Economic efficiency of using urban sewage sludge in combination with zeolite-containing agricultural ore at cultivating crops of grain fallow row-crop rotation

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Abstract. Further intensification of agricultural production and crop yield growth will be accompanied by an increase in the cost of non-renewable energy, including through the increasing use of fertilizers. Therefore, in the future, it is important to develop and use energy-efficient production technologies that use less energy to produce agricultural products. The paper shows the influence of reclamation norms of urban sewage sludge (USS) and their combinations with natural zeolite on the economic efficiency of growing crops of grain fallow row crop rotation. Studies showed that the use of urban sewage sludge as a fertilizer and the integrated use of USS with zeolite-containing agricultural ore pay off economically. The maximum net income was provided by the combined application of urban sewage sludge at the rates of 160 and 180 t/ha in combination with zeolite. The amount of conditional net income from their application was 13.51-13.62 thousand rubles/ha.

1. Introduction

Currently, the involvement of non-traditional mineral resources, which Russia is rich in, in the sphere of agricultural production, is becoming more and more urgent. These materials include, first of all, nanostructured highly siliceous rocks, such as opal cristobalite (gaize, terra silicea, diatomites) and zeolites [1-4].

For effective use of various means of biologization and melioration, in order to increase the productivity of agroecoses, it is necessary to develop agricultural and biological bases of technological techniques that allow optimizing their use on the basis of a systematic approach to the study of soil fertility. The development of technological methods for increasing the productivity of agricultural crops should be associated with specific soil and climate conditions, environmental restrictions, taking into account their energy intensity and energy efficiency [5, 6].

In this regard, the development and implementation of technological methods to increase the productivity of agroecoses in agricultural landscapes with the economical use of resources is an actual direction of modern agriculture.

According to Soviet and foreign scientists, the share of fertilizers in the formation of the entire crop is 30-50%, in obtaining an increase in the crop – 50-80%. The cost of their use varies between 10-25% of all costs in crop production. However, in order to select and implement the most effective norms, forms, methods and terms of application of fertilizers, their economic assessment is necessary [7, 8]. In the Russian Federation, the use of local raw materials and agricultural ores is limited, so there is a
need for scientific justification of the development and application of methods of agricultural, biological and chemical reclamation of Chernozem soils of the forest-steppe Volga region, as well as their environmental and economic assessment [9].

The urbanization of the world’s population leads to the constant accumulation of huge amounts of organic waste, including municipal waste, in the form of sewage sludge, which is practically not used anywhere and is excluded from the biological cycle of substances in agriculture [10, 11]. Taking into account international experience, it is possible to consider the use of up to 1 million tons (in terms of dry matter) of generated sewage sludge (SS) as an organic and mineral fertilizer [1]. In Russia, about 10% of SS is processed, which, due to a decrease in fertilizer production, can to a certain extent fill the acute deficit balance in nitrogen, phosphorus, organic matter and a number of other ingredients, including trace elements [12]. The introduction of biological ameliorant helps to equalize the negative balance of nutrition elements in the soil when they are taken out by plants, as well as to change the ratio of the processes of mineralization and huminification of plant residues [13]. Research on agricultural utilization of SS carried out in Russia and abroad [14] show that a differentiated approach to their use as a fertilizer is required, as sewage sludge is individual in composition. The feasibility of using SS depends on the composition, type of soil, cultivated crops, etc. [15, 16].

2. Materials and methods

Research on the impact of reclamation regulations of sewage sludge the city of Penza in pure form and in combination with zeolite on economic efficiency of cultivation of grain crops of a grain fallow crop rotation was conducted on the collection site of Penza SAU in the period from 2014 to 2018. To solve the set task the field experiment was laid according to the scheme: 1. Without SS and zeolite (control); 2. Zeolite 10 t/ha; 3. SS 100 t/ha; 4. SS 120 t/ha; 5. SS 140 t/ha; 6. SS 160 t/ha; 7. SS180 t/ha; 8. SS 100 t/ha + zeolite 10 t/ha; 9. SS 120 t/ha + zeolite 10 t/ha; 10. SS 140 t/ha + zeolite 10 t/ha; 11. SS 160 t/ha + zeolite 10 t/ha; 12. SS 180 t/ha + zeolite 10 t/ha.

The repeatability of the experiment is three-fold, the variants in the experiment are placed by the method of randomized repetitions, and the accounting area of one plot is 4 m². The object of the study was grain fallow crop rotation: bare fallow, winter wheat, corn, spring wheat, oats.

In the experiment, we used sewage sludge from Penza, which is characterized by the following indicators: pH value – 6.0 units, hydrolytic acidity – 2.4 mg-EQ/100 g of sludge, and the sum of exchange bases – 31.6 mg-EQ /100 g of sludge. The content of food elements: nitrogen - 291, phosphorus - 116 and potassium - 120 mg/100 g of sludge; carbon of organic matter - 21.2 %. Zeolite ore with a content of 41% clinoptilolite was used as a chemical ameliorant in the experiment.

When determining the actual economic efficiency of individual crops, the yield increase was estimated at current prices. This makes it possible to identify the feasibility of investing in the resulting crop increase from fertilizers.

The evaluation of the effectiveness of fertilizers is expressed by the increase in yield, the payback of the unit of applied fertilizers, the amount of net income and profitability. In our research, after determining the increase in crop yield of crop rotation, a monetary assessment was carried out at purchase prices. The cost of obtaining this increase included: a) the cost of fertilizers at wholesale prices; b) the cost of delivery and application of fertilizers (per 1 hundredweight), and c) the cost of cleaning and improving additional products. At the same time, the costs of urban sewage sludge and zeolite-containing agricultural ore were attributed to three subsequent crop rotation crops.

3. Results

Further intensification of agricultural production and crop yield growth will be accompanied by an increase in the cost of non-renewable energy, including through the increasing use of land reclamation and fertilizers. Therefore, in the future, it is important to develop and use energy-efficient production technologies that use less energy to produce agricultural products.

Analysis of the actual payback, payment and economic efficiency of fertilizer use allows identifying reserves for their increase in agricultural production at different levels of management:
farm, district, region. The economic efficiency of mineral and organic fertilizers is determined for individual crops. The average indicators of economic efficiency of fertilizers are determined by the entire crop industry.

When determining the actual efficiency of fertilizer use, the calculations are based on the amount of fertilizers entered for the corresponding crop and statistical and accounting data on crop yields, production costs, sales prices, labor costs, and so on. The most stable and objective indicators of the effectiveness of fertilizers are obtained by analyzing data on yields and increases, revenues and costs for four to five years or more.

The most reliable method for evaluating the effectiveness of used fertilizers is production experience. In this case, all factors (soil fertility, its processing, terrain, cultivated crop variety, predecessor, agricultural technology), in addition to the studied, must be compared, i.e. the principles of the only difference must be strictly observed.

The calculation of economic efficiency showed that only the introduction of zeolite at the rate of 10 t/ha provided additional profit in the amount of 2.61 thousand rubles/ha. The effect and aftereffect of urban sewage sludge without zeolite and in combination with zeolite allowed getting additional profit, depending on their norms in the amount of 6.53-10.29, and depending on combinations with zeolite – 9.59-13.62 thousand rubles/ha. Moreover, the maximum income was provided by the joint application of urban sewage sludge rates of 160 and 180 t/ha with zeolite. The amount of conditional net income from their implementation was 13.51-13.62 thousand rubles/ha (table).

**Table 1. Economic efficiency of the use of USS and zeolite.**

| Variant | Cost increase in the crop yield, thousand rubles/ha | Increase costs, thousand rubles/ha | Notional net income, thousand rubles/ha |
|---------|----------------------------------------------------|-----------------------------------|----------------------------------------|
| 1. Without zeolite and USS (Control) | – | – | – |
| 2. Zeolite 10 t/ha | 5.46 | 2.85 | 2.61 |
| 3. SS 100 t/ha | 11.46 | 4.93 | 6.53 |
| 4. SS 120 t/ha | 13.56 | 5.70 | 7.86 |
| 5. SS 140 t/ha | 14.82 | 6.12 | 8.70 |
| 6. SS 160 t/ha | 17.04 | 6.84 | 10.20 |
| 7. SS180 t/ha | 17.16 | 6.87 | 10.29 |
| 8. SS 100 t/ha + zeolite 10 t/ha | 16.56 | 6.97 | 9.59 |
| 9. SS 120 t/ha + zeolite 10 t/ra | 18.06 | 7.52 | 10.54 |
| 10. SS 140 t/ha + zeolite 10 t/ha | 19.80 | 8.09 | 11.71 |
| 11. SS 160 t/ha + zeolite 10 t/ha | 22.32 | 8.81 | 13.51 |
| 12. SS180 t/ha + zeolite 10 t/ha | 22.50 | 8.88 | 13.62 |

4. **Summary**
An alternative to mineral and organic fertilizers can be the use of sewage sludge and zeolite-containing agricultural ores as non-traditional fertilizers. At the same time, the problem of their utilization is being solved. Silt sludge of urban sewage contain a wide range of trace elements necessary for the full growth of all types of crops, and are a valuable organic and mineral fertilizer. SS is particularly rich in nitrogen and digestible phosphates. The analysis of economic efficiency confirms the feasibility of using USS, zeolite and their combinations to increase and stabilize the fertility of meadow-chernozem soil and increase the productivity of agricultural crops.

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