OPTIMAL DISTRIBUTION OF THE AMOUNT OF WORK AMONG THE TRACTOR AGGREGATES CONSIDERING SET AGROTECHNICAL TERMS

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Abstract. The article deals with an economic-mathematical model of optimal distribution of the amount of work among the tractor aggregates considering the fixed agrotechnical terms for the execution of production processes in the field crop cultivation. A method of linear programming is applied to solve this task. A theoretical relationship is presented between the rated costs per hectare and the performance characteristics of the tractor aggregate. This is shown by an example of a calculation of the optimal distribution of the amount of work among four tractor aggregates performed in ploughing and sowing. The developed model provides an opportunity to make a motivated conclusion how to perform the work with optimal variable expenses reducing the losses of crops after harvest owing to fixed agrotechnical terms as well as to justify the structure of the technical provisions of the production processes.
Key words: amount of work, specific costs, tractor aggregate, economic-mathematical simulation.

Introduction

At the present time, there is a wide choice of sets of machines and tractors on the market of agricultural machinery with various energy capacity and efficiency. Therefore, it is important for the producer of agricultural products to know what circumstances determine efficient use of agricultural machinery, and methods of its choice. The choice of a tractor aggregate must proceed from a condition that it should meet the production requirements and economic efficiency. Similar conclusions were made also by other scientists (Thornley J. H. M., France J., 2007). The solution of this issue is possible when economic-mathematical methods are applied which allow to obtain an answer to the questions how the particular amount of work is distributed among the tractor aggregates, which of the selected variants is optimal, and to take into consideration all the economic and agrotechnical conditions by using mathematical models and solving them as a task of linear programming.

Materials and methods

The aim of the paper is the development of an economic model for the choice of an optimal distribution variant of the amount of work among the tractor aggregates keeping to set agrotechnical terms, the optimality criterion being variable costs that reflect the level of the current expenses and capital investments.

Application of the model will enable the producer of agricultural products to make motivated conclusions on the efficient implementation of the production processes.

Theoretical foundations of mathematical simulation of the production processes in agriculture are used to solve the advanced task. The economic and agrotechnical conditions are expressed by means of linear inequalities and equations, applying economic-mathematical methods (Asejeva A., Kopiks N., Viesturs D., 2006; Pavlov B. V., Pushkareva P. V., Scheglov P. S., 1982; Taha, Hemdi A., 2005; Frans G., Torili G. H. M., 1987). The functional dependencies are established using the theoretical foundations of completing machine-and-tractor aggregates. The mathematical model was calculated using the superstructures of the MS Excel software.

Research results and discussion

Usually any farm employs various machines which differ by their efficiency and variable costs, although, they carry out the same amount of work. Their efficient use when performing the assigned amount of work and keeping to fixed agrotechnical terms requires finding of optimal distribution among the tractor aggregates. A preset amount of work may be carried out by tractor aggregates in different configurations.

Let us discuss an example of an economic model for optimised choice of the distribution of the amount of work among the tractor aggregates keeping to set agrotechnical terms. A grain producing farm has to carry out the following amount of work: to plough and to sow 150 ha of land. This work has to be completed within 10 days – ploughing in five days and sowing in the same period of time. The farm has tractor aggregates which are presented in Table 1. (According to the data of the Central Statistical Bureau of the Republic of Latvia, tractors with a capacity of 80kW and more than 100kW are generally used on the farms with areas under crop 150 ha and more). The work shall be carried out to a preset extent by means of the aggregates indicated in the table with minimum variable costs and in fixed agrotechnical terms as any deviation from them influences the crop capacity.

The determination of optimal distribution of the assigned amount of work among the tractor aggregates presented in Table 1 which ensure minimal costs and completion of the work in fixed agrotechnical terms requires minimisation of the target function.

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Table 1

Information on the tractor aggregates

Aggregate	Working width, m	Costs* LVL/ha	Price of the aggregate		Efficiency of the aggregate, ha/h
			Agricultural machine, LVL	Tractor, LVL	
Ploughing aggregates					
MTZ 1025+Kverneland ES-80 200	1.5	16.21	5378	11381	1.2
John Deere 8200 + Kverneland DC-100	3	18.12	11407	66249	2.4
Sowing aggregates					
MTZ 1025 + Amazone AD 252	2.5	17.94	8894	11381	2.75
John Deere 8200 + Amazone AD 452	4.5	26.20	19239	66249	4.95

* Repair and maintenance costs are not considered since in this case they do not depend on efficiency and differ in proportion with the performed work.

Source: authors' calculations based on "Armus" Ltd

$$C_{\min} = \sum_{i=1}^{m} \sum_{i=1}^{n} c_{ij} x_{ij} \tag{1}$$

where:

c_{ij} - costs per hectare of the i-th type of work (ploughing, sowing) performed by the tractor aggregate, j-th configuration of the tractor aggregate;

x_{ij} - amount of the i-th type of work performed by the j-th configuration of the tractor aggregate;

m - number of the types of work to be performed;

n - number of the types of work performed by aggregates of different configurations.

This amount of work shall be carried out on condition:

$$\sum_{i=1}^{n} x_{ij} = a_1 ; \sum_{i=1}^{n} x_{ij} = b_1 \tag{2}$$

where:

a_1 - amount of the ploughing operation;

b_1 - amount of the sowing operation.

All the operations shall be completed in fixed agrotechnical terms

$$\sum_{x=1}^{n} d_{ij}^{-1} x_{ij} \le t_{ij} \tag{3}$$

where:

d_{ij}^{-1} - daily output of a tractor aggregate in the j-th configuration;

t_{ij} - fixed agrotechnical term for the i-th kind of work performed by a tractor aggregate in the j-th configuration.

The variables may not have negative values:

$$x_{ij} \ge 0 \tag{4}$$

The presented mathematical model for the determination of the optimal distribution of a particular amount of work among the existing tractor aggregates and its execution in a fixed agrotechnical term is treated as a task of linear programming. The results obtained for the optimal distribution of a particular amount of work which ensures minimal costs are presented in Table 2.

It is evident from Table 2 that the ploughing aggregate MTZ 1025+Kverneland ES-80 200 has to carry out 40% of the amount of work intended for ploughing but the aggregate John Deere 8200 + Kverneland DC-100 - 60%, respectively. Execution of this amount of work takes place in a fixed agrotechnical term. The sowing aggregate MTZ 1025 + Amazone AD 252 fulfils 91.7% of the amount of work allotted for sowing, while the aggregate John Deere 8200 + Amazone AD 452 - 8.3%, respectively.

This distribution of the tractor aggregates by the types and amount of the work to be completed in a fixed agrotechnical term is optimal for which the variable costs constitute LVL 5396.73.

The results also show that the aggregate John Deere 8200 + Kverneland DC-100 performing the amount of the ploughing work has a reserve of time equalling 1.25 days but during the sowing period it has 4.75 days of the calculated period of time. It means that in any other configuration the particular aggregate can make use of this time doing other types of work but it can be redistributed among other aggregates at insignificant temporary load (less than a day's output).

Table 2

Optimal distribution of a particular amount of work among the tractor aggregates

Aggregate	Amount of the performed work, ha	Duration of the performed work, days	Number of the working days in the period	Variable costs, LVL
Ploughing				
MTZ 1025+Kverneland ES-80 200	60	5	5	972.50
John Deere 8200 + Kverneland DC-100	90	3.75		1630.64
	150			
Sowing				
MTZ 1025 + Amazone AD 252	137.5	5	5	2466.07
John Deere 8200 + Amazone AD 452	12.5	0.25		327.52
Total	150		10	5396.73

Source: the data of Table 2 are based on the authors' calculations

Table 3 shows individual scenarios from the calculated distribution process of the amount of the above-mentioned work to be completed in fixed agrotechnical terms, and the changes in variable costs.

Table 3 outlines that in various scenarios of the distribution of the amounts of work to be completed (and there are lots of them) the variable costs are different from the optimal value presented in Table 2; neither fulfilling the imposed restrictions. Therefore, a condition is not fulfilled in Scenario 1 to complete the preset amount of the ploughing and sowing operations in fixed agrotechnical terms. It is implemented by 20% less. In Scenario 2, a condition is not fulfilled to complete the preset amount of the ploughing work.

Consequently, the particular model for the determination of the optimal distribution of a particular amount of work among the existing tractor aggregates and its execution in fixed agrotechnical terms allows an optimal distribution of the work among the existing tractor aggregates in order to finish it in a preset agrotechnical term with minimal costs.

The optimal variable costs will change if the same aggregates carry out the total amount of work with variable values of imposed conditions. Besides, the value of the amount of the work to be completed by the tractor aggregates of each configuration has a limit of its efficient execution. Figure 1 shows variations in the optimal variable costs depending on the established amount of the work to be performed and its distribution among the aggregates.

It is apparent from Figure 1 that the optimal variable costs increase with the increase of the amount of the work. If the amount of work is 100 ha (ploughing, sowing), it is distributed among the aggregates in the following way – during ploughing the aggregate MTZ 1025 + Kverneland ES-80 200 shall carry out 60% of the amount of work, while the aggregate John Deere 8200 + Kverneland DC-100 - 40%. During the sowing operation, the aggregate MTZ 1025 + Amazone AD 252 shall perform 100% of the amount of work, while the aggregate John Deere 8200 + Amazone AD 452 – 0 %, the optimal variable costs constituting LVL 4430. When the amount of the ploughing operation is 200 ha, these aggregates cannot manage the amount of work due to the violation of the imposed condition (the agrotechnical term). Execution of the amount of work in a fixed agrotechnical term by two ploughing aggregates makes 90%, since their capacity and the established length of the working day (T_{work}.-10 h) does not allow fulfilling such an amount of work. During the sowing operation both the aggregates finish the amount of work completely, 50% each. It is possible to fulfil the preset amount of the ploughing work without keeping to set agrotechnical terms; however, this leads to a decrease in the crop capacity.

The limit of the amount of the work to be performed for the particular configuration of the tractor aggregates is 180 ha at the above mentioned limitations (type of work, amount of work, agrotechnical terms). At such an amount of work its distribution among the tractor aggregates is the following: the ploughing aggregate MTZ 1025 + Kverneland ES-80 200 shall carry out 33%, while the aggregate John Deere 8200 + Kverneland DC-100 - 67%. During the sowing operation the aggregate MTZ 1025 + Amazone AD 252 shall perform 76% of the amount of work, while the aggregate John Deere 8200 + Amazone AD 452 – 24 %, the optimal variable costs constituting LVL 6029.10.

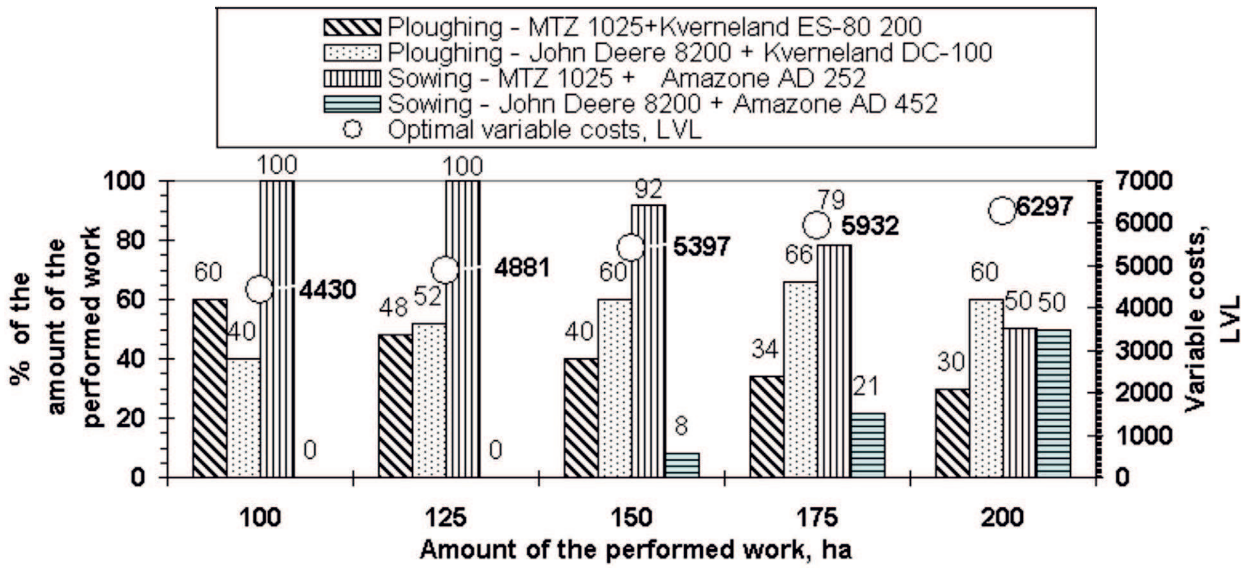
The value of the variable costs depends on the other factors as well. The optimal costs change with the changes in the target function (Equation 1) coefficients reflecting the costs of the unit of the performed work with its variables x_{ij} for each aggregate. For example, if coefficients c_{ij} in the previous case, when the optimal distribution (150 ha) of the work to be performed (ploughing and sowing) is determined, are

Table 3

Individual scenarios for the distribution of the above-mentioned work to be completed in fixed agrotechnical terms, and the changes in variable costs.

Aggregate	Amount of the performed work, ha	Duration of the performed work, days	Number of the working days in the period	Variable costs, LVL
Scenario 1		Ploughing		
MTZ 1025+Kverneland ES-80 200	60	5	5	972.50
John Deere 8200 + Kverneland DC-100	60	2.5		1087.10
	120			
		Sowing		
MTZ 1025 + Amazone AD 252	60	2,18	5	1076.10
John Deere 8200 + Amazone AD 452	60	1.21		1572.09
	120		10	4707.79
Scenario 2		Ploughing		
MTZ 1025+Kverneland ES-80 200	60	5	5	972.50
John Deere 8200 + Kverneland DC-100	75	3.13		1358.87
	135			
		Sowing		
MTZ 1025 + Amazone AD 252	75	2.73	5	1345.13
John Deere 8200 + Amazone AD 452	75	1.52		1965.12
	150		10	5641.62

Source: the data of Table 3 are based on the authors' calculations



Source: the data of Figure are based on the authors' calculations

Fig. 1. **Variations in the optimal variable costs depending on the established amount of the work to be performed and its distribution among the aggregates**

replaced by a value which corresponds to the 200 ha amount of the performed work (150 ha – ploughing 16.21 and 18.12 LVL/ha, sowing 17.94 and 26.20 LVL/ha; 200 ha - 14.73 and 14.95 LVL/ha, sowing 15.42 and 20.77 LVL/ha), then the optimal costs decrease by 15%, constituting LVL 4610.15 at the previous optimal distribution of the amount of the executed work which corresponds to a condition when the distribution is 150 ha. This indicates that the value of the coefficients mentioned is of great importance for the calculation of the minimal costs as their values depend on the price and technical parameters of the aggregate. Another very important factor for the execution of the i-th kind of work is the value of the fixed agrotechnical term t_{ij} (Kopiks, N., Viesturs, D., 2010).

The example of the discussed model shows that the application of economic-mathematical methods makes it possible to obtain an optimal value for the distribution of a preset amount of the work among the tractor aggregates allowing to use efficiently the technical means and solve the production tasks.

This method may be applied also to an entire complex of previously planned agricultural operations performed by various tractor aggregates keeping to set agrotechnical terms violation of which may affect the crop capacity.

Conclusions

Optimal distribution of the amount of work among individual tractor aggregates is necessary In order to minimise the rated costs.

The presented economic-mathematical model provides a possibility to calculate an optimal variant for the distribution of the amount of work among the tractor aggregates considering the fixed agrotechnical terms, and to determine an optimal structure of the technical provision of the production processes.

Bibliography

1. Asejeva, A., Kopiks, N., Viesturs, D. (2006). The Choice of an Optimum Ploughing and Sowing Aggregate for Different Amounts of Work. *Proceedings of the International Scientific Conference "Economic Science for Rural Development,"* № 10. Jelgava, pp. 139-144.
2. Frans, G., Torili, G..H.M. (1987). Matematicheskije modeli v seljskom hozjaistve *(Mathematical Models in Agriculture).* Perevod s angliskovo. Moskva, Agropromizdat, 400 str.
3. Kopiks, N., Viesturs, D. (2010). Research into Models of Choice of Tractor Aggregates: *9th International Scientific Conference Engineering for Rural Development Proceedings*, Volume 9. Jelgava, pp. 139-143
4. Pavlov, B. V., Pushkareva, P. V., Scheglov, P. S. (1982). Projektirovanije kompleksnoij mehanizaciji seljskohozjaistvennih predprijatij *(Designing Complex Mechanization in Agricultural Enterprises)*. Izdateljstvo M. "Kolos", 288 str.
5. Taha, Hemdi A (2005). Vedenije v isledovanije operacij *(Introduction to Operations Research)*. 7 – izdanije: Perevod s angliskovo. Moskva, Izdateljskij dom "Viljams", 192 str.
6. Thornley, J.H.M., France, J. (2007). Mathematical Models in Agriculture: Quantitative Methods. CABI, p. 906.