The assessment modeling of the innovative technologies implementation effectiveness in crop production

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Abstract. The research results of a model for effectiveness assessing of the "No-Till" innovative technology implementation in which the soil is not cultivated in the traditional, mechanical and usual for us way by plowing, but is covered with crushed plant crops remains, are presented. A system-cognitive analysis of the No-Till technology implementation effectiveness assessment applied in the intelligent system "Eidos" is realized while modeling.

1. Introduction
The innovative activity of agricultural enterprises is problematic due to the low investment attractiveness of the industry. Despite the fact that agriculture has a high investment potential, there is a food shortage in the world, and the starvation problem in some countries is very acute.

One of the ways to reduce energy and resource consumption is the new technologies application for soil cultivation. The zero or surface tillage usage reduces fuel consumption by 5-6 times, while labor productivity increasing and time gaining. The development of low-cost energy-saving technologies for the basic agricultural crops cultivation based on the optimal seeding rates usage, fertilization and an integrated system for crops protecting from pests. The preliminary costs for the new technologies application in crop production require personnel training to work on the new high-performance equipment and the innovative processes implementation.

The implementation and application of the latest inventions in the crop production were investigated by scientists P.A. Kostychev, N.M. Tulaykov, N.I. Fedotova, who came to the conclusion that in the south of Russia shallow plowing contributes to the moisture preservation in the soil bulk and increases crop productivity during drought. Recently, the works of T.S. Maltsev, who proposed to carry out subsoiling (by 40-50 cm) without moving the horizons of the plowing layer, have attracted widespread attention of the agronomic community. A special moldboardless plow is used for such cultivating. According to Maltsev, the annual soil plowing with the plow layer turnover worsens its structure. While plowing according to his method, plant remains fall into the plow layer, which are not subjected to strong erosion, and therefore are better humified. The deep moldboardless tillage by T.S. Maltsev is recommended to carry out once in 5-6 years, and in the interval moldboardless soil shallow plowing.

The working purpose is the assessment modeling of the innovative technologies application effectiveness to determine the prospects for the latest inventions implementation in the crop production by agricultural enterprises.
2. Materials and methods
The system of adaptive landscape farming in the Volgograd region for the period up to 2025, developed by A.I. Ivanov et al., determines that the priority direction of the soil cultivation systems implementation in grain-fallow and grain-tilled crop rotations will be a combination of non-moldboard, moldboard, surface and land-reclamation cultivations, which will increase the plants moisture supply by 20-25%.

It is noted that while switching to shallow, surface and zero tillage of zonal soils, which are prone to rapid and strong compaction, it becomes necessary to use techniques that contribute to the decompaction of the soil lower layers to increase its water infiltration and to prevent water erosion.

The basis of modern approaches to the crops cultivation are new technologies of minimal (Mini Till) and zero (No-Till, translated as "no tillage") soil cultivation using special agricultural machinery and non-traditional agronomic techniques related to resource-saving technologies.

The «Mini Till» technology is implemented with the field plowing, however, plowing and sowing is carried out directly on top of unharvested crop remains. While the «No-Till» technology application, the soil is not cultivated, and its surface is covered with specially crushed plant remains - mulch. Both techniques simplify farming greatly by eliminating the hassle of removing straw and other crop remains for farmers, both provide a safer microbiological environment for crops, and both provide higher yields than obsolete soil cultivation methods.

New technologies reduce the tillage and planting cost, often by more than half, and the yield can be doubled. The new systems regulate the moisture in the soil, so that the plants braid and grow without rain during drought. Plants suffer less from moisture excess in too rainy summers. Bacteria find the most favorable conditions for development in the soil, proliferate at an incredible rate; they often adapt the land to strong fertility. Gases, moisture, bacterial spores, dust of various kinds are absorbed from the atmosphere in the most energetic way. The ripening of plants is accelerated, as a result they suffer less from parasites, for example, from rust, are less exposed to burning-out in the south and freezing in the far north. It is widely known that no-till soil cultivation technology is not practiced on poorly drained and waterlogged soils. It is also not recommended for a number of reasons to start this technology implementing on sandy soils. If, nevertheless, this method is applied on soil with poor moisture, then the crop productivity will decrease and losses will occur.

Before the direct sowing technology implementing, the unevenness of the soil surface must be leveled. If this is not done, the seed planters will not work effectively on uneven soils. This leads to the poor stems formation, because the seeds can get to the surface of the soil, or they will be at a shallow depth or too deep to germinate. In order to ensure efficient farming, it is necessary to place the seeds at the same depth, which can only be achieved if the soil surface is smooth. The variety of crop types in the rotation allows you to create a good seedbed for subsequent crops, reduce populations of weeds, pests and diseases, and to manage the equipment workload. The use of plant remains in agricultural systems allows you to increase soil fertility, which over time will have a positive effect on the overall productivity and crops yield.

To create an assessing model for the No-Till technology implementation effectiveness, quantitative factors are used that are "blurry", since their exact value is very often impossible to estimate due to various limitations: the difficulty of making correct measurements; insufficient statistical data for a reliable description of probabilistic characteristics and laws [1]. It is advisable to use the system-cognitive analysis, implemented in the intelligent system "Eidos" to assess the effectiveness of the innovative technology application by the fuzzy data [2, 3].

A fuzzy variable is characterized by a triple \((X, U, R(X, u))\), where \(X\) is the name of the variable, \(U\) is a ground set (finite or infinite), \(u\) is the general name of the set elements \(U, R(X, u)\) is a fuzzy subset of the set \(U\), which is a fuzzy constraint on the values of the variable \(u\) due to \(X\).

The fuzzy variable \(u\) is the base variable for \(X\). The assignment equation for \(X = u: R(X)\) and reflects that \(x\) is assigned the value \(u\) given the constraint \(R(X)\). The degree to which this equality is satisfied will be called the compatibility of the value \(u\) with \(R(X)\) and denoted by \(c(u)\).
By definition $c(u) = \mu_{R(X)}(u), u \in U$, where $\mu_{R(X)}(u)$ is the degree of $u$ belonging to the $R$ ($X$ restriction).

To assess the effectiveness of the No-Till technology, a system-cognitive analysis was carried out, implemented in the intelligent system "Eidos", which makes it possible to formalize values, identify cause-and-effect relationships between controlled parameters and formulate a conclusion under indeterminacy conditions.

To obtain an integral effectiveness assessment of the No-Till technology implementation, the following model was applied:

$$Et = < Sm, Cri, Sr, Vr, Mc >,$$

where $Sm$ is soil moisture;
$Cri$ is the crop rotation intensity;
$Sr$ is the surface roughness;
$Vr$ is the vegetation remains;
$Mc$ is the mechanisms cleaning.

The linguistic variable "Implementation efficiency" of the No-Till technology contains the term set:

$Tei = \{ \text{low (l), below average (ba), medium (m), above average (aa), high (h)} \}$.

For the linguistic variables "Soil moisture", "Crop rotation intensity", "Surface roughness", "Vegetation Remains" and "Mechanisms cleaning", a three-level classification is applied. To perform modeling based on empirical data, 40 rules have been developed. The rule base fragment is shown in Table 1.

**Table 1.** The rule base for predicting the implementation effectiveness of the No-Till technology.

| Implementation efficiency | Soil moisture | Crop rotation intensity | Surface roughness | Vegetation remains | Mechanisms cleaning |
|---------------------------|---------------|-------------------------|-------------------|--------------------|---------------------|
| h                         | h             | h                       | l                 | h                  | h                   |
| aa                        | h             | h                       | m                 | h                  | h                   |
| aa                        | h             | h                       | h                 | h                  | h                   |
| m                         | h             | h                       | m                 | m                  | h                   |

3. Results and discussion

The levels of instances similarity of the training sample to the gradations of the No-Till technology "Implementation efficiency" class, which exceed 75%, have been determined. While verification of models INF1-INF7, the model INF7 was determined, this has the highest reliability of identification and non-identification of objects. For the "High", "Above average", "Medium", "Below average" and "Low" gradations of the No-Till technology "Implementation efficiency" class, the results of a SWOT - analysis were obtained, which determine the strength and direction of the main factors influence.

The factors influence degree on the «Implementation efficiency" for the "High" gradation is shown in Fig. 1. The factors influence degree on the "Implementation efficiency" for the "Medium" gradation is shown in Fig. 2.
Figure 1. The factors influence degree on the "Implementation efficiency" grade "High".

Figure 2. The factors influence degree on the "Implementation efficiency" grade "Medium".

The factors influence degree on the "Implementation efficiency" of the "Low" gradation is shown in Fig. 3.
Figure 3. The factors influence degree on the "Implementation efficiency" gradation "Low".

To achieve high efficiency of the No-Till technology implementation, it is first of all necessary to ensure high soil moisture, the field surface must be flat, and it is also necessary to ensure high crop rotation intensity. The low No-Till technology implementation efficiency is provided by small vegetation remains during sowing, low soil moisture and poor mechanisms cleaning.

Revealing the strength and direction of the main factors influence makes it possible to choose recommendations for the formation of such conditions that will allow achieving high grain yield with the highest degree of determinism.

4. Conclusion
The intelligent system "Eidos" provides the ability to simulate complex dynamic systems and comparative analysis of options implementation, and also allows you to develop an action plan to achieve the expected result by innovative technology application for growing grain crops.

According to the No-Till technology, the soil is not subjected to intensive tillage and retains its natural structure. Plants form a root system in the form of an interwoven carpet on the soil surface and the soil itself forms a capillary system for delivering water from the lower layers of the soil to the top. Sowing is carried out in the "mulch" holes, that is, in the remains of the crushed and processed previous culture, which stays on the surface of the soil. Straw and “mulch”, evenly spread over the field, ensure high yields of grain crops.

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