Ecological and economic efficiency of tillage resource-saving technologies

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Abstract. Under existing conditions, intensive exploitation of land resources is accompanied by negative changes in agrogenic ecosystems. As a result of the anthropogenic impact on the soil cover, fertility and yield are reduced. To maintain the equilibrium of agrogenic ecosystems from the effects of anthropogenic factors causing soil degradation and loss of its fertility, it is necessary to introduce new technologies that combine safe ecological principles with the production of a stable yield of grain crops. The use of modern technologies of tillage provides the greatest economic effect and is able to increase soil fertility and the level of ecological purity of agricultural products, which is of great importance.

1. Introduction
At present, in the world agricultural practice, the traditional intensive cultivation technologies are replaced by resource-saving technologies for minimal and zero tillage [1]. Resource-saving technologies of tillage arouse increasing interest due to the reduction of energy intensity of production, labour and fuel costs [2].

The production of grain crops is a key area in the agro-industrial complex of the Krasnoyarsk Territory possessing vast sowing areas. The share of the Krasnoyarsk Territory accounts for more than 60% of the produced marketable grain in the East Siberian region [3].

In connection with the aggravation of environmental problems in agriculture and the reduction of soil fertility, with a constant increase in the cost of agricultural production, the question of the active introduction of resource-saving technologies in the Krasnoyarsk Territory arose.

The purpose of the research is an economic and environmental assessment of the use of resource-saving technologies in the cultivation of crops in the Krasnoyarsk Territory.

2. Object and methods of research
Studies were conducted in the period of 2015-2017 on the territory of the Minino experimental farm located 4 km from Krasnoyarsk city.

The paper considers three methods of basic tillage: “classic” autumn ploughing to a depth of 20-22 cm and pre-sowing cultivation in spring, “minimal” consisting of autumn and spring disking with a heavy harrow of 8-10 cm and “zero” (no-till technology) without machining.
3. Results and discussion

The main task of farming is the sustainable production of high-quality and competitive crop products with the preservation and improvement of soil fertility. The dump processing system does not meet modern environmental requirements [4, 5].

Integral indicator and assessment of the use effectiveness of various tillage technologies is the yield of cultivated crops. The impact of the main tillage systems on the yield of grain crops is presented in table 1.

| Crop   | Tillage method   | Year        | Average value | Yield increase |
|--------|------------------|-------------|---------------|---------------|
|        |                  | 2015 | 2016 | 2017 |               |                |
| Wheat  | Ploughing        | 39.5 | 27.0 | 21.9 | 29.47 | no            |
|        | Minimal tillage  | 42.5 | 24.0 | 20.6 | 29.03 | -0.44         |
|        | No-till technology | 41.3 | 28.0 | 21.9 | 30.40 | +0.93         |
| Oat    | Ploughing        | 42.3 | 47.7 | 36.8 | 42.27 | no            |
|        | Minimal tillage  | 41.9 | 42.8 | 33.5 | 39.40 | -2.87         |
|        | No-till technology | 39.6 | 37.8 | 35.1 | 37.50 | -4.77         |
| Barley | Ploughing        | -   | 24.0 | 23.9 | 23.95 | no            |
|        | Minimal tillage  | -   | 23.2 | 24.2 | 23.70 | -0.25         |
|        | No-till technology | -   | 23.2 | 22.0 | 22.60 | -1.35         |

The use of resource-saving technologies of tillage reduces the cost of production for growing crops. The structure of production costs in the cultivation of crops in the conditions of the Krasnoyarsk region forest-steppe landscape is presented in table 2.

| Technology       | Salary | Seeds | Fertilizers and plant protection products | Fuel | Depreciation and current repair | Other costs | Total costs |
|------------------|--------|-------|------------------------------------------|------|---------------------------------|-------------|-------------|
| Ploughing        | 1044.8 | 1760.0 | 2332.0                                  | 1879.1 | 2247.9                          | 214.8      | 9478.7      |
| Minimal tillage  | 771.8  | 1760.0 | 2332.0                                  | 1213.2 | 2104.2                          | 214.8      | 8396.1      |
| No-till technology | 653.3  | 1760.0 | 2332.0                                  | 818.2  | 1961.9                          | 214.8      | 7740.2      |

The use of resource-saving processing technologies significantly reduces production costs, which leads to increased profits and profitability. A high level of profitability of direct sowing is associated with a reduction in the cost of tillage and fuel economy. When using the minimum technology, labour costs are reduced by 35.5%, fuel - by 40.3%, while using the direct sowing technology, labour costs were reduced by 49.1%, fuel - by 64.2% than using traditional technology with autumn ploughing. The level of profitability of grain crops depending on the system of the main tillage is presented in table 3.

| Crop | Tillage method   | Year        | Average value |
|------|------------------|-------------|---------------|
| Wheat| Ploughing        | 154.20 | 73.76 | 40.94 | 89.63 |
|      | Minimal tillage  | 208.77 | 74.37 | 49.66 | 110.93 |
|      | No-till technology | 225.48 | 120.67 | 72.59 | 139.58 |
| Oat  | Ploughing        | 123.13 | 151.62 | 94.12 | 122.96 |
|      | Minimal tillage  | 149.52 | 154.88 | 99.50 | 134.63 |
Anthropogenic interference with the natural environment leads not only to various environmental pollution, but also to climate change. Global climate change is perhaps one of the most important problems of the 21st century. The main cause of warming is the increase in the greenhouse effect due to the increase in the concentration of greenhouse gases in the atmosphere (CO2, CH4, N2O). The main role in the formation of heat traps in the upper atmosphere is played by carbon dioxide [6].

To estimate carbon dioxide emissions from the road transport sector for the fuels used, regional coefficients of conversion of burned fuel to CO2 emissions (calorific net values, carbon emission factors, fraction of oxidized carbon) were calculated [7].

The estimate of carbon dioxide emissions from fuel combustion by road is calculated using the formula:

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E = M \times K_1 \times TH3 \times K_2 \times 44/12, \tag{1}
\]

where \(E\) – annual CO2 emissions in weight units (tons / year); \(M\) – actual fuel consumption per year (tons / year); \(K_1\) – coefficient of carbon oxidation in the fuel (indicates the proportion of carbon burned), for diesel fuel 0.995; \(NCV\) – net calorific value (J / t), for diesel fuel 43.02 TJ / thous. tons; \(K_2\) – carbon emission factor (tons C / J), for diesel fuel 19.98 tC / TJ; 44/12 – coefficient for converting carbon emissions of C to carbon dioxide CO2.

Gas emissions from spent fuel are reduced by 40.3% using the minimum technology and 64.2% using the direct sowing technology (table 4). The use of modern tillage technologies contributes to solving the ecological problems of farming and increasing the level of ecological purity of agricultural products.

Table 4. Evaluation of carbon dioxide emissions from diesel combustion, depending on the technology of cultivation of the soil.

| Tillage method          | Fuel consumption, kg / ha | CO2 emissions in kg / ha |
|-------------------------|---------------------------|-------------------------|
| Ploughing               | 29.3                      | 91.88                   |
| Minimal tillage         | 17.5                      | 54.88                   |
| No-till technology      | 10.5                      | 32.93                   |

Soil cover is the most important carbon storage system in terrestrial ecosystems and contains approximately 75% of the total carbon [8]. The soil cover contains 3.3 times more carbon than the atmosphere (760 Gt) and 4.5 times more than living organisms (560 Gt) [9].

Global soil carbon (C) is 2500 \(\times\) 109 tons (Gt) and includes organic soil carbon of 1,550 Gt and inorganic carbon of the soil of 950 Gt. The soil organic carbon content at a depth of 1 m is 30 t / ha in arid climates and up to 800 t / ha in peat soils in cold regions.

The degradation and dehumidification of arable soil during agricultural exposure led to a decrease in soil organic carbon to 60% in soils in temperate regions and up to 75% or more in tropic soils.

One of the proposed methods for reducing the level of CO2 in the atmosphere is to increase its content in the soil. The average lifetime of carbon in the atmosphere leaves 5 years, 10 years in the plant-related form, and 35 years in the soil cover [10]. The carbon associated with the clay fraction can have an average residence time of 100 – 1000 years [11].

Conversion of atmospheric carbon to plant biomass in its long-term preservation in soil organic matter with minimal risk of immediate return to the atmosphere is designated soil carbon sequestration.
Currently, soil carbon sequestration is the most cost-effective conservation strategy for controlling the content of greenhouse gases in the atmosphere [13].

In the near future, by soil sequestration of organic carbon, it is possible to block the size of CO2 emissions from burning fossil fuels. According to the 4/1000 Initiative for Sustainable Agriculture Development, an increase in soil carbon by just 0.004 percent will stop the current increase in CO2 emissions into the atmosphere [12].

Soil sequestration is a rather new aspect of carbon biogeochemical cycle research within the framework of the problem of global climate change and terrestrial ecosystems [11, 14]. The most commonly used methods for assessing soil carbon sequestration are calculating the balance of organic matter and determining changes in the total content of organic carbon in soil or its reserves over a period of time [15, 16]. The calculations take into account the depth of the determined thickness (usually 20, 40 or 100 cm) and the bulk density of the soil [17].

Calculations were made on the thickness of the arable horizon (0-30 cm). The content of organic carbon in the soil was recalculated from the humus content, using a coefficient of 0.580. Evaluation of soil carbon sequestration depending on the technology of cultivation of the soil is presented in table 5.

Table 5. Assessment of soil carbon sequestration depending on soil cultivation technology.

| Tillage method       | Content of Chumus, g / 100 g | Addition density, g / cm³ | C humus reserves, t / ha | Changes in stocks of C humus, t / ha for 3 years |
|----------------------|-----------------------------|---------------------------|--------------------------|-------------------------------------------------|
|                      | 2014 | 2017 | 2014 | 2017 |                                             |
| Ploughing            | 2.23 | 2.19 | 0.83 | 55.46 | 54.60 | - 0.87                                      |
| Minimal tillage      | 2.29 | 2.31 | 0.99 | 68.05 | 68.56 | 0.52                                        |
| No-till technology   | 2.31 | 2.36 | 1.11 | 76.88 | 78.61 | 1.74                                        |

Organic carbon in soil is a valuable and renewable resource, increasing its content contributes to improving the environmental situation. Therefore, society should consider resource-saving technologies as one of the ways to improve the environmental situation and solve the problem of global climate change.

4. Conclusion

The use of resource-saving processing technologies significantly reduces production costs. Resource-saving technologies offer an important alternative approach, combining safe environmental principles with the production of a stable crop of grain crops. The use of modern technologies of tillage will provide the greatest economic effect and, most importantly, can increase soil fertility and the level of ecological purity of agricultural products.

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