RESEARCH INTO MODELS OF CHOICE OF TRACTOR AGGREGATES

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Abstract. The article deals with three different models of the choice of tractor aggregates characterised by different installed conditions of the performed work. Such conditions are: a definite amount of the performed work; fixed agrotechnical terms for completion of the work; possible losses of the yield of crops because of deferred completion of the work in relation to the optimum terms. A method of economico-mathematical simulation is applied. The essence of the method for the choice of tractor aggregates lies in the determination of minimal specific variable losses taking into account the factors indicated above. Using the results of the data calculation, a limit was shown for efficient application of aggregates selected from each of the models. The proposed method allows motivated choice of an economically efficient tractor aggregate depending on the installed conditions of the performed work, as well as prognostication of economic expediency for renovation of the machinery mentioned above. Solver, a superstructure of the MS Excel, was used for the calculation of the mathematical model solving it as a task of optimising non-linear programming. As an example, there is given a choice of sowing tractor aggregates, using various models.

Key words: amount of work, specific costs, tractor aggregate, economico-mathematical simulation.

Introduction

In many ways the development of agricultural production depends on a justified level of technical provision of production processes, on the whole, and on the choice of efficient tractor aggregates.

Application of economico-mathematical methods, considering the impact of technical and economic factors when the choice of tractor aggregates is made, allows their motivated selection and improvement of technical provision thereby ensuring efficient agricultural production. In this manner non-traditional ways are opened for the solution of the production tasks using new information technologies.

Materials and methods

The aim of the work is research in economico-mathematical models for the choice of an optimal tractor aggregate, taking into account the following factors: the impact of a definite amount of the performed work; fixed agrotechnical terms; possible losses of the yield of crops because of deferred completion of the work; presentation of these models to the producer of the agricultural products for a motivated decision which of the tractor aggregates should be chosen as the optimal one, considering the requirements and conditions of a farm modifying and adapting new technologies for cultivation of agricultural crops.

In order to solve the assigned task, there were used: economico-mathematical models, the method of parametric optimisation of functional dependencies reflecting the character of the investigated process [1-4]. Functional dependencies were established on the theoretical foundations of completing machine-and-tractor aggregates.

Results and discussion

We will discuss the impact of the above-mentioned conditions of the performed work upon the efficiency of the tractor aggregate in an example of the choice of a sowing aggregate, using three different models. The data about the aggregates, obtained from the Armuss Company, a distributor of agricultural machinery, are presented in Table 1.

The basic input data: the technological speed of aggregates – 8 km·h^{-1}; deprecation costs – 17 %; the annual load of the tractor – 1200 h; the hourly wage rate – 1.34 LVL; the price of fuel – 0.57 LVL·kg^{-1}; the length of the working day – 10 h (duration of the work of the aggregate during the day).

The first model allows determination of the efficiency limit of the use of the aggregate performing a definite amount of work. For this purpose we determine the optimal specific variables of costs for the completion of a corresponding amount of work by one of the basic parameters of the aggregate – the working width.

Table 1

Data about the aggregates, obtained from the Armuss Company

Composition of the aggregate		Price, LVL		Working width of the aggregate, m	Consumption of fuel, kg·ha^{-1}
Tractor	Machine	Tractor	Machine		
McCormick MC115	Kverneland Accord M-drill	30100	19200	3.0	6.0
McCormick XTX145	Kverneland Accord M-drill	48400	25500	4.0	8.5

For this we apply a mathematical model of the choice of a tractor aggregate by the criterion of the installed costs when a definite amount of work is performed, the model having the following general appearance:

$$Z = F(T, P) \tag{1}$$

where Z – installed costs;
T – vector of the technical parameters {B, V, Q} (the working width of the agricultural machine, the technological speed of the aggregate, the consumption of fuel);
P – vector of the price indices {C_T, ρ, C_M, C_Q, α} (the price of the tractor, the ratio of the particular operation in the total annual amount of work, the price of the agricultural machine, the price of fuel, the hourly wage rate for the work).

Deductions for repairs and technical maintenance are calculated in proportion with the performed work. They are not included into the discussed function of specific variable costs because deduction for them is made in proportion with the performed work.

Superstructures of the MS Excel programme are used for the calculation of the mathematical model solving it as a task of optimising non-linear programming.

As a result of the calculation of the first mathematical model, solving it as an optimisation task of non-linear programming, we determine the optimal value of the variables of the costs and the corresponding amount of the performed work.

The optimal installed costs (Zopt) for the aggregate McCormick MC115 + Kverneland Accord M-drill (the working width – 3 m) were 12.18 LVL·ha^{-1}, the amount of work – 540 ha, and for the aggregate McCormick XTX145 + Kverneland Accord M-drill (4 m) – 12.63 LVL·ha^{-1}, 685 ha, respectively, without taking into consideration the costs for repair and technical maintenance. The value of the amount of the work obtained in the optimisation process for the given sowing aggregates is the limit of their efficient application.

Figure 1 shows variations in the installed costs depending on the working width and the amount of work of the aggregate McCormick MC115 + Kverneland Accord M-drill (3 m). The outlined area depicts variations in the values of the installed costs within the range from 10 to 15 LVL·ha^{-1} depending on the working width and the amount of work. In this area of the values of the installed costs there is the optimal value Z_{opt} = 12.18 LVL·ha^{-1} with the coordinates (B = 3 m, Ω = 540 ha). When a definite amount of work is performed by means of an aggregate having a small working width, the costs for the wages, fuel, and amortisation of the tractor increase, but when the working width is great, the price of the aggregate and the amortisation costs increase. Among the multitude of the allowed solutions, the discussed model makes it possible to determine the optimal value of the installed costs for a particular tractor aggregate and the limit of its efficient application.

We use the second mathematical model to choose a tractor aggregate when the work is performed taking into account fixed agrotechnical terms. Therefore, an additional parameter of time {T} is introduced into the vector of technical parameters {B, V, Q} used for the calculation of the first model.

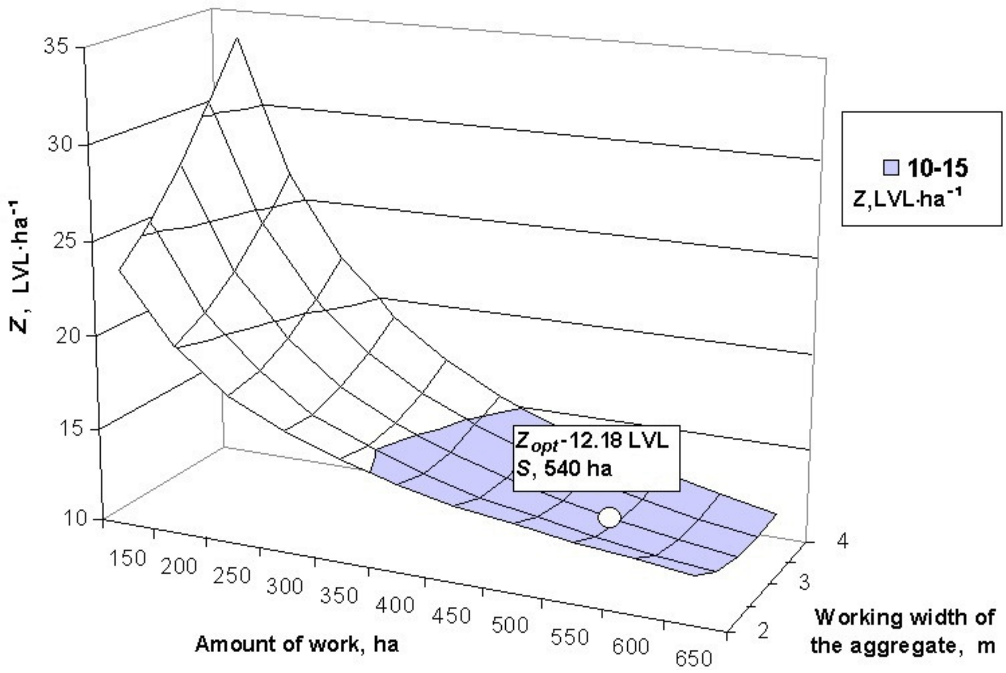

Fig. 1. **Variations in the installed costs depending on the working width and the amount of work of the aggregate (aggregate McCormick MC115 + Kverneland Accord M-drill (3 m))**

Figure 2 shows variations in the installed costs depending on the working width of the aggregate and the amount of the performed work considering fixed agrotechnical terms ($A \leq 10$ days) for its execution by means of the aggregate McCormick MC115 + Kverneland Accord M-drill (3 m) – the second model, and without the installed agrotechnical terms – the first model.

It is evident from Figure 2 that in the case of the fixed agrotechnical terms ($A = 10$ days) the value of the optimal installed costs for the aggregate McCormick MC115 + Kverneland Accord M-drill (3 m) increases by 7.56 $LVL \cdot ha^{-1}$, but the limit of efficient use of this aggregate was 240 ha.

For the aggregate McCormick XTX145 + Kverneland Accord M-drill (4 m) the value of the optimal installed costs was 19.85 $LVL \cdot ha^{-1}$ in the case of fixed agrotechnical terms ($A = 10$ days), which is by 7.22 $LVL \cdot ha^{-1}$ more in contrast to a case when the agrotechnical terms are not fixed but the limit of efficient use of this aggregate was 320 ha.

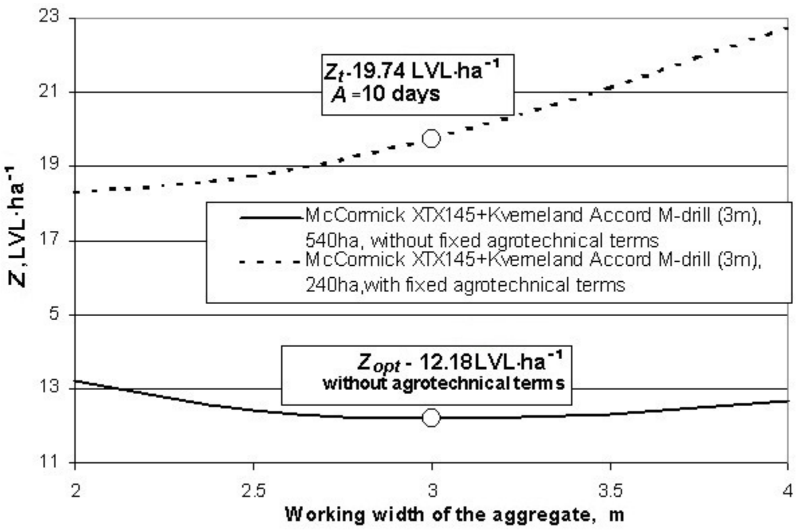

Fig. 2. **Variations in the variable costs and the amount of the performed work with fixed agrotechnical terms A = 10 days and without fixed agrotechnical terms**

It is also evident from the graphs of the figures 1 and 2 that the imposed limitations – the amount of the performed work, agrotechnical terms – narrow down the number of additional solutions which ensure a minimal value of the specific installed costs, changing, consequently, the limits of the efficient use of the aggregate.

Therefore, when a mathematical model is developed in the production activity, the choice of the limitations should correspond to a strictly allowed value, which is in agreement with the discussed process (efficient implementation of terminology).

The third mathematical model of the choice of a tractor aggregate, taking into account the factor of time of the performed work, considers the possible losses of the yield of crops because of deferred completion of the work and is characterised by the peculiarity that the price of the crops due to possible losses of the yield $\{C_U\}$ is included into the vector of price indices $\{C_{T,}\ \rho, C_M, C_{Q,}\ \alpha\}$. In this case, the functional dependencies included into the price indices take into consideration during the calculation process of the model the possible losses of the yield. This is important since it enables determination of the limit of efficient use of the aggregate considering this index.

If completion of the work is deferred in relation to the optimum terms in sowing, the ratio of the losses of the yield constitutes –0.005 per unit of time (24 hours). The values of the coefficients of the losses of the yield are taken from the data in publications [5, 6]. Additional input data are: the planned yield – 5 $t \cdot ha^{-1}$; the price of the grain – 75 $LVL \cdot t^{-1}$.

Figure 3 shows variations in the specific installed costs of the sowing aggregates depending on the amount of the performed work and taking into consideration the costs due to possible losses of the yields.

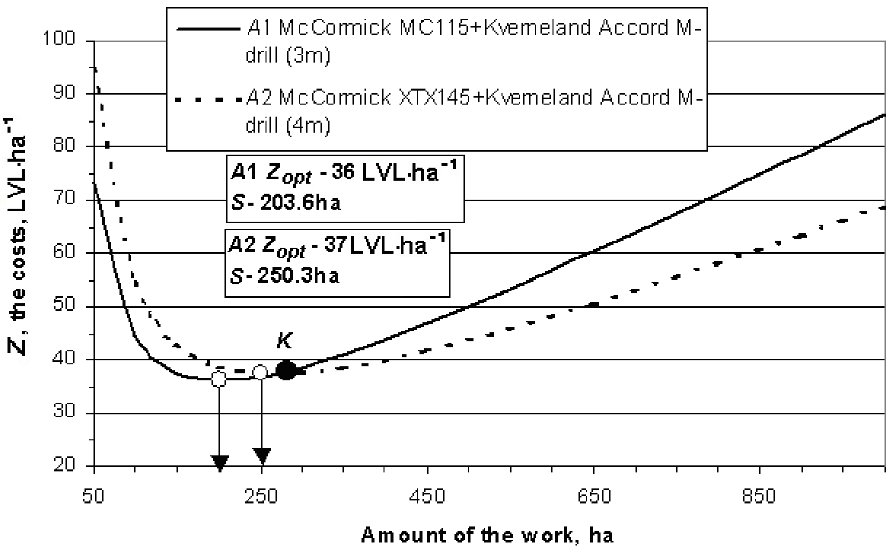

Fig. 3. **Variations in the specific installed costs of the sowing aggregates depending on the amount of the performed work and the possible losses of the yields**

It is evident from the graph in Figure 3 that each aggregate has its own limit of efficient use. So, for the aggregate $A1$ it is S – 203.6 ha, the optimal value of the specific installed costs being Z_{opt} – 36 $LVL \cdot ha^{-1}$. For the aggregate $A2$: S – 250.3 ha; Z_{opt} – 37 $LVL \cdot ha^{-1}$. Point K is a limit of equal economic efficiency of the use of these two sowing aggregates, where the amounts of the performed work and specific installed costs ($S_1 = S_2$ and $Z_1 = Z_2$) of the sowing aggregates $A1$ and $A2$ are equal. Before point K (from the beginning of the coordinates) the sowing aggregate $A1$ is more efficient in comparison with A2 ($Z_1 < Z_2$). After point K the sowing aggregate $A2$ is more efficient in comparison with $A1$ ($Z_1 > Z_2$). It is also evident from Figure 3 that, in terms of possible losses of the yield, the highly productive aggregates are most efficient.

The analysis of the data indicates that it is important for the choice of optional aggregates to take into account the factor of time during which a definite amount of work is performed, as well as the losses of the yield because of deferred optional agrotechnical terms for the completion of work.

Conclusions

1. The presented models of the choice of tractor aggregates depending on the amount of the performed work, fixed agrotechnical terms, possible losses of the yield because of deferred completion of the work in relation to the optimum terms show that the limit of efficient use of the aggregate essentially depends on the factors indicated above and that it has quite a definite value for each of the above-mentioned factors.
2. The economico-mathematical model of the choice of a tractor aggregate allows determination of the limit of its efficient use and the optimal installed costs. So, for instance, when the first model was used, the limit of the efficient amount of work was 540 ha and the optimal installed costs were 12.18 $LVL \cdot ha^{-1}$; when the second model was used, the limit of the efficient amount of work was 240 ha and the optimal installed costs were 19.74 $LVL \cdot ha^{-1}$; in the case of the third model these indices were respectively 203.6 ha and 36 $LVL \cdot ha^{-1}$.
3. The impact of the factors discussed above upon the choice of aggregates shows that, in case there are no fixed terms for the completion of work, it is purposeful to apply the first model; if the agrotechnical terms are fixed, the second model is used; and when the execution of the work is connected with losses of the yields of crops because of deferred completion of work, the third model is used.
4. The discussed economico-mathematical models of the choice of tractor aggregates make it possible to obtain information for a justified decision as to the choice and purchase of machine-and-tractor aggregates and the formation of a structure of tractors on an agricultural enterprise.

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