RATIONAL ORGANISATION AND ECONOMIC MANAGEMENT OF A LARGE SUGARCANE PLANTATION

Luis Maria Blaquier, Julio Calizaya, Mario Bertoletti and Mario Comín
Ledesma SAAS, Argentina

ABSTRACT

Management of a 30,000 ha sugarcane plantation involves certain specific problems, which necessarily call for a mass type organisation and a systematic standardisation of operations. A real case is contemplated in this paper, which explains how the sugarcane plantation was divided into ecologic units and a master plan of varieties was drawn up; economic factors which lead to the establishment of the economic life of an optimum variety in each ecologic unit; rational organisation of irrigation to take full advantage of the scarce resource water; and a methodology for the identification, appraisal and selection of new varieties with acceptable sanitary, cultural and yield characteristics. Finally, an evaluation is made of results obtained to date, which are only partial since this vast program is still being completed.

INTRODUCTION

Ledesma SA is an enterprise located in the north of the Argentine Republic, in the province of Jujuy (latitude 24°S, longitude 65°W). It was established more than a century ago and is at present an agro-industrial complex consisting of:
a) a sugar cane plantation of 30,000 net ha with an annual production of 2.5 million tons of cane; in addition, purchases from independent cane growers total 250,000 tons a year;
b) a sugar mill with an annual production of 275,000 tons (70% refined, 30% raw), with an installed grinding capacity of 18,000 tons of cane per day;
c) a sugarcane bagasse processing plant for the production of cellulose and paper with an annual production of 34,000 tons;
d) an alcohol plant with an annual output of 32 million litres;
e) a staff of 300 professionals and technicians, 6,000 employees and 7,000 temporary labourers employed for the annual harvesting;
f) necessary services for operating the complex: irrigation through 250 km of main canals and more than 1,000 km of irrigation ditches, workshops, warehouses, powerhouses with a 50,000 kW capacity, a 250 km industrial railroad, a 500 km road network, 500 tractors, 160 automotives, 1 jet, administration offices and laboratories, 3 computer units, 2 small towns, 1 hospital, primary and technical schools, social centers, etc. In order to give some idea as to dimension, industrial, administration and service buildings occupy a total surface of 165,000 meters².

Ledesma contributes 21% of the total Argentine sugar production.

The plantation has in the past been subject to a non-rational operation: more than 30 different varieties are at present cultivated, which often cover very small areas and are grown in inadequate locations for a given variety under
certain soil conditions, climate, harvesting method, etc. The plantation is a huge and inefficiently designed checkerboard.

Crops are harvested annually, normally from May through November. Manual, semi-mechanical and mechanical harvesting methods are used simultaneously. The general trend is to reduce manual labour to a minimum. Cane fields are replanted when yields decrease either through aging of the stump or some other cause; and once the cane is harvested, legumes are sown, and sugarcane is then planted in February or March to be harvested for the first time the following year. That is, the first crop is harvested from 15 to 20-month old cane; thenceforth annual harvesting takes place.

The geographic zone where Ledesma operates has an approximate average annual rainfall of 800 mm with rainy summers and dry winters. Extensive irrigation is therefore necessary. The whole plantation, and especially the low lying areas, are exposed to winter frosts during harvest time.

In view of the extent of operations, the company decided to study, design and implement a special program for the rational exploitation of the sugarcane plantation, both from a technical and economic point of view.

METHODS

The method to arrive at this goal comprises several stages. The basic and fundamental factor considered is the ecologic unit concept.

Ecologic Unit

A study was carried out with the aim of dividing the plantation into ecologic units. An ecologic unit is a reasonably homogeneous section of the cultivated area insofar as type of soil, climate and possible harvest methods are concerned. The following classification variables were used for defining or characterising a homogeneous unit:

1 Stone
   1.1 Absent
   1.2 Moderate
   1.3 Abundant

2 Soil texture
   2.1 Sandy
   2.2 Sand-free
   2.3 Clear
   2.4 Clay-free
   2.5 Clayey

3 State of soil conservation*
   3.1 Good
   3.2 Medium
   3.3 Bad

4 pH of soil
   4.1 Acid
   4.2 Slightly acid
   4.3 Neutral
   4.4 Slightly alkaline
   4.5 Alkaline

5 Salinity of soil
   5.1 Non-saline
   5.2 Slightly saline
   5.3 Moderately saline
   5.4 Strongly saline

6 Water-table†
   6.1 Harmful
   6.2 Non-harmful

7 Frosts
   7.1 Absent
   7.2 Moderate
   7.3 Heavy

8 Possible harvest method
   8.1 Mechanical
   8.2 Semi-mechanical
   8.3 Manual
   8.4 Manual until drainage of soil or elimination of stone is completed; then mechanical.

* This simplified classification contemplates factors such as erosion, content of organic matter and cave-in of salts.
† This simplified classification contemplates level, fluctuation and especially the quality of the water.
In addition, it was established that the surface of an ecologic unit should measure between 100 and 400 ha.

An ecologic unit is agronomically treated as a unit; that is, simultaneously planted with only one variety, and cultivated, harvested, replanted and eventually abandoned also simultaneously. In addition, as will be noted further on, ecologic units are maintained at similar humidity levels on the basis of a differential irrigation method. Ecologic units with low humidity retention are watered more frequently than those with a high retention, so that the average humidity of the different units is maintained at comparable levels.

Once the study was completed it was possible to divide the plantation into 140 different ecologic units. For example, ecologic unit no. 13 covers a surface of 120 ha with the following characteristics:

1.1 Absence of stone
2.4 Clay-free soil
3.2 Medium soil conservation
4.4 Slightly alkaline soil
5.2 Slightly saline soil
6.2 Non-harmful water-table
7.3 Heavy frosts
8.3 Manual harvesting

Afterwards it was determined which of the known commercial varieties were best suited to each ecologic unit.

In the above-mentioned ecologic unit no. 13, it was found that varieties NA 56-83, CP 44-101 and NCo 310 were the most adequate as they perform satisfactorily under most characteristics of this ecologic unit. For example, variety NA 56-83 is adaptable to heavy soils (clay-free) and freezing conditions (early ripening); variety NCo 310 is also adaptable to heavy soils and tolerates frost very well.

The study disclosed that the entire sugarcane plantation can be exploited with 8 optimum varieties and another 6 semi-optimum varieties, that is to say, varieties that can be used as a replacement where those first mentioned are not suitable for reasons explained in the master plan.

A master plan of varieties was drawn up. It specifies one variety for each ecologic unit, and was prepared on the basis of the following criteria:

1) Optimum varieties for each ecologic unit;
2) A rational harvesting program beginning with freezing or moderate frost areas, advancing towards the heavy frost areas, and continuing towards frost-free areas. Harvesting must begin in freezing or moderate frost areas and not in the heavy frost zone for the following reasons:

a) If harvesting is begun in the heavy frost area so as to ensure that the cane will not deteriorate in the event of a frost, there is the danger of a late frost in August which would be detrimental to the new crop, with consequent heavy losses;

b) On the other hand, if harvesting should begin in protected areas and only continue in the freezing zone after the first frost, the extent of this zone would make it impossible to complete harvesting in 35 days (maximum tolerance period for temperatures 4 or 5 C below zero, after which cane deterioration is greatly accentuated).
c) Consequently, the solution is to commence harvesting in moderate
freezing areas (1 or 2 C below zero); and after 30 days, continue
with the freezing areas. In this way, should a frost occur during
July, the remaining cane can be harvested in a maximum of 30 or
35 days, and the harvesting process can be continued in the mo-
derate freezing areas where the cane has not been badly damaged,
and end up in the protected zone.

3) A restriction determined by a safety policy: no given variety can cover
more than 25% of the plantation. This policy reduces the risk in-
curred in over-extension of any given variety. When this restriction
could not be met, selection of semi-optimum varieties was considered.

The master plan is valid for several years. Replanting in the next few years
will comprise all currently existent varieties in each ecologic unit, which will
be simultaneously replaced by the variety indicated in the master plan. Since
the economic life span of a variety oscillates under our conditions between
6 and 7 years, as will be seen below, approximately 15% annual renewal of
the plantation is required. For this reason implementation of ecologic units
as outlined above will progressively increase to reach 100% of the plantation
within 7 or 8 years.

The master plan is not inflexible; it will regularly be brought up to date as
existent varieties age and adequate substitutes are found. However, a master
plan will be available at any moment for identifying the variety suitable for
each ecologic unit.

<table>
<thead>
<tr>
<th>TABLE 1. Estimate of the economic life span of a variety.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age or year of harvest (n)</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6*</td>
</tr>
<tr>
<td>7</td>
</tr>
</tbody>
</table>

* Maximum average annual profit.
† Economic life.

Economic replanting

The ecologic units planted with the varieties selected in the master plan
will naturally show decreasing yields in successive annual harvests. Thus the
concept of economic life of a variety can be introduced. We shall illustrate how,
under decreasing yield conditions, it is convenient at a given moment to replant
the cane of an ecologic unit. For this purpose we shall use a simple numerical
example.
For example a variety planted in an ecologic unit shows a yield decrease through age as detailed in columns 1 and 2 of Table 1. First harvest yield totals 14 000 kg of sugar per ha; second harvest 12 000; third harvest 11 000 and so on. Column 3 shows gross income from sugar sales, at a rate of $0.20 per kg. First harvest sales total $2 800 per ha; second harvest 2 400 and so on. Columns 4 and 5 illustrate operational expenses of the ecologic unit, excluding depreciation of the initial plantation. Column 4 shows that fixed expenses (for example cultivation and irrigation) are independent of cane or sugar production. These fixed expenses total $400 a year per ha. On the other hand, variable costs shown in column 5 decrease with a drop in yield, as they are in direct relation to the cane production (for example harvesting and transport), sugar output (tonnage of processed sugar) and sugar sales (for example sales commissions, sales taxes and freight). In a first harvest, with a yield of 14 000 kg of sugar per ha, variable costs amount to $600 per ha; in the second year, with a yield of 12 000 kg per ha, $560 per ha, and so on. Operating profit shown in column (6) is the difference:

\[ \text{gallon income} - \text{operational expenses} \]

Column 6 illustrates the general principle: operating profit decreases with age. Column 7 details the cost of planting and cultivating the cane during the first year, which is $2 000 per ha. This is the necessary initial investment for renewing the plantation. During this first year the cost is double: expenses are incurred and no output is obtained. Finally column 8 shows an estimate of the average annual profit when the cane is renewed after harvest n. The general expression is:

\[ \frac{\sum_{1}^{n} \text{Operating profit} - \text{Investment}}{n + 1} \]

For example, if the cane is replanted after the second harvest \((n = 2)\) the average annual profit is calculated at

\[ \frac{\$1 800 \text{ per ha} + \$1 440 \text{ per ha} - \$2 000 \text{ per ha}}{3} = \$413 \text{ per ha} \]

(Denominator is 3 because the year of planting is taken into account).

From column 8 it can be seen that the average annual profit increases up to an age of 6 years and then decreases. The economic life of a variety in an ecologic unit is defined as the age span which produces the highest average profit. The economic life of our example is 6 years. The cane has to be replanted when the yield is 8 000 kg of sugar per ha. Average profit is $797 per ha per annum.

Interpretation of the economic life concept is as follows: if (1) the drop in yield, (2) prices, (3) costs, and (4) initial investment remain constant, it is convenient to replant the cane once its economic life is completed. In this way profit is maintained at a high level.

The economic life (6 years in our example) and the minimum acceptable yield (8 000 kg per ha in our example) depend on the variety and the ecologic
unit in which it is planted. The economic life of the same variety in another ecologic unit may be different, and yet another variety in the same ecologic unit may also present a different economic life. For this reason one cannot generalise on the economic life of a variety; the economic life of a variety only in a given ecologic unit can be considered.

Let us now analyse the case shown in Table 1. If the initial investment had been larger, say $2,500 per ha instead of $2,000 (Table 2) the maximum annual profit would decrease to $730 instead of $797 per ha and the economic life would increase to 7 years instead of 6. A larger initial investment, provided the rest of the characteristics remain constant, represents less profit and a longer economic life.

**TABLE 2. Estimate of the economic life span of a variety with higher capital investment.**

<table>
<thead>
<tr>
<th>Age or year of harvest (n)</th>
<th>Yield (kg sugar per ha)</th>
<th>Gross income ($ per ha)</th>
<th>Operating expenses ($ per ha)</th>
<th>Capital investment ($ per ha)</th>
<th>Annual profit ($ per ha)</th>
<th>Average annual profit ($ per ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14,000</td>
<td>2,800</td>
<td>400</td>
<td>600</td>
<td>1,800</td>
<td>2,500</td>
</tr>
<tr>
<td>1</td>
<td>12,000</td>
<td>2,400</td>
<td>400</td>
<td>550</td>
<td>1,440</td>
<td>2,600</td>
</tr>
<tr>
<td>2</td>
<td>11,000</td>
<td>2,200</td>
<td>400</td>
<td>500</td>
<td>1,300</td>
<td>2,500</td>
</tr>
<tr>
<td>3</td>
<td>10,000</td>
<td>2,000</td>
<td>400</td>
<td>440</td>
<td>1,160</td>
<td>2,160</td>
</tr>
<tr>
<td>4</td>
<td>9,000</td>
<td>1,800</td>
<td>400</td>
<td>400</td>
<td>1,000</td>
<td>2,000</td>
</tr>
<tr>
<td>5</td>
<td>8,000</td>
<td>1,600</td>
<td>400</td>
<td>320</td>
<td>880</td>
<td>2,250</td>
</tr>
<tr>
<td>6</td>
<td>7,000</td>
<td>1,400</td>
<td>400</td>
<td>250</td>
<td>740</td>
<td>2,750†</td>
</tr>
<tr>
<td>7</td>
<td>6,000</td>
<td>1,200</td>
<td>400</td>
<td>200</td>
<td>600</td>
<td>716*</td>
</tr>
</tbody>
</table>

* Maximum average annual profit.
† Economic life.

Let us now consider another variation of Table 1. Suppose the sales price were 30% higher. This represents an increase in operating profit, as seen in Table 3. In addition, the maximum annual profit increases ($1,360 instead of $797 per ha) and the economic life decreases (5 years instead of 6). An increase of operating profit in turn reduces the economic life. From the above we can conclude that the economic life of a variety is not an absolute value, but depends on the ecologic environment (which affects yields) and the economic parameters such as sales prices, costs and investments.

The calculation used in Table 1 for the estimation of economic life is approximate. A more precise calculation would take into account other factors, such as:

1) time patterns of the $\frac{TC}{ha}$ and $\frac{TS}{ha}$ indices

2) the existence of different variable operating costs, in proportion to:
   - harvested cane
   - processed sugar
   - sales

3) discounted cash flow methods of evaluation

4) the possibility of replanting with a different variety in the ecologic unit.
Nevertheless, the simplified method used shows that, when decreasing yields occur, there also exists a finite economic life. The present paper does not aim at showing the complicated economic and financial calculations necessary, but rather illustrate the economic life concept. The model used in Ledesma is of a sequential type and will be computer programmed. It is more accurate — and therefore more complicated — than that described here. Every year it will be decided whether to replant the variety in a given ecologic unit, or to continue for another year in view of the expected operating profit for the following year and the expected average profit if the field is replanted. Each year a list is prepared of ecologic units where replanting is considered advisable, in

<table>
<thead>
<tr>
<th>TABLE 3. Estimate of the economic life span of a variety with a higher sales price.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Age or year of harvest (n)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>5†</td>
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<tr>
<td>6</td>
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<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

* Maximum average annual profit
† Economic life

the order of profit/loss per ha in case of non-renewal. This is necessary in case financial, commercial or replanting capacity reasons should prevent the replanting of all of the ecologic units which have reached the end of their economic life span. In this case replanting priority is given to ecologic units with the highest decrease in profit.

Rationalisation of irrigation

Another fundamental aspect for the rational management of a plantation is planned irrigation. In Ledesma, water is a limiting factor. Rainfall is not sufficient and the availability of irrigation water is limited. Watering was traditionally uniform, based on principles such as 4 irrigations for all the cane. In controlled experiments which included irrigation, response to water varied according to the soil and the variety. This led to the planning of differential irrigation which would take the fullest advantage of the water applied. At the moment the plantation is divided into 500 irrigation units, and a water balance is carried in each case, where rainfall and irrigation is credited and evapo-transpiration is debited. Balances in each irrigation unit are calculated every day, and the more deficient have watering priority.

In order to implement this system, extensive studies had to be carried out to determine the available moisture of the soil (1) of each irrigation unit.
At the same time, evapo-transpiration was measured by means of lysimeters installed in various parts of the plantation and a network of type A evaporation tanks was installed in order to simplify the work. Once evapo-transpiration and evaporation were determined, the fortnightly factor was calculated:

\[ f = \frac{E_t}{E} \]  

1) The available moisture of the soil is the amount of water that can be stored down to root depth and which is available for absorption by plants.

2) \( E_t = \) Evapo-transpiration (measured by lysimeter)  
\( E = \) Evaporation (measured by type A evaporation tanks)

This is the factor commonly used together with the daily readings of evaporation by means of the equation:

\[ E_t = f \times E \]

In order to establish the replacement level of the available moisture, controlled experiments on humidity, and replacements at 20, 40, 60 and 80% of available water were installed; preliminary conclusions indicated that no significant differences exist between replacements at 40, 60 and 80%, for which reason a transitory replacement level was established at 40%; in other words, irrigation takes place when 60% of the available moisture has been consumed.

The water balance is at the moment being computer programmed, and the output will be a daily list of irrigation units which have fallen below the economic humidity limit.

Adoption of new varieties

Another important aspect of the economic management of the plantation is the introduction of acceptable new varieties. The company has a permanent program for the evaluation of new commercial varieties released by official and private agencies. For this purpose new varieties are planted in experimental plots every year and their performance is carefully evaluated and compared with that of the principal varieties already under cultivation. The search and appraisal of new varieties is the responsibility of the Investigation Department, which has drawn up a Procedure for the adoption of New Varieties.

A new variety is approved and commercially adopted if its performance meets certain standards. The entire process comprises four stages: search of varieties for study, comparative testing at Ledesma under field conditions, multiplication of seed, and commercial adoption:

1) Search for varieties for study

Experiments are always carried out with varieties approved and recommended by official investigation centers, whether produced locally or introduced from qualified sources.

2) Comparative experiments at Ledesma

Comparative experiments are carried out in five special plots located at different points of the plantation, representative of the main prevailing conditions. Every year an experiment is launched comparing ten new varieties with five commercial established varieties. Each experiment lasts five years. The cultural, sanitary and milling charac-
teristics of the varieties under study are carefully recorded, and yields are analyzed by statistical methods (analysis of variance in randomised blocks designs). A given variety is approved when (a) it does not present agronomic, sanitary or milling characteristics below those of the test-plot varieties, and (b) produces a yield significantly above the best test-plot variety under testing.

3) Multiplication of seed
Multiplication of varieties approved in the first stage takes place in seed producing lots. During this stage cultural, sanitary and yield conditions are carefully surveyed and recorded.

4) Commercial distribution
This takes place in one or several ecologic units for which the variety has been recommended.

### TABLE 4. Comparative summary of examples.

<table>
<thead>
<tr>
<th>Case</th>
<th>Economic life span (years)</th>
<th>Average yield (kg sugar/ha)</th>
<th>Annual average profit ($ per ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>6</td>
<td>10667</td>
<td>797</td>
</tr>
<tr>
<td>Table 2 (higher initial investments than in Table 1)</td>
<td>7</td>
<td>10140</td>
<td>730</td>
</tr>
<tr>
<td>Table 3 (higher sale price than in Table 1)</td>
<td>5</td>
<td>11200</td>
<td>1960</td>
</tr>
</tbody>
</table>

RESULTS AND CONCLUSIONS

We cannot offer a final statement on results, as the method described is in its first years of operation. Nevertheless, highly promising results have already been attained.

The ecologic unit concept, upon dividing the plantation into 140 zones, has introduced a standardisation and mass production principle which greatly simplifies programming and operating tasks, reduces unitary costs and provides reliable information for decision-making.

The master plan and the estimation of the economic life span also simplify routine decisions. The decision to replant an ecologic unit is the result of an objective calculation based on (a) historic yield decrease of the variety and (b) certain parameters estimated with reasonable precision such as prices, costs and investments. The master plan guides the decision as to which variety should be planted in an ecologic unit, taking into consideration the whole of the plantation and not merely an isolated ecologic unit. In this manner each partial decision to replant becomes integrated within a long term general plan.

In general we can say that an operation based on the ecologic unit, economic life span and master plan concepts provides qualified managerial assistance and replaces decisions taken on incomplete information, under pressure of time and without considering the whole of the operation, by simpler, more rational and better integrated decisions.
The procedure for the adoption of new varieties is another aspect which is giving positive results. Adoption of a new variety is a decision of the utmost importance; erroneous appraisals can, in time, be economically disastrous. The procedure establishes several principles which are essential: testing of new varieties already approved by investigation centers; substitution of subjectivity in the selection by objectivity resulting from experimentation, observation and evaluation; comparison with the principal commercial varieties under cultivation; evaluation of the reaction of the variety under study to prevailing conditions; exhaustive checking of the sanitary, agronomic and economic peculiarities of the variety; and its controlled and methodical introduction. The increase in output observed during the last decade is a successful result of the new policies for the introduction of varieties (see Table 5).

### Table 5. Ledesma: Yield of the last 20 years, in 5-year periods.

<table>
<thead>
<tr>
<th>Period</th>
<th>Average yield (kg sugar per ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953/57</td>
<td>7,490</td>
</tr>
<tr>
<td>1958/62</td>
<td>7,890</td>
</tr>
<tr>
<td>1963/67</td>
<td>9,260</td>
</tr>
<tr>
<td>1968/72</td>
<td>9,810</td>
</tr>
</tbody>
</table>

Finally, rationalisation of irrigation has led to a considerable improvement in the use of the limited water facility. Not only has a better use of the water been achieved, but the system has also revealed certain previously undetected problems, such as the need to redesign the distribution network in accordance with the requirements of the different zones. In addition, losses through insufficient water supply can be estimated and new irrigation investments can be evaluated and decided with regard to the profit to be expected.

### Resumen

La explotación de un cañaveral extenso de 30 000 ha presenta problemas particulares, que obligan a una organización de tipo masivo y a una sistemática standarización de las operaciones.

En el presente artículo se describe un caso real, explicando cómo se dividió el cañaveral en unidades ecológicas y se construyó un plan maestro de variedades; los conceptos económicos que conducen a la fijación de la vida económica de la variedad óptima en cada unidad ecológica; la organización racional de riego para optimizar el recurso escaso agua; y la metodología para ubicar, evaluar y seleccionar nuevas variedades con buenas características sanitarias, culturales y de rendimiento. Por último, se evalúan los resultados obtenidos hasta el presente, que son parciales, porque este vasto programa está aun en su etapa de implementación.