Operational Research

Project report

Emanuele Kaled Matarazzo - s280143
Elena Roxana Marolicaru - s287503
Felipe Spoturno - s287530
Giulia Terzolo - s281990

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Contents

1 Introduction to the problem

1.1 Robust Planting Plans in Horticulture

In Horticulture, typically, growers need to elaborate planting and harvesting plans in order to maximize their profits taking into account different variables. These variables include from plant growths profiles and climate changes, to prices of planting and harvesting in different periods of the year.

The problem in this work is addressed as a two-stage stochastic programming problem in which the first stage is the elaboration of the planting plan (how much tonnes of each crop and for each variety to plant), the second stage is the elaboration of the harvesting plan (when to harvest each crop and variety, and how much), and the different scenarios will be different weather profiles for the year (built on the basis of the previous years experience).

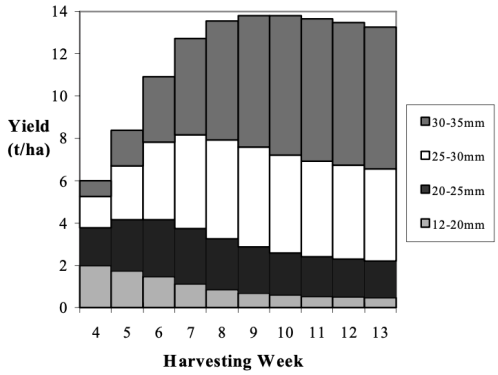

Figure 1: Example of the growing profile for a specific variant of sprout.

1.2 Mathematical model

A crop in this problem is defined as a particular variety of Brussels sprouts planted in a given week at a given spacing, and the problem is to decide how much of each of a set of possible crops should be planted. The following sets will be used for the modelling of the problem.

Set	Index
crop	$i \in [1, I]$
variety	$v \in [1, V]$
week	$j \in [1, J]$
size band	$k \in [1, K]$
customer	$m \in [1, M]$
disease	$q \in [1, Q]$
scenario	$s \in [1, S]$

Table 1: Problem sets.

1.2.1 Problem parameters

Based on what was presented on Sec. 1.1, the following parameters will be used on the model.

Parameter	Explanation
c'	Cost of land [£/ha]
c_{sij}	Cost of harvesting crop i in week j under scenario s [£/ha]
d_{mj}	Demand of customer m in week j [t]
f_{mj}	Profit from satisfying the demand of customer m in week j [£/t]
s_{sj}	Profit from selling surplus-to-demand sprouts on the open market in week j under scenario s [£/t]
y_{sijk}	Yield of crop i in week j in size band k under scenario s [t/ha]
a	Area of grower's land [ha]
c^-	Cost of extra land required by grower [£/ha]
c^+	Value of land unused by grower [£/ha]
p_{smj}	Penalty for failure to satisfy demand of customer m under scenario s [£/t]
r_{iq}	Susceptibility of crop i disease q $\{0, 1\}$
u_q	Upper limit on the proportion of crop harvested each week that is susceptible to disease q
$prob_s$	Probability of scenario s

Table 2: Problem parameters.

1.2.2 Problem variables

Based on what was presented on Sec. 1.1, the following variables will be used on the model.

Parameter	Explanation
F_{smjk}	Weight of sprouts sold in week j to customer m in size band k under scenario s [t]
H_{sij}	Area of crop i harvested in week j under scenario s [ha]
S_{sjk}	Weight of surplus-to-demand sprouts of size k sold on the open market in week j under scenario s [t]
L^-	Area of extra land required by grower [ha]
L^+	Area of land unused by grower [ha]
P_{smj}	Shortage in demand of customer m in week j under scenario s [t]
A_i	Total area of crop i planted [ha]

Table 3: Problem variables.

1.3 Cost function

Taking into account all the parameters and variables the following cost function is defined:

$$OF = (1-\omega)\cdot \mathbb{E}_s\left(\text{Profit}_s\right) - \omega \cdot \mathbb{E}_s\left(\left|\text{Profit}_\text{s} - \mathbb{E}\left(\text{Profit}_\text{s}\right)\right|\right) \tag{1}$$

where ω is called the risk aversion coefficient and models how the variance on the profits affects the objective function, and the profit is defined as following:

$$\begin{gathered}\text{Profit}_\text{s} = \sum_{j,k} s_{sj}\cdot S_{sjk} + \sum_{m,j,k} f_{mj}\cdot F_{smjk} - \sum_{i,j} c_{sij}\cdot H_{sij} + c^+\cdot L^+ + \\ -c^-\cdot L^- - c'\cdot \sum_i A_i - \sum_{m,j} p_{smj}\cdot P_{smj}\end{gathered} \tag{2}$$

as shown the profit is incremented by the sell of harvested sprouts (F_{smjk}), thanks to their sell in the free market (S_{sjk}), or thanks to the value of the unused land (L^+). On the other hand it is decremented by the cost of using additional land (L^-), the total planted area (A_i) and the cost of buying sprouts on the free market in order to satisfy the demmand (P_{smj}).

1.3.1 Constrains

Marketing constrain

The weight of sprouts sold to customers is obtained by the harvested weight substructing the ammount that is being sold on the free market.

$$\sum_i y_{sijk}\cdot H_{sij} = S_{sjk} + \sum_m F_{sjkm} \quad , \quad \forall s,j,k \tag{3}$$

Demand constrain

The weekly shortfall is the difference between the demand and the ammount supplied.

$$P_{smj} = d_{mj} - \sum_k F_{sjkm} \quad , \quad \forall s,j,m \tag{4}$$

Sell on open market

Land use Constraints

Disease Constraint

Individual Variety Limit

Individual Crop Limit

2 Results and analysis