Chapter 9
A Mixed Integer Programming Approach for Sugar Cane Cultivation and Harvest Planning

Sanjay Dominik Jena
Pontificia Universidade Católica do Rio de Janeiro, Brazil

Marcus Vinicius Soledade Poggi de Aragão
Pontificia Universidade Católica do Rio de Janeiro, Brazil

ABSTRACT
The planning of agricultural cultivation and harvesting is a complex task. However, this area of study is still relatively young. This chapter focuses on the tactical and operational planning for sugar cane cultivation and harvesting which determines the best moment to harvest the fields, maximizing the total profit given by the sugar content within the cane. It considers resources such as cutting and transport crews, processing capacities in sugar cane mills, the use of maturation products and the application of vinasse on harvested fields. The mixed integer programming model extends the classical Packing formulation, adding a network flow structure to represent the harvest scheduling. All experiments were performed with real-world instances provided by a Brazilian sugar cane producer. The suggested solutions are discussed in terms of quality and use in practice.

INTRODUCTION
Sugar cane is a sub-tropical and tropical genus of tall growing crop, counting 37 species plus a number of hybrid species. According to the Food and Agriculture Organization of the United Nations (FAO, 2008), sugar cane is one of the most important commodities in the world, commonly being further processed to sugar or agro fuel. With more than 420 billion tons of harvested sugar cane in the year 2005, Brazil is by far the largest producer of this grass worldwide, followed by India, China and Thailand. Among all agricultural commodities produced in Brazil, sugar cane is its most produced measured in biomass and its fourth most lucrative. Internationally, sugar cane is a highly competitive market. Recent international studies
A Mixed Integer Programming Approach for Sugar Cane Cultivation and Harvest Planning

(Higgins, 2007; Gala et al., 2008; Boehlje et al., 2002) showed great opportunities to improve the value chain and reduce costs in the operational planning in order to remain competitive.

Sugar Cane Harvest Process

The sugar cane harvest typically begins in May, sometimes April and prolongates to November, the time of the year when the sugar cane plants normally reach their maturation peaks. The maturation of sugar cane is measured in percentage of sucrose in the sugar cane, denoted by Pol and reduced sugar, denoted by AR. The maturation periods vary widely around the world from six to 24 months.

Manual and mechanical cutting crews cut the plants on the fields, chopping down the stems but leaving the roots to re-grow in time for the following harvest. The harvest is then immediately transported to the industrial sector, i.e. sugar cane mills, by trucks, rail wagons or by manual carriage (cart pulled by a bullock or a donkey). Figure 1 illustrates example routes for cutting and transporting. The cutting crews travel from one field to another harvesting the cane. The transportation crews commute between the fields and the mills.

In the mills, the sugar cane is crushed and the cane juice is extracted. The bagasse leftover, also referred to as fiber, is burned in boilers. The induced steam drives the turbines that generate the power for the mills. The sugar cane is further processed either to sugar or to ethanol. The sugar is also referred to as the total recoverable sugar (also referred to as ATR, originated in the Portuguese term Açúcar Total Recuperável, used in Brazil). For the sugar production, the sugar cane juice undergoes further processes such as heating, filtering and evaporation. The result is a syrup which is centrifuged to separate the sugar crystals from the molasses. To produce ethanol, the juice also undergoes processes as heating, filtering and evaporation. Afterwards, the juice is fermented in large vats, centrifuged and distillated to separate the ethanol.

A side effect of the alcohol distillation process is a residual industrial liquid called vinasse. Vinasse is a corrosive contaminant that contains high levels of organic matter, potassium, calcium and moderate amounts of nitrogen and phosphorus (Gómez and Rodríguez, 2000). However, vinasse is an efficient fertilizer, thus its application to harvested plantation fields has become common practice.

The use of maturation products is a common approach in agriculture to influence the natural maturation curve of plants. In the context of sugar cane, often used products are growth regulators which decrease the growth of the cane and therefore lead to an increase of the relative quantity of sugar within the plant. Growth regulators are commonly used to pre-pone a field’s yield in order to provide raw material, i.e. sugar cane, for the mills. Thus, the use of such maturation products

![Figure 1. Example routes for cutting and transportation crews](image-url)
Related Content

Estimation of the Temperatures in an Experimental Infrared Heated Greenhouse Using Neural Network Models
[www.igi-global.com/article/estimation-temperatures-experimental-infrared-heated/78155?camid=4v1a](www.igi-global.com/article/estimation-temperatures-experimental-infrared-heated/78155?camid=4v1a)

A Web-Based Tool for Spatio-Multidimensional Analysis of Geographic and Complex Data
Sandro Bimonte (2012). *New Technologies for Constructing Complex Agricultural and Environmental Systems* (pp. 32-58).
[www.igi-global.com/chapter/web-based-tool-spatio-multidimensional/63754?camid=4v1a](www.igi-global.com/chapter/web-based-tool-spatio-multidimensional/63754?camid=4v1a)

Using Spatial Statistics Tools on Remote-Sensing Data to Identify Fire Regime Linked with Savanna Vegetation Degradation
[www.igi-global.com/article/using-spatial-statistics-tools-remote/76653?camid=4v1a](www.igi-global.com/article/using-spatial-statistics-tools-remote/76653?camid=4v1a)

Corporate Environmental Management Information Systems Influence of Green IT on IT Management and IT Controlling
[www.igi-global.com/chapter/corporate-environmental-management-information-systems/51769?camid=4v1a](www.igi-global.com/chapter/corporate-environmental-management-information-systems/51769?camid=4v1a)