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# Approaching Optimization Problems Using the Solver Tool in Order to Ensure Farm Economic Efficiency

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Optimization problems with applicability in the agricultural economics and agribusiness usually require highly complex algorithms for solving. The Solver tool, which is an add-in to Microsoft Excel software, may represent a simplified resource, made available to the stakeholders that can be used successfully in achieving the objective function of the problems and thus to ensure the economic efficiency for the production process. Farm management and farm economics involves finding solutions to optimize the cropland structure and production factors. The paper aims to provide a working model using the Solver tool but can be also extrapolated to various fields of activity.

Keywords: optimization, Solver Add-in, objective function, economic efficiency, farm management

JEL Code: M11, Q12

## 1. Introduction

Low values in farm economic efficiency is one of the risks in general economy because agriculture is the source of food for the whole population and the one that can decisively influence the food industry.

Mathematical programming models owns a particularly important place both in theory and in economic practice (Viziteu et al., 2018). Economic theory has benefited from the interdisciplinary approach that allowed the deepening of the analysis regarding the maximum efficiency of complex systems, the discovery of new concepts of the economic optimum, the improvement of the research and knowledge methods, the economic practice being enriched with particularly useful tools for economic analysis and for substantiating decisions

Optimization problems are real world problems we encounter in many areas such as mathematics, engineering, science, business and economics. In these problems, we find mthe optimal, or most efficient, way of using limited resources to achieve the objective of the situation. This may be maximizing the profit, minimizing the cost, minimizing the total distance travelled or minimizing the total time to complete a project (Chandrakantha L., 2014). The orientation of agricultural production in specific conditions of time and place, in relation to the natural and economic environment is achieved at the level of agricultural holdings, through the process of specialization of production. In achieving this goal, the use of mathematical methods gives good results in solving problems, such as: optimizing the land use structure or optimization of crop structure (Brezuleanu S., 2008). As the agricultural land within the agricultural holdings is, in general, non-uniform, taking the form of various categories of use, the establishment of the optimal structure for these categories is of particular importance. Every agricultural holding and farm is interested in finding possibilities, under pre-established conditions, for the transition of land from lower categories to higher categories and in finding the optimal balance.

The crop production index decreased by 5.6% in 2019 while the agricultural services index increased by 32% related to 2018 (fig. 1).

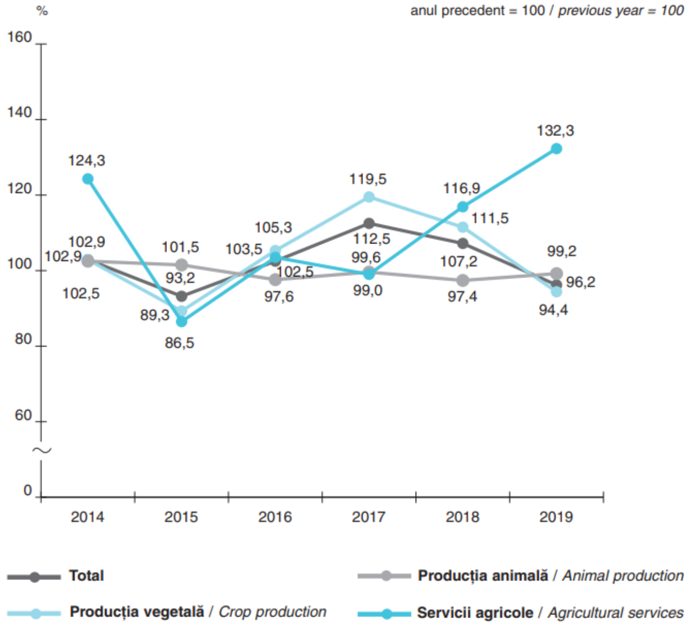


Figure 1 Agricultural output indices for Romania (2014-2019)
*(Source: National Institute of Statistics, 2020)*

The necesity of Solver tool for the linear programming optimization problems in agriculture is given by the large share (fig. 1) that crop production owns in total agricultural output ( 70 %).

Table 1 Output of the agricultural branch for Romania (2017-2019)

| | 2017 | 2018 | 2019 |
|---|---|---|---|
| | *Thou lei current prices* | | |
| ***Total*** | **78494105** | **86349291** | **89989063** |
| *Crop production* | 53216739 | 61216194 | 62967346 |
| *Animal production* | 24331854 | 23903451 | 25228818 |
| *Agricultural services* | 945512 | 1229646 | 1792899 |
| | *Structure (%)* | | |
| ***Total*** | **100.0** | **100.0** | **100.0** |
| *Crop production* | 67.8 | 70.9 | 70.0 |
| *Animal production* | 31.0 | 27.7 | 28.0 |
| *Agricultural services* | 1.2 | 1.4 | 2.0 |
| | *Agricultural output indices (previous year = 100)* | | |
| ***Total*** | **112.5** | **107.2** | **96.2** |
| *Crop production* | 119.5 | 111.5 | 94.4 |
| *Animal production* | 99.6 | 97.4 | 99.2 |
| *Agricultural services* | 99.0 | 116.9 | 132.3 |

*Source: National Institute of Statistics, 2020*

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## 2. Material and method

The method used is linear programming. Given the very large amount of computations, the linear programming method implies the use of computer. The optimization of the land use structure by linear programming requires elaboration of the mathematic model which is further used within the software.

One of the tools through which the optimal structure of use categories or crops within a farm can be determined is the Solver Add-in from Microsoft Excel.

Solver is a Microsoft Excel add-on that can be used for "what if" analysis for the students or the researchers. Solver is used to find a value (maximum or minimum) for a formula in a cell, called an objective function, which is subject to restrictions or limitations on the values of other formula cells in a worksheet. Solver works with a group of cells, called decision variables or, more simply, variable cells, that participate in the calculation of formulas in the target and constraint cells. Solver adjusts the values in the cells with decision variables to meet the constraints and produce the desired result for the objective function from the target cell.

Excel Solver provides a simple, yet effective, medium for allowing users to explore linear programming problems. It can be used for large problems containing hundreds of variables and constraints, and does these relatively quickly, but as a teaching tool using small illustrative problems it is very potent, particularly as the user must appreciate the structure of a LP when entering it into the spreadsheet (Saleh S., Latif T., 2008).

## 3. Results and discussions

Solver can be used to determine the maximum or minimum value of a cell by modifying other cells. For example, it can be changed the volume of the projected budget and, consequently, it can be seen the effect on the amount of projected profit.

The *Solver* tool can be installed folowing the path: *Excel Options>Add-ins>Solver Add-in>Go (fig. 2)*

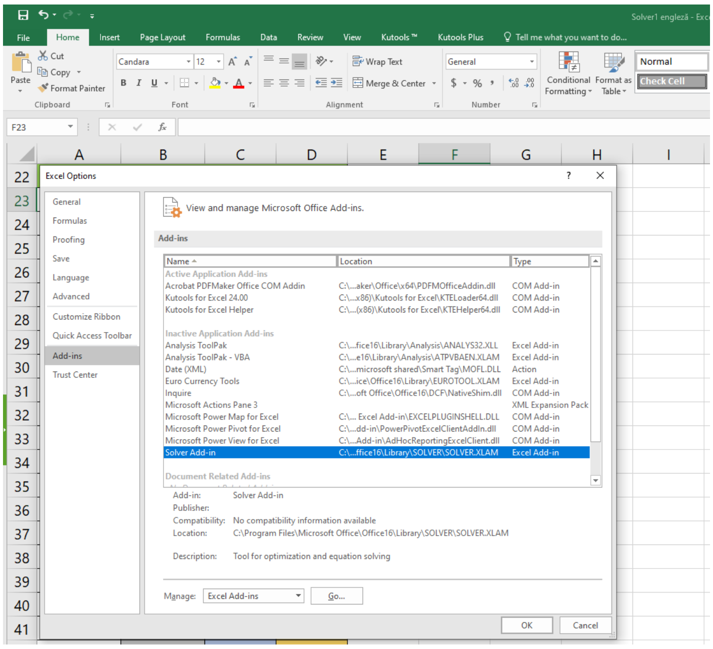


Figure 2. Installing Solver Add-in

The steps to be followed in solving a linear programming problem (using the Microsoft Excel program and the Solver add-in) are:

1. Preparing the data in order to be introduced into *Solver*:
   a. The variables that represent different categories of use are established. For the more accentuated detailing, the subgroups from the categories of land use in relation to the favorability class can also be taken into account.
   The names of the variables are written on the first column and the optimal values necessary to achieve the proposed objective will be calculated on the second (fig. 3). Initially (before solving) the default values are 0.

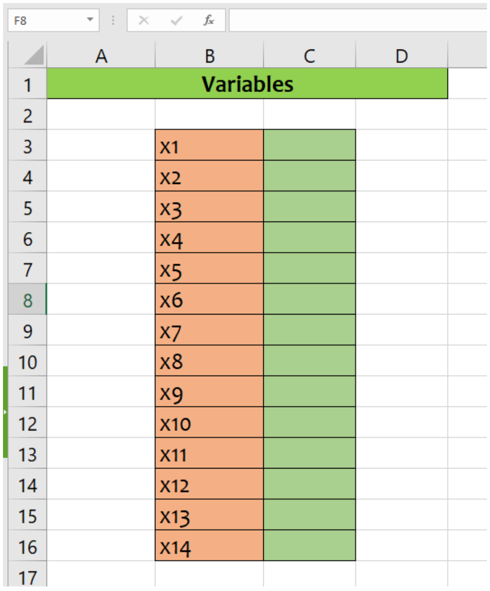


Figure 3. Variables in Solver Add-in

   b. Choosing the objective function convenient to the agricultural holding/farm, based on the most representative economic criterion. If the criterion is the turnover value, the efficiency function is:

$$f(x) - \sum_{i=1}^{n} x_i \cdot Ca_i \to \max \quad \text{where:}$$

*$x_i$- the surface of the land use category "i"*
*$Ca_i$ – turnover per unit area (ha)*

   For the objective function (fig. 4) is must be specified the type (maximization, minimization, etc.) and then it has to be written the objective function in the form "= $2750X_1+2200X_2+$....", where $X_1$, $X_2$ represents the values of the variables, respectively the values in the green cells (see the previous image) and not the name of the unknowns (orange cells)

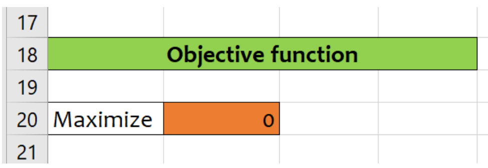


Figure 4. Objective function in Solver Add-in

c. Specifying the constraints of the model.

The first restriction concerns the framework in which changes can be made from one category of use to another and is expressed by the sum of the areas of all categories of use equal to the total area of the agricultural holding:

$$\sum_{i=1}^{n} x_i = S$$

where:

$x_i$ – *the surface of the land use category "i"*

*S – represents the total agricultural area of the agricultural holding*

*i – 1,2, ....n;*

The second type of restriction concerns the maximum and minimum limits within the categories of use may change:

$$\sum_{i=1}^{n} x_i \gtrless S_i$$

where:

*$S_i$ - minimum or maximum area of land use category i*

The third type of restrictions concerns production- obtaining a maximum or a minimum of production:

$$\sum_{i=1}^{n} x_i q_i \lessgtr Q_i$$

where:

*$q_i$ – the yield;*

*$Q_i$ - the minimum or maximum total production to be achieved.*

In the "*Constraint*" column (fig. 4) will be filled with restrictions similar to the cell for the objective function, ie of the type "= X1 + X2 + X3" where X1, X2, X3 represent the values of the variables (not their name).

| | A | B | C | D |
|---|---|---|---|---|
| 22 | Constraints | | | |
| 23 | No | Constraint | Sign | Value |
| 24 | 1 | 0 | = | 200 |
| 25 | 2 | 0 | < | 110 |
| 26 | 3 | 0 | < | 35 |
| 27 | 4 | 0 | < | 25 |
| 28 | 5 | 0 | < | 35 |
| 29 | 6 | 0 | < | 22 |
| 30 | 7 | 0 | = | 0 |
| 31 | 8 | 0 | = | 0 |
| 32 | 9 | 0 | > | 100 |
| 33 | 10 | 0 | > | 25 |
| 34 | 11 | 0 | > | 18 |
| 35 | 12 | 0 | > | 20 |
| 36 | 13 | 0 | > | 16 |
| 37 | 14 | 0 | > | 250000 |
| 38 | 15 | 0 | > | 120000 |
| 39 | 16 | 0 | > | 10 |
| 40 | 17 | 0 | > | 3 |
| 41 | 18 | 0 | > | 1 |
| 42 | 19 | 0 | > | 600000 |

Figure 5. The constraints of the model

2. From the "*Data*" menu, it will be selected the "*Solver*" tool (fig. 5) after it has been previously integrated/installed

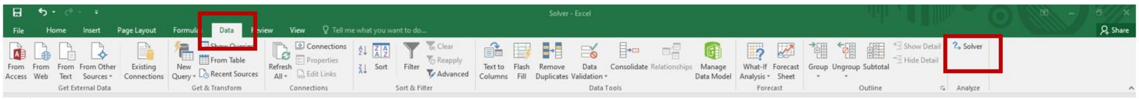


Figure 6. Data menu for Solver

3. Following this operation, the effective data entry box will appear in the solver program (fig. 7), helping the user to structure the data from the previous tables.

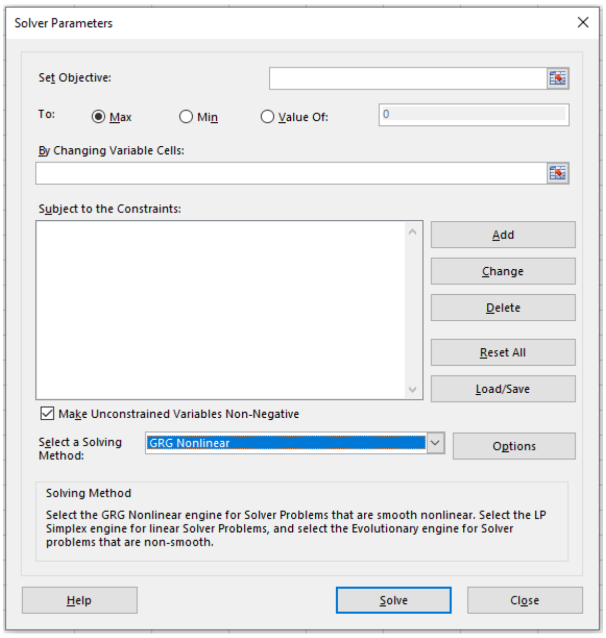


Figure 7. Solver parameters

In the " *Set objective* " box (fig. 8) it has to be written a cell reference. The target cell must contain a formula. For the current application the cell is the one selected, located after "*Maximize*":

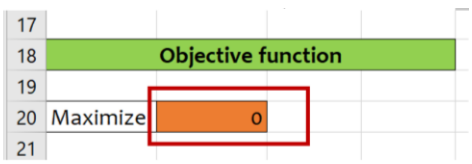


Figure 8. Set objective cell

As objective functions, the following can generally be chosen:

a) If it is desired the target cell value to be maximum, it must be selected "*Max*".

b) If it is desired the target cell value is to be kept to a minimum, it must be selected "*Min*".

c) If it is desired the target cell value to have a certain value, it must be selected "*Value of*", then to be typed the value in the box.
In the "*By changing variable cells*" box, a reference for each decision variable cell area will be entered. Non-adjacent references will be separated by commas. Variable cells must be in direct or indirect relationship with the target cell. Up to 200 variable cells can be specified. There will be selected the values of the variables representing the surfaces of the land use categories that we need to optimize (fig. 9).

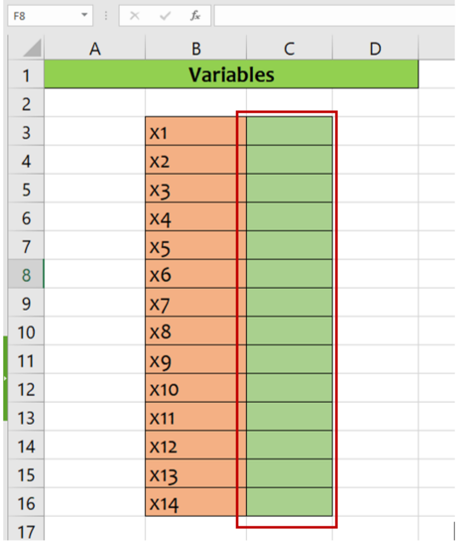


Figure 9. Variables values

In the *"Subject to the constraints" box,* any restrictions we wish to apply will be introduced by performing the following:

a) In the dialog box "*Solver parameters*", will be clicked „*Add*" button (fig. 10).

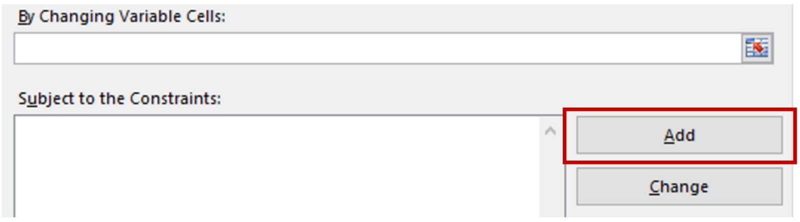


Figure 10. Adding constraints to Solver

b) In the "*Cell reference*" box se it will be entered the cell reference of the cell area for which is desired to limit the value (fig. 11).

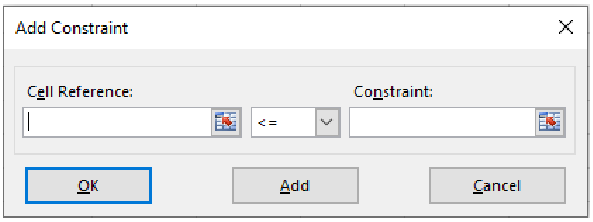


Figure 11. Cell reference box for the constraints

c) Click on relation sign (<=, =,> =,) and select the desired value as the relationship between the cell referred to and the value of the constraint.

Available variants:

a) To accept the restriction and to add another one, click on "*Add*".

b) To accept the restriction and return to the "*Solver parameters*" dialog box, click Ok.

It is possible to modify or delete an existing constraint by doing the following:

a) In the "*Solver parameters*" dialog box, click on the constraint to be deleted.

b) Click "*Change*", then make changes or click *Delete (fig. 12)*

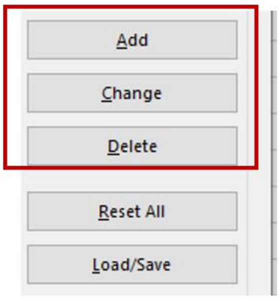


Figure 12. Constraints menu in solver

4. Select option "*Make unconstrained variables nonnegative*"
5. Select the solution method - „*Select a solving method*" and choose "*Simplex LP*"
6. Click on „*Solve*" (fig. 13)

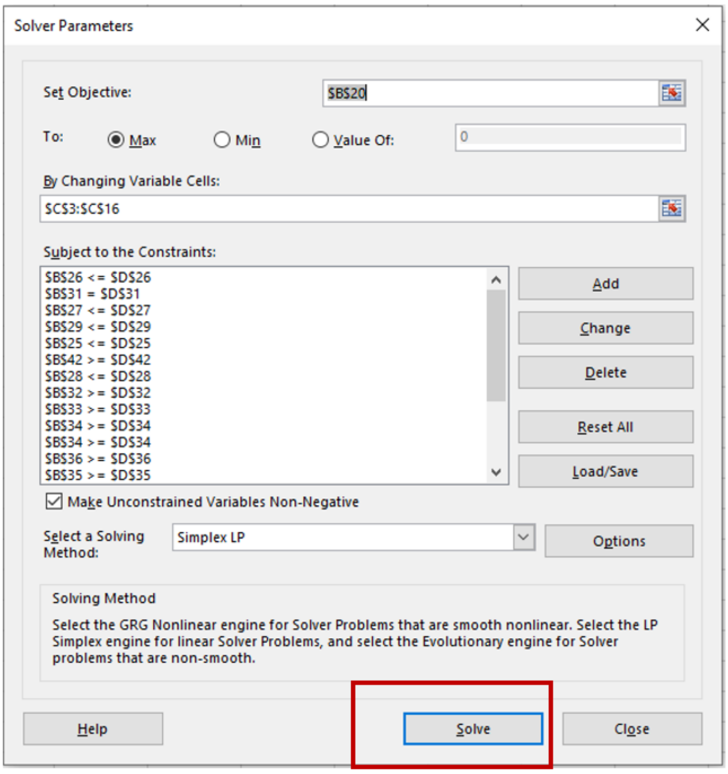


Figure 13. The Solver model before solving

7. After problem problem has been solved with the help of the add-in-in, the column with variables/unknown values should be populated with values (fig. 14). The sum of the values should correlate with the initial condition. They can also be 0.

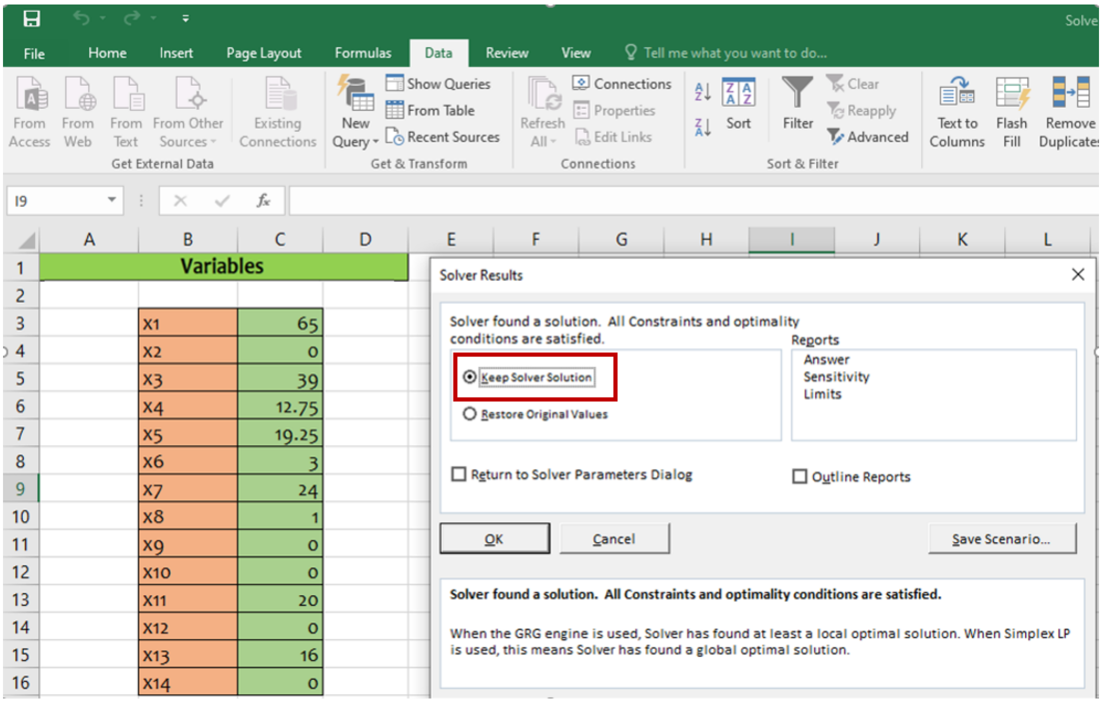

Figure 14. Solutions obtained

8. Proceed as follows:
   a) To keep the solution values in the worksheet, in the "*Solver results*" dialog box select "*Keep solver solution*" and then click "*Ok*"
   b) To restore the previous original values, click on "*Restore original values*".
   c) The solution finding process can be interrupted by pressing *Escape*. Microsoft Excel recalculates the worksheet with the last values found for decision variable cells.
9. In order to create a report after Solver finds a solution, you can click a report type in the *Reports* box. The report is created in a new worksheet in the workbook. If Solver does not find a solution, only certain reports or no reports is available.
10. To save the decision cell values as a scenario to display later, click "*Save scenario*" in the "*Solver results*" dialog box, then type a name for the scenario.
11. The solution obtained is critically assessed and it is determined what share of the available agricultural area should be associated with each proposed land use category.

## 4. Conclusions

Solving the optimization problems within the agricultural activity as an agricultural management activity practiced in order to increase the efficiency of the farm can represent a work direction oriented towards the development of the agricultural field and the improvement of the resources use.

Linear programming is a useful method for achieving an optimal land use structure and consequently to ensure economic efficiency.

The Solver model is effective in quickly determining the optimal structure of a farm. Approaching optimization problems with this tool is a way to familiarize students and researchers with linear programming - a method that is more difficult to approach.

The solutions are variants that an farmer can use to achieve the objectives of the unit, being able to immediately see the effects of changing the parameters and to take the necesary measures in order to increase the added value and the global efficiency.

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