[[1]](#footnote-1)

The Vineyard in Ojacastro

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This report deals with a modeling and optimization real case, belonging to the Universidad Pontificia Comillas (ICAI) subject, operation research.

The objective of this project is to enhance the skills we have learned about modeling and optimization.

The structure of the report is following the next points:

* **Problem statement**: explain the problem and its restrictions as well as the necessary data to solve it in the best way.
* **Description and hypotheses**:  after having read the statement of the problem, we will raise the hypotheses and try to find the different possibilities to develop it taking into account the constraints
* **Mathematical formulation of the optimization problem**: we will try to translate the information obtained and the hypotheses developed in the previous points into mathematical language, with the aim of using them to solve the problem using GAMS.
* **Code**: at this point of the report, the gams encoded script is shown, after having used the mathematical formulation to develop it.
* **Results**: we will provide our solutions, supporting them with tables and another GAMS information. We will also explain why it has sense and which type of linear problem represents our statement.
* **Extension of the case study**: this point focuses on the student’s creative skills. We have decided some changes of the statement in order to
* **Conclusions:** the last breath of the problem and personal opinion about the project.

Related to our problem, we have to decide whether installing water systems in our vineyard. Depending on in which part of the total area are we installing those systems, our grapes production will increase more or less, so we need to optimize a propery solution.

Next points at this report will show how have we done the resolve.

# **Problem Statement**

We are the owners of a large vineyard in Ojacastro, La Rioja, and are considering installing new watering systems in some of the portions that compose the vineyard. We are deciding to install either 2 or 3 systems over 2 or 3 of the portions, which are 10 ha each. The total area is divided into several square portions of land where a new watering system can be installed. Each plot has an average increase in the annual production in tonnes that depends on the watering system being installed. The annual amortization of the water system in € if it is installed (number in the middle) and a cost of maintenance in € (number at the bottom) are also shown in the following table. These numbers have been estimated by our chief oenologist. The forecasted grape price for our variety of grapes is 0,85 € per-kg.

Imagen que contiene Tabla

Descripción generada automáticamente

Design a Mixed-Integer Programming problem to select optimally the water system installation to maximize the global profit of the vineyard. The total amortization should not exceed 3000 €. The total maintenance cost should be lower than one fifth of the total expected income. Then, analyze the impact of the following investment conditions:

a) The portions where the system is installed should be contiguous (horizontal, vertical or diagonal).

b) If we select the portion (Y, a) then we need to select (X, a) and (X, b).

c) If the selected portion is in the column “a” the rest of portions should be selected in the same row.

d) If there is a selected portion in the row X”, if there are any other portions selected, they should belong to the same column.

# **Description and Hypotheses**

After reading the statement, we have come to the conclusion that we are the owners of a large vineyard divided by square portions, each of 10 ha., and we have to make the decision of installing 2 or 3 water systems over 2 or 3 of the portions our vineyard is divided by.

Depending on the combination portion-system we are choosing, our total profit will be modified.

We have to take in account some cost as annual amortization and maintenance cost of a water system. Besides, each combination will support a different increase in the annual production in tonnes. We have estimated our grape price, which has a value 0.85 € per Kg, and as we want to work with tonnes, this price can be expressed as 850 € per t.

As in every modeling and optimization problem, we have to follow with some constraints that will reduce the possible combinations

We will use MIP (Mixed Integer Problem) in order to solve the optimization problem, as we will be using both integer and binary variables.

However, looking at the statement table, we have detected that this problem is infeasible as the total amortization cost will always exceeds 3000€.

# **Mathematical Formulation of the Optimization problem**

Now we are going to describing the mathematical formulation of our problem, separating sets, parameters, variables, etc.

## Sets

 portions {X, Y, Z}

 water Systems {a, b, c, d, e, f}

## Parameters

annual amortization of system  installed

in portion  [€]

average production increase in portion installing

system  [t]

maintenance cost of system  installed

in portion  [€]

lower bound

upper bound

grapes estimated price [€/kg]

total amortization [€]

## Variables

objective function value

 whether if the system  is installed in portion 

## Equations

Limitation of total amortization [€].

Total maintenance cost should be lower than one fifth of the total expected income. [€].

Number of systems [systems].

(3.1)

Number of systems [systems].

(3.2)

The portions where the system is installed should be contiguous (horizontal, vertical or diagonal) [portions].

(4.1)

The portions where the system is installed should be contiguous (horizontal, vertical or diagonal) [portions].

(4.2)

If we select the portion (Y, a) then we need to select (X, a)

and (X, b).

[portions] (5)

If the selected portion is in the column “a” the rest of portions should be selected in the same row [portions].

(6)

If there is a selected portion in the row X”, the rest of portions selected should belong to the same column [portions].

(7)

The systems installed must be non-negative [systems].

 (8

## Objective Function

The objective function corresponds to the maximization of the global profit of the Vineyard [€].

# **Code**

**$title TheVineyardInOjacastro**

**option optcr** = 0;

**sets**

i 'Portions' **/X, Y, Z/**

j 'Systems' **/a, b, c, d, e, f/;**

**scalar** ta 'Total amortization (6000 €)' **/6000/;**

**table**  ip (i, j) ‘Average increase in production in tonnes in portion i installing system j'

a b c d e f

X **30 40 25 28 35 26**

Y **26 21 27 40 35 40**

Z **25 18 20 25 30 25**;

**table** a(i,j) 'Annual amortization in € of water system j in portion i'

a b c d e f

X **3000 4000 2500 2300 3200 3300**

Y **3200 2700 4000 5000 2000 4500**

Z **2800 2000 2000 2800 3000 2200**;

**table** mc(i,j) 'Maintenance cost of system j in portion i'

a b c d e f

X **1000 1200 900 1100 1200 1300**

Y **1200 800 1400 1500 1200 1500**

Z **1200 700 800 1000 1100 900**;

**parameter**

p 'Grapes price [€ per kg]' **/0.85**/;

**parameter**

M1 'upper bound' **/2**/;

**parameter**

m 'lower bound' **/1**/;

**variables**

OFV 'Objective function value. Global profit of the vineyard'

X(i,j) 'Indicator if system j is installed in the portion i'

**binary variable** X;

**equations**

EQ\_OF 'objective function'

NSYS2 'Number of systems installed'

NSYS3

AMOR 'Limitation of total amortization'

MCOST 'Total maintenance cost should be lower than one fifth of the total expected income.'

EQ\_CON1(i,j) 'The portions where the system is installed should be contiguous (horizontal, vertical or diagonal)'

EQ\_CON2(i,j)

EQ\_YA 'If we select the portion (Y, a) then we need to select (X, a) and (X, b)'

EQ\_ACOLUMN(i) 'If the selected portion is in the column “a” the rest of portions should be selected in the same row'

EQ\_XROW(j) 'If there is a selected portion in the row X”, if there are any other portions selected, they should belong to the same column';

EQ\_OF.. OFV =E= sum((i,j), X(i,j)\*(ip(i,j)\*1000\*p - a(i,j) - mc(i,j)));

NSYS2.. 2 =L= sum[(i,j), X(i,j)];

NSYS3.. 3 =G= sum[(i,j), X(i,j)];

AMOR.. sum[(i,j), X(i,j)\*a(i,j)] =L= ta;

MCOST.. sum[(i,j), X(i,j)\*mc(i,j)] =L= 1/5\*OFV;

EQ\_CON1(i,j).. M1+(1-X(i,j)) =G= X(i+1,j) + X(i-1, j)+ X(i, j+1)+ X(i, j-1)+ X(i+1, j+1)+ X(i+1, j-1)+ X(i-1, j+1)+ X(i-1, j-1);

EQ\_CON2(i,j).. m\*X(i,j) =L= X(i+1,j) + X(i-1, j)+ X(i, j+1)+ X(i, j-1)+ X(i+1, j+1)+ X(i+1, j-1)+ X(i-1, j+1)+ X(i-1, j-1);

EQ\_YA.. X("X","a") + X("X","b") =G= 2\*X("Y","a");

EQ\_ACOLUMN(i).. m\*X(i,"a") =L= sum(j,X(i,j+1));

EQ\_XROW(j).. m\*X("X",j) =L= sum(i,X(i+1,j));

**model vineyard** **/ALL/**;

**solve vineyard using mip maximizing OFV**;

**display X.L, OFV.L**;

# **Results**

As we deduced at the first section of this report, our problem is infeasible, as the maximum amortization cost will be surpassed in every combination of portion and system.

That’s why we had to change this scalar in order to get a possible solution for our problem.

Depending on the new value por the total amortization, GAMS has chosen different portions with different OFV (Objective function value)

We have decided to show the results for an amortization total value of 6000 €, a quantity that sounds reasonable for us.

As we are using binary variables and also integer, we have to solve the case using MIP, as we have studied in class.

Texto

Descripción generada automáticamente

As we can view, GAMS have made the optimization problem using the input levels that we coded, and the global profit for the vineyards is 51.900 €. Now we are showing which combinations of portions are the ones used for installing **two systems**.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Portions | a | b | c | d | e | f |
| X |  |  |  |  | X |  |
| Y |  |  |  |  | X |  |
| Z |  |  |  |  |  |  |

Here we can see that Gams have decided to install the system ‘e’ at portions (X, e) and (Y, e). As we can see in the table below, it has sense to choose these portions as they both have high increases at annual production (35 t). Although their amortization cost is also higher than others, as we declared its total value 6000 €, the solution meets with all the constraints.

|  |  |
| --- | --- |
| Portions | e |
| X | 35 t  3200 €  1200 € |
| Y | 35 t  2000 €  1200 € |

Table 1. Data of portions used.

|  |  |
| --- | --- |
| Portions | e |
| X | 25350 € |
| Y | 26550 € |
| **total** | 51.900 € |

Table 2. Marginal profit of each portions.

Now we are appreciating the marginal cost of each portion. This sum of the two values is the result of the equations that gives the OFV.

As this is a small MIP problem, we must set the relative tolerance to 0. This will assure that the solver offers the optimal solution. On the contrary, the solver stops when the relative tolerance is satisfied. Its default value is 0.1. The way to do this in GAMS is:

OPTION OPTCR=0;

This instruction must be written in any part of the code but always before the SOLVE.

# **Extension of the Case Study**

Now we would like to propose some possible extensions of the problem. These changes may increase our global profit.

1. Remove the maximum amortization value in order to be able to choose those combinations(portion-system) that have the higher increase in the annual production.
2. Other possibility is introducing a constraint whom sets a minimum profit value to be achieved.
3. Get other types of systems with different characteristics.

We have also investigated about Insect farms, which are one of the greatest development businesses during the last decade, due to its constant search for new food alternatives for animals and humans.

This business has low maintenance costs and long-term profitability, so our proposal is:

Using our watering systems in order to keeping insect farms wet.

# **Conclusions**

Through this problem, we have been able to use the knowledge acquired throughout the course to solve a real case and develop a GAMS code that gives us a solution to this problem.

After meeting for several days to carry out the work, we have managed to understand the concepts that we have previously treated in class, as the final development and solution depends on them.

We have developed our skills using GAMS as programmation language, which can be useful in a near future if we decide to work with data analysis.

We really think that areas related to mathematics and programming are highly demanded today’s, so having a contact with a real case is very favorable for our future as engineers.

We also believe that to create and organize this report can give us many useful abilities about presentation projects, that we can use later in moments as our final degree project report.

We want to say that we have had problems in order to copy the text form GAMS and paste in this word as the templated explained. That’s why is not clear enough.

1. [↑](#footnote-ref-1)