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Tactical optimization of the oil palm agribusiness supply chain

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ABSTRACT

A dynamic mathematical programming model of the oil palm harvest and extraction supply chain is presented. The model in question has nonlinear and mixed integer features both in its objective function and constraints. The nonlinear nature of the problem is treated in the solving procedure by adequately redefining some original variables, creating and penalizing some others, generating valid inequalities and modifying certain constraints. As a result, an equivalent MIP model is obtained and validated by a computational simulation experiment.

1. Introduction

The global food requirement is expected to increase by 60% around 2050 [1]. In the context provided by climate change, natural resource constraints and competing demands (especially for biofuel production raw materials), among other factors, such an increment constitutes a considerable worldwide challenge for agriculture and food supply chains [2], further enhanced by more demanding public health [3] and environmental standards. In this context, agribusiness activity planning and conduction are becoming central issues for the coming future, inasmuch as they are capable of critically affecting human well being and environmental conservation through supply chain productivity, quality and sustainability. Although not aiming at all the needs that have lately come up in this field, the present work intends to deal with the most outstanding tactical issues affecting the oil palm supply chain. The level of decision in a supply chain depends on three dimensions: type of decision maker, decision process frequency and economic impact. Accordingly, tactical decisions have medium to low economic impact, take 1 day to several weeks, tend to require somewhat permanent planning, and are often in the hands of medium-hierarchy decision makers.

The plantation whose functioning was modeled in the present case is divided into sections made up of land plots which, in turn, are internally aligned in furrows where the palms are planted at appropriate growing distances that also facilitate fruit harvest. The latter is usually carried out by groups of workers who load the product in animal drawn carts moving along rough and uneasy paths. The different work teams, who are responsible for harvesting the fruit in a pre-established number of land plots that is determined prior to each production cycle, take their daily load to internal stockpiling centers (ISCs)

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located on access roads. The road network is divided in zones that are traveled by truck-type vehicles in which the fruit is taken from the ISCs to larger external stockpiling centers (ESCs), located on road intersections. One important consideration about these vehicles is that they must guarantee safe load transportation under difficult circumstances: road, weather and geographical conditions. At a final stage, bulk transportation from the ESCs to the processing plant is carried out along main roads. The vehicles used for this purpose must comply with certain technical requirements concerning capacity and speed. Along these lines, an alternative that has been recently taken into consideration consists in supporting the operation with the use of cableways, which are potentially advantageous when it comes to load transportation during the rainy season. However, as this possibility is still under evaluation, it was not included in the current work. At the stockpiling centers, the whole process is supported by equipment used to lift the fruit from the floor and load it into the vehicles. This task can be performed by either attaching certain devices to the vehicles or independently by cranes or forklift trucks.

Unlike fruit gathering itself, which is carried out in a single-step, crop transportation is divided in two stages: the first one goes from the ISCs to the ESCs, while the second one goes from the ESCs to the oil extraction plant; both requiring specific organizational schemes (i.e., directly or indirectly hired personnel, in the latter case through worker cooperatives). The performance at each echelon is determined by the throughput capacity of the trucks, be they company-owned or subcontracted. The impact of this factor on organizational schemes is precisely the object of the sensibility analysis included in the present work. Fig. 1 illustrates the supply chain under scrutiny.

Some recent proposals have dealt with the possibility to use mechanical traction vehicles to carry out the gathering process, with the further aim of increasing the efficiency of the operation and adapting it to eventual legislation changes tending to prohibit animal work. The selection of the two gathering alternatives in question is due to aspects such as: 1. Physical characteristics of the roads, where care must be taken not to damage the roots of the plants; 2. Mobilization difficulties due to land conditions, especially during the rainy season, which brings along frequent floods; 3. Soil compaction, which takes a toll on plant nutrition and correlates directly with vehicle weight. At the moment, these aspects favor animal traction, which continues to be the most advantageous alternative. Nonetheless, both alternatives can be treated in similar ways, which is the reason why the model developed in this work is useful for both gathering modes.

The throughput capacity of the ISCs is a multiple of the throughput capacity of the supplying trucks, which travel exclusively between the ISCs and the ESC that is allotted to the harvesting area, without needing to approach other ISCs to be filled to their maximum capacity. Thus, by cutting down trip length, a more efficient flow of raw material is achieved at this echelon of the supply chain.

Equal rotating conditions for all the worker cooperatives have to be established because the productivity of each plot is a function of tree age, which changes every year. Consequently, the company-owned trucks are assigned to the areas with the least prospected productivity. As a complement, the procurement of the necessary work force, animals and vehicles, which has to be ascertained prior to each harvest season, results from calculating the number of trips that are necessary to satisfy the balance between expected supply and demand.

In order to assure the continuity of the production process, it must begin only when the raw material stocked at the plant has reached a pre-established minimum amount. This measure is useful to avoid losses resulting from unforeseen interruptions in the production system.

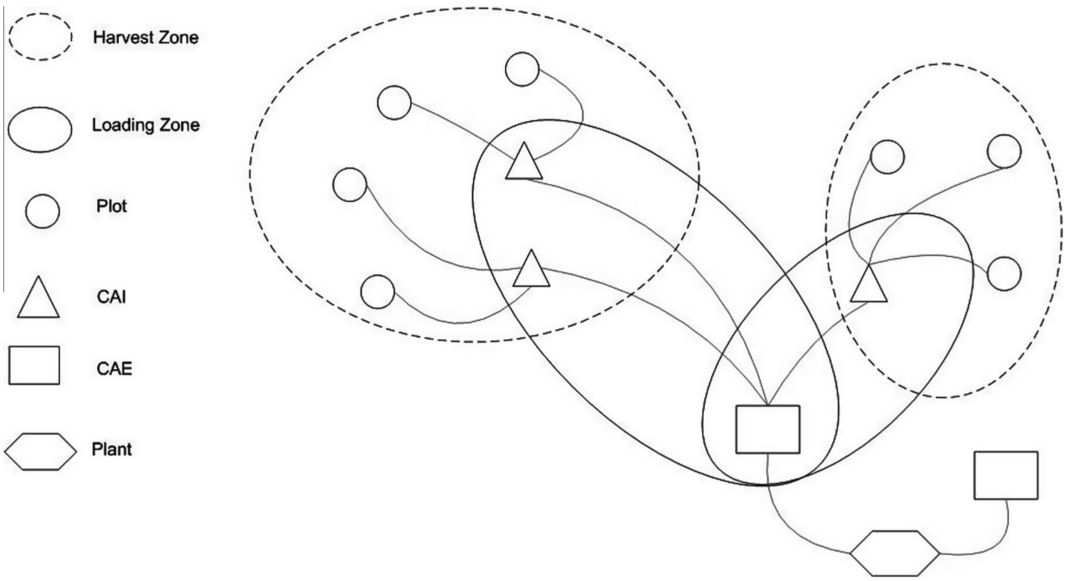

Fig. 1. Supply chain scheme.