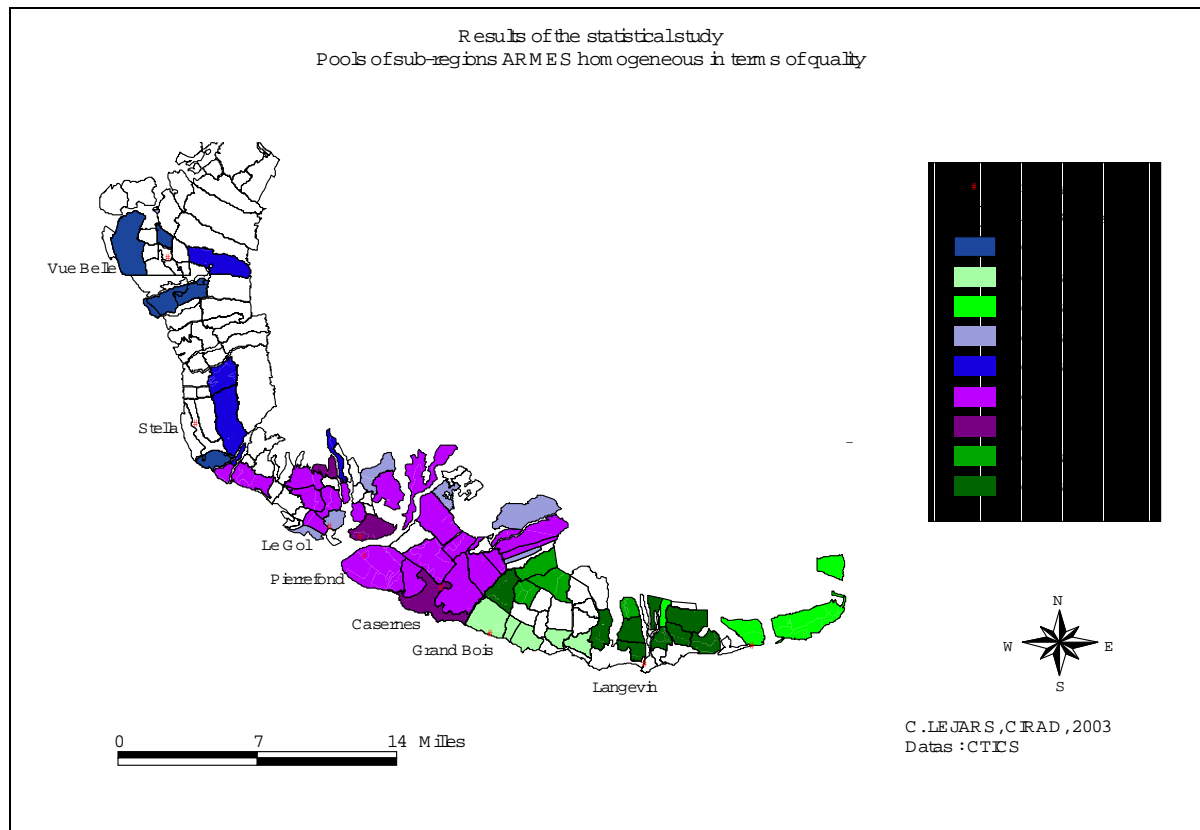


Figure 6. Groups of ARMES sub-areas resulting from hierarchical classification.

Simulating New Scenarios for Supply Management

Modelling method

CIRAD has developed a specific simulation tool called MAGI (Laurent, 2002) to assist millers and growers in designing and assessing new ways of managing supply at the mill area level. MAGI and its conceptual background are described in other papers presented at this Congress (Le Gal *et al.*, 2003; Gaucher *et al.*, 2003).

MAGI addresses a wide range of issues, such as reorganising the mill area due to mill closure or relocation of transloading stations, or introducing new rules governing delivery allocation. It models the planning and operation of a crushing season on a weekly basis, and calculates total sugar production at the mill area level. Scenarios are based on a description of the supply area structure at three levels: production unit (PU), transloading station and mill. In terms of quality, a PU can be a plot, a farm, a climatic zone or a homogeneous area. Each PU is characterised by its 'richesse' curve and its delivery allocation. The supply area is split into PUs, and cane flows from the PU to the mill are described. Agricultural and milling capacities and season characteristics (e.g. opening and closing dates and length of milling season) were taken into account when simulating the mill supply.

In this study, MAGI was used to compare scenarios based on variations in cane quality within the supply area and throughout the season. Different rules governing PU delivery allocations were simulated to ascertain the benefits from these variations. PU delimitation resulted both from the statistical study described below and from the seven existing delivery areas. These were homogeneous quality areas characterised by a specific ‘richesse’ curve.

Alternative supply scenarios tested

The four scenarios described in this paper have the following common circumstances:

- The supply area structure used for each scenario is based on an existing delivery area.
- The total amount of PU delivery allocations per week did not exceed the weekly milling capacity.
- Estimation of potential transloading flow rate was based on historical data of the maximum daily tonnage delivered, sampled and transported to the mill, and depended on the storage capacity at each transloading station.
- PU potential loading flow rate (cane cutting, loading and transport capacity from PU to transloading centre) was not taken into account.
- An average ‘richesse’ curve was calculated for the past four years, for each PU.
- Variations between weeks and PUs did not exceed 20% of the benchmark allocation. According to Le Gol millers, allocations are comparable with existing capacities.

The scenarios differ according to the supply area structure and delivery allocation rules:

- The benchmark scenario (scenario 1) and scenario 2 consider the current seven delivery areas as PUs (Figure 7a).
- In scenarios 3 and 4, PU definition was based on the groups that resulted from the statistical study (Figure 7b). The delivery areas of Stella, Vue Belle and Pierrefonds were unaltered. Le Gol, Casernes, Langevin and Grand Bois were divided into two or three sub-areas.

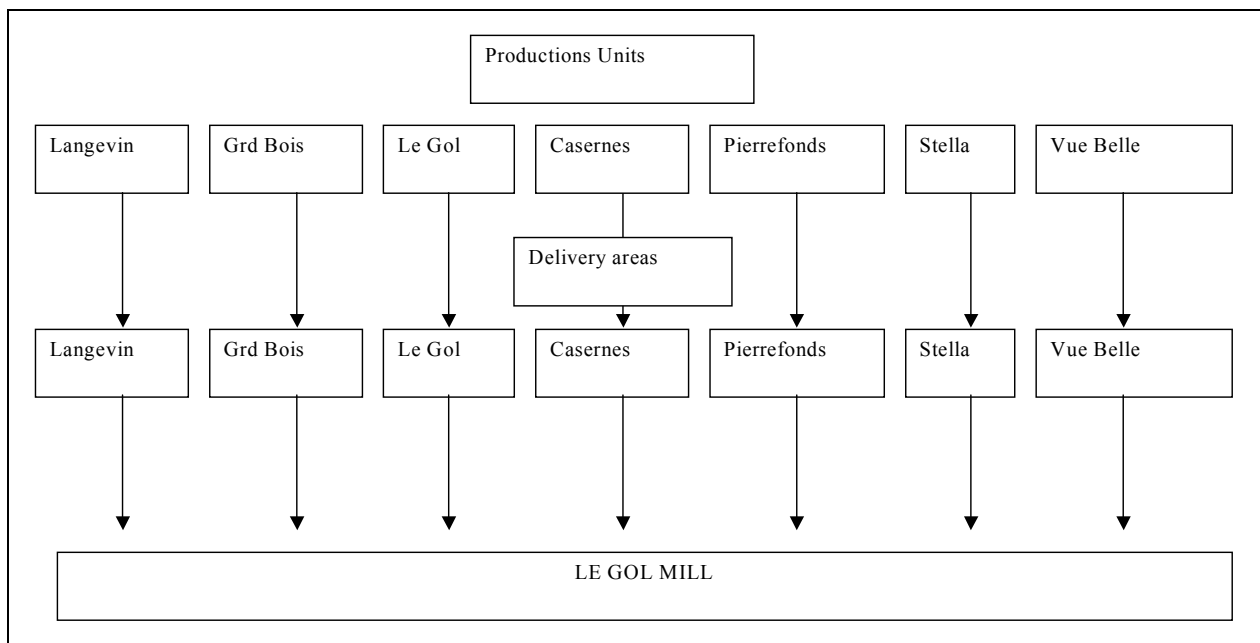


Figure 7a. Supply area structure for scenarios 1 and 2.

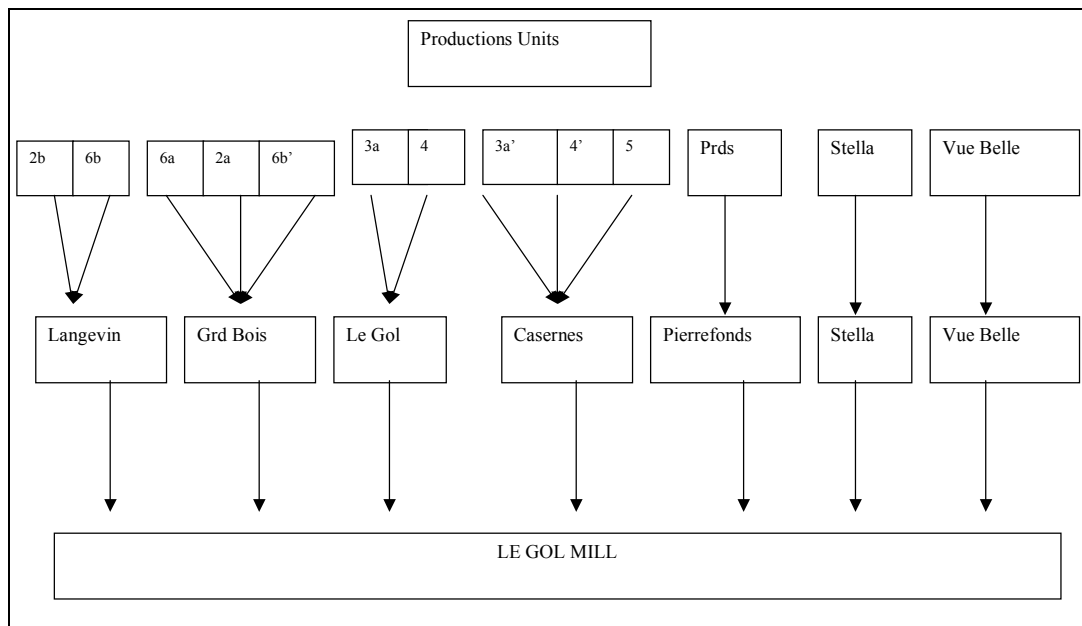


Figure 7b. Supply area structure for scenarios 3 and 4.

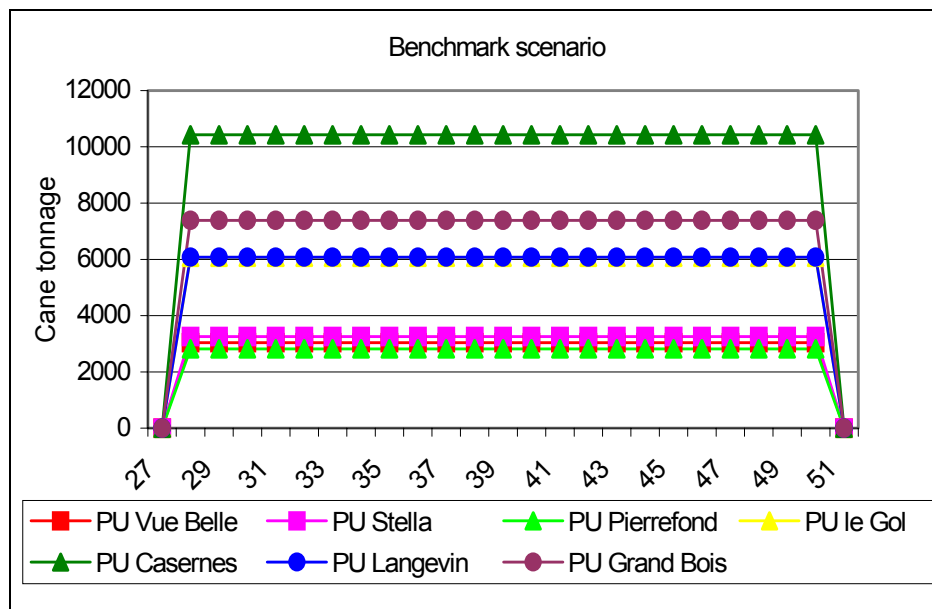


Figure 8. Benchmark scenario: Delivery allocation per delivery area.

Delivery allocation rules were modified for each scenario:

- *Benchmark scenario.* Uniform delivery allocations were applied throughout the season on each delivery area (Figure 8).
- *Scenario 2.* Allocation rules were modified for each delivery area:
 - Opening and closing dates of transloading centres were shifted according to the 'richesse' curve (more or less two weeks).
 - Delivery allocations were modified to give priority to the production units with the highest quality (Figure 9a,b). Allocations for Vue Belle and Stella increased by 15% at the beginning of the season and were decreased at the end of the season. Accordingly, Grand Bois and Langevin allocations were decreased during the first part of the season and increased at the end, in respect of the weekly milling capacity. Such modifications were also carried out between Le Gol, Pierrefonds and Casernes.

- *Scenario 3* (Figure 10). Allocations were uniform for each delivery area. Allocation transfers were carried out between PUs within each delivery area, giving priority to the PUs with the highest cane quality.

Scenario 4 (Figure 11) is a combination of scenarios 2 and 3. Allocations were distributed for each delivery zone according to scenario 2, and allocation transfers were carried out within each delivery area according to scenario 3.

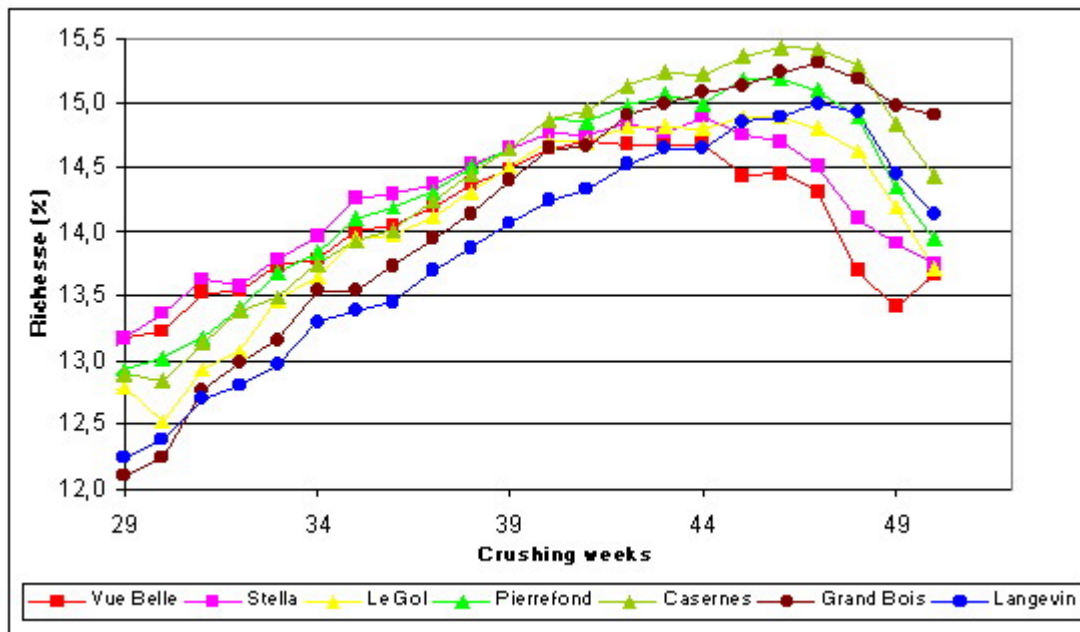


Figure 9a. 'Richesse' curves for the seven delivery areas (Le Gol mill).

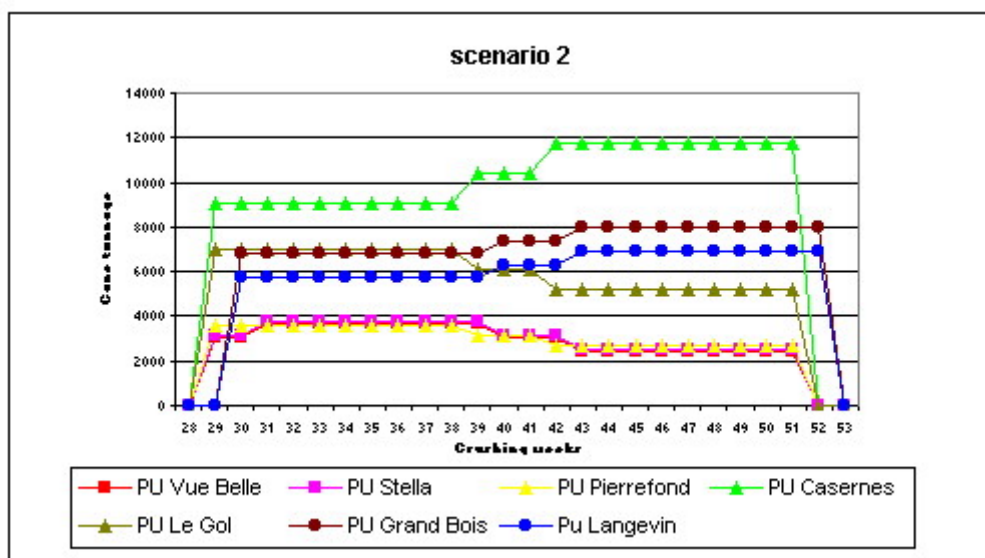


Figure 9b. Scenario 2: Delivery allocation per delivery area.

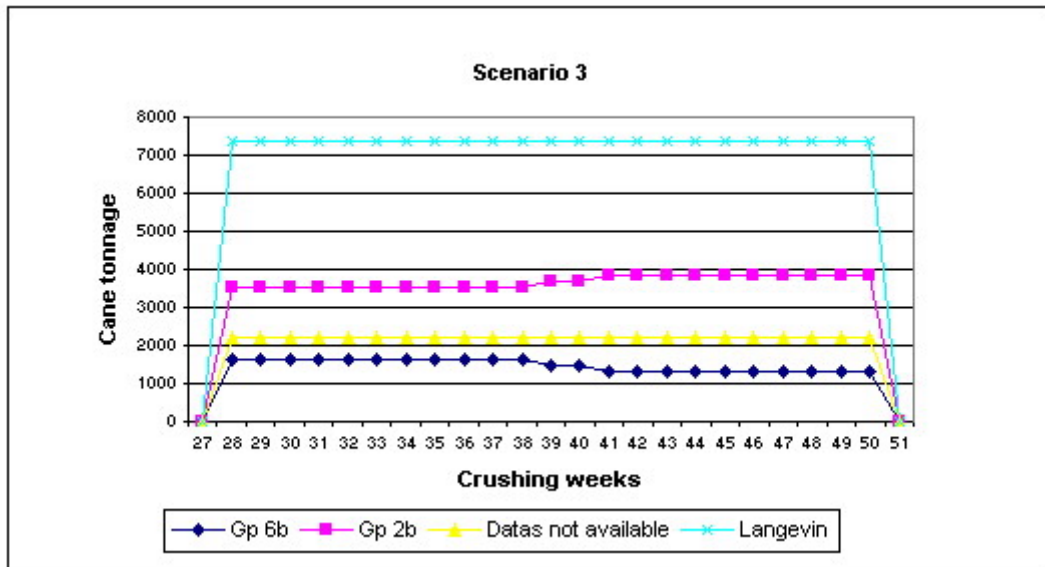


Figure 10. Scenario 3: Redistribution of allocation for Langevin delivery area.

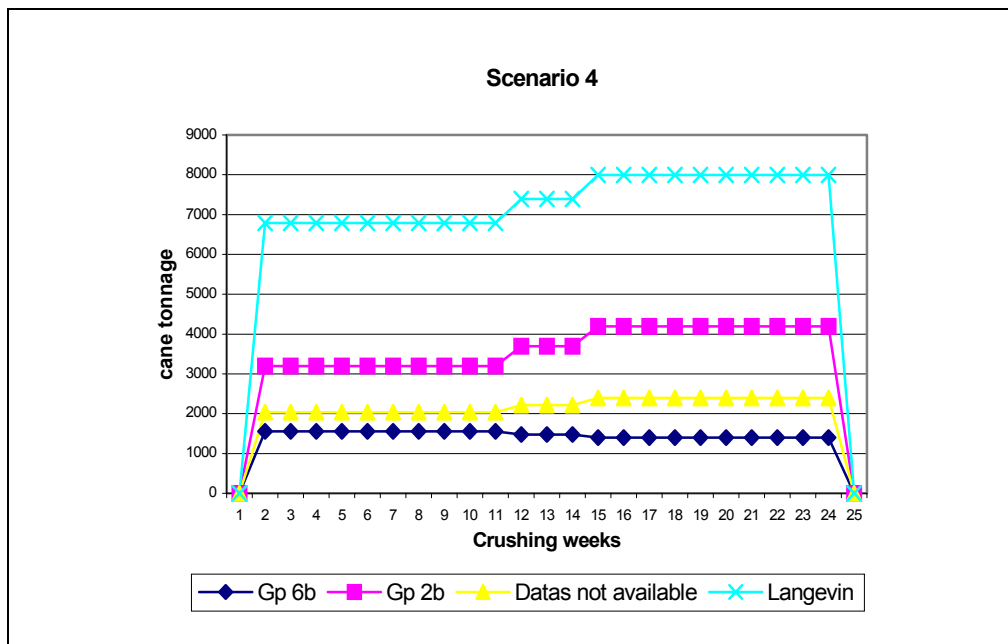


Figure 11. Scenario 4: Delivery allocation for two zones in the Langevin delivery area.

Simulation Results

Sugar production was simulated for the four scenarios (Figure 12). Expected gains varied from 2% (scenario 2) to 5% (scenario 4) of the current production (benchmark scenario).

The results show (i) the value of incorporating variations in cane quality into mill supply management, and (ii) the relevance of statistical analysis in increasing zoning accuracy.

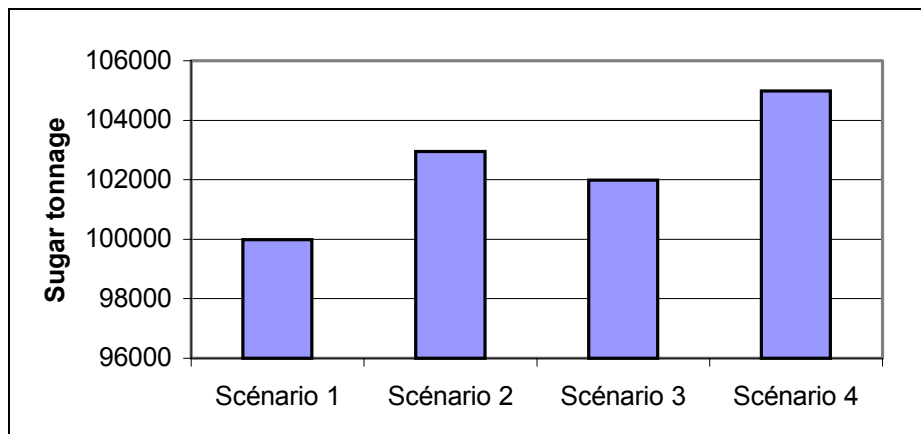


Figure 12. Total sugar production for scenarios 1 to 4.

Conclusion

This statistical study shows that it is possible to differentiate homogeneous quality sub-areas in a mill supply area, although variability within each sub-area is still high. Despite the study being based on a La Réunion case study, the methodology should be relevant to other situations where quality data are available.

The simulation results point out the value of zoning that has been designed statistically. The new scenarios show potential gains in sugar production varying from 2 to 5% of the benchmark, depending on zoning accuracy. Further investigation will be necessary to determine the most relevant scale and size of each subdivision within the supply area.

At this stage of the study, few constraints in terms of the harvesting and transfer capacities of PUs have been used in the simulations. The impact on harvest management at the farm level and logistics have yet to be evaluated for each scenario.

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