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Innovative Applications of O.R.

Mathematical programming accelerates implementation of agro-industrial sugarcane complex

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ABSTRACT

With the current demand for Brazilian sugarcane, the importance to investors of a faster implementation of agro-industrial complexes has been increasing. Estimates suggest that a 4-year implementation may enhance financial value creation by 10% when compared to the usual 6-year implementation. Given a desired production and a target implementation horizon, the quadratic programming model presented in this paper offers a feasible plantation schedule with minimum deviation from the plan. The model was used as an important tool in two business plans.

1. Introduction

Since the 16th century sugarcane has been one of the Brazilian economy's most important drivers. Sugar had been the primary sugarcane product until the 1970's when the Brazilian government introduced a program called Pro-Álcool to stimulate ethanol production and consumption. The success of the program can still be observed today when one considers that Brazil has the largest ethanol-based fleet in the world, and accounted for around a third of the world's production of 52,500 million cubic meters in 2007.

Along with the success of ethanol usage in Brazil since there are no light vehicle fuel options besides E25 and E100 (Ex means x% of ethanol in the fuel blend), Brazilian exports of sugar have been increasing over the last 10 years, and in 2006 Brazil accounted for about 40% of the total world sugar trade [1].

Juice and bagasse are the two products generated after crushing sugarcane. Juice is the raw material of the distillery and the sugar factory. Different processes transform sugarcane juice into either ethanol or sugar. Bagasse, on the other hand, is used to feed boilers and, in the end, to supply all the energy required by the factory during the harvest season. Over time, energetic efficiency has been improving causing a generation surplus, with mills and distilleries starting to sell energy to the grid. Energy generation has become the third most economically relevant sugarcane derivative.

Several other reasons such as global warming and security issues related to the main oil producing areas have been further stimulating the global adoption of ethanol as a feasible fuel alternative. Countries and Regions such as China, EU, India, Thailand, and the US have increased their ethanol usage as a mandated blending fuel, and consequently, producers are expecting a structural shift in the product's price and consumption in the years to come.

The reasons described above have been motivating sugarcane growers and millers to increase production: between 20 and 30 new green field projects are expected to be concluded in the Central and Southern Region of Brazil in the 2008/2009 season and production is expected to continue growing by more than 10%/year on average, a growth rate that has been observed since 2000.

In this exciting context, the author has been helping companies to evaluate the implementation and financial standing of such enterprises. One of the most critical issues is the creation of a plantation schedule that speeds up the production ramp-up phase. The model and issues related to it are described in detail below.

2. Sugarcane cycle

Sugarcane is a semi-perennial crop, with an optimized economic life cycle of about 6 years. Depending on the growing region, yields, and economical constraints, one can find optimal life cycles ranging from 4 to 10 years. The grower decides the optimal cycle by identifying the number of cuts that would generate the best financial margin.

It is considered in this paper that within a cycle of T years, sugarcane is harvested $T-1$ times, i.e., once a year except for the first year since it is advisable to rest land for six months, and the most

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profitable varieties of sugarcane grows for around 18 months before the first harvest.

Sugarcane can be divided into two classes of crop: a plant crop (plant grows for 18 months before harvesting) and a ratoon crop (around 1 year after the previous harvest). A ratoon is the sugarcane re-growth after the harvest. After the 4th ratoon and the 5th harvest, land is ploughed and another sugarcane cycle starts. Higgins and Muchow [2] offer a broader overview of the terms and processes associated with the sugarcane plantation.

The main component of the recommended sugarcane cycle is the sugarcane yield which is composed by land and sugar yields. Sugar yields (kg of extractable sugar per ton of cane) are reasonably constant over the sugarcane lifespan, although it is strongly influenced by the harvest time during the harvest season. Land yields, on the other hand, decrease over time as crop ages. Table 1 presents a typical decay of land yields in the Central and Southern Region of Brazil.

Although land yield decreases as the number of harvests increases, sugarcane quality is about the same if harvested on the same date, and the price paid per ton of cane remains the same over the entire cycle. In fact, sugarcane pricing is a complex issue but its main component is defined according to the sugar yield of a sample of cane stalks upon delivery.

For the case under analysis, Fig. 1 shows the financial margins according to different sugarcane planting cycles. It is easy to see that a cycle length of 6 years present the better performance, while 5 years has also shown a comparable result.

3. Plantation planning and schedule

Plantation planning has long been studied. One of the earliest examples of linear programming application deals with farm planning and is due to Heady [3]. Glen [4] offered a thorough revision of mathematical models in farm planning with dozens of applications, and Weintraub and Romero [5] offer a more recent review of the literature available. The problem continues to require new approaches [6,7]. Recent application of OR methods in the sugarcane field can be found in [8,9].

Table 1
Sugarcane yield decreases as the number of harvests increases.

Crop class/ phase	From	To	Approximate period	Sugarcane yield (t of cane/ hectare)
Resting	Ploughing	Planting	6 months	–
Cane plant	Planting	Y1[a]	18 months	110
1st ratoon	Y1	Y2	1 year	94
2nd ratoon	Y2	Y3	1 year	84
3rd ratoon	Y3	Y4	1 year	78
4th ratoon	Y4	Y5	1 year	74

[a] Y*x* represents the date of cut *x*.

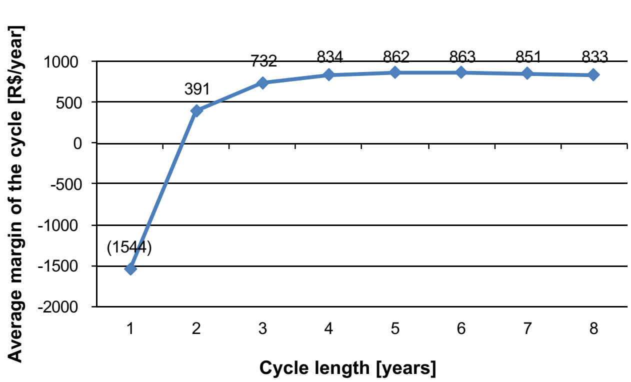

Fig. 1. Financial margins according to different sugarcane planting cycles; R$ stands for 'Real', the Brazilian currency.

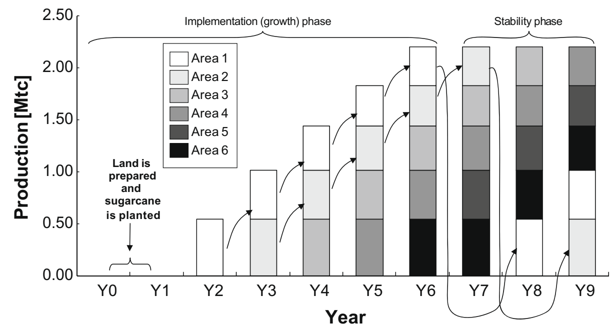

Fig. 2. In a typical implementation of an agro-industrial complex, the plantation schedule requires six years to reach maximum capacity.

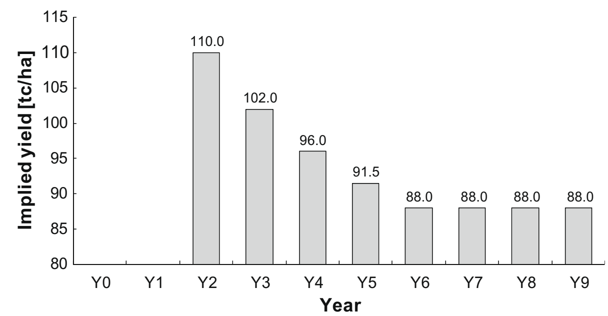

Fig. 3. At the beginning of the implementation, effective yields are greater given the higher proportion of high yield land.

On the other hand, historically, the sugarcane plantation schedule has not been an issue. Brazilian mills used to grow financed by internal resources and hence growth rates were easily manageable. Considering the 6-year cycle of sugarcane, a company has to plant $\frac{1}{6}$ of the total area to reach production stability by the end of the sixth year. Fig. 2 shows sugarcane production for the first 9 years after the start of the enterprise, for a property producing 2.2 million tons of cane per year. Production of the same area (same color of the bars in Fig. 2) decreases over time, as the number of harvests increases and yields decrease. For the schedule shown in Fig. 2, Fig. 3 presents the implied yield, that is, the average yield achieved in the harvested area.

4. Why accelerate the implementation?

The present, lucrative moment which the sugar and ethanol sector is undergoing has brought in several new and wealthy players such as mutual funds, venture capitalists and a broad range of potential investors from Australia (e.g. CSR Sugar), Brazil (Brenco, Cosan, Petrobras), Europe (Bunge, Louis Dreyfus, Société Générale, Südzucker, Tereos), Japan (Mitsui), and the US (ADM, Cargill) amongst others. The abundant resources, and the positive moment for the sugar and ethanol industry, have been encouraging the acceleration of investment. As usual, the interest from investors is not only to have a fair return on their investment, but also to receive a payback upon the investment as soon as possible. Investments by operating companies generally pursue early and generous dividends, while financial investors often expect to have a successful and profitable exit strategy.