Long-term Planning of Sugar Cane Production Via Linear Programming Techniques

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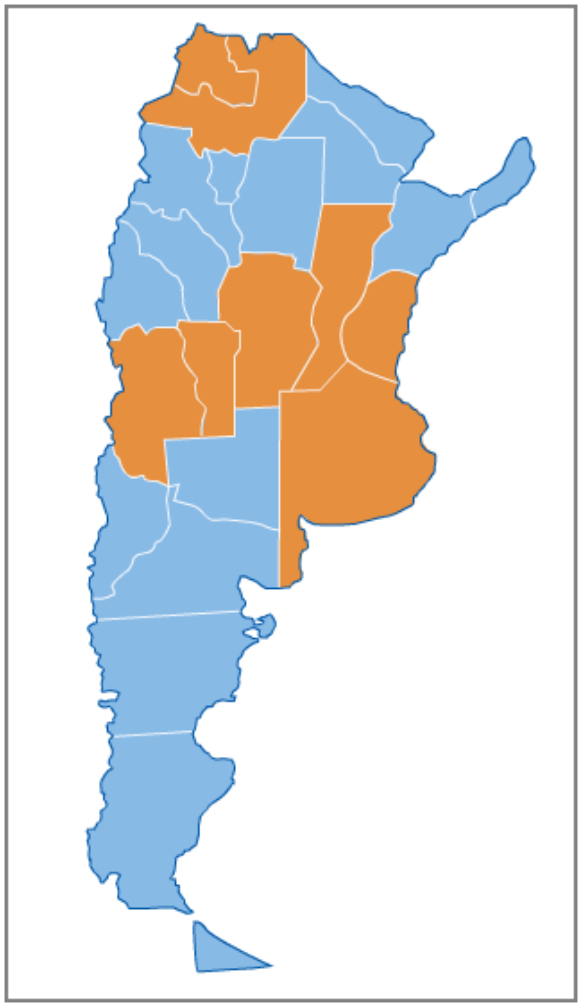
Outline

- Overview of the company and the soiling problem
- Problem, Objectives and Model
  - Model features
  - Software application
- Conclusions and current challenges

Overview of the company

- **Ledesma SAAI:** Argentine company, leader in the sugar, paper, citric fruits, and citric juice markets.
- By adding new technologies and investing, Ledesma transformed its original sugar mill and refinery into an agricultural/industrial complex, involving different activities in many Argentine provinces.

Overview of the company



- Over 6.000 employees.
- Agricultural/industrial complex:
  - 37,000 hectares planted with sugar cane.
  - Sugar, alcohol, cellulose, and paper plants.
  - 600 km of roads built and maintained by the company.
  - 1,400 km of irrigation channels.
- Other plants throughout the country, and headquarters in Buenos Aires.

Overview of the company

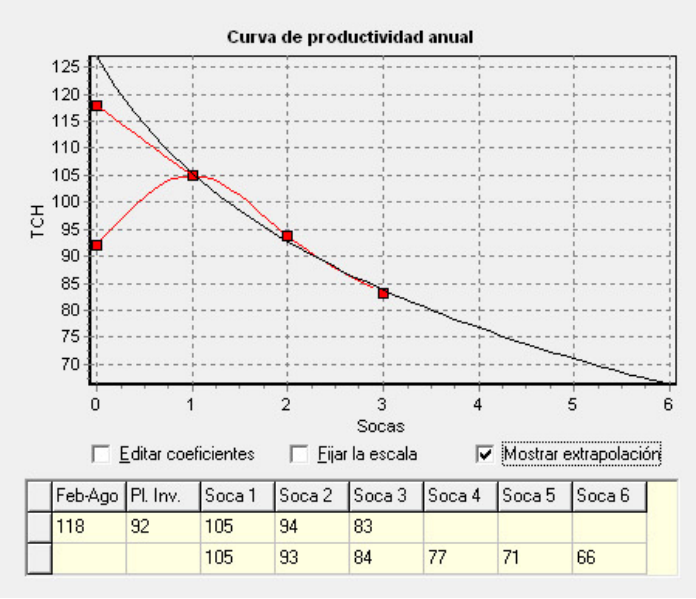
- Over 3.000.000 tn. of sugar cane harvested per year during the harvest period.
  Target soiling: from 20% to 25% of the total area per year during soiling months.
  - Harvesting: From April to November.
  - Soiling: From December to March and
    from June to November.

The sugar cane yield and soiling

- Every time a sugar cane plant is harvested it grows again, but the product yield decreases as the plant grows older.
- Sugar cane yields are represented as a logarithmic function of plant age.
- When an area is soiled its yields goes back to the inital values.
- There is a finite capacity for soiling.

New plants yields and summer soiling

- Winter soiled plants yields are lesser in the first year than in the second year
- Summer soiled plants cannot be harvested in the first winter, but yields more in the first harvest (second winter)
- There are other constraints for soiling in different areas and seasons



	Feb-Ago	Pl. Inv.	Soca 1	Soca 2	Soca 3	Soca 4	Soca 5	Soca 6
	118	92	105	94	83			
			105	93	84	77	71	66

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Objectives

- In 2004, Ledesma decided to increase sugar cane yields through increasing soiling disregarding costs.
- Constrained yearly soiled area to 20-25% of total area
- We developed a linear programming model in order to help on the decisions of which areas should be soiled each year on

  a 20 year horizon scenario.

Model

- The area is divided in 6 big semi-independent estates, each one subdivided in
  - ecological units with same conditions within each one.
  - handling units where each ation is done on the hole unit.
- Total area is 37.000 ha. divided into 900 handling units

Model - Constraints

- Max area soiled per year
- Max area soiled per estate per year
- Max area soiled per season
- Max area soiled per estate per season

Model - Constraints

- Constraints related to growing model (network flow) (special case for max age).
- limit variatons year to year
- Sugar cane variety removal
- OF: maximize sugar cane yield of the hole horizon

Linear programming model

- The linear programming model from May, 2010
  for 20 year horizon and max 7 year old plant and 900 h.u.:
  - 189.046 variables,
  - 389.024 constraints,
  - 2.819.831 nonzero elements (density 0.0038 %).
- The model was coded in a proprietary modelling language.
- Model generation and solution (with Mosek 5 LP solver)
  in less than 30 minutes.

Computational application

- We developed a software tool to manage scenarios, solve the model, and analyze the results.
- Possibility of fixing some model variables and solving for the remaining decisions.

Computational application

- Set of pre-solving warnings, in order to detect possible infeasibilities and unwanted situations.

Current status

- The model provides acceptable solutions after heuristics to obtain integer solutions.
  - Small linear to integer gap.
  - The model outputs are taken as suggestions for the manually-generated plan.
- **Ultimate goal:** Replace the manual planning by the model solution, with manual changes *a posteriori* and/or variable fixings.

$\Rightarrow$ We are currently undergoing a tuning process, in order to tackle minor solution shortcomings and data errors detected by the model.

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Conclusions and current challenges

- The soiling problem for the sugar business of Ledesma SAAI can be succesfully modeled with linear programming.
  - The solution times are acceptable.
  - The solution quality is reasonable, although the tuning process is not finished.
- Strong resistance to results that contadicts common practices
  - Summer soiling is not always good.
  - Best h.u. should be soiled more often.
  - Soiling area per state should not be a constraint.

Conclusions and current challenges

- Future upgrades:
  - Include transportation costs to mill.
  - Include harvesting order in the model.
  - Add sugar yields to the equation (not the same as sugar cane matter yields)

Conclusions and current challenges

- Two special cases
  - Soiling is not always good - non-saturated summers
  - The worst h.u. is not always the best candidate, and sometimes the best should be soiled.