

Strategic and tactical Urban Farm design, a conception and sizing problem

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1 Introduction

During the last decades, urban agriculture have been brought up to date in developed countries. Adapting existing peri-urban farms and creating new urban farms with robust and sustainable business models are major issues to enable this new development. Indeed, urban farm systems are more constrained than rural ones by infrastructures and practices restrictions and higher costs (investments, logistics). But urban farms can easily integrate multifunctionality, combining production, leisure activities, environmental or logistic services (Mougeot, 2000 ; Ogier & al., 2013).

Many works have been made on Sustainable Food Supply Chain and Agri-Food Supply chain since the 2000s. Ahumada and Villalobos (2009) developed production-delivery tactical models to maximize the producer income. Other works concern the storage of perishable products (Costa, 2011) but they often focus on an industrial fresh products buyer point of view (Tan & Çömden, 2012), with a few variety of products. Multiproduct market gardening has been less studied than specialized systems like dairy or grain systems.

We develop a strategic and tactical model to integrate and optimize both fruit and vegetable production and logistics in urban sites selection and multifunctional farming system design (goods and services production).

2 Materials and Methods

We use mix integer linear programming to establish a model for fresh fruit and vegetable production. We aim at maximizing the annual farm result, answering a fixed daily demand. Our main variables are the area a_i to grow using management practices i , the beginning date of each plot cultivation d_i and the workers to hire to produce mo_d . We introduce other variables to consider the perishability of the products in different ways. As Ahumada and Villalobos (2009), we use a storage cold room loss function and cold room limited capacity. But we also allow a standing storage on the plot, associated to another loss function: the crops can be harvested some days after the ideal harvest time. The selling price is lowered according to storage time, both on the plot and in the cold room. We force the unsold products left on the plots (losses) to be harvested before a management practice dependent deadline, to limit diseases and insects proliferation.

Considering short time perishability (a few days) make us work on a tow-day step. It enables a good combination of different crop management practices on the farm to have the best labor affectation. Perishability, considered at a tactical level, has major consequences on the strategic farming system sizing. Climate is not taken into account as we do not need operational outputs, but management practices beginning can only vary in a small time period, to guarantee realistic solutions. Treasury and water consumption can be used as constraints according to the contexts.

This deterministic problem integrates lot sizing problems. Dependences between areas, harvest and delivery dates of several products, growing tasks and labor make this problem highly combinatorial and hard to solve on big data sets.

3 Results - Discussion

Following results are obtained using Cplex 12.6 on Intel Core i7-4600U 2.10GHz processor and 8.0 Go of RAM. Given a certain demand, the model affects areas to the plots cultivated with different management practices, which are represented by a production curve (x kg.m⁻² reaching maturity on day d), a set of cultivation tasks and some parameters such as the range of areas in which the management practices are defined. With our data set, the best profitability is obtained combining 5 management practices, ($i4$, $i5$) for product 1, ($i6$, $i8$, $i9$) for product 2 (Fig. 1). 90% of the available area is used.

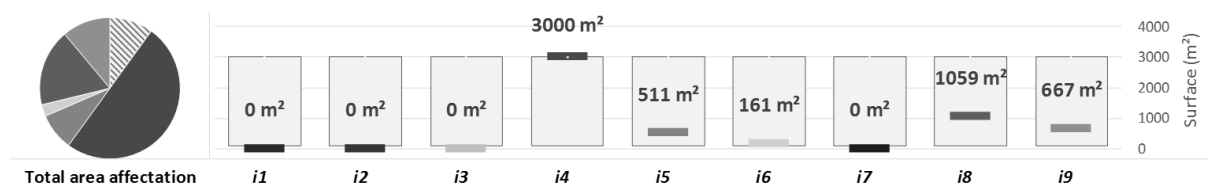


Figure 1. Plot areas obtained by the model

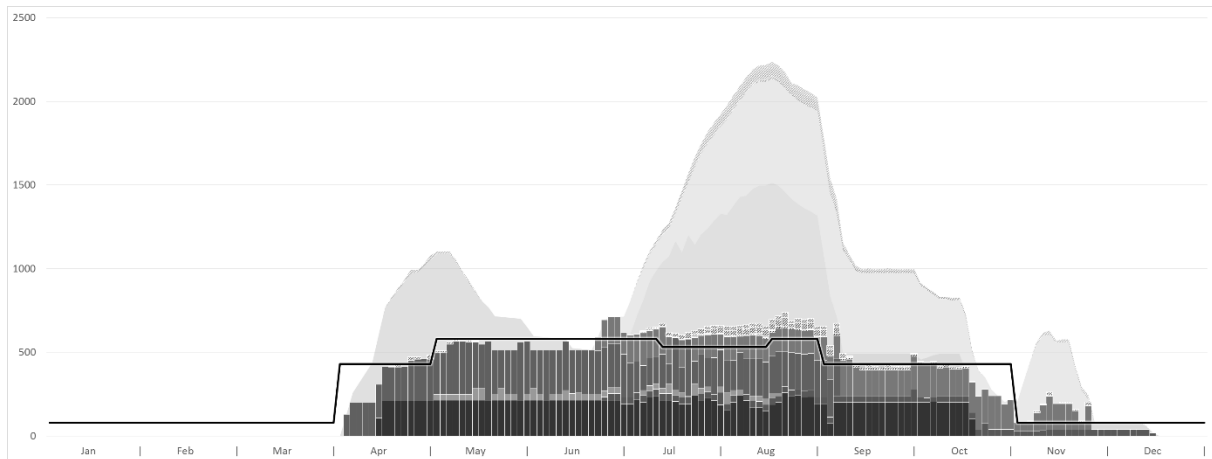


Figure 2. Demand (line), quantities harvested each day (dark bars) and on-plot available quantities (light areas)

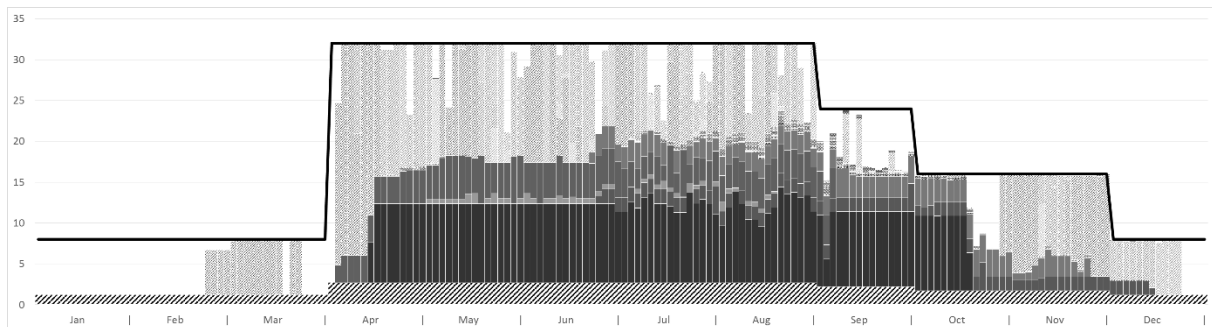


Figure 3. Labor to hire (line) to harvest (dark bars) and cultivate (light bars), including idle time (stripes)

To answer the demand, 1 permanent farmer and 3 seasonal workers are needed (Fig. 3). Operations planning takes into account the daily demand (quantities and prices) of two clients to affect the workers to the harvest or to malleable cultivation tasks, such as weeding or trimming. Fig. 2 shows two major phases in April and August when too much products are available on the farm compared to the demand and products are stored several days in cold room (not depicted here). On this test data set, the model enable to deliver 81% of product 1 demand and 88% of product 2 demand, with 9% of losses over the year, to reach an result of 281 k€.

According to the data set parameters, the optimal solution is reach in 2 to 50 minutes, as no work has been not to improve the resolution process yet. Realistic farm designs have been obtained with real data set, producing different varieties of strawberries, tomatoes and lettuce to deliver 2 to 4 clients.

4 Conclusions

Using mix integer linear programming, we manage to model the tactical combination of different fruit and vegetable productions and its impact on the strategic sizing of urban farms. The model gives good results on real data set and are currently compared with field experimentation.

Besides the resolution process improvement, next steps will consist to integrate logistics (supply and delivery) in the model to select the best farm locations in a city, and services to get relevant tactical and strategic models of multifunctional urban farms. Variability and robustness will also be integrated.

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