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Client selection and combination for farm perishable products

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Abstract: This paper deals with the problem of selecting the most profitable combination of clients to sell a given perishable production of a vegetable farm. A farmer has pre-qualified a pool of potential clients, characterized by specific product mixes, prices, supply contract durations and farm workers requirements to prepare and deliver the order. The farmer is allowed to purchase products from surrounding farms to meet the contracts specifications, if the farm production is not sufficient. We present a Mixed Integer Linear Programming model to maximize the profit of farm sales with production and workforce capacities. We develop submodels to describe the demand characteristics of four targeted clients categories: farmers' market, community supported agriculture, contract demand and wholesalers. Theoretical complexity of the model and preliminary computational results are discussed.

Keywords: Perishable products, Client selection, Job and activity scheduling, Agriculture

1. INTRODUCTION / PROBLEM STATEMENT

Eating local and with as few intermediates as possible, has been on the wish list of an increasing number of consumers. But supplying local fresh products to consumers can be quite a challenge for urban or peri-urban farmers.

First, there is a strong link between the targeted markets and the choice of products and production methods. A farmer who sells products via a Community Supported Agriculture Network [1], needs to produce a wide range of products all year-long, whereas he can specialize in a few products if he chooses to sell to a wholesaler. The complexity of the production system is very different in this two cases, as are the equipment investments. The farmer has to consider the trade-off between low-volume/high-value markets (like in direct-selling via the CSA) and high-volume/low-value markets like in wholesale market. Second, in industrialized countries like France, workforce is expensive. Direct selling and diversified production are labor intensive activities. Multiple competing production, delivery and selling activities cause extra labor needs.

We develop a decision support system to help diversified market gardeners producing and selling fresh vegetables in local supply chains. Our model selects the most profitable combination of clients to supply over a one-year horizon given the farm production, the daily demand specificities and the farm resources. We take account of fresh product perishability and the seasonal nature of the production.

The remainder is organized as follows: after an literature review in section 2, the model is described in section 3, with a focus on the different demands characterization. Thereafter, we analyze theoretically the model structure and its complexity. Computational results are reported in section 5.

[1] CSA, see section 3.3

2. STATE OF THE ART

Agri-food supply chains are complex to manage due to the product long lead times and limited shelf-life and to the demand and price variability (Ahumada and Villalobos (2009)). The farmer is advised to select clients able to conclude contracts ensuring volumes and prices, in order to secure his profitability. Client selection problems, as well as supplier selection problems, are typical multi-criteria problems, involving both qualitative and quantitative criteria (Singh (2014), Aghdaie and Alimardani (2015)). Many models have been developed for the supplier selection problem, by using different techniques to make a compromise from the conflicting criteria. In their supplier selection methods review, De Boer et al. (2001) presented linear weighting models, total cost of ownership models, statistical and artificial intelligence models, as well as mathematical programming models. Mathematical programming models consider several products simultaneously. Multiple criteria decision models (MCDM) provide effective frameworks for supplier or client selection. Shyur and Shih (2006) developed an five-step MCDM hybridizing analytic network process (ANP) and technique for order performance by similarity to idea solution (TOPSIS) approaches. The steps they define differed from the ones identified in the review of De Boer et al. (2001): 1. Identification of necessary criteria for vendor selection; Recognition of the interdependence between criteria; Eliciting the weights of criteria; Evaluation of vendors; Negotiation for the purchase.

Wetzstein et al. (2016) distinguished two kinds of supplier selection problems: Single sourcing supplier selection, where the only decision to make is "which supplier is the best?" and multiple sourcing supplier selection, where order quantities are split among different suppliers with

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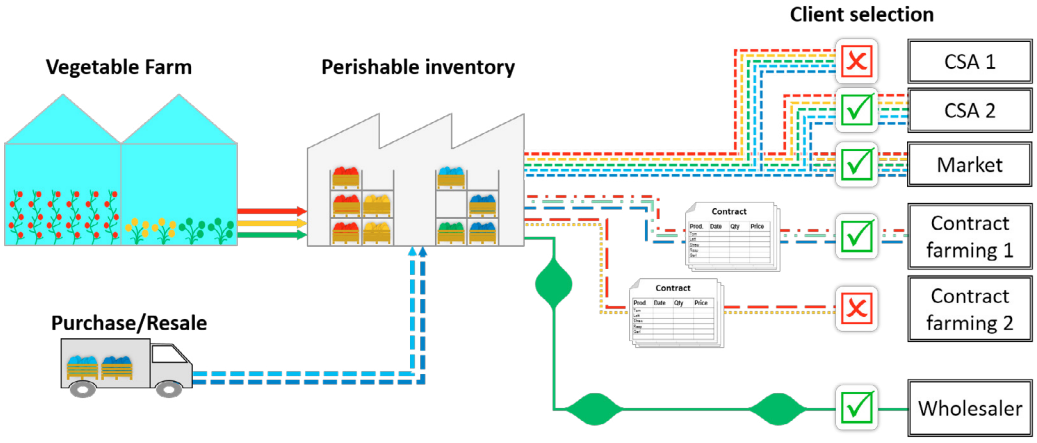

Fig. 1. The farmer has to select the most profitable combination of markets.

different limitations. The problem we study falls into the second category, as different clients are combined to sell a given production according to their time-varying demands and prices.

Client selection problem has not received much attention in the production system and operations research literature. Moreover, inventory management is seldom considered in the client or supplier selection models (De Boer et al. (2001)), despite it obvious importance, especially when dealing with perishable products. Yet, He et al. (2009) pointed out that combining different categories of clients gives the chance to exploit the different timing of the producing and selling season at the various markets. Ahumada and Villalobos (2011) developed a tactical model to determine the area of tomato and pepper to grow and to manage the product shipment to warehouses, distribution centers or directly to final clients, to satisfy client demands. Customer selection problems are linked to market segmentation and targeting and are mainly addressed in marketing sciences for problems such as direct marketing problems (see Kaishev et al. (2013) or Liao et al. (2011)). In most models, studied problems can be considered as 'single-deal' or 'package' models, to cite De Boer et al. (2001). Models dealing with interdependent product demand and product mix over-time variations, which are frequent in agriculture, are scarce.

3. THE VEGETABLE FARM CLIENT SELECTION MODEL

We consider a farmer producing a range P^{f} of perishable products p, such as vegetables. At each of the time horizon period $t \in T$, the farm yields $Y_{p,t}$ kg of product p. The farmer can target several markets in a reasonable distance of his farm, each of them having specific characteristics. The farmers wants to know which markets to select to get the best profit from its production (figure 1). We here consider four categories of markets:

(1) *Farmers' market:* Farmers can sell their products directly to consumers on farmers' markets if they can get a market spot. They need to have sufficient diversity and quantities for the market to be profitable, since market fixed costs are high: allocation of several vendors, rent for the spot, transport.

(2) *Community supported agriculture (CSA)*: in CSA system, customers are contractually engaged with one or several farmers in a season-long commitment to received at defined dates a given quantity of vegetables, bread or other food products. The farmer expects direct selling high-value added but he has to produce a great diversity of products all year long and to dedicate time to prepare and deliver the products.

(3) *Contract demand:* business clients, such as public catering or grocery stores, launch calls for tenders defining the products, quantities and prices needed on defined delivery dates for the next year(s). Prices are lower than in direct selling, but the contract enable the farmer to plan high volumes production efficiently.

(4) *Wholesales:* wholesalers can buy high volumes with low prices when the farmer can not target other markets high volumes to high value markets or when workforce is scarce to prepare, deliver and sell the products.

To target clients such as CSA, farmers' markets or contract demand, the farmer has to meet the entire demand, in quantity, quality and diversity of products during all the contract duration. Clients may ask for products that are not produced on the farm or not available at a specific period; the farmer can purchase quantity $pr_{p,t}$ of products from surrounding farms to meet the contract specifications.

The Mixed Integer Linear Programming model presented in the following sections aims at helping the farmer to select the most profitable combination of clients, considering a given farm production, perishable inventories and workforce capacity. This decision support model orientates the farmer's production and distribution systems at the beginning of a farming season. Depending on the type of the targeted markets, the model is used as a strategic or tactical decision support. We do not consider operational uncertainties, such as changes of delivery days, or vehicle routing problems.

3.1 Farm profit and resources

The model aims at maximizing the farmer revenue *Rev* which is composed of the revenues of farmers markets