Development of evaluation model effectiveness of modern technologies in crop production

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Abstract. Effectiveness assessment of modern technologies and machines introduction is one of the most important economic objectives in agricultural production. The purpose of this paper is to develop a formalized effectiveness evaluation system of introduction of modern technologies and machines in crop production. This system is based on the use of modern software for creation of crop production process flow diagrams, business planning, and optimization of machines and technologies parameters. It is proposed to formulate the process of economic effectiveness evaluation of new technologies in crop production as a permanent operating three-stage indiscrete cyclic model for a particular industry, facility, district or region. In the first stage of calculations income and expenses staggered over a period of time and obtained through the new technologies or more modern tools are defined, using detailed process flow diagrams, fodder balance and other estimation forms. During the second stage project success criteria are determined by calculation of stability analysis and evaluation of feasibility and effectiveness of new technologies. Finally, in the third stage it is necessary to solve a task of introduced technologies parameters adaptation and optimization. The effectiveness evaluation system of introduction of modern technologies and machines in crop production, proposed in this paper, allows for quicker decision making regarding reasonability of replacing machines and technologies with new ones.

1. Introduction
Effectiveness assessment of modern technologies and machines introduction is the basis for development of every sphere, including agriculture. Only in conditions of expanded reproduction and on the basis of modern achievements of science and technology production maintains its competitiveness in the long term. Upgrading of the agricultural equipment and tractor park of the agricultural facility is a multilateral process, with regard not only to increase in productivity, logistical and labor resources cost savings, optimization of business processes, real-time provision of additional information, but also with significant investment costs, which can exceed all the presented advantages [1]. In such conditions the administration of the facility faces a challenge – to evaluate the effectiveness of a new technology correctly.

This problem was studied by such authors as J. Li, Z. Yang, R. Stevens, P. Sherwood, Y. Han, L. Orea, J. Homolka and others [2-13].

Summarizing the domestic and foreign experience in this sphere we can conclude that there is an objective need for in-depth consideration of this area.
The purpose of this paper is to develop a formalized effectiveness evaluation system of introduction of modern technologies and machines in crop production that will allow making quick decisions concerning the advisability of replacing the existing technologies with new ones.

2. Methodology
Economic aspects of introduction of modern technologies and machines in crop production act as a research object. The methodology of the research involves the analysis of features of the economic mechanism for replacement of existing systems and introduction of new ones in the Russian Federation. In the study the following methods were used: abstract-logical, situational and system analysis, economic-statistical and the expert evaluation method.

3. Discussion and Results
It is proposed to formulate the economical effectiveness evaluation process in the area of crop farming as a three-step non-discrete cyclic model, operating permanently in the system of a particular area, facility or a region.

Launch of this model starts with acquisition of preliminary data on the replacement of existing technologies and equipment. To do so it is proposed to create a register of modern technologies and equipment on the level of district offices for agriculture, best suited to the specifics of the territory. Research conducted by the system of test machines zone stations should be put at the core of this work. As their number has declined compared to the Soviet period, and their accessibility for agricultural producers has become even more challenging, these registers should be available for everyone at every time. An additional option of posting might be a system of Information and Counseling Service of the agro-industrial complex.

Materials obtained from experiments conducted by public machine trial stations are source data for creation of this base. In its modern form the system consists of 14 organizations combined into a single system – “Probers Association” AIST. Annually machine trial stations are working testing domestic and foreign models of agricultural equipment in real conditions of agricultural production. In 2018, according to annual reports of MTS, 545 models of agricultural equipment and 18 new technologies were tested (table 1).

| №  | Machine Trial Station      | Number of tests conducted | Number of studies |
|----|---------------------------|---------------------------|-------------------|
| 1  | Altai                     | 54                        | -                 |
| 2  | Amur                      | -                         | -                 |
| 3  | Vladimir                  | 52                        | -                 |
| 4  | Kalininsk                 | -                         | -                 |
| 5  | Kirov                     | 23                        | -                 |
| 6  | Kuban                     | 56                        | -                 |
| 7  | Volga region              | 90                        | -                 |
| 8  | Podolsk                   | 44                        | -                 |
| 9  | North-West                | 56                        | -                 |
| 10 | North Caucasus            | 57                        | -                 |
| 11 | Siberia                   | 43                        | -                 |
| 12 | Central-Chernozem         | 70                        | 18                |
| 13 | Central                   | -                         | -                 |
|    | Total                     | 545                       | 18                |

Table 1. Number of equipment tests conducted in 2018.
Such amount of tests and data obtained should be effectively used in the practical activities of the agro-industrial complex.

Launch of the implemented model can be carried out through implementation of the hourly operating costs method. Use of average simplifying approaches allows capacity for quick technology assessment and perspective options.

The next step is a transition to the first stage of calculations. By means of detailed technological maps, fodder balance and other billing forms revenues and expenses staggered over a period of time and derived from implementation of a modern set of technologies are defined. Technological maps are a usual instrument for experts of agricultural facilities which they use for preparation of data in the area of crop production. Almost all experts possess the skills of document preparation. Nowadays there is a big number of software allowing automating the process of technological maps development considering the specifics of terms of a particular facility and even a particular field. Though in a traditional form technological map is not quite suitable for preparation of data used in the business plan.

The original version included a power engine and agricultural machines data base (including other necessary data such as exchange rates, wage scale, standard crop rotation, etc.), which provides up-to-date information necessary for effectiveness estimation of modern technologies and domestic and foreign machines.

The user is offered to choose an operation and composition of a unit using a simple menu, and, if necessary, to add data (such as yield, amount of processing, fertilizer rate, etc.). To use this data in business plan creation a window “Month” was added (figure 1). As a result, the program distributes operations and costs to periods and then summarizes them under relevant lines.

![Diagram](image)

Figure 1. The process of identifying economical parameters of modern technologies and machinery units in crop farming.

As a result a list of monthly operations is created. The program uses an algorithm that does not require consistent operations entering. Operations list is ordered automatically and operations related to
one time period are processed automatically either. When clicking the button “Calculation” under the list of operations, parameters of operations are calculated.

Results of calculation are presented in the form of a report. Further development of the program allows creating the form of a report on a monthly basis (table 2).

**Table 2.** Monthly report form (the latest month) a.

| Operation                          | The composition of the unit | Amount of fuel, kg (Type of fuel) | Amount of oil, kg | Labor costs, man-hours | Salary, rub | Energy costs, rub | Power machines | Farm machinery | Direct operating costs |
|-----------------------------------|-----------------------------|----------------------------------|-------------------|------------------------|-------------|-------------------|-----------------|-----------------|------------------------|
| Mowing, threshing, grinding       | 1.83 (Diesel)              | 7.08 (Diesel)                    | 0.45              | 0.298                  | 185.528     | 228.018           |                 |                 |                         |
| spring crops Don-1500(i)          |                             |                                  |                   |                        |             |                   |                 |                 |                         |
| Yield, centners per hectar not less 10-20 |                             |                                  |                   |                        |             |                   |                 |                 |                         |
| Grain transportation KAMAZ-55102  | 0.00 (kW)                  | 0.00                             | 0.363             | 103.135                | 0.00        | 0.00              | 1.32            | 181.448         |                         |
| Yield, centners per hectar 15     |                             |                                  |                   |                        |             |                   |                 |                 |                         |
| Handling of seeds (grains) OZS-20 | 0.00                       | 0.51                             | 0.838             | 372.576                | 0.00        | 284.831           | 12.68           | 89.38           |                         |
| Yield, centners per hectar 15     |                             |                                  |                   |                        |             |                   |                 |                 |                         |
| Total for July                    | 8.91                       | 0.51                             | 0.838             | 372.576                | 0.00        | 284.831           | 1328.48         | 181.448         | 2075.52                |
|                                  | 0.00                       |                                  |                   |                        |             |                   | 12.68           | 89.38           | 141.76                 |
|                                  | 0.00                       |                                  |                   |                        |             |                   | 0.00            | 0.00            | 115.94                 |
|                                  | 4.71                       |                                  |                   |                        |             |                   |                 |                 | 3.2                    |
| Diesel, kg                       | 8.91                       |                                  |                   |                        |             |                   |                 |                 |                         |
| Petrol, kg                       | 0.00                       |                                  |                   |                        |             |                   |                 |                 |                         |
| Electricity, kW                  | 0.00                       |                                  |                   |                        |             |                   |                 |                 |                         |
| Oil, kg                          |                            |                                  |                   |                        |             |                   |                 |                 |                         |
| Total:                           | 38.41                      | 1.73                             | 2.24              | 110.02                 | 1191.03     | 1607.71           | 4398.11         |                 |                         |
Specific gravity, %

|          | 25.03 | 27.08 | 36.55 | 2.63 | 7.92 | 0.77 |
|----------|-------|-------|-------|------|------|------|

Total energy consumption, in detail:

|                     | Diesel, kg | Petrol, kg | Oil, kg | Electricity, kW |
|---------------------|------------|------------|---------|-----------------|
| Amount              | 37.21      | 0.57       | 1.73    | 0.63            |
| Cost of             | 1101.97    | 16.39      | 69.84   | 2.84            |

The form of a report includes the following lines: the amount of fuel, amount of oil (kg), labor costs (man-hours), salary (rub), energy costs (rub), depreciation, maintenance and repair for power machines and farm machinery (rub).

In the bottom part of the report month totals are calculated and detailed data on energy sources is given – the total figure is divided into diesel, petrol, oil and electricity.

The latest month report form is complemented by total data for all operating time – article by article at first, and then – detailed summarized energy costs (natural and monetary).

Production costs are calculated by clicking the “Production costs” button in the list of operations. Filling out the menu system (with information on amount and price of seeds, mineral and organic fertilizers, plant protection, simplified tax and farm expenses) allows calculating the figures for 1 hectare and overall crop acreage (table 3). Unfortunately, this report is the reason data cannot be transferred into business-plan, as they require some processing. Materials costs can be transferred from this report, and farm expenses should be divided into 12 (number of months), after this they can be used in the calculations.

Obtained detailed information makes it possible to move onto the next (second) stage of technology assessment. For this it is proposed to use a truncated form of a business-plan, including such sections as executive summary, production plan and financial plan. This would be enough for necessities and sources of finances, technological features of implemented technology and financial results of new technology introduction estimation. Introduction of business-planning into activities of agricultural facilities require certain preparation of data used for calculations. It is vital to consider not only main articles of expenses (fuel, electricity, plant protection, fertilizers, etc.), but also time periods when these expenses really take place. Besides it is important to identify depreciation charges in a separate article, as usually the scheme for their accounting in the business-planning is different from the standard one, used when estimating economical effectiveness.

### Table 3. Production costs report.

|                              | Amount  | Price | Sum     |
|------------------------------|---------|-------|---------|
| Direct operating costs, rub  |         |       | 2201861.64 |
| Salary                       | -       | -     | 579633.56  |
| Energy costs                 | -       | -     | 567558.64  |
| Power machines depreciation  | -       | -     | 780387.96  |
| Power machines maintenance and repair | -   | -     | 55818.40  |
## Table 1: Costs Breakdown

| Item                                                                 | First year of action | Second year of action | Third year of action | Total | Notes |
|----------------------------------------------------------------------|----------------------|-----------------------|----------------------|-------|-------|
| Farm machinery depreciation                                           | -                    | -                     | -                    | 199675.08 |       |
| Farm machinery maintenance and repair                                 | -                    | -                     | -                    | 16788.00 |       |
| Seeds, centers                                                        | 2.00                 | 1200.00               | -                    | 1056000.00 |       |
| Mineral fertilizers, centers                                          |                      |                       |                      |       |       |
| Nitric                                                                | 1.00                 | 960.00                | -                    | 422400.00 |       |
| Phosphoric                                                            | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Potash                                                                | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Complex fertilizers                                                   | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Organic fertilizers, tons                                            |                      |                       |                      |       |       |
| First year of action                                                  | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Second year of action                                                 | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Third year of action                                                  | 0.00                 | 0.00                  | -                    | 0.00   |       |
| Plant protection products, kg                                          |                      |                       |                      |       |       |
| Herbicides                                                            | 0.0000               | 0.00                  | -                    | 0.00   |       |
| Pesticides                                                            | 0.0300               | 3700.00               | -                    | 48840.00 |       |
| Growth regulators                                                     | 0.2000               | 640.00                | -                    | 56320.00 |       |
| Other costs, rub                                                       |                      |                       |                      | -     | 0.00  |
| All direct costs, rub                                                 | -                    | -                     | -                    | 3785421.64 |       |
| Deductions for social needs, rub                                      | -                    | -                     | -                    | -     | ******  
31.10% of salary
| General, overhead costs, rub                                          | -                    | -                     | -                    | -     |       |
| 20.00% of direct operating costs                                     | -                    | -                     | -                    | -     |       |
| All production costs                                                  | -                    | -                     | -                    | 4406059.97 |       |
| The cost of 1 center products                                         | -                    | -                     | -                    | 500.69 |       |

*Flow chart number: 18. Crop: Spring Wheat. Yield: 20.0 centners per hectare

When projects effectiveness indicators are defined by calculation of results of sustainability analysis (general, financial, productive and probabilistic), we can evaluate the ability to realize and the effectiveness of new technologies. As the basis for these calculations, national software, such as Projects Expert Professional (version 6 and higher) and Alt-Invest (version 5 and higher), can be used. They contain two different approaches which complement each other. Project Expert helps to adjust the calculation of particular requirements for a project in a more flexible way, but can be used only by experts that have a lot of experience of working in this program. Alt-Invest (similar to MS Excel) is clearer for users, which makes it more accessible.

Integral indicators of the project effectiveness can be used as the main evaluation indicators. Among others the following can be named: net present value (NPV), productivity index (PI), which are used in the system. The first one described an absolute value of project revenue (rub), and the second one – its relative value, compared to investment costs. Internal rate of return (IRR), which shows the maximum allowable cost of the attracted capital, and payback (PB) can also be used. Other indicators are auxiliary.

Four kinds of sustainability analysis can be identified: sensitivity analysis (general), break-even analysis (describes sustainability of production activities), three-piece analysis (financial sustainability) and Monte-Carlo probability analysis. All four kinds of sustainability analysis allow to examine the feasibility of the project on introduction of new technologies and equipment considering all possible features related to certain conditions of a facility.

This stage allows producing a clear decision on introduction of a new technology. If obtained calculations provide a negative answer, we can move to the third stage – the optimization of implemented technology parameters. It is possible, that features of a certain facility were not considered
when forming the initial task, which has led to a negative answer. That is why on the third stage it is necessary to solve the problem of adaptation and optimization of introduced equipment parameters. This can be provided by means of the expert evaluation method implementation or using the software with the embedded optimization functions (for example, through the linear programming method, etc.). The results of this stage will be refined versions of technology, parameters of machines inside the units, which will help to obtain a positive outcome from the modern technologies introduction.

4. Conclusions
Despite particular questions, the proposed system allows providing a clear answer about the effectiveness and feasibility of new technologies and machinery units in terms of a certain facility or a region. The detailed step-by-step calculation provides high accuracy and credibility of the obtained result. Besides, during dramatic changes of external parameters of equipment usage – prices on machinery, equipment, exchange rates, cost inflation, purchase prices reduction, etc. – it is quite simple to calculate the impact of these new factors on the performance of introduced technologies basing on existing calculations.

Use of specialized software allows reducing the time spent on every stage of evaluation of the modern technologies and machinery unit’s introduction effectiveness significantly, starting from preparation of data sources for business-plans creation and followed by optimization of parameters of technological systems for a certain facility terms, and also allows for increasing the reliability of the results obtained. As a result of the proposed system, the unreasonable costs appearing from innovative projects realizations will be reduced, the number of non-effective projects will be reduced, especially realized by means of funds allocated from budgets of different levels.

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