

OPTIMIZATION MODEL FOR FERTILIZATION OPERATIONS

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Abstract

The aim of the present study is to present an option for reducing the technological operation costs of fertilization. The research paper examines the available equipment of a specific agricultural producer (PA) in the Republic of Bulgaria. The characteristics of the fertilizing machines and the energy sources in the agricultural holding are made, the hourly productivity of the assembled units is calculated and the transport costs are optimized by solving a transport task under certain conditions. The proposed algorithm for describing a transport task and its subsequent solution, using MS Excel Solver significantly speeds up the calculation procedures and helps to reduce costs when performing the technological operation fertilization.

Key words: fertilizing machines, transport task, Solver.

INTRODUCTION

On the one hand, the proper fertilization is an important factor for plants. Many of our plant problems come from a lack of fertilization - even diseases and pests, as a weak plant is more susceptible and easier to get sick. On the other hand, when we talk about fertilization, the maxim "the more, the more" does not apply.

In today's competitive market, obtaining the maximum yield, in compliance with the health requirements of a crop, with minimum fertilizer costs is the most critical part of creating a successful agriculture. The economic reality of the overall agricultural industry is forcing producers to look for ways to increase the yield of existing agricultural land.

Fertilization is a very important technological process, because if not carried out properly it allows the saturation of the soil with chemicals. The basis for the development of each project in agriculture is the technological maps, which give the technology and resources for the production of a specific agricultural product.

The technological maps for mechanization of fertilization provide relatively constant information about the agro-technical term, the number and duration of working days, the composition of the unit, the required number of tractors and CCM. With this treatment we aim to apply a method for optimizing the transport

costs of fertilization in a sample farm of a farmer.

MATERIALS AND METHODS

The characteristics of fertilizer machines and energy sources are taken from the prospectuses of the machines. The main parameter required for the study is the performance of the MTA. It is a function of the working width of the machines (Palevski, 1990).

For fertilizer spreaders, the working width depends on the type of fertilizer (Trankov, 1993).

The hourly productivity of the assembled aggregates is calculated as follows:

$$Wh = \frac{Bp \cdot S}{10000} [\text{ha}], \quad (1)$$

where:

Bp - the working width of the aggregate [m];

S - the way of the aggregate for one hour [m].

For a maximum correctness of the calculations, we should take out 30%, which is the time spent for curves, pauses, fertilizer loading, etc.

Algorithm for solving a transport problem with the possibilities of MS Excel Solver (used MS EXCEL 2010)

MS Excel has a module for solving optimization tasks. The module is called Solver and can be found in the Data menu (Figure 1). It must be activated before using it for the first time. This is done in the following sequence:

- MS Excel starts;
- from the File menu select Options;
- the Option dialog box of Excel appears;
- submenu Add-Ins → Manage select Excel Add-ins;
- The dialog box closes with OK.

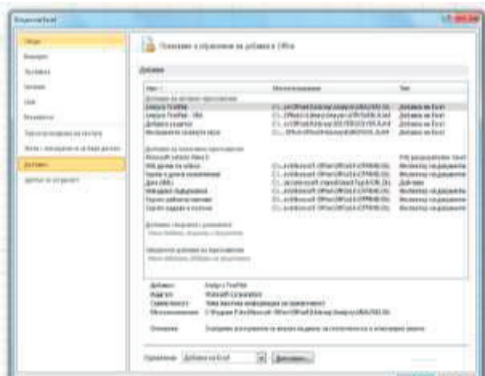


Figure 1. Solver Activation Dialog Box

In this way we already have the program for solving optimization problems. Such an approach has also been used in the development of (Ivanova et al., 2011; Ivanova et al., 2018; Marinov, 2016).

RESULTS AND DISCUSSIONS

The farm is located in the region of Dobrich, Bulgaria. It grows mainly cereals on an area of about 1200 ha.

MTA for fertilization

The following MTAs are used for on-farm fertilization:

1. tractor "Kubota GX135M" + "AMAZONE ZM"

2. John Deere 8270R tractor + AMAZONE ZM
 The working width of both units is 24 m.

The speed is on two levels 10 and 15 km/h.

For MTA "1" and "2" of the made characteristics we can calculate the energy required for the processing of 1 ha.

$$Wh_1 = \frac{24 \cdot 10000}{10000} = 24 - 30\% = 16.8 \text{ ha/h}$$

$$Wh_2 = \frac{24 \cdot 15000}{10000} = 36 - 30\% = 25.2 \text{ ha/h}$$

The calculations show that the MTA is quite productive - for 8 hours a day the two units fertilize 400 ha or for 3 days the whole farm could be fertilized. In order for the machines to

be loaded, the services of colleagues - manufacturers are performed.

Terms of reference for optimizing transport costs during fertilization:

Perform the fertilization operation with the two MTA units on the following fields:

1. field1 - 4.6 xa x 200 кг/xa = 920 кг within a base distance of 0.7 km
2. field2 - 4.2 xa x 200 кг/xa = 840 кг within a base distance of 0.6 km
3. field3 - 6.3 xa x 200 кг/xa = 1260 кг within a base distance of 1km
4. field4 - 8.1 xa x 200 кг/xa = 1620 кг within a base distance of 1.8 km

The data for the average fuel consumption during transport have been established experimentally - 0.244 L/km and the calculations are made at an average fuel price of BGN 2 (Figure 2).



Figure 2. Experimental data

Task. Solve the following transport task

Bj \ Ai	B1	B2	B3	B4	ai
A1	0,34	0	0	1,85	2540
A2	0	0,29	0,68	0	2100
bj	920	840	1260	1620	4640
					4640

Solution: The given transport task is closed because we have a balance between production and consumption, ie.

$$\sum_{i=1}^2 a_i = \sum_{j=1}^4 b_j = 4640.$$

We solve the obtained closed transport task according to the solving algorithm in MS Excel (Solver). In Figure 3 is given a spreadsheet

with the mathematical model of the specified problem.

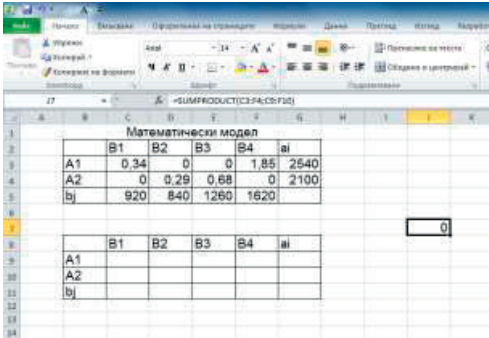


Figure 3. Spreadsheet with the task model

Filling in the worksheet:

1. Enter the values of transport costs in cells \$ C \$ 43: \$ F \$ 4, in cells \$ G \$ 3: \$ G \$ 4 - the constants of matrix A (ai), and in cells \$ C \$ 11: \$ F \$ 11 - the constants of matrix B (b) of the task.
2. In cell \$ J \$ 7 we enter the formula by which the value of the objective function is calculated, ie. = SUMPRODUCT (C3: F4; C9: F10).
3. In the second table in cell C11 we enter the formula = SUM (C9: C10) and after clicking the mouse appears zero.

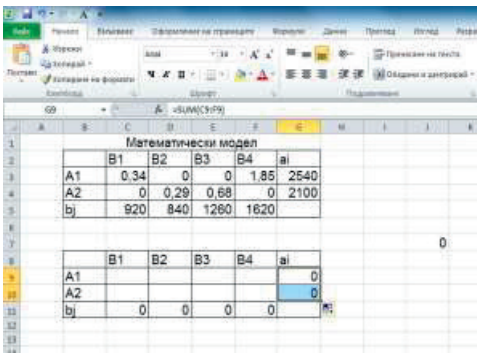


Figure 4. A Dialogue Box expressing the function for summing the quantities of the consumers

And then it is copied to the other cells D11: F11, where a zero value also appears. Similarly, enter a formula for cell G 9 and copy to cell G 10.

When compiling the formula, it is necessary to use absolute addressing of the cells that contain the variables of the task (the \$ sign is placed in

front of the column name and/or the row number).

For large tasks, it is convenient to use the built-in function, SUMPRODUCT, which calculates a scalar product of two vectors of equal dimension (Figure 4).

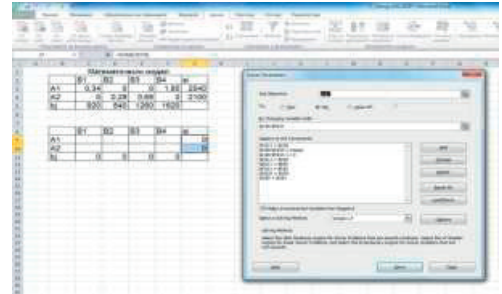


Figure 5. "Solver Parameters" dialog box

After entering the input data and activating the formula from the menu Data → Solver, an empty Solver Parameters dialog box opens, in which the formula for calculating the value of the target function is shown in Figure 5.

It is recommended that the cell with the target function be current before calling Solver - in this case cell \$ J \$ 7.

In Equal to the radio button corresponding to the criterion of the model is selected, in the specific task Min is selected.

In by Changing Cells, the cells in which the values of the task variables are located are entered. In the specific task, these are the cells \$ C \$ 11: \$ F \$ 13 which minimize the target function.

In the field Subject to the Constraints the restrictive conditions are entered through the buttons located next to it - in this case Add, or change by the Change button and deletion of already existing restrictions by the Delete button.

When you click the Add button, a dialog box with restrictive conditions appears.

The Add Constraint dialog box consists of the following fields:

Cell Reference - enter the cells on the left side of the restriction conditions. Several restrictions of the same type can be introduced at the same time.

Constraint type: <=, =, >=.

Constraint - enter the cells on the right side of the restrictive conditions.

After the current restriction has been entered, the Add button is selected if a new restriction is to be entered, or OK if the entry is completed.

We check the Make Unconstrained Variables Non-Negative option because all variables in the task must meet a non-negative condition. It is not recommended to change the other items in the dialog box. Finally, with the OK button we return to the Solver Parameters dialog box.

In Figure 5. the Solver Parameters dialog box for the considered task is shown.

From the Solver Parameters dialog box, select the Solver button to perform the task. The solution of the problem is shown in Figure 6.

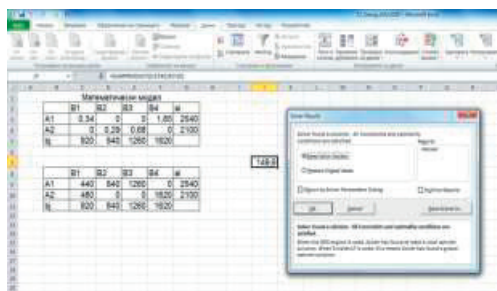


Figure 6. The spreadsheet and the dialog box Solver Results

The Solver Results dialog box provides information about the result of the performed optimization. In the present case, it turns out that for the obtained solution all restrictive conditions and optimality conditions are satisfied. The optimal solutions are from the \$ C \$ \$ 9: \$ F \$ 10 cells and an optimal plan is obtained $L_{min} = 149.6$.

The Solver Results dialog box allows you to save the optimal solution found (with the Keep Solver Solution button) or to restore the original appearance of the worksheet (with the Restore Original Values radio button).

From this dialog box it is possible to create a report on the solution of the task (Answer Report).

Based on the proposed description and the presented solution of a transport problem in the

environment of MS Excel, by using the capabilities of MS Excel Solver, the following conclusions can be made:

The proposed algorithm for describing a transport task and its subsequent solution, using MS Excel Solver, is easily applicable;

The use of software applications significantly speeds up computational procedures;

The considered functionality of the "Solver" add-on can be used both for solving transport-type tasks and for solving tasks in other areas as well.

CONCLUSIONS

The following conclusions can be drawn from the present study:

- The proposed algorithm for describing a transport task and its subsequent solution, using software applications significantly speeds up computational procedures and is an easily applicable method for optimization.
- Through the optimization the transport costs for fertilization are minimized to BGN 149.6.
- In view of the load on the equipment owned by the farm, it could increase its arable land or offer services with fertilization equipment to other farmers.

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