Greening of processes in soil cultivation

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Abstract. The article analyzes the factors affecting the soil, which directly affect the yield. Modern domestic agricultural machinery mainly has technical and technological solutions that make it possible to significantly advance in the direction of ecological balance of the impact of crop production on soils. These include non-fallow, combined techniques of basic and pre-sowing tillage, as well as the use of a new complex of heavy agrophilic running systems of heavy mobile power facilities.

1 Introduction

The soil is the upper loose layer of the lithosphere. Soil is a three–phase medium comprising solid (mineral and organic particles), liquid (water) and gaseous (air) components. It is a product of the complex interaction of climate, plants, animals and microorganisms.

The soil is constantly evolving and changing, as a result of which there is a wide variety of its types.

Soil fertility determines the excess or lack of humus. The soil is like a living organism, within which complex processes take place. The surface layers of the soil contain the remains of plant and animal organisms, the decomposition of which leads to the formation of humus. Humus is the top fertile layer of the earth. It contains the basic elements of plant nutrition. The main reason for the decrease in the humus content in the soil is the methods of artificially increasing soil fertility (fertilization, land reclamation, etc.) [1, 2].

Mechanical tillage is a very energy–intensive agricultural enterprise characterized by active intrusion into natural ecosystems. Dump treatment is one of the most difficult interventions in the natural structure of the soil, the negative consequences of which are difficult to foresee for a long time. The wind erosion that broke out in the 30s in several countries served as a powerful impetus for the introduction of flat-cut non-fall tillage with the preservation of crop residues. The dramatic history of the introduction of non-tillage tillage is well known in our country. Along with research and development on the system of non-fallow tillage, the main merit of the researchers is that it was shown that it was possible to replace deep tillage in two or three fields of grain-steam crop rotation with peeling; a systematic solution was found to minimize tillage in relation to specific conditions,

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accompanied by a certain proportion of pure steam in the crop rotation, optimally late sowing of rough crops, etc. [3, 4, 5].

Scientists constantly point out the need for a rational combination of dump and non-dump tillage in order to ecologically balance mechanical treatments in relation to southern Russian agricultural landscapes [6].

2 Research methodology

Before considering at least briefly new technical means for the processes of ecologically acceptable and ecologically balanced tillage, let us mention the main functions of tillage [7]:

1. Optimization of soil density and structural condition. On soils whose equilibrium density is close to optimal for the cultivation of specific crops, the loosening function of tillage is reduced, and zero treatment becomes possible. In particular, it can be considered proven that when the content of water-bearing aggregates (soil particles larger than 0.25 mm) exceeds 40% in loamy soils, the possibilities of minimizing tillage increase dramatically.

2. Regulation of the water balance of soils and landscapes. Here, the role of soil treatment is to ensure the transfer of precipitation into the soil column, reduce surface runoff and reduce physical evaporation from the soil surface, especially in conditions of drought. This is complemented by mulching of the soil surface, anti-erosion organization of the territory, forest and other land reclamation.

3. Prevention of soil erosion and deflation. Soil protection from water erosion is entirely related to the regulation of surface runoff, water permeability and the structural condition of soils. Soil protection from deflation is ensured by the preservation of a certain amount of plant residues on the surface; this task is solved by mulching treatments.

4. Regulation of the regime of formation of organic matter and biogenic elements, placement of fertilizers and meliorants in the arable layer. The intensity of mineralization of organic matter in the soil depends on the nature and frequency of mechanical processing. This process is most active when using a plowing system. In extensive agriculture, plowing is the most important means of releasing nutrients from organic matter. Mixing of the soil contributes to the infection of the entire arable layer and to the intensification of the processes of mineralization of organic matter in the entire volume of the soil.

Non-waste treatment, along with the prevention of erosion losses of humus, also ensures a reduction in its biological losses. Further minimization of tillage weakens the processes of mineralization of organic matter.

During mulching treatments, an increase in the content of mobile forms of elements in the upper part of the arable layer is noted. The differential in agrochemical indicators, increasing over time, leads to a shortage of crops compared to plowing. This fact is often considered as a reason for the periodic turnover of the reservoir. However, an alternative is to apply fertilizers to the middle and lower part of the arable layer with combined non-fall tools.

The application of organic fertilizers requires ploughing.

Plowing is also necessary for sealing chemical meliorants. Even chernozems acidify with prolonged minimization of surface treatment.

5. Regulation of phyto-sanitary conditions. Before the advent of pesticides, tillage, along with crop rotation, carried out the main functions of weed control, diseases and pests; at the same time, the turnover of the formation played an important role. The introduction of cloudless treatment in most cases worsens the phytosanitary situation. When processing is minimized, the contamination of crops increases. The development of mulching treatment in erosive conditions was accompanied by the use of pesticides and herbicides. However, this contradicts the objectives of biologization of soil cultivation. But overcoming the contamination of crops can be achieved by using high-precision mechanical action during...
certain periods of vegetation of weeds. The combination of rational alternation of crops in crop rotation, optimization of clean or occupied steam, the use of intermediate crops, accurate (according to agricultural practices) field work can solve the problem without herbicides or with very limited use.

6. Creating optimal conditions for sowing. This function of tillage acquires special importance when using high agricultural technologies. There are no special difficulties in the plowing system, although the use of special planners, sometimes cutters, is required. Certain difficulties arise in the system of mulching treatments: post-harvest residues create a mechanical obstacle to high-quality seed sealing; decomposition of post-harvest residues forms a number of substances harmful to plants. However, in a mulching treatment system, it is important to preserve the mulch after sowing. It is necessary that plant residues are isolated from seeds by clean soil during the sowing process.

7. Energy saving and cost-effectiveness. Minimizing tillage is of particular importance here. The great advantage of minimal and especially zero treatments is fuel economy, reduction of labor costs, and carrying out work in a short time. These advantages, however, are offset by the increased costs of pesticides and the increased cost of technical means. Choosing the optimal solution requires special technical and economic studies.

3 Results and discussion

Currently, a number of research institutes, including VNIPTIMESH, have developed a system of technical means for non-fallow layer-by-layer tillage [8]. Figure 1 shows the UNS-3 unit with a T-150 tractor for non-pile layered continuous tillage to a depth of 45 cm with the preservation of part of the crop residues, the same tool was created for a class 5.0 tractor. Figure 2 shows the KAO-10 g implement for basic non-fallow layer-by-layer tillage to a Class 5.0 tractor.

A working body for basic layer-by-layer tillage is also presented here. The same tool was created for a Class 3.0 tractor. Finally, for shallow tillage (up to 12...14 cm), a combined technical means KUM-4 with a working width of 4 m for a class 3.0 tractor and KM-8 with a working width of 8 m for a class 5.0 tractor has been created (Figure 3). These machines carry out combined layer-by-layer processing using disc working bodies, rigid pointed paws, mulching rollers and rotary levellers. They are designed to prepare the soil for winter crops using non-fallow precursors.

A lot of work in relation to the conditions of the Krasnodar Territory was carried out by prof. E.I. Trubilin [9] on the return of the non-grain part of the grain crop to the soil during processing for the purpose of ecological balance of the soil.

The SibIME team has developed a number of technical means for non-waste, combined ecologically balanced tillage in relation to the conditions of Siberia.

Fig. 1. Unit UNS-3 + tractor T-150 (class 3.0).
Technologies and means of mechanization of fertilizers, herbicides and pesticides are closely related to environmental problems of the environment.

The development of technologies and the improvement of the designs of technical means for surface application of tuks went in the direction of reducing the unevenness of their sieving. By now, the unevenness of the spreading has decreased from 40 to 20 and even 12% over the more than forty-year history of the development and study of ground spreaders. A number of studies have been carried out at a high scientific level, in which the influence of vibrations of frame structures of aggregates due to irregularities of meso- and microrelief on fluctuations in uneven seeding is studied [10]. It should be emphasized that the tasks of reducing the uneven sowing of fertilizers arose not only in connection with the need to equalize the harvest – although this is also an environmental problem, but also in connection with the desire to ensure balanced assimilation of the necessary amount of nutrients by the soil. And the need, or rather the requirement of greening agriculture, led to the processing of differentiated targeted application. This problem was discussed earlier. Here we will only show the general scheme of the unit for the targeted application of tuks, developed by VNIPTIMEX in accordance with the exact requirements of the environment (Figure 4). It was the desire to accurately comply with environmentally sound parameters, in particular, that led to the emergence of precision technologies [11].

The herbicide and pesticide application system has been developing similarly in recent years: an addressable technology based on pattern recognition and high-precision sprayers has been developed. Let us now consider the impact of mobile power systems on the soil as a disturbance of the ecological balance. According to Dr. V.A. Rusanov [7], an increase in pressure on the soil leads to a significant decrease in yield (Table 1).
Table 1. Dependence of yield on soil pressure.

<table>
<thead>
<tr>
<th>Pressure value, kg/cm²</th>
<th>Yield change, %</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>barley</td>
<td>wheat</td>
<td></td>
</tr>
<tr>
<td>Self-sealing of the soil</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>102</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>95</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>90</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>48</td>
<td>68</td>
<td></td>
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</tbody>
</table>

Let's summarize the table data into a graph (Figure 5), from which it can be seen that the yield significantly depends on soil compaction and can reach a drop, for example, barley, up to 52%.

**Fig. 4.** Functional diagram of a machine for targeted application of differentiated doses of mineral fertilizers: 1 – tractor with fertilizer; 2 – loose tuks; 3 – container; 4 – multi-processor; 5 – clogged areas; 6 – eroded areas; 7 – the content of nutrients in the soil; 8 – removal of nutrients from the soil; 9 – suspension of liquid nitrogen fertilizers; 10 – container for liquid fertilizers; 11 – rod; 12 – video camera; 13 – sprayer P1, P2, P3, P4, P5 – processors; BP – memory block; V – video monitor; TA – keyboard.
Fig. 5. Change in yield from soil density.

It was also found that soil compaction by tractors of various classes and brands leads to a shortage of crops in significant quantities (Table 2).

Table 2. Crop shortage of various crops during soil compaction by tractors.

<table>
<thead>
<tr>
<th>Tractor brand</th>
<th>Pressure kPa at ( P_{\text{kp}} = 0 )</th>
<th>Compaction sediment, cm</th>
<th>Compaction multiplicity</th>
<th>Crop shortage, %</th>
<th>Coefficient of variation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTZ-80</td>
<td>150</td>
<td>6.2</td>
<td>1</td>
<td>9.0</td>
<td>80.8</td>
</tr>
<tr>
<td>YMZ-6</td>
<td>2-3</td>
<td>14.1</td>
<td>4-5</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>DT-75</td>
<td>14.1</td>
<td>8.2</td>
<td>1</td>
<td>36.3</td>
<td></td>
</tr>
<tr>
<td>T-74</td>
<td>5.5</td>
<td>13.3</td>
<td>4-5</td>
<td>53.1</td>
<td></td>
</tr>
<tr>
<td>T-150K</td>
<td>180</td>
<td>7.5</td>
<td>2-3</td>
<td>35.4</td>
<td></td>
</tr>
<tr>
<td>K-700</td>
<td>200</td>
<td>8.5</td>
<td>4-5</td>
<td>39.2</td>
<td></td>
</tr>
<tr>
<td>K-700A</td>
<td>2-3</td>
<td>28.0</td>
<td>4-5</td>
<td>29.5</td>
<td></td>
</tr>
</tbody>
</table>

Based on many years of research, VIM has developed so-called agrophilic tires for tractors, grain harvesters and forage harvesters; MES with these tires have significantly less negative impact on the soil. As a result, it turned out to be possible to obtain higher yields (Table 3). Finally, we present the data of Prof. Z.A. Rusanov on the particularly characteristic effect of new running systems on soil condition and the yield of seeded grasses on the example of experiments in the Moscow region (Table 4).

Table 3. Results of experiments on the cultivation of winter wheat using soil-protective movers (Krasnodar region).

<table>
<thead>
<tr>
<th>Propellers</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>serial tires</td>
<td>mock-up profile tires</td>
</tr>
<tr>
<td>The density of the soil in the layer is 0...30 cm, g/cm³</td>
<td>1.23</td>
</tr>
<tr>
<td>Soil hardness in a layer of 0...30 cm, MPa</td>
<td>2.02</td>
</tr>
<tr>
<td>Soil moisture in a layer of 0...60 cm, %</td>
<td>20.8</td>
</tr>
<tr>
<td>Yield of winter wheat, kg/ha</td>
<td>56.1</td>
</tr>
<tr>
<td>SGD_0.5, c/ha</td>
<td>20</td>
</tr>
</tbody>
</table>
The above tables clearly show the environmental efficiency of using new wheel thrusters with wide-profile tires. However, the results of research and development of new wheeled running systems presented here do not fully solve the problem of an ecologically balanced impact on the soil. The fact is that wheel thrusters, in addition to increased soil compaction (now to a lesser extent in the case of using agrophilic tires), produce additional grinding and abrasion of the soil. This happens due to the slipping of the wheels of the undercarriage of a wheeled tractor, which reaches 11% at rated thrust and 17% in extreme cases. Additional energy consumption relative to the technological process is associated, among other things, with additional soil grinding and dust formation. This is confirmed not only by special studies and tests on MIS, but also by production experience. Thus, during the mass transition to the use of wheeled tractors T-150K instead of tracked T-74 in the eighties (and somewhat earlier), the phenomenon of significant fuel overspending and increased dust formation was everywhere noted. Moreover, the designers of KHTZ installed a more powerful 165 hp engine modification on the T-150K wheeled tractor compared to the modification installed on the tracked version of the T-150 ($N = 150$ hp), despite the more complex transmission.

In order to increase the efficiency of using a tracked running system, in an effort to combine the advantages of a caterpillar in the field and its disadvantages compared to a wheel when driving on a hard surface, a number of foreign companies and domestic NATI are developing rubber-reinforced or rubber-metal tracks. In the case of a significant reduction in the cost of such tracks, they will undoubtedly find wide application in the agro-industrial complex.

Finally, the third stage has now begun, relatively speaking, in the search for a balance of environmental requirements, economic efficiency and improvement of the machine use system in relation to running MEA systems.

VNIPTIMEX has developed a light-shift crawler mover for the K-701 tractor. Such a mover is equipped with a 0.67 m wide crawler belt with a total support surface area of 4.0 m²; naturally, it provides significantly less pressure on the soil than any low-profile tires and does not slip [12, 13].

### 4 Conclusion

Modern domestic agroengineering science, in general, has technical and technological solutions to make significant progress in the direction of an ecologically balanced impact on the soil in the production of crop production. This includes non-fallow and combined technologies of basic and pre-sowing tillage, the use of sets of new agrophilic running systems of heavy MES.
References


7. V.A. Rusanov, *The problem of soil re-compaction by movers and effective ways to solve it* (Kolos, Moscow, 1998)


11. V.M. Drincha, *Development of agroengineering science and prospects of agrotechnologies* (VIM, Moscow, 2002)
