The Choice of an Optimum Ploughing and Sowing Aggregates for Different Scopes of Work

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Abstract

The article deals with an issue of the choice of a machine and tractor aggregate from the aspect of its economic expediency. A model has been developed for finding an optimum of variable costs on the basis of their minimisation as a function of the working width and the corresponding scope of work. Solver, a superstructure of MS Excel, was used for solving it as a task of optimising non-linear programming. Design data which characterise the sowing and ploughing aggregates by minimum variable costs and the corresponding scope of work are presented.

***Key words**:* Optimisation, specific costs, working width, aggregate.

Introduction

Currently there is a sufficiently wide choice on the market of agricultural machines that can be aggregated with tractors forming a great number of machine and tractor aggregates characterised by different energy intensity and efficiency. The offer of machines for agricultural production is continuously growing, the engineering parameters of the aggregates being different. In such a situation it is important to make a correct choice of an aggregate. Specifically that by the size of the areas under crop, the farms of Latvia have a great dispersion rate. For instance, the number of farms with the areas of 20.1-50.1 ha amounts to 3.7% of the total number, with their area under crop being 14.0% of the total area; for farms with the areas between 50.1 and 100.0 ha - the respective figures are 1.4% and 11.7%; and for the farms which areas exceed 300 ha – the respective figures are 0.3% and 24.5% [Lauku saimniecības..., 2004.]. This applies to farms engaged in the production of grain, where the area under crop constitutes 50.3% of the total area under crop of all the farms engaged in different fields of agricultural production. Since the farm areas under crop are so different, the technical means will also differ considerably by their power and efficiency. Thus an economically motivated choice of a machine and tractor aggregate is one of the most important tasks to ensure the output of competitive products.

In order to make a decision on the purchase of machines, a method for the choice of a tractor aggregate considering its price, the scope of work, and efficiency by minimising the function of specific variable costs and using a computer software MS Excel has been worked out.

Materials and methods

The aim of the article is to develop a method for the determination of the optimum value of specific variable costs, the corresponding scopes of work for a particular tractor aggregate by means of economic and mathematical optimisation methods, as well as to give recommendations for the producer of agricultural machines under the current market conditions of agricultural machines to be able to make a motivated choice of a tractor aggregate in compliance with the requirements and conditions of the farm.

To achieve the set aim, it is necessary to determine the mathematical structure of the optimisation model to be created and express the variable costs as a function of the working width and the corresponding scope of the performed work. It is also necessary to prepare a tabular version of the optimisation model of the presented variable costs for the calculation by means of a computer software MS Excel.

Results and discussion

The essence of the method for the choice of a tractor aggregate is the determination of minimum specific variable costs for the corresponding scope of work according to one of the basic parameters – the working width. A particular case of choosing the sowing and ploughing tractor aggregate is used for the discussion of this method.

At first, we will deduce a model by means of which it is possible to find the optimum specific variable costs according to an accepted parameter of the tractor aggregate.

To calculate the minimum specific variable costs, it is necessary to express them as a function of the working width of the tractor aggregate for the corresponding scope of the performed work. It is expressed as:

$$\mathbf{Z} = F(a, p, q, a_1);$$

The scheme of the mathematical model for the function of the variable costs is presented in Figure 1.

Let us consider the constituents of the minimisation function – the model characterising the specific variable costs.

$a = \mathbf{f}(\mathbf{c}, \mathbf{b}, \boldsymbol{\alpha}, \boldsymbol{\Omega})$ – specific depreciation deductions relating to an agricultural machine, where:

c – value of a unit of the working width of an agricultural machine;

b – working width;

α – depreciation coefficient;

Ω – scope of work.

Changing the working width of an agricultural machine leads to the change of its price and, consequently affects the value of variable.

If the agricultural machine performs other operations as well, then the coefficient of the specific share of the operation is also included into the total scope of the performed work.

$p = \mathrm{f}(\boldsymbol{\gamma}, \mathbf{v}, \mathbf{b}, \boldsymbol{\tau})$ – specific salary, where:

γ – hourly rate;

v – speed of the movement of the aggregate;

b – working width of the aggregate;

τ – coefficient of the use of the working time.

$q = \mathrm{f}(\boldsymbol{\theta}, \mathbf{v}, \mathbf{b}, \boldsymbol{\tau})$ – specific consumption of fuel, where:

θ – hourly consumption of fuel;

v – speed of the movement of the aggregate;

b – working width of the aggregate;

τ – coefficient of the use of the working time.

$a_1 = \mathrm{f}(\mathbf{c}_1, \boldsymbol{\omega}, \mathbf{v}, \mathbf{b}, \boldsymbol{\tau})$ – specific depreciation deductions per tractor, where:

$\mathbf{c}_1$ – price of the tractor;

α – depreciation coefficient;

ω – annual loading of the tractor in hours;

v – speed of the movement of the aggregate;

b – working width of the aggregate;

τ – coefficient of the use of the working time.

All the constituent minimisation functions of the specific variable costs depend on the working width of the tractor aggregate.

Deductions for repairs and maintenance are calculated proportionally to the performed work. They are not included into the discussed function of specific variable costs since they are not connected with the working width of the aggregate.

The use of the function allows to draw a dependence graph between the specific variable costs, the working width of the aggregate and the given value of the scope of the performed work in order to determine the character of the dependence. The case is considered in Figure 1 (the basic input data for the discussed example: the scope of work - 200 and 500 ha; the price of one metre of

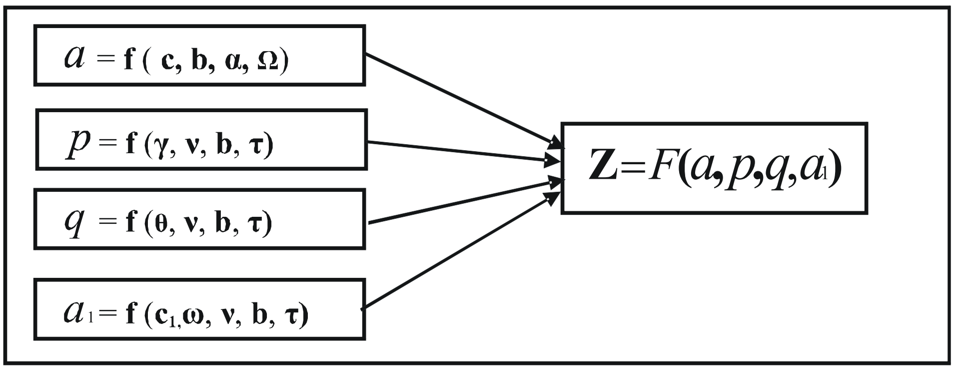


Fig. 1 **The scheme of the model for the minimisation function of variable costs**

the working width of a sowing machine – LVL 3500; the price of a tractor - LVL 51330; the annual loading – 1200 h; the technological speed of the movement of the aggregate - 11 km/h; the price of fuel – 0.45 LVL/kg without the returned excise tax; the salary - 1 LVL/h, etc.).

It is evident from Figure 2 that the dependence of the presented specific costs on the working width of the aggregate is not of a linear character. The segments of the curves drawn as thick lines represent the optimum values of the specific variable costs; they have a valley for the respective working width of the aggregate and the scope of work. The optimum working width of the aggregate increases with the increase in the scope of the performed work, which indicates in this case the expediency of the use of expensive machines. The performance of huge scopes of work by aggregates having great working width is economically more profitable than the respective performance by several aggregates having narrow working width (expenses increase on salaries, consumption of fuel, etc.). It is obvious from Figure 2 that the use of machine and tractor aggregates to perform great scopes of work is characterised by the fact that the variable costs change slower than their optimum value. The prices of aggregates, as well as, affect the character of variable costs: the higher is their specific price, the more they stand out against the aggregates of lower prices (see Figure 3).

The optimum value of specific variable costs can be determined by means of the minimisation model described above in case its function is differentiated and equated to 0. Yet it is possible to avoid the use of the formulae which, when some assumptions are changed, may be unacceptable, but the superstructure Solver of the software MS Excel can be used to solve it as an optimisation task of a non-linear programming.

Tables 1 and 2 show the optimisation results of specific variable costs at the respective scopes

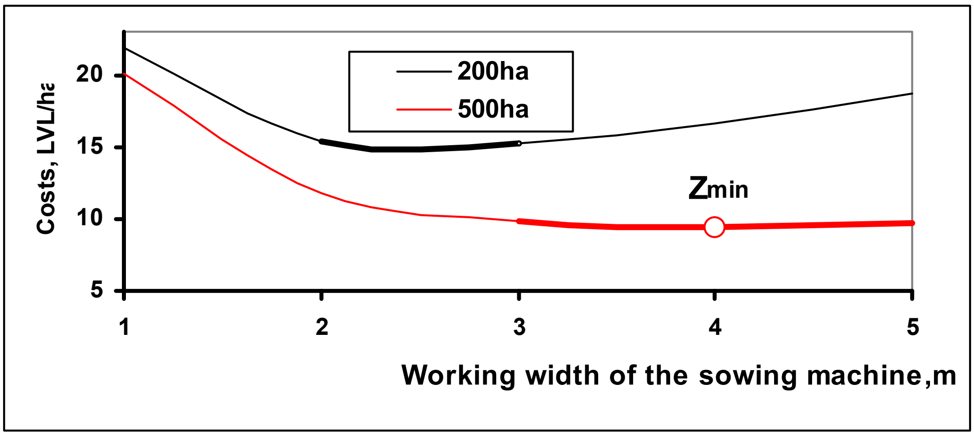
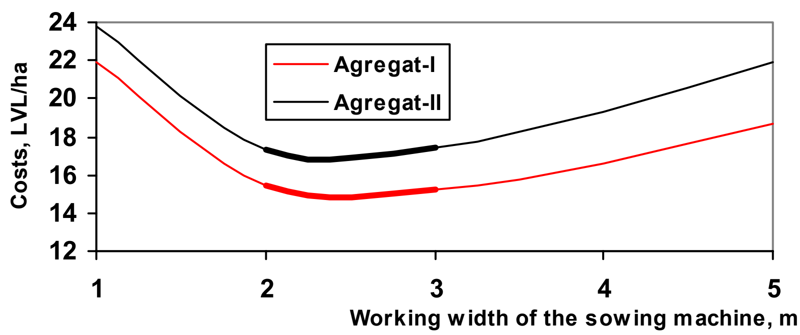


Fig. 2 **Changes of variable costs depending on the working width of the sowing machine**



Note: The price of Agregat-II is higher by 20%.

Fig. 3 **Changes in the specific variable costs depending on the prices of the aggregates (the scope of work 200 ha)** of work (Figures 3 and 4) for various sowing and ploughing aggregates.

General input data for sowing and ploughing aggregates are the following: the working width; the price of the sowing machine, the plough and the tractor (presented in Tables 1 and 2); the coefficient of the depreciation deductions - 0.17 for the sowing machine and the tractor; the annual loading of the tractor - 1200 h; the price of fuel – 0.45 LVL/kg, without the excise tax; the salary - 1 LVL/h; the technological speed - 11 km/h of the aggregate (Mc CORMICK MTX-200+ Accord Kverneland MSC- 14 km/h), for the ploughing aggregates - 8 km/h.

Restrictions on the variable working width - **b** should exceed 0 to avoid senseless variants when they are checked, which will lead to the division error by 0 when the specific salary, the specific fuel consumption and other indices are calculated. For the sowing aggregates it is accepted that **b** ≥ 1 but for the ploughing aggregates **b** ≥ 0.35.

The data of Tables 1 and 2 confirm the conclusions laid out for the analysis of the optimisation function. They also enable making a

Table 1

Minimum variable costs for various sowing machines

Description of aggregate	Working width, m	Scope of work, ha	Costs, LVL/ha	Price of the sowing machines, LVL	Price of the tractor, LVL
1	2	3	4	5	6
MTZ 952+Accord Kverneland DA	2.5	**335**	**6.39**	6300	9661
MTZ 952+Accord Kverneland DA	3	**560**	**5.32**	8750	9661
John Deere 7810+ Accord Kverneland DAX	4	**428**	**9.46**	11900	51330
John Deere 7810+ Accord Kverneland DV	5	**785**	**7.58**	17500	51330
Direct sowing machine					
Mc CORMICK MTX-200+ Accord Kverneland MSC	4	**1350**	**7.9**	31500	60298

Table 2

Minimum variable costs for various ploughing aggregates

Description of aggregate	Working width, m	Scope of work, ha	Costs, LVL/ha	Price of the plough, LVL	Price of the aggregate LVL
1	2	3	4	5	6
MTZ 952+AB100	1.00	**40**	**21.98**	2590	9661
MTZ 952+ AB100	1.50	**80**	**14.67**	3464	9661
John Deere 7810+ EM100	1.80	**115**	**28.99**	9824	51330
Mc CORMICK MTX-200+ EM100	2.25	**225**	**17.16**	11364	60298
Mc CORMICK MTX-200+ EG85	2.70	**405**	**14.29**	17013	60298

motivated choice of a tractor aggregate in compliance with the requirements and conditions of the farm. What are the limits to the scope of work when a particular tractor aggregate is economically efficient? According to Tables 1 and 2, and Figure 3 it is also possible to determine the period in which the particular work is completed if the values are divided by the efficiency of the corresponding aggregate.

One should also remark the following. If a farm already has a tractor, then it is necessary to meet the following condition when choosing an agricultural machine: the working width $\mathbf{B}_{opt}$ obtained as a result of optimisation should correspond to the possible working width by the efficiency $\mathbf{B}_N$ of the existing tractor, i.e. $\mathbf{B}_{opt} \leq \mathbf{B}_N$.

Acquisition of such information will enable the producer to make a motivated choice of a machine and tractor aggregate taking into account the scope of his work and capital investments, the salaries and their impact on the prime cost of the product.

Conclusions

1. The presented optimisation model of specific variable costs allows the producer to obtain agricultural information on:
   - a machine and tractor aggregate, its economic efficiency considering the current scope of work and the time of its completion;
   - the impact of costs on the prime cost of the product and the efficiency of capital investments.
2. The proposed method for the assessment of the machine and tractor aggregates will allow:
   - to determine the allowable deviation value of the working width from its optimum value which does not essentially affect the costs at its choice;
   - to make motivated decisions when choosing and purchasing machine and tractor aggregates considering their economic expediency.

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The choice of an optimum ploughing and sowing aggregates for different scopes of work

At present the choice of agricultural machines on the market is comparatively wide. The aggregation of agricultural machines with tractors allows to make various machine and tractor aggregates with different energy provision and efficiency. As the technical parameters of the aggregates differ, it is important to evaluate the choice of aggregates considering the conditions for their efficient use.

Therefore the choice of an economically motivated machinery and tractor aggregate is one of the most important tasks in order to ensure competitive production. It is necessary to clarify a method for the correct choice.

The paper deals with a method for the choice of aggregates considering their economic profitability; a model for the optimisation of variable costs has been developed on the basis of cost minimisation by means of the software MS Excel and solving it as an optimisation task of a nonlinear programming.

The evaluation method of tractor aggregates elaborated taking into consideration their economic profitability provide a possibility to find the optimum aggregate according to the value of variable costs and the scope of performed work, which is an important basis for competitive production.

Optimālu augsnes apstrādes un sējas agregātu izvēle dažādiem darba apjomiem

Pašreiz lauksaimniecības mašīnu tirgū ir pietiekami liela mašīnu izvēle. Lauksaimniecības mašīnas agregatējot ar traktoriem, var izveidot dažādus mašīnu-traktoru agregātus, kas atšķiras ar energonodrošinājumu un ražīgumu. Tā kā agregātu tehniskie parametri ir dažādi, tādā situācijā agregātu izvēlei ir svarīgi tos novērtēt, ņemot vērā apstākļus to efektīvai lietošanai.

Tāpēc ekonomiski pamatota mašīnu-traktoru agregāta izvēle ir viens no svarīgākiem uzdevumiem konkurētspējīgas produkcijas ražošanas nodrošināšanai. Nepieciešams izzināt izvēles metodi.

Darbā apskatīta metode mašīnu-traktoru agregāta izvēlei, ievērojot ekonomisko izdevīgumu; izstrādāts modelis mainīgo izmaksu optimizācijai uz to minimizācijas pamata, izmantojot programmu MS Excel un risinot to kā nelineārās programmēšanas optimizācijas uzdevumu.

Izstrādātā traktoru agregātu novērtēšanas metode, ievērojot ekonomisko izdevīgumu, dod iespēju izvēlēties optimālo agregātu pēc mainīgo izmaksu lieluma un attiecīgā izpildāmo darbu apjoma, kas ir svarīgs konkurētspējīgas produkcijas ražošanas pamats.