

Basic scientific principles for the selection of effective anti-erosion technologies for the soil protection system of minimal tillage in the southern regions of the Russian Federation

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Abstract. The article presents an analysis of existing research in the field of evidence-based anti-erosion technologies for tillage. The main principles of soil-protective resource-saving agriculture are disclosed, such as: reduction of tillage; preservation of plant residues on the surface; use of crop rotations for three types of botanical crops. A scientific substantiation of the principles for choosing effective anti-erosion technologies for a soil protection system of minimal tillage and a complex of soil-cultivating technical means for the southern regions of the Russian Federation is given, taking into account the criteria for evaluating the effectiveness of their application. For technologies, such scientific principles as: reduction of tillage operations; preservation of plant residues on the surface of the cultivated soil layer and sowing of cover crops; the use of crop rotations. For the technical means used in the anti-erosion technologies of the soil protection system of minimum tillage, the following principles are considered: environmental safety; the quality of the products received; energy efficiency; the use of digital technologies, taking into account the rational management of the quality of tillage. The application of the developed scientific principles for the selection of effective anti-erosion technologies of the soil protection system of minimum tillage with the appropriate set of technical means of tillage will ensure the efficient production of environmentally friendly and high-quality products of the crop complex of the Russian Federation, while the selected set of machines and cultivation technology should have a minimal negative impact on the environment.

1 Introduction

In modern agriculture, mechanical tillage is an important link in the overall farming system of any agrarian formation of the country. As the analysis shows, when using existing modern methods and technologies for cultivating crop products, from 35 to 40% of energy resources and from 25 to 30% of labor costs are spent for tillage [1]. At the same time, the main agrotechnical and agrotechnological means of implementing the processes of formation of soil regimes, accelerating biological processes in it, and maintaining optimal indicators of

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the phytosanitary state of the soil cover is mechanized tillage [2].

Soil cultivation has many functional tasks, especially in the anti-erosion technologies of the soil protection system of minimal tillage. In this case, the following main tasks should be highlighted, such as:

- formation of a fertile cultivated soil layer with good thermal, nutrient and water-air modes of plant functioning;
- ensuring the anti-erosion stability of the soil cover;
- destruction of weeds and pathogens;
- creation of an optimal structural state of the soil by forming optimal in terms of geometric and weight indicators of its aggregates.

To solve these problems, it is necessary to form effective anti-erosion technologies of the soil protection system and a set of machines for them. As the analysis shows, there are three stages in the formation of these technologies and a set of machines for them [3]:

1. Based on the principles of differentiation [4], there is a substantiation and definition of one or another anti-erosion technology of tillage.
2. Substantiation of a rational complex of technical means in the chosen technology with an assessment of their energy efficiency.
3. The choice of an optimized composition of technical means that will be adapted for a given tillage technology.

An analysis of existing studies has shown that the creation of evidence-based anti-erosion technologies lacks the basic principles of soil-protective resource-saving agriculture, such as: reducing tillage; preservation of plant residues on the surface; use of crop rotations for three types of botanical crops.

Scientists Xuezhen Wang, Hao Zhou, Shengsheng Wang from Henan University of Science and Technology have researched the erosion control technologies of the soil protection system such as minimum tillage, including loosening, mulching with straw, and no tillage before sowing. As a result, these technologies have been shown to be effective in conserving soil water, improving soil properties, and maintaining agricultural productivity in China, especially in high-risk farming areas dominated by wind erosion. However, Chinese scientists had a question in choosing the optimal set of technical means, which at that time did not exist [5].

According to foreign studies [6-7], at present, due to the use of traditional tillage and frequent operations with heavy sowing equipment, tillage implements in agricultural formations, soil over consolidation has become a global problem that affects all soils at the agricultural level and can lead to huge economic losses.

A general analysis of the studies that were carried out by domestic and foreign researchers makes it possible to conclude that it is necessary to further develop scientific principles for choosing effective anti-erosion technologies for soil protection systems for minimal tillage, which will ensure a clear relationship between tillage methods and processes occurring in it.

2 Materials and methods

In the course of the research, analytical methods were used to summarize the results obtained by both domestic and foreign researchers, using their literary sources, which reveal the problem of developing or choosing effective anti-erosion technologies for a soil protection system of minimal tillage and a complex of tillage machines for them.

3 Results

The main scientific principles for the selection of effective anti-erosion technologies for the

soil protection system of minimal tillage for the southern regions of the Russian Federation are the basis on which all modern developments of technical means, as well as new mechanized technologies for the production of crop production, should be formed.

The main goal of the formation of technologies for the soil protection system of minimal tillage is the effective production of crop production with an even balance of all elements of the main indicators of technical means and technologies.

The scientific formation of the choice of effective anti-erosion technologies of the soil protection system should be based on two systemic principles, both for the technologies themselves and for technical means.

The general methodology for selecting the necessary anti-erosion technologies of the soil protection system should include the entire algorithm and data system that were determined in the process of approbation of technical means of agricultural engineering using appropriate technological processes and materials.

As the analysis of existing studies in the field of anti-erosion technologies of the soil protection system of minimum tillage, taking into account resource-saving agriculture, showed, the following scientific principles should be distinguished for these technologies, as shown in Figure 1:

- reduction of tillage operations;
- preservation of plant residues on the surface of the cultivated soil layer and sowing of cover crops;
- the use of crop rotations.

For the technical means used in the anti-erosion technologies of the soil protection system of minimum tillage, the basis is such principles as:

- environmental Safety;
- the quality of the resulting products;
- energy efficiency;
- the use of digital technologies, taking into account the rational management of the quality of tillage [1].

After analyzing the scientific principles outlined above. For anti-erosion technologies of the soil protection system of minimum tillage, the reduction in operations makes it possible to minimize disturbance of the soil cultural layer by mechanical processing while maximizing the preservation of organic matter and its natural structure.

The preservation of plant residues on the surface of the cultivated soil layer and the sowing of cover crops will allow maintaining and further improving the protective organic cover that forms on the surface of the soil cultural layer. For this, it is mandatory to use ground cover crops and crop residues. The application of this approach will allow preserving soil moisture, activating the biological activity of the soil during the formation of bio humus, as well as comprehensively combating weeds and pests.

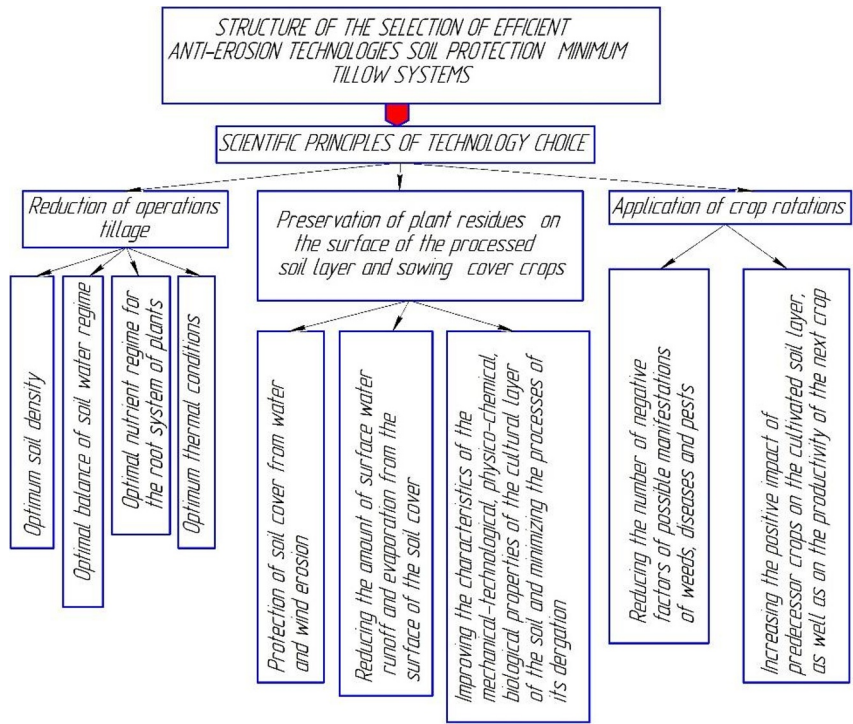


Fig. 1. Block diagram for determining effective anti-erosion technologies of soil protection system of minimum tillage based on scientific principles.

The use of crop rotations is an effective way to improve the soil. The alternation of crops using crop rotation makes it possible to vary the plan for applying both organic and mineral fertilizers, which ensures significant crop yields with a balanced quality. At the same time, a positive balance of humus in the soil is maintained. Crop rotation when changing crops makes it possible to change the appropriate tillage technology. Such a change in tillage processes creates unfavorable conditions for the functioning of weeds.

The environmental safety of the technical means used in the technologies of the soil protection system is one of the most important principles that reduce the negative anthropogenic load in the "man - technical means - soil" system. To maintain maximum environmental safety, technical means in anti-erosion technologies must comply with such requirements as:

- agrotechnological and operational compliance with the chosen rational method or method of tillage;
- precise adjustment and continuous monitoring of the main indicators of machine tillage;
- high-quality acquisition of the composition of the means of movement (tractor) with the technical means (unit) to ensure rational loading of the engine;
- operation of an improved running system of machine-tractor units that minimize the destructurization of cultivated soil layers.

Compliance with these requirements will ensure the balance of environmental safety of technical means for science-based machine technologies of the soil protection system.

The quality of the products obtained for the crop-growing complex of our country largely depends on the effective anti-erosion technologies of the soil protection system of minimal tillage in the southern regions of the Russian Federation. The quality itself is mainly influenced both positively and negatively by external and internal factors. The external ones are:

- requirements for product quality in accordance with regulatory documents;
- timely and high-quality supply of fuel and energy resources for the agro-industrial complex;
- features of the influence of abiotic factors on product quality.

Internal factors are characterized by a set of such unified indicators as: agrotechnological; ergonomic; energy; ecological. They are discussed in more detail in the block diagram presented in Figure 2.

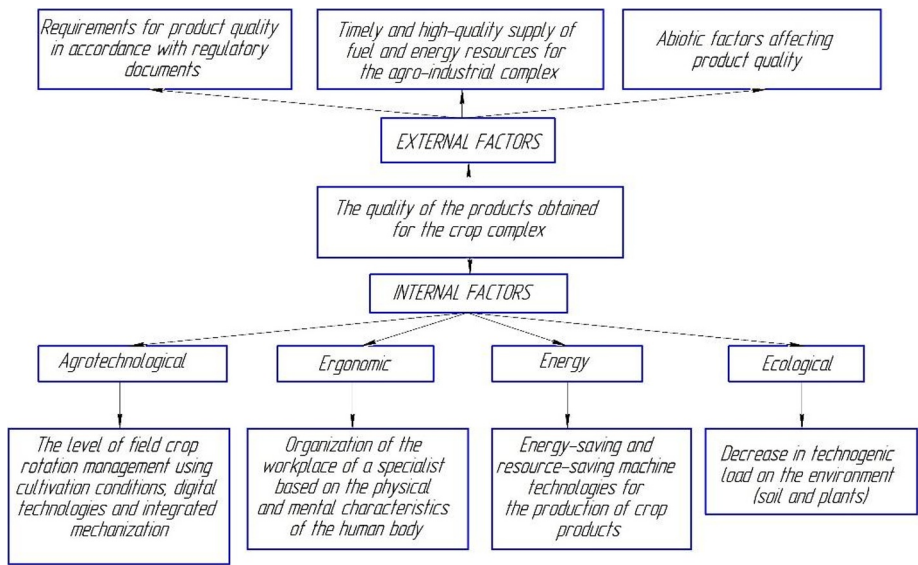


Fig. 2. Structural scheme for determining the quality of products for the crop complex.

From the analysis of the block diagram, it can be seen that the quality of the products obtained for the crop complex directly depends not only on abiotic factors, but also on complex mechanization, energy and resource-saving machine technologies that provide for increased ergonomic indicators of the organization of the human workplace, as well as reducing the technogenic load on the environment. As a result, the scientific substantiation of effective anti-erosion technologies of the soil protection system of minimal tillage, providing one of the complex indicators of product quality is one of the key factors.

The energy efficiency of the introduction of technologies of the soil protection system of minimal soil tillage largely depends on the rational value of the energy intensity of the technological process of tillage, which is equal to the maximum load of the energy tool in the composition with the machine unit. At the same time, the main drawback in the justification of soil-cultivating machine units is the analysis and subsequent composition of both a separate operation and a separate unit, which leads to irrational use of the efficiency of the power tool. Often in practice, some operations are performed out of order, which leads to non-fulfillment of agricultural requirements. As a result, the main indicators of the physical and mechanical properties of the soil deteriorate and at the same time the energy intensity of its processing processes increases.

Therefore, the technologies of the soil protection system of minimum tillage in terms of energy efficiency should be developed in such operational areas as:

- post-harvest moisture-accumulating surface loosening of the soil layer along the stubble background at a depth of 3 to 10 cm;
- autumn non-moldboard moisture-absorbing medium loosening of the soil layer to a

depth of 10 to 30 cm;

- deep chisel moisture-accumulative loosening to a depth of 30 to 45 cm;
- spring moisture-covering surface loosening to a depth of 3 to 10 cm;
- pre-sowing moisture-saving mulching - leveling treatment of the soil layer with simultaneous compaction under the seed bed, as well as combing out weeds in the initial stage of their vegetation.

These operational areas will increase energy efficiency while ensuring optimal thermal and moisture-air conditions in the sowing word of the soil layer. In addition to the operations, it is necessary to select the technological train of the working bodies of tillage machines. There are five technological loops in total. The first includes the use of a combined disc cultivator, toothed needle harrow, needle rotary harrow, or a combined unit with light stubble cultivator, leveler and rollers. This operation is performed immediately after cleaning.

The second involves the use of combined heavy stubble cultivators or cultivators-rippers with rotary tooth harrows and rollers. This plume is necessary for performing winter non-moldboard moisture absorption to a depth of 10 to 30 cm.

The third loop is based on a combination of deep chisel loosening to a depth of 45 cm with leveling the soil with heavy toothed rollers. This operation destroys the plow pan and contributes to the creation of optimal conditions for the absorption of precipitation from the soil surface and their penetration into the lower layers.

The fourth train includes chisel-shaped working bodies on reinforced S-shaped spring racks with a bar-tooth equalizer and a rotary roller. Such a complex of implements makes it possible to carry out spring surface moisture-covering loosening to a processing depth of 4 to 8 cm. As a result, weeds are destroyed in the initial phase of their vegetation. At the same time, the use of herbicides is practically excluded, which entails a more environmentally friendly crop of grain crops.

The use of the fifth loop of working bodies implies a combination of such working bodies as a lancet share on a C-shaped spring-loaded rack, a leveling bar, a cast-iron presser and a double tubular-slatted roller. As a result, this plume forms a system - a compactor, which is the testamentary stage of pre-sowing tillage. Such a system provides moisture-saving, leveling and mulching tillage to a depth of 4 to 8 cm, while forming a compacted seed bed, as well as repeated combing of weeds in the “white thread” phase.

The use of all five technological loops in the anti-erosion technologies of the soil protection system of minimum tillage in the southern regions of the Russian Federation will allow, under extreme conditions, to completely prepare the soil for sowing crop seeds.

However, the use of the technological loops described above requires their appropriate justification. Consistent use of each element of the working body when tilling the soil during the passage of the combined unit should ensure the complete destruction of weed seedlings, the necessary degree of grinding i of the cultivated soil layer, reducing the bedding to minimum values and ensuring the optimal soil density index ρ , which will create better conditions for sowing, subsequent germination and development of seedlings of cultivated plants.

The technological scheme of the sequential impact on the soil of various types of working bodies is shown in Figure 3.

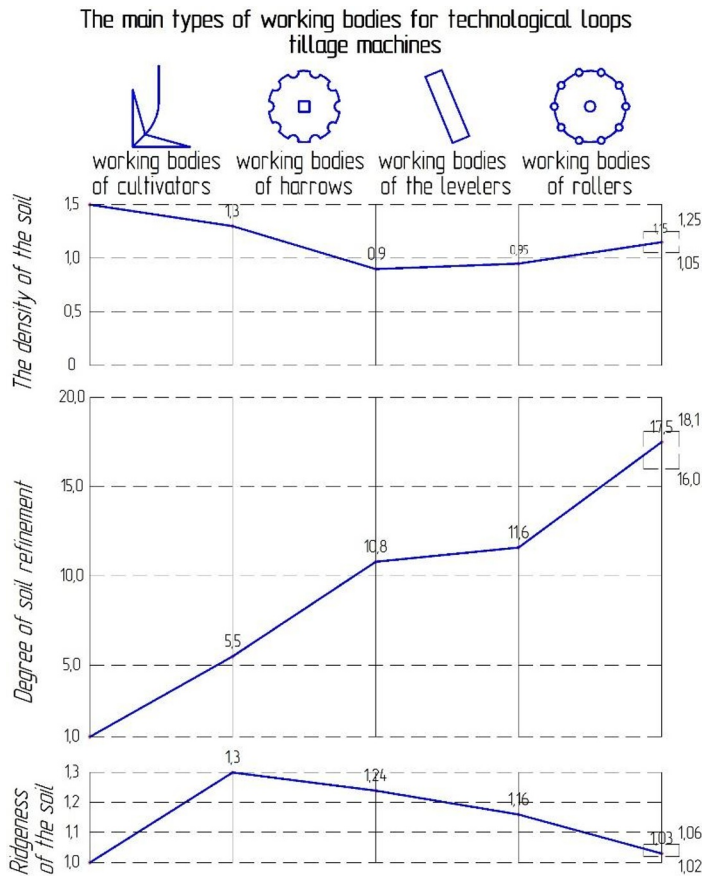


Fig. 3. Diagrams of changes in the main indicators of tillage after the successive impact of various types of working bodies.

The use of diagrams of changes in the main results of tillage after the successive impact of various types of organs of workers on the increase, the degree of crushing and ridges lie in the structure of digital technologies when choosing technical means, using the soil protection system of minimal tillage in anti-erosion technologies, taking into account natural management by a characteristic crop rotation. All possible formulas for determining the data will form the structure of the algorithm for determining the configuration of the combined tillage unit, depending on its functional purpose.

- A striking application of the application of digital technology.
- electronic system of adaptation to the terrain LEMKEN ContourTrack (Germany);
 - electronic control of the plow Hybridcontrol (Germany);
 - control system based on ROW-GUARD cameras (Austria);

The use of the LEMKEN ContourTrack electronic system provides a high speed of the organs in depth during cultivation [11]. High load control system for tractors, consuming the most energy for power units. The electronic control of the Hybridcontrol plow automatically rotates its body when using the direction of movement of the unit in plowing [12]. The ROW-GUARD control system created in Austria allows you to perform technological operations with weeding calls with sufficient confidence [13]. Systems are also produced in the Russian Federation. At the Russian Research Institute of Information and Feasibility Studies, according to the engineering and technical assignment, the AIC developed an integrated

decision support computer system for managing the technological processes of growing plants, which is part of the prefabricated complex of mathematical models [14, 15].

An example of a complex automated information system for the algorithm for determining the configuration of a combined technical tool, depending on its functional purpose, in the management of technological processes in crop production, is shown in Figure 4.

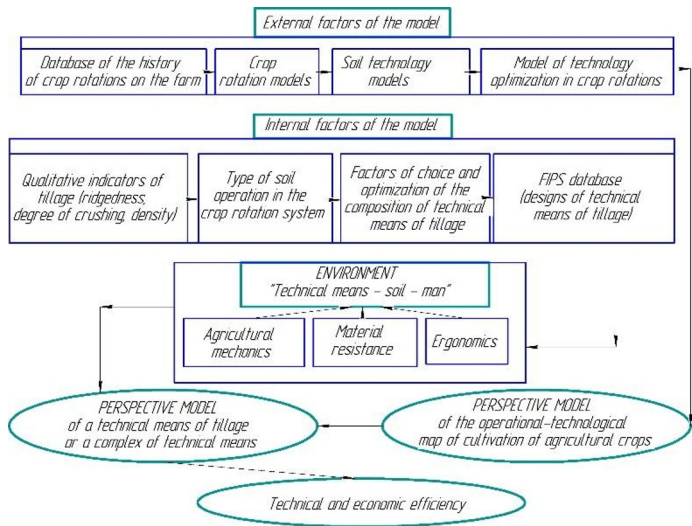


Fig. 4. Modeling provision with an integrated automatic control system for a complex of technical means based on the selected operational and technological map of the cultivation of agricultural crops.

The basis for building this model is a clear historical relationship between the database of the history of previous crop rotations and their complex influence with the operational and technological processes of mechanized cultivation of a particular crop product on its quality and soil fertility. At the same time, the model must constantly solve problems that arise in the production and sale of products. The solution of such problems is associated with a large increase in the volume of received initial data and their processing. The more data, the more accurate the result will be, which will be the basis for making the right decision on the management of the mechanized tillage process or processes associated with other elements of technological operations for the cultivation of crops.

4 Conclusion

Analysis of the scientific principles outlined above for anti-erosion technologies of the soil protection system of minimum soil tillage reduction of operations makes it possible to minimize disturbance of the soil cultural layer by mechanical processing while maximizing the preservation of organic matter and its natural structure.

The use of all five technological loops in the anti-erosion technologies of the soil protection system of minimum tillage in the southern regions of the Russian Federation will allow, under extreme conditions, to completely prepare the soil for sowing crop seeds.

As the values of the diagram show, leveling and compacting working bodies should provide an optimal density index at the level of 1.05–1.25 g/cm³, the rational value of the required grinding degree i should be in the range from 16.0 to 18.1. As a result of the

successive impact of the plume of the working bodies, it is necessary to ensure the value of the coefficient k of ridges in the range of 1.02-1.06, which corresponds to the anti-erosion micro relief index that prevents particles larger than 1 mm in size from rolling freely over the field surface under the action of wind.

The use of a diagram of changes in the main indicators of tillage after the successive impact of various types of working bodies in terms of density, degree of crushing and ridge size should form the basis for the use of digital technologies in the selection of technical means used in anti-erosion technologies of the soil protection system of minimum tillage, taking into account the rational management of field crop rotation.

The use of the developed model software with an automatic control system for a set of technical means based on the selected operational and technological map of the cultivation of agricultural crops will ensure the efficient production of environmentally friendly and high-quality products of the crop complex of the Russian Federation, while the selected set of machines and cultivation technology should have a minimal negative impact on the environment.

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