Efficiency of biologization of agriculture in Western Siberia  
(on the example of the Omsk region)

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Abstract. Biological intensification of agriculture is one of the main factors in maintaining soil fertility and optimizing the mineral nutrition of plants, while ensuring an increase in crop yields and improving the quality of farmed products while saving resources and environmental safety. On the basis of studying the effectiveness of biologization techniques in agriculture of the chernozem forest-steppe of Western Siberia (on the example of the Omsk region), the optimal options for the rational use of fertilizers in combination with local biological resources, which reduce the dose of fertilizers and increase the return on additional products, are determined. The environmental focus of research associated with the study of the possibility of maximum involvement of biological resources in the region’s agriculture is undoubtedly relevant in modern conditions.

1. Introduction

In modern conditions, an increase in crop production is possible due to the intensification of agricultural production through the use of scientifically based fertilizer systems, thus ensuring not only increased crop yields, but also conservation, as well as increased soil fertility and ecological balance of agrolandscapes [1, 2].

Currently, in agricultural production due to the shortage of nutrients and their constant alienation from the crop, with a small amount of application of mineral fertilizers, for example, in the Omsk region about 2 kg of a.v. / ha of arable land are brought in, as well as their high cost and economic condition farms there is an urgent need to search for alternative means and methods of preserving and increasing soil fertility from sources of biological origin.

The use of biological resources provides for the optimization of the structure of sown areas, the use of crop rotation with legumes and perennial grasses, the use of organic and bacterial fertilizers. Moreover, the priority in the use of already known agrobiological agents and techniques does not reduce the significance of the use of chemical and technogenic factors [1, 4].
In this regard, issues of developing the integrated use of mineral fertilizers and biological resources in agriculture, cost-effective techniques and systems for their application of crop rotation, taking into account soil and climatic conditions and agroecological factors, are of particular importance.

2. Purpose of study
The purpose of this study is the economic justification and the study of practical methods of using biological resources on chernozem soils of Western Siberia in combination with chemicals that ensure the conservation of soil fertility and increase the productivity of agrophytocenoses. To achieve the goal, bioenergy and economic estimates of the use of agrobiological resources in the forest-steppe of Western Siberia (based on the example of the Omsk region) were calculated.

Objects and research methods. The studies were conducted on the experimental field of the laboratory of agrochemistry of the Federal State Budget Scientific Institution Omsk ANC in 1991-2009. It should be noted that only the research results, the established relationships and patterns obtained in long-term stationary experiments provide objective information on the effectiveness of the studied factors and can be extrapolated to agriculture in Western Siberia. This territory belongs to the southern part of the forest-steppe zone of the West Siberian lowland on stationary experiments based on a six-field grain-grass (1986 bookmark) and a five-field grain-park (1987 bookmark) crop rotation. Crop rotation: alfalfa 3 years of use - wheat - wheat - oats and steam - wheat - soybeans - wheat - barley, respectively. Crop rotations are deployed in time and space.

The experimental plot is represented by leached “chernozem”, medium-power, medium-humus, medium-loamy, heavy loam, with an average content of mobile phosphorus, very high - exchange potassium, and the reaction of the medium is close to neutral (pHsalt - 6.7).

The experimental designs are presented in tables 1 and 2. The total area of the plots is 160-200 m², accounting 36.0-51.2 m², with a systematic placement in 4-fold repetition. As fertilizers, Naa, AF and Kx were used. Phosphorus fertilizers were applied locally in the spring before sowing, to a depth of 6-8 cm, ammonium nitrate and potassium chloride - scattered under pre-sowing cultivation. Half-rotted litter manure (at a dose of 60 t/ha) was introduced in the fall after harvesting the trailing crop (oats) once per rotation. Grain straw was crushed during harvesting and left in the field in an amount corresponding to its harvest.

In all experiments, the traditional technology of cultivating grain, fodder, and leguminous crops was used. With appropriate serial sowing technology. Sowed crops of zoned varieties.

3. Results
In modern agriculture, the development of alternative agricultural technologies of agricultural crops focused on the biologization of farming systems is of great importance. Biological technologies do not provide for a complete rejection of mineral fertilizers, but imply a reasonable combination of environmentally friendly techniques of agricultural technology with agrochemical and biological agents [1].

The development of biological resources to preserve soil fertility and increase the productivity of agrophytocenoses should be based on improving the structure of sown areas, the development of crop rotation with perennial leguminous grasses and their mixtures with bluegrass, the use of organic (manure, straw) and bacterial fertilizers, cultivation of agrochemically effective varieties and hybrids.

Currently, there are not enough materials available for a full-fledged analysis of biologized fertilizer application systems from the perspective of economic efficiency, since they do not reveal their profitability in terms of net income, cost and profitability of invested material resources in their implementation [3, 6]. In recent years, due to the intensification of agricultural production and the exponential increase in the cost of non-renewable energy, including the use of chemicals, as well as due to the instability of the economy, when evaluating the effectiveness of individual agricultural practices and technologies as a whole, they are increasingly used along with traditional economic indicators [3] a bioenergy or energy efficiency assessment, which consists in comparing the amount of accumulated biological energy with the cost of anthropogenic [5]. In this case, the payback of the produced energy (energy coefficient - η) is calculated for all energy costs, including additional, associated with one or
another agricultural reception, as well as net income (profit) or gross energy increment. Such a comprehensive assessment (agronomic, economic and energy efficiency) of the use of means of biological intensification of production improves the objectivity of the conclusions made as a result of research.

The calculation of the economic efficiency of the use of chemicals in combination with the methods of biologization of agriculture was carried out in accordance with the methodology, at prices for crop products, fertilizers and plant protection products at the end of the research work [3]. Initial data on economic efficiency were obtained by calculating technological maps of cultivated crops in agroecosystems for each option, in accordance with the applicable technical means and agricultural production conditions in the southern forest-steppe of Western Siberia.

An economic assessment of the use of mineral fertilizers, manure, straw in the system of grain-grass crop rotation showed that with an increase in the total fertilizer rate per 1 ha of crop rotation, the profitability level decreased, the cost of both grain and all crop production in terms of grain units increased (table 1, 2).

The maximum level of profitability is 83 and 192% and profit is 3416; 5175 rub/ha, respectively, obtained on the option of making chopped straw during harvesting. The lowest economic indicators were obtained with the combined use of manure and mineral fertilizers (N28P65K28 + manure). Profit from grain production amounted to 1152 rubles/ha, profitability - 14%.

Table 1. The economic efficiency of the use of mineral and organic fertilizers in grain-grass rotation (1991-2009).

| Option                  | Productivity t/ha of grain | Cost gross output, rub | Cost price, rub/t | Profit, rub/ha | Profitability, % |
|-------------------------|---------------------------|------------------------|-------------------|---------------|-----------------|
| No fertilizer           | 2.05                      | 7034                   | 1974              | 2987          | -               |
| Straw                   | 2.20                      | 7548                   | 1878              | 3416          | 83              |
| Manure                 | 2.35                      | 8063                   | 2314              | 2648          | 49              |
| Manure+Straw           | 2.34                      | 8028                   | 2312              | 2618          | 48              |
| N13P45                 | 2.36                      | 8097                   | 2483              | 2228          | 38              |
| N13P45+Straw           | 2.44                      | 8372                   | 2421              | 2465          | 42              |
| N13P45+Manure          | 2.52                      | 8646                   | 2835              | 1502          | 21              |
| N13P45+Manure+Straw   | 2.55                      | 8449                   | 2816              | 1268          | 18              |
| N28P65K28              | 2.68                      | 9195                   | 2616              | 2183          | 31              |
| N28P65K28+Straw       | 2.68                      | 9195                   | 2616              | 2183          | 31              |
| N28P65K28+Manure      | 2.74                      | 9401                   | 3011              | 1152          | 14              |
| N28P65K28+Manure+Straw| 2.76                      | 9470                   | 2989              | 1221          | 15              |
| Average manure factor  | 2.40 a                    | 8240 a                 | 2331 a            | 2577 a        | 33 a            |
|                        | 2.54                      | 8676                   | 2713              | 1735          | 28              |
| Average straw factor   | 2.45 a                    | 8406 a                 | 2539 a            | 2117 a        | 38 a            |
|                        | 2.50                      | 8510                   | 2509              | 2195          | 40              |

* in the numerator with fertilizer, in the denominator without fertilizer.

Table 2. Economic efficiency of the use of mineral and organic fertilizers in grain-grass crop rotation (1991-2009).

| Option                  | Productivity t/ha of grain | Cost gross output, rub | Cost price, rub/t | Profit, rub/ha | Profitability, % |
|-------------------------|---------------------------|------------------------|-------------------|---------------|-----------------|

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Table 3. Rating assessment of the use of mineral and organic fertilizers (manure, straw) in the grain-grass rotation (1991-2009).

| Option                  | Profit from 1 ha, % of control | Index cost recovery | Cost price, % to control | Rating |
|-------------------------|--------------------------------|---------------------|--------------------------|--------|
| No fertilizer           | 1 a                            | 2 b                 | 1 a                      | 2 b    | 1 a | 2 b |
| Straw                   | 2.26                           | 7425                | 2.13                     | 7425   | 1246| 4770| 180|
| Manure                  | 2.51                           | 8750                | 2.51                     | 8750   | 1591| 4757| 119|
| Manure + Straw          | 2.45                           | 8541                | 2.45                     | 8541   | 1621| 4570| 115|
| N_{13}P_{45}            | 2.49                           | 8680                | 2.49                     | 8680   | 1781| 4244| 96  |
| N_{13}P_{45} + Straw    | 2.54                           | 8854                | 2.54                     | 8854   | 1754| 4398| 99  |
| N_{13}P_{45} + Manure   | 2.69                           | 9377                | 2.69                     | 9377   | 2123| 3666| 64  |
| N_{13}P_{45} + Manure + Straw | 2.70       | 9412                | 2.70                     | 9412   | 2116| 3698| 65  |
| N_{28}P_{65}K_{28}      | 2.82                           | 9831                | 2.82                     | 9831   | 1955| 4318| 78  |
| N_{28}P_{65}K_{28} + Straw | 2.87          | 10004               | 2.87                     | 10004  | 1927| 4474| 81  |
| N_{28}P_{65}K_{28} + Manure | 2.96         | 10318               | 2.96                     | 10318  | 2285| 3554| 53  |
| N_{28}P_{65}K_{28} + Manure + Straw | 2.99  | 10423               | 2.99                     | 10423  | 2252| 3690| 55  |
| N_{28}P_{65}K_{28} + Manure + Straw | 3.00  | 10533               | 3.00                     | 10533  | 2252| 3690| 55  |
| N_{28}P_{65}K_{28} + Manure + Straw | 3.01  | 10643               | 3.01                     | 10643  | 2252| 3690| 55  |

Rating evaluation of fertilizer application efficiency in crop rotation proposed by B.S. Koshelev [3], allows not to differentiate, but in conjunction with economic indicators and the output of crop production from 1 ha, to evaluate and highlight the most acceptable version of the fertilizer application system in crop rotation (table 3).
According to calculations, the most effective economic indicator is the option of making straw. The following position is shared by the options of introducing manure and cultivating crops without the use of fertilizers.

Manure has good fertilizing properties in terms of increasing productivity and preserving soil fertility, but science and practice have long established that it is not economically feasible to use manure further than 5 km from livestock complexes, which limits its widespread use in crop production.

The cultivation of crops without the use of fertilizers causes irreparable damage to soil fertility, but science and practice have long established that it is not economically feasible to use manure.

In previous chapters, we found that the rational use of fertilizers in combination with straw has a positive effect on the nutritional regime of plants. This is due to the high energy costs (27.68 GJ / ha) for the introduction of manure and the insufficient increase in the energy content in the crop in these agroecosystems, necessary to cover the costs of technogenic energy for production. There are significant differences in the energy content of the main products.

The bioenergetic assessment of crop cultivation in a grain-grass crop rotation with different levels of biologization indicates that the maximum level of man-made energy costs was obtained using options using manure (table 4).

### Table 4. Bioenergy efficiency of fertilizer application in grain-grass crop rotation (1991-2009).

| Option                        | Expenses total energy, GJ/ha | Gross output energy in the crop, GJ/ha | Increment gross energy, GJ/ha | Energetic coefficient (tJ) |
|-------------------------------|-----------------------------|----------------------------------------|-------------------------------|---------------------------|
| No fertilizer                 | 18.06                       | 33.44                                  | 15.38                         | 1.85                      |
| Straw                         | 16.91                       | 35.88                                  | 18.97                         | 2.12                      |
| Manure                        | 27.68                       | 38.33                                  | 10.64                         | 1.39                      |
| Manure + Straw                | 26.14                       | 38.17                                  | 12.03                         | 1.46                      |
| N<sub>13</sub>P<sub>35</sub>   | 19.39                       | 38.49                                  | 19.10                         | 1.99                      |
| N<sub>13</sub>P<sub>35</sub>+ Straw | 19.51                      | 39.80                                  | 20.29                         | 2.04                      |
| N<sub>13</sub>P<sub>35</sub>+ Manure | 30.17                      | 41.10                                  | 10.93                         | 1.36                      |
| N<sub>13</sub>P<sub>35</sub>+ Manure + Straw | 28.69                      | 41.57                                  | 12.88                         | 1.45                      |
| N<sub>28</sub>P<sub>66</sub>K<sub>28</sub> | 23.18                      | 43.71                                  | 20.53                         | 1.89                      |
| N<sub>28</sub>P<sub>66</sub>K<sub>28</sub> + Straw | 21.44                      | 43.71                                  | 22.27                         | 2.04                      |
| N<sub>28</sub>P<sub>66</sub>K<sub>28</sub> + Manure | 32.31                      | 44.69                                  | 12.38                         | 1.38                      |
| N<sub>28</sub>P<sub>66</sub>K<sub>28</sub> + Manure + Straw | 30.57                      | 45.02                                  | 14.45                         | 1.47                      |
| Average manure factor         | 19.75<sup>a</sup>           | 39.17<sup>a</sup>                      | 19.42<sup>a</sup>             | 1.99<sup>a</sup>          |
| Average straw factor          | 29.26                       | 41.48                                  | 12.22                         | 1.42                      |
| Average straw                 | 25.13<sup>a</sup>           | 39.96<sup>a</sup>                      | 14.83<sup>a</sup>             | 1.64<sup>a</sup>          |

<sup>a</sup> in the numerator with fertilizer, in the denominator without fertilizer.

This is due to the high energy costs (27.68 GJ / ha) for the introduction of manure and the insufficient increase in the energy content in the crop in these agroecosystems, necessary to cover the costs of technogenic energy for production. There are significant differences in the energy content of the main products. Thus, the highest energy content was noted on the variant with the maximum saturation of a hectare of arable land with fertilizers (N<sub>28</sub>P<sub>66</sub>K<sub>28</sub> + manure + straw) - 45.02 GJ/ha, the lowest on the variant without fertilizers - 33.44 GJ/ha.

When applying straw in the crop rotation, there is a tendency to increase the yield of cultivated crops, however, the use of this organic fertilizer in agricultural production reduces energy costs by an average of 1.25 GJ/ha and an increase in incremental energy by 1.98 GJ/ha compared to the version without straw.
The analysis of energy coefficients showed that the energy accumulated in the crop yield in all variants of experience is significantly higher than that spent on production. The largest value of the energy coefficient ($\eta$) in the variant of applying only straw is 2.12; fertilizer systems providing for the application of mineral fertilizers in combination with straw are not significantly inferior to it ($\eta=2.04$).

The process of production in crop rotation with different levels of biologization can be considered energetically favorable, since in all cases the energy coefficient is $\eta>1$, since the energy spent on production is completely blocked by the energy received from the crop.

Thus, based on the economic and bioenergy assessment of biologized fertilizer application systems in grain-grass rotation, it has been established that it is economically feasible to introduce mineral fertilizers in a dose of not more than 60 kg dv/ha in combination with straw chopped during harvesting. The effectiveness of the integrated use of mineral fertilizers and manure is significantly inferior to similar options with straw.

4. Conclusion

Based on the study of the effectiveness of biologization techniques in the region’s agriculture, the optimal options for the rational use of fertilizers in combination with local biological resources are determined, indicators of more complete use of the species and varietal diversity of cultivated plants are established, which allow lowering the dose of fertilizers and increasing the return on additional products. All this has a positive effect on product quality, soil fertility and economic performance of agricultural enterprises.

Economic and bioenergy calculations indicate the effectiveness of the use of biologized fertilizer systems in crop production. The use of the organomineral ($\text{N}_{12.17}\text{P}_{18.45} + \text{straw}$) fertilizer system in crop rotation ensures the conservation of soil fertility, increases productivity by 15-20% and economic production efficiency.

Currently, research on the topic continues in extended stationary experiments, the results of lengthy studies are analyzed with the available data and will be presented in publications.

Let us consider the problem of design of the optimal sequence for servicing the requests for repair according to the criterion $F_T(\pi) = \sum_{k=1}^{n} \varphi_k(x)$, where $\varphi_k(x) = \max(x - T_k, 0)$, $k = \overline{1, n}$, $x$ is a moment for completion of servicing the request.

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