Project designing of crop production agricultural technologies

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Abstract. Conventionally, crop cultivation technologies are improved by developing (creating) more effective elements and implementing them in a fragmented way using a transformational approach. It has been found that a morphological approach is more promising and effective for these purposes when creating and implementing the holistic production agricultural technologies and the corresponding technological systems. For its implementation, the methods of engineering design of complex systems are proposed to be used. The presented paper outlines the main methodological issues of engineering technological design of agricultural cultivation technologies. The purpose of the research is the development of methodological provisions for the formation and selection of promising technological processes in technological modules when cultivating crops. To form options of technologies, the methods of morphological analysis are used. When selecting acceptable, promising and effective options for the designed projects, the decision-making theory methods are used. The analysis of scientific works shows that almost all the presented models have the same drawback: the lack of a mechanism for the formation and selection of promising technological processes implemented in a particular technology and so far, there is no effective methodological approach for its implementation. According to the results of scientific research, it was found that in the formation of systems of mechanization of plant growing processes, it is advisable to use the methods and techniques of engineering design of individual technological processes and technical equipment that have not been developed so far. A block hierarchical approach to the designing of crop production agricultural technologies is proposed. In the design process, the following basic principles must be maintained: a systematic approach, focus on obtaining optimal solutions, a comprehensive (multi-criteria) approach, a functional approach, iterative design process, focus on the final result, a combination of formalized and heuristic methods, the principle of open systems, the principle of modeling objects, the principle of functional completeness, etc. A general logical scheme of the process of engineering design of agricultural plant technology objects is proposed, where the main stages and design stages, design tasks and the main methods for solving them are defined.

1. Introduction
In today’s conditions characterized by an acute shortage of energy, labor, material, technical and financial resources in Siberian agricultural enterprises, the development of agricultural cultivation technologies requires a comprehensive implementation of the achievements of different research institutions, linked in a unified system of technological and technical solutions that ensure the production of competitive rentable products in specific natural-production conditions and efficient use of all applied resources (soil, climatic, plant, labor, logistical, financial and others). Therefore, one of
the main tasks at the present development stage of agricultural production is the development of integrated systems implemented at the level of machine technology in the relevant agricultural sectors.

The design issues of such technologies are considered at the level of both theoretical and applied research in the works of many Russian scientists. In this regard, A.A. Zhuchenko put forward, justified and developed an adaptive crop production strategy, the basis of which is based on the differentiated use of natural, biological, technological, technical and labor resources. [1]. K.R. Ismagilov developed the concept and methodology for adapting crops to the landscape of a specific field, that based on the development of a basic technological project, systematic monitoring of the level of external factors, the state of crops and plants, adjusting the basic technology taking into account changing conditions and deviations of the state of crops from the intended parameters [2]. In the research of V.V. Blednykh and Yu.E. Mikhailov [3], it is proposed to use the average long-term actual productivity as the initial model for designing technologies. An interesting approach was proposed by N.A. Shvetsova [4], according to which it is advisable to use an expert system to evaluate and select effective technologies. S.P. Fedorov [5] proposes to carry out technological design of mechanized processes of crop production using two options: using technological projects and technological design, including the development of a comprehensive program for the development of agriculture. A.N. Tseplyaev, M.N. Shaprov, V.G. Abezin [6] use a graph model based on a network schedule for cultivating crops to select crop cultivation technologies (using melon cultivation as an example), which provides for the implementation of all activities for soil preparation, sowing, row cultivation, harvesting, etc. Moreover, the definition of an effective technology option is proposed to be carried out according to the formulas of generalized energy consumption coefficients. V.P. Yakushev considers the technological scheme of crop cultivation as a multi-step process [7], which provides for the management of the vegetative development of plants discretely depending on the time of the necessary and appropriate agrotechnical operations.

In general, it should be noted that when designing technologies, many complicated problems arise that are caused by the multiple nature of not only the initial situations, but also their possible solutions. In this regard, O.V. Belov [8] notes that the multivariance of technologies is ensured by a wide selection of methods and technical means. In addition, it is largely determined by the difference in soil-climatic and production conditions for the cultivation of crops. It is noted the search for the optimal option of the developed technology is a complex search problem, in the implementation of which the optimization criteria will turn into a minimum of labor and energy costs.

Considering the idea of designing technological processes in crop production, D. N. Radnaev [9] proposes a multi-level model of such design, in which the design task is to determine the system characteristics of the technological process, providing the agrotechnical requirements of tillage and sowing with the lowest unit costs, under specified technical constraints. V. D. Popov [10] proposes to collect and process information about the operating conditions of the system, that is, information on natural, climatic, economic and other conditions is provided and systematized. At the final stage, the design of technologies and a set of technical means implemented in it is carried out.

The ideas of designing technologies for the cultivation of agricultural crops are reflected in the research of A.K. Nanaenko [11]. The technology is proposed to be divided naturally into subsystems-complexes corresponding to its real content. It is presented as a complex system, where the letters denote the subsystems, and the numbers indicate the signals connecting the complexes between themselves and systems of a higher order.

An analysis of scientific works shows that almost all of the presented models have the same drawback: the lack of a mechanism for the formation and selection of promising technological processes implemented in a particular technology and so far there is no effective methodological approach for its implementation.

The purpose of this study is the development of guidelines for the formation and selection of promising technological processes in technological modules in the cultivation of crops.

Hypothesis: This goal can be achieved by using the method of engineering design of agricultural cultivation technologies implemented in specific soil and climatic conditions.
2. Materials and methods

In the engineering design of crop cultivation technologies, the central part is held by the issues of possible options formation for the designed projects, their subsequent evaluation and the selection of effective ones for subsequent experimental verification and implementation into production.

To form a complete set of possible options for the projected object (particular technological processes (PTP)), we used the morphological method of system analysis [12]. The essence of this method is a systematic study of all possible options for constructing an object those arise from its structure.

When using this method, the project was divided into parts that can conditionally be considered independent, each of these parts having several possible options for construction (solution). An option of constructing the object as a whole was obtained by taking one of the possible solutions for each part. The number of such options is equal to the number of possible combinations, and each time one solution is taken for each of the parts of the object. Each possible option is denoted by $P_{ki}^k$, where the subscript $i$ refers to a part of the object, and the superscript $k$ refers to a specific version of the construction of the $i$-th part of the object. Each part of the object has a finite number of alternative solutions, which together form a matrix of alternative options for constructing this object:

$$
\begin{bmatrix}
P_{11}^1, & P_{12}^2, & \ldots, & P_{1n}^n \\
P_{21}^1, & P_{22}^2, & \ldots, & P_{2n}^n \\
\vdots, & \vdots, & \ddots, & \vdots \\
P_{k1}^1, & P_{k2}^2, & \ldots, & P_{kn}^n
\end{bmatrix}.
$$

If we select one alternative in each row of the matrix and then combine them into a single whole, we will get one of the possible options for constructing the projected object.

The next stage is the formation of all possible options for constructing the designed object. For this purpose, an appropriate scientific and technical search is carried out in order to identify possible methods and technical means for performing PTP in technological modules for the cultivation of grain crops, and then using morphological analysis methods to form a multiplicity $M_v$ of possible variants of technological schemes for cultivating these crops.

To select the most effective of them, we used a five-step procedure for evaluating, comparing and choosing options:

1. The selection of options at the stage of morphological analysis of the design object. Herein taken into consideration were: the compatibility of the technological process (TP) in the system - for example, after subsurface tillage processing during early spring tillage, rotary implements of the BIG-3A and BMSh types should be used; recommendations of the National Research University on zoning of the methods and working bodies of machines - for example, for the steppe zone it is recommended to use subsurface methods of tillage; the possibility of practical implementation of this option (availability of technical means (TM), financial feasibility, etc.). Due to this selection, the number of possible options was reduced within the framework of individual technological modules and technology options in general. At this stage, it was not planned to get an unambiguous solution (number of remaining options is large $n >> 1$).

2. The selection of options taking into account the totality of conditions and limitations that determine at the stage of substantiating the initial data for the design of technologies and integrated TP.

The set $Y = \{Y_1, Y_2, \ldots, Y_R\}$ includes data on the soil-climatic and production conditions for the functioning of the designed facilities, which are important precisely for the selection of TP options in technological modules and technology options in general. Herein important are: data on soil type, field topography, rainfall and their distribution by months of the growing season, field dimensions, etc. Conditions determine the feasibility of implementing specific technological solutions.

The set $O_S = \{O_{S1}, O_{S2}, \ldots, O_{Sk}\}$ of restrictions on the structure of the design object and the parameters of the TP and TM includes restrictions of the type: apply only soil protection technology,
when performing TP in the early to early period, use the MTU only with caterpillar tractors, use resource-saving technological methods, etc. Variants satisfying the totality \( \{Y, O_s\} \) of initial data and restrictions are called admissible. In the general case, there may be many \( M_0 \) such variants. At this stage of the assessment and selection of options, the relevant recommendations of SRE and expert methods were used.

For a visual representation of the structure of the designed TP, structural schemes and graph models (network graphics, process grids) were used. They facilitate the understanding and analysis of complex objects. For an example in fig. 1 is shown a generalized structural diagram of soil tillage systems in the cultivation of agricultural crops. In each technological module, the main factors are noted, on which the choice of method and technical means for its implementation depends.

The general logical scheme for selecting feasible \( M_D \) options from among possible \( M_B \), taking into account the functioning conditions of the designed objects using the example of basic tillage, is shown in Fig. 2.

3. The selection of promising options from among the admissible \( M_D \) was carried out using a set of particular criteria \( K = \{K_1, K_2, \ldots, K_m\} \) and reasonable restrictions on the numerical values of these criteria \( O_K = \{O_{K1}, O_{K2}, \ldots, O_{Km}\} \) (for example, specific labor costs for the production of 1.0 Hundredweight of grain is not more than 0.2 man-hours).

Options of PTP and technologies (integrated TP) for crop cultivation, satisfying the aggregate \( D = \{Y, O_s, K, O_K\} \) of initial data and requirements, will be called strictly admissible. In a general case, there may exist a subset \( M_{SD} \) of such options. From this subset, you need to choose the most effective (Pareto-optimal option) of the designed object.

At the stages 1 to 3 of preliminary selection of promising options for the designed technological objects, an in-depth study is not carried out with defining technical and economic indicators, since such an analysis of all the formed options (technological schemes) is associated with a large time and money expenditures, and sometimes almost impossible (due to lack of reliable information). Therefore, the selection problem was solved herein on the basis of the analysis of available scientific and technical information, using experience of designers and expert methods.

4. After identifying a subset of \( M_{SD} \) of strictly permissible options for the projected object (for example, technologies for cultivating crops in a specific natural production subzone), these options were ranked according to a set of previously substantiated criteria. The ranking was carried out both by particular and complex criteria. For the latter case, a more complete assessment of the options is given.
Designations:
Pc - preceding crop; Bi - biological requirements of the i-th crop; Pr — field relief;
Tp - type of soil; Mp - mechanical composition of soil; Zp - level and character of field contamination;
Vp - soil moisture; Op - preceding tillage; Yi - level of intensification;
Et - economic requirements; Ek - environmental requirements

**Figure 1.** Generalized block diagram of soil tillage system in cultivating crops.

At the stage of selection of promising options for PTP, the following particular indicators were used in technological modules: quality of TP performance, ecological compatibility of TP, yield of cultivated crops. Note that the quality of TP performance and ecological compatibility of TP are complex group indicators. Therefore, their component indicators were specified in relation to both technological modules and the implementation conditions of the designed TP.
Figure 2. General scheme of formation of admissible options for PTP in technological modules (main tillage as example).

For instance, for the main tillage technological module, particular indicators of the TP performance quality were the following: depth of tillage, stubble conservation degree, weed infestation or crops, moisture accumulation in the layer 0 to 100 cm at the time of sowing, etc.

In fact, at this stage, there have been chosen the methods for implementing TP in technological modules (TM) and types of technical means without specifying their sizes (working width, productivity, etc.).

With a multi-criteria assessment of PTP and integrated TP for cultivating crops, complex criteria were formed for decision-making. For this purpose, we use the methods of qualimetry, the Harrington desirability function, and the completeness coefficient determined by experts using the method of general definition tables [12]. After determining the values of the complex criteria, the options were ranked, and 2 to 4 best options were selected for subsequent analysis.

5. The next stage of the assessment and selection of PTP in TM and integrated TP is associated with the assessment of costs for the implementation of promising options identified earlier. Herein, in addition to indicators of quality and ecological compatibility of TP, there were specific labor costs, energy and material consumption of TP, cost of work and resulting products determined. Herein,
integrated criteria were also formed from particular indicators and the remaining options after the 4th stage were ranked by them.

At this stage, we have already considered the issue of choosing the machines (tools) size dimensions for the implementation of promising PTPs (choosing energy class of the means, working width of the unit, etc.). Here we are talking about the choice of rational machine-tractor units (MTU).

To solve this problem, multi-criteria MTU ranking was used according to technical and economic indicators (productivity or unit labor costs, unit fuel consumption, unit energy and material consumption, unit operating costs).

When ranking the MTU options, along with the integrated quality indicators of PTP in the form of average weighted of the partial indices $U_j$ and the Harrington’s desirability function, an MTU competitiveness level was also defined [12].

Comparing and interconnecting the data obtained with formalized and expert methods allows us to get effective (rational, Pareto-optimal) options when developing crop cultivation technologies.

3. Results

Given the complexity of the task, we select a promising process option with the example of a soil tillage system using the practical manual SibNIIZKhim [14], which can be considered as an expert system.

To substantiate the directions of improving the systems and methods of basic tillage in the current year, there were expert methods and information analysis methods used.

To conduct an expert assessment, a group of 10 people was formed, which included specialists in the field of agricultural technology (3 people, including 2 doctors of sciences) and mechanization of tillage (7 people). The survey findings were processed using methods of mathematical statistics.

The results of processing the obtained data on the evaluation of basic tillage systems are presented in the context of the main agrolandscape provinces of the Novosibirsk Region. Moreover, in each of the provinces, two specific features were identified that impacted the results of assessing the primary tillage systems. Thus, zonal types of soils and soils with the presence of solonetzic complexes were distinguished on flat landscapes, and slope angles of up to 3 ° and more than 3 ° on landscapes with rough terrain.

As an example, in table. 1 there is shown the results of an expert assessment of the basic tillage systems in relation to the conditions of the agrolandscape province Pa – Barabinskaya, which is part of the northern forest-steppe zone.

When analyzing information materials on the effectiveness of the methods of basic tillage in different soil and climatic zones of Western Siberia [12,13-19], the following was established:

Table 1. Summary data on assessment of basic tillage systems, Soil-climatic zone - northern forest-steppe, Agrolandscape Province: Pa – Barabinskaya.

| Basic tillage system | Type of soil | black earth in complex with salt licks |
|---------------------|--------------|----------------------------------------|
|                     | $\bar{a}_i$ | $V$ | $\sigma$ | $R$ | $\bar{a}_i$ | $V$ | $\sigma$ | $R$ |
| 1. Dump tillage:    |             |     |          |     |             |     |          |     |
| – deep              | 4.0         | 0.20| 0.079    | 8   | 1.9         | 0.64| 0.048    | 9   |
| – different depths  | 4.9         | 0.24| 0.097    | 6   | 2.1         | 0.47| 0.054    | 7   |
| 2. Subsoil tillage: |             |     |          |     |             |     |          |     |
| – deep              | 4.7         | 0.35| 0.093    | 7   | 6.2         | 0.40| 0.158    | 3   |
| – different depths  | 6.3         | 0.42| 0.125    | 3   | 6.5         | 0.23| 0.166    | 2   |
| 3. Combined tillage |             |     |          |     |             |     |          |     |
| (interleaving dump  |             |     |          |     |             |     |          |     |
| and subsoil        |             |     |          |     |             |     |          |     |
| tillage)            |             |     |          |     |             |     |          |     |
| 4. Minimum          |             |     |          |     |             |     |          |     |
| (combination of shallow and | 6.1         | 0.24| 0.121    | 5   | 3.5         | 0.56| 0.089    | 6   |
5. Minimum mulching tillage (with the formation of a mulching layer)

|   | 6.2 | 0.30 | 0.123 | 4 | 4.2 | 0.42 | 0.107 | 5 |

6. Zero tillage (no treatment)

|   | 3.9 | 0.33 | 0.077 | 9 | 1.8 | 0.62 | 0.048 | 8 |

7. Adaptive (subject to changing conditions)

|   | 7.7 | 0.14 | 0.153 | 1 | 7.7 | 0.22 | 0.196 | 1 |

Notes:
- \( \bar{a} \) – average score of basic tillage system in points;
- \( V \) – coefficient of variation;
- \( \sigma \) – significance (importance) factor;
- \( R \) – rank (place)

1. When averaging data from many years of experience, the difference in the average yield of grain (in particular, spring wheat) between the options does not exceed 10 ... 15%. However, in some years (usually dry), this difference is 2 or more times higher.

2. On a slightly littered land with reduced moisture and nitrate reserves in a meter soil layer, decreased wetting of the autumn-winter-spring and vegetative periods, the final assessment of the treatment methods will be as follows: plowing - 2.2 points \( [(3 + 1 + 5 + 1 + 1) : 5 = 2.2] \), moldless loosening 4.2 points \( [(5 + 5 + 5 + 5 + 1) : 5 = 4.2] \), small flat cutting - 3 points \( [(3 + 3 + 3 + 3 + 3) : 5 = 3] \), zero tillage - 1.8 points \( [(1 + 1 + 1 + 1 + 5) : 5 = 1.8] \). In this case, moldless loosening will be more effective.

3. When developing and forming a subset of admissible options (\( M_D \)) from among the possible, we introduced an assessment of PTP in technological modules for compliance with general trends in improving the basic components of crop production agricultural technologies (improving soil cultivation systems in crop rotation, improving fertilizer systems, plant protection, etc.). Using expert assessment (on a 10-point scale), it was defined that the following tillage systems are most promising for the given agri-production province: adaptive soil protection with differentiation by weather conditions (average score 7.6; coefficient of variation 0.11); minimum mulching (average score of 6.2; coefficient of variation 0.15) and subsoil different depths (average score of 6.2; coefficient of variation 0.21). All options include the preservation of plant residues on the field surface or their incorporation into a layer of 0 to 10 cm.

When conducting an information search, 34 possible methods of basic tillage were identified (\( M_v = 34 \)). Of these, taking into account the methodological approaches presented, using expert methods for the forest-steppe conditions of the Priobsk plateau, 14 options were selected for further analysis (\( M_D = 14 \)).

4. Using expert methods, admissible options for basic tillage (\( M_v = 14 \)) were evaluated by the degree of the implemented tasks (requirements) that were formulated for them in relation to the province indicated above (Table 2).

5. Following the results of evaluating the options for TP for basic tillage according to particular indicators when cultivating crops in the forest-steppe (Table 3), options 1 (basic), 7 and 8 were selected for subsequent analysis and experimental value verification of the complex indicator. Flat cutting-zero tillage (option 7) provides for the cultivating of strips with a width of 0.4 m to a depth of 10 ... 12 cm with the interleaving of uncultivated strips of the same width (tilling with a cultivator such as KTS-10.1, through the paw).
Table 2. Expert assessment of TP for basic tillage by degree of implemented requirements formulated for them when cultivating crops in the Priobsk plateau forest-steppe (fragment).

| Main requirements for basic tillage technological process in Priobsk plateau forest-steppe | Assessed degree of implementing TP formulated requirements (in fractions of 1) Options for implementation of TP and machines (tools) |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| 1. Making up conditions for accumulating and preservation of moisture in soil                                                                                                                                                                                                                       |
| Options for implementation of TP and machines (tools)                                                                                                                                                                                   |
| 1                                                                                                                                                                                                                                           |
| 2                                                                                                                                                                                                                                           |
| 3                                                                                                                                                                                                                                           |
| 4                                                                                                                                                                                                                                           |
| 5                                                                                                                                                                                                                                           |
| 6                                                                                                                                                                                                                                           |
| 7                                                                                                                                                                                                                                           |
| 8                                                                                                                                                                                                                                           |
| 0.8 0.5 0.6 0.5 0.8 0.6 0.7 |                                                                 |
| 2. Soil erosion prevention                                                                                                                                                                                                                      |
| 0.7 0.4 0.4 0.5 0.5 0.7 0.6 0.7 |                                                                 |
| 3. Building up required structure of tillage layer                                                                                                                                                                                             |
| 0.4 0.5 0.6 0.5 0.6 0.5 0.6 0.7 |                                                                 |
| 4. Destruction of weeds                                                                                                                                                                                                                       |
| 0.6 0.6 0.5 0.5 0.5 0.5 0.4 0.3 |                                                                 |
| 5. Soil nutrient mobilization                                                                                                                                                                                                                  |
| 0.7 0.5 0.4 0.5 0.5 0.4 0.4 0.4 |                                                                 |
| Total score | 3.2 2.5 2.4 2.5 2.7 3.0 2.6 3.0 |

Note: Methods of tillage and implements: 1 - moldless loosening (22 ... 27 cm), SibIME racks; 2 - surface loosening of 10 ... 14 cm, BDM; 3 - peeling at 5 ... 8 cm, LDH; 4 - cultivation of 10 ... 14 cm, CTS; 5 - combined tillage tool type "Leader"; 6 - continuous plane-cutting by 10 ... 12 cm with a strip recess of 28 ... 30 cm, PRG; 7 - plane-cut-zero, KTS; 8 - surface strip (4 ... 6 cm) + slotting, BIG + racks "Paraplau".

Table 3. Evaluation of TP options for basic tillage according to particular indicators when cultivating crops in forest-steppe.

| Indicators for evaluating of TP options for basic tillage and coefficients of their significance (δi) | TP options for basic tillage (see table 2.4) |
|---------------------------------------------------------------------------------------------------|---------------------------------------------|
| Quality of technological processes (TP), δi=0.62 points                                                                                                    | 1 basic 5 6 7 8                              |
| Specific fuel consumption, δi=0.20, l / ha                                                                                                                   | 13.8 7.8 8.4 6.5 6.6                         |
| Unit labor costs for the implementation of TP, δi=0.18, man-hours/ha                                                                                       | 0.58 0.44 0.40 0.34 0.36                     |
| 4. Comprehensive assessment (additive convolution of indicators)                                                                                             | 1.00 1.32 1.45 1.70 1.61                     |
| Option 8 provides for strip tillage at different depths and includes strips tilled with BIG-type working bodies, stubble without tillling with snapping with Paraplau type racks. |

In a similar way, an information-logical analysis of the methods for performing TP in other technological modules was carried out. The following are recognized as the most promising options (for technological modules):

- post-harvest tillage - tilling with rotary implements BMSh and BIG-3A, tilling with spring harrows, husking;
- main tillage - strip multi-depth tillage by cultivators of the KGS type, combined tillage - BIG-3A + Paraplau racks;
- early spring tillage - tilling with rotary tools BMSh and BIG-3A, tilling with spring harrows;
- pre-sowing tillage - peeling with hydraulic disc cultivators LDH with rolling by rollers of ZKKSh type, cultivation by aggregates of KBM type, double-harrow harrowing with harrows BZTS and BZSS;
- sowing - groove-tape with combined RO, strip sowing with SKP-2,1 type seeders, direct sowing
with tillage and sowing units with the introducing of a starting dose of fertilizers, plant growth regulators and bacterial fertilizers (BU);  
- crop care - post-emergence harrowing with BZSS or BIG-3A, spraying of crops with pesticides on demand (taking into account economic thresholds of harmfulness) with trailed and self-propelled hydraulic boom sprayers.

When cultivating crops in the forest-steppe zone, soil-protective subsurface tillage with the formation of a mulched soil layer is implemented. The emphasis is on minimizing the tilling and reducing the cost of production.

Taking into account the above remarks, there was formed a structural diagram of the technology of cultivating grain crops with the simultaneous introduction of nitrogen-fixing bacteria remedies into the soil (Fig. 3).

Figure 3. Structural diagram of technology of grain crops cultivation with simultaneous introduction of nitrogen-fixing bacteria remedy into soil, BFWF – bacterial fertilizer working fluid.

4. Discussion
The methodological aspects of the engineering design of crop production agricultural technologies are considered, based on the logical diagram of the design process of technological objects and the main approaches to designing a variety of options for objects and selection the most effective ones for inclusion in machine technology for crop production in the specific natural production conditions.

To evaluate options at various hierarchical levels, a set of agreed indicators is substantiated. The formulas for calculating the operational-technological and technical and economic indicators allow at the final stage of the formation of agricultural technologies to choose the most promising process option in the corresponding technological module. The given example of the formation and selection of effective (promising) methods for primary tillage determines that, in addition to the yield of cultivated crops, when choosing promising methods for basic tillage, it is necessary to take into account the costs of these processes and their effect on the conservation and reproduction of soil
fertility. With this multi-criteria approach, the minimum mulching treatments become the most promising, based on mulching and surface loosening of the soil with preservation of plant debris on the soil surface or with incorporation into the upper soil layer. One of the ways to reduce the cost of basic tillage may be to switch to methods of strip-layer cultivation.

The analysis of the basic and spring tillage systems in the studied zones showed that none of them is universal. Each of them in specific weather conditions shows its advantages and disadvantages. Therefore, the soil tillage system must be adaptive and combine the most effective soil tillage methods in specific natural and production conditions in such a way as to maximize the use of their advantages and minimize the impact of disadvantages.

The presented method for the formation (designing) of agricultural technologies of crop production determines that it is advisable to use two more operational and technological indicators in addition to the performance indicator of technological process - specific fuel consumption and unit labor costs for the implementation of the analyzed TP. These indicators can be determined by testing prototypes of machines or calculated on condition of aggregation of these machines with tractors of the same class. In our case, the calculation method was used when aggregating machines with a tractor of the T-150K.09 type. The values of the importance (significance) coefficients of the indicators used in this totality were determined by experts. The result of evaluating the TP options for the basic tillage, selected at the previous stage, is shown in table 3.

The most complete assessment of both individual technological processes and the established technologies for the cultivation of crops as a whole is carried out at the stage of their experimental verification. Here it is possible to obtain reliable baseline data for determining the operational and technological, also technical and economic indicators of the designed facilities (TP, TM, technology). The final choice of options is carried out on the basis of their multicriteria assessment using methods of decision theory.

Our proposed method for the engineering design of agricultural technologies for crop production, the search for ways to evaluate and select effective technological processes in their formation, are completely correspond to the generally accepted direction of improving machine technology for cultivating agricultural crops.

5. Conclusions
1. In the formation of systems for plant growing processes mechanization, methods and techniques of engineering design of particular technological processes and technical means are widely used. Unfortunately, the issues of designing more complex objects (crop cultivation technologies, technological systems of crop production, engineering systems of agricultural enterprises, etc.) have not been developed to date.
2. A block hierarchical approach to the design of crop production agricultural technologies is proposed. In the design process, the following basic principles must be maintained: systematic approach, focus on obtaining optimal solutions, comprehensive (multi-criteria) approach, functional approach, iterative design process, focus on the final result, combination of formalized and heuristic methods, principle of open systems, principle of modeling objects, principle of functional completeness, etc.
3. A general logic diagram of the engineering design process of agricultural plant technology objects is proposed, where the main stages and design stages, design tasks and basic methods for solving them are defined. Methods of morphological analysis are used to form options. When choosing acceptable, promising and effective options for the designed objects, the methods of decision theory were used.

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