THE CHOICE OF AN OPTIMUM PLOUGHING AND SOWING AGGREGATE FOR DIFFERENT AMOUNTS 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 economical 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 amount of work. Solver, a superstructure of the MS Excel, was used for solving it as a task of optimising non-linear programming. Design data are presented, which characterise the sowing and ploughing aggregates by minimal variable costs and the corresponding amount of work.

Key words: optimisation, specific costs, working width, aggregate.

Introduction

There is a sufficiently wide choice on the market of agricultural machines at the present time 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 continually growing, the efficiency and engineering parameters of the aggregates being different. In such a situation it is important to make a correct choice of an aggregate. Specifically, 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 is 3.7 % of the total number, their area under crop being 14.0 % of the total area; for the interval 50.1-100.0 ha – respectively 1.4 % and 11.7 %; and for the areas over 300 ha – 0.3 % and 24.5 % [1]. Such a difference in the size of the areas under crop applies to farms engaged in the production of grain, where the area under crop makes 50.3 % of the total area under crop of all the farms engaged in different fields of agricultural production. Since the areas under crop for the production of grain on the farms are so different, the technical means will also differ considerably by their power and efficiency. That is why an economically motivated choice of a machine and tractor aggregate is one of the important tasks in order to ensure the output of competitive products.

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

Material and methods

The aim of the work is to develop a model how to choose a particular tractor aggregate by the criterion of optimal variable costs, the corresponding amount of work by using economical and mathematical optimisation methods, as well as to work out recommendations for the producer of agricultural machines under the current market conditions of agricultural machines so that he could make a more motivated choice of a tractor aggregate in compliance with the requirements and conditions of the farm and the current situation in the market of agricultural machines.

To achieve this 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 since it affects all the basic constituents of the respective amount of the work to be performed.

It is also necessary to prepare a tabular version of the optimisation model of the presented variable costs for the calculation by means of the computer programme MS Excel.

Results and discussion

The essence of the method for the choice of a tractor aggregate is the determination of minimal specific variable costs for the corresponding amount of work according to one of its basic parameters – the working width. To discuss this method, let us take a particular case of choosing the sowing and ploughing tractor aggregate.

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

To calculate the minimal specific variable costs, it is necessary to express them as a function of the working width of the tractor aggregate fort he corresponding amount of the performed work. We will write it down as:

$$Z = f(a, p, q, a_1). \tag{1}$$

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

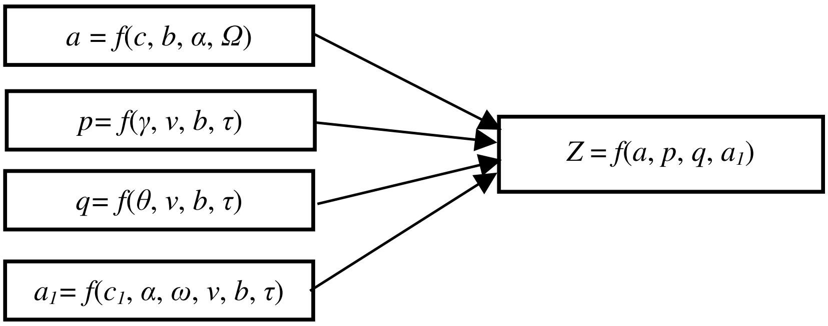

Fig. 1. **The scheme of the model of the minimisation function of variable costs**

Let us consider the constituents of the minimisation function.

$a = f(c, b, \alpha, \Omega)$ – specific amortisation deductions relating to an agricultural machine,

where c – the value of a unit of the working width of an agricultural machine;
b – the working width;
α – the amortisation coefficient;
Ω – the amount of work.

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

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

$p= f(\gamma, v, b, \tau)$ – the specific salary,

where γ – the hourly rate;
v – the speed of the movement of the aggregate;
b – the working width of the aggregate;
τ – the coefficient of the use of the working time.

$q= f(\theta, v, b, \tau)$ – the specific consumption of fuel,

where θ – the hourly consumption of fuel;
v – the speed of the movement of the aggregate;
b – the working width of the aggregate;
τ – the coefficient of the use of the working time.

$a_1= f(c_1, \alpha, \omega, v, b, \tau)$ – specific amortisation deductions per tractor,

where c_1 – the price of the tractor;
α – the amortisation coefficient;
ω – annual loading of the tractor in hours;
v – the speed of the movement of the aggregate;
b – the working width of the aggregate;
τ – the coefficient of the use of the working time.

All the constituent functions include the parameter of the working width of the tractor aggregate, consequently, the value of the variable costs depends on its variations.

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

By using the said function one can draw a dependence graph between the specific variable costs, and the working width of the aggregate and the given value of the amount of the performed work in order to determine the character of the said dependence. Let us consider the case from Fig. 1. (The basic input data for the discussed example: the amount of work - 200 and 500 ha; the price of one metre of the working width of a sowing machine – 3500 Ls; the price of a tractor – 51330 Ls; the annual loading – 1200 h; the technological speed of the movement of the aggregate – 11 km/h; the price of fuel – 0.45 Ls/kg without the returned excise tax; the salary – 1 Ls/h, etc.).

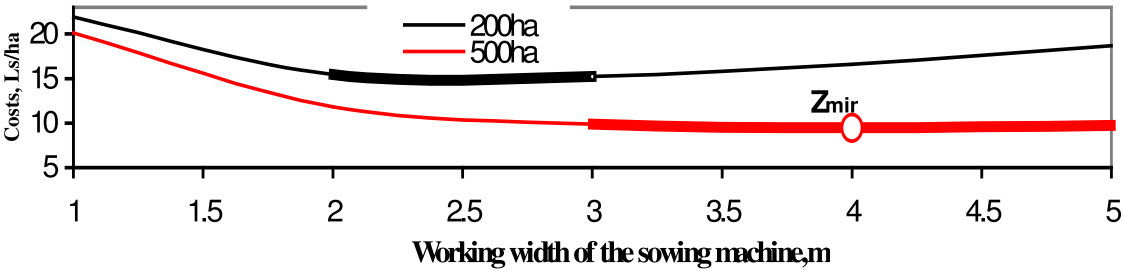

Fig. 2. **Changes of variable costs depending on the working width of the sowing machine**

It is evident from Fig. 2 that the dependence of the presented 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 amount of work. The optimum working width of the aggregate increases with the increase in the amount of the performed work, which indicates in this case the expediency of the use of expensive machines. Doing huge amounts of work by aggregates of great working width is economically more profitable than by several aggregates of narrow working width (expenses increase on salaries, consumption of fuel, etc.). It is obvious from Fig. 2 that the use of machine and tractor aggregates to do great amounts of work is characterised by the fact the change of variable costs takes place slower than their optimum value. The prices of aggregates, too, affect the character of variable costs: the higher is their specific price, the more they stand out against the aggregates of lower prices (see Fig. 3).

The optimum value of specific variable costs can be determined by means of the minimisation model described above if its function is differentiated and equated to 0. Yet one can do without formulae which, when some assumptions are changed, may be unacceptable but the superstructure Solver of the programme MS Excel can be used to solve it as an optimisation task of non-linear programming.

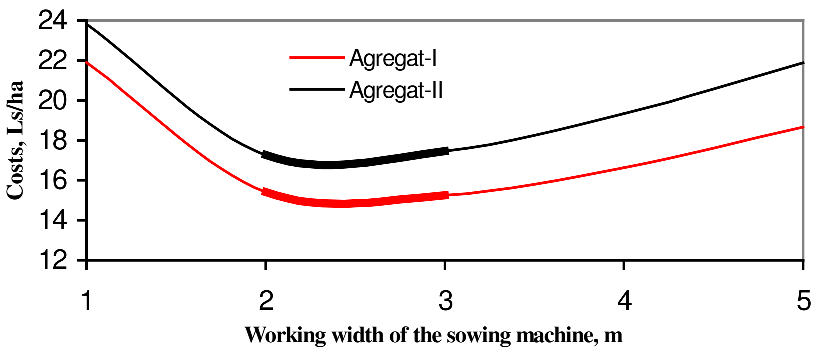

Fig. 3. **Changes in the specific variable costs depending on the prices of the aggregates (The amount of work 200 ha).** The price of Agregat-II is higher by 20 %

The optimal value of the variable costs can be determined by the model described above if its function is differentiated and equated to 0. Yet it is possible not to deduce formulae which cannot be acceptable when some assumptions are made but to use Solver, a superstructure of the MS Excel programme, and solve it as an optimisation task of non-linear programming.

Tables 1, 2 show the optimisation results of variable costs at the respective amounts of work (Fig. 3 and 4) for various sowing and ploughing aggregates.

General input data for sowing and ploughing aggregates: the working width; the price of the sowing machine, the plough and the tractor (presented in Tables 1 and 2); the coefficient of the amortisation deductions – 0.17 for the sowing machine and the tractor; the annual loading of the tractor – 1200 h; the price of fuel – 0.45 Ls/kg, without the excise tax; the salary – 1 Ls/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 be more than 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 determined. For the sowing aggregates it is accepted that $b \geq 1$ but for the ploughing aggregates $b \geq 0.35$.

Table 1

Minimal variable costs for various sowing machines

Aggregate	Working width, m	Amount of work, ha	Costs, Ls/ha	Price of the sowing machines, Ls	Price of the tractor, Ls
1	2	3	4	5	6
MTZ 952+Accord Kverneland DA-2.5	2.5	**335**	**6.39**	6300	9661
MTZ 952+Accord Kverneland DA-3	3.0	**560**	**5.32**	8750	9661
John Deere 7810+ Accord Kverneland DAX	4.0	**428**	**9.46**	11900	51330
John Deere 7810+ Accord Kverneland DV	5.0	**785**	**7.58**	17500	51330
Direct sowing machine					
Mc CORMICK MTX-200+ Accord Kverneland MSC	4.0	**1350**	**7.90**	31500	60298

Table 2

Minimal variable costs for various ploughing aggregates

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

The data from Tables 1, 2 confirm the conclusions, laid out above, of the analysis of the optimisation function. They enable also making a motivated choice of a tractor aggregate in compliance with the requirements and conditions of the farm. What are the limits to the amount of work when a particular tractor aggregate is economically efficient? According to Tables 1, 2 and Fig. 3 it is also possible to determine the period in which the particular work is completed if their values are divided by the efficiency of the corresponding aggregate.

It is important for the choice of a tractor aggregate to complete the amount of work in optimum agrotechnical terms since this promotes the yields of crops and reduces the losses during the harvest.

Fig. 4 reflects the dependence of the variations in the duration of the work of the tractor aggregates which differ from each other by their efficiency of performing various amounts of work (depreciation considering the specific weight of the particular amount of work, salaries and fuel). It is obvious from Fig. 4 that the duration of the performed work within the discussed range of amounts (50÷375 ha) for the aggregate MTZ 952+Accord Kverneland DA (B-2.5 m) is 1.8÷13.6 days but for the aggregate MTZ 952+Accord Kverneland DA (B-3 m) – 1.5-11.4 days.

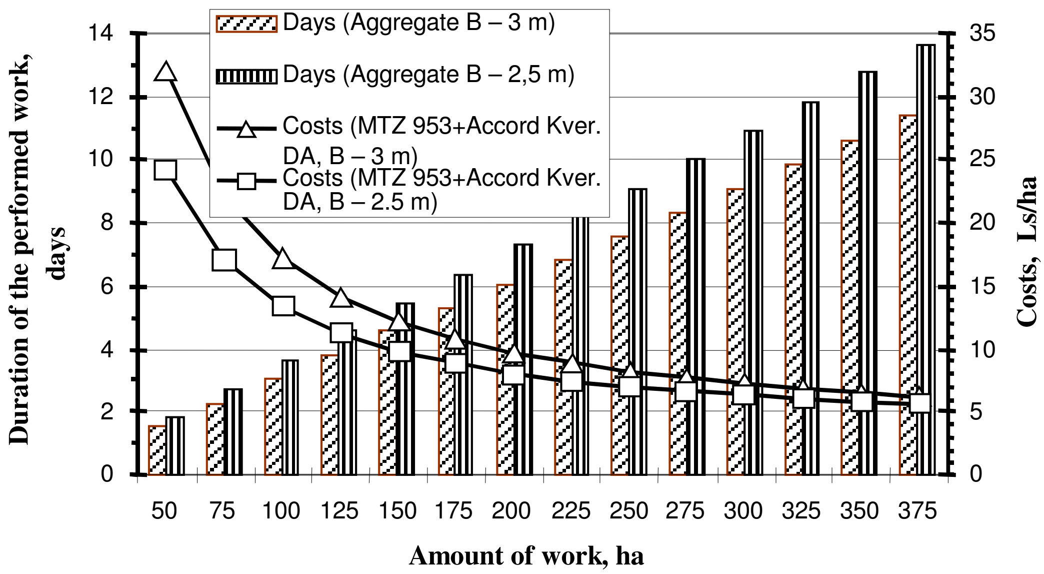

Fig. 4. **Variations in the duration of the performed work of tractor aggregates and the indicated costs depending on their working width and the amount of work**

Determination of these factors (indicated costs and the duration of the performed work) allows economically substantiated choice of a tractor aggregate. The data show that the level of technical provision at the expense of the productive aggregates not only raises efficiency but also to increased yields of the crop.

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

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

Conclusions

The analysis of the obtained data shows that there is an economically motivated level of technical provision for performing of various amounts of work.

The presented optimisation model of specific variable costs allows the producer to obtain agricultural information:

- about a machine and tractor aggregate, its economic efficiency considering the current amount of work and the term of its completion;
- about the impact of the variable costs upon the prime cost of the product and the efficiency of capital investments;

- to make motivated decisions when choosing and purchasing machine and tractor aggregates considering their economical expediency.

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