

Assessment of environmental stability of agroserous soil according to indicator of energy potential of organic substances

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Abstract. Studies of the group and fractional composition of humus have determined that the long-term use of soil (for 20 years) without the use of fertilizers (control) leads to a decrease in the content of humic acids and fulvic acids relative to the initial soil, which indicates an increase in mineralization of the soil humus. Under the influence of a long application of high doses of mineral fertilizers, the content of mobile fractions of humic and fulvic acids in the field rotation increases in the humus content. In systems of agriculture that are not balanced by organic matter, which are predominant in most farms of the Republic of Tatarstan, the use of very high doses of potassium fertilizers is not justified energetically. To compensate for losses of humus and its energy potential in calculating organic fertilizers on backgrounds with high doses of mineral fertilizers, the humification coefficients of organic residues should be increased by 30-40% during the rotational period of 5-6 years, which will reduce the loss of energy reserves and thereby improve the ecological stability of soils and the stability of agricultural landscapes

1. Introduction

The characteristics and direction of the matter flows and energy in the ecosystem, which take part in forming of soils fertility, stability and its productivity level, is determined by the qualitative and quantitative composition of the soil organic matter [1]. The energy function of the soil is related to the energy of its organic and mineral parts. Humus also retains a free form of energy, which can perform work without reducing the entropy of soils [2].

The organic matter of the soil is a source of energy for the organisms inhabiting the soil and it supplies plants with basic nutrients. The energy potential of the organic matter of the soil determines its fertility and ecological stability. To assess the potential of soil resources, to study the ecological capacity and bioenergy potential of the territory, it is necessary to determine the energy potential of the organic matter of the soil.

Evaluation of the humus state of agrogenic soils and the energy potential of humus and organic substances in the ones which are used in systems of agriculture that are not balanced by organic matter with intensive application of mineral fertilizers presents both scientific and practical interest. Scientifically substantiated solution of these issues is also significant for developing fertility models of agrogenic soils and developing techniques for increasing their environmental sustainability [3].

In modern agriculture, agro-forest soils of arable land are subjected to great anthropogenic pressure and, according to a number of researchers, the intensive use of mineral fertilizers contributes to the destabilization of the humus state of soils [4, 5].

The assessment of the ecological stability of the agro-forest soil in terms of the energy potential of its organic substances during the long-term intensive application of mineral fertilizers in the conditions



of stationary field experience in the Prekamje region of the Republic of Tatarstan is carried out for the first time.

2. Materials and methods

For the statistical evaluation of humus content in arable agroseric soils of the Prekamje region of the Republic of Tatarstan, soil and agrochemical survey materials were used. Field experience included studying efficiency of various doses of potassium (40, 80, 120, 160, 200 kg/ha) in nitrogen supply at three levels of soil (60, 120, 180 kg/ha).

Field experiment was organized in 1992 on agroseric soil of the stationary experimental field of the Department of Agrochemistry and Soil Science of the Kazan State Agrarian University in the conditions of field crop rotation with grain crops. Alternation of crops in crop rotation was as follows: 1. Spring wheat; 2. Barley; 3. Oats; 4. Fallow land; 5. Winter rye.

The soil of the experimental plot is agros and medium loamy, before the beginning of the experiment it was characterized by the following agrochemical indicators: the content of humus - 2.8-3.5%; the amount of exchange bases 19-25 mg/eq; hydrolytic acidity 3-4 mg/eq; the degree of saturation with bases 77-85%; pH of sol. 5.5-6.0; the content of mobile forms of phosphorus and potassium - 100-120 and 110-130 mg per kg of soil, respectively, i.e. it is medium provided by these elements of nutrition.

In order to assess the ecological stability of the soil in intensive farming 20 years after the completion of the 4th rotation of the crop rotation, we studied the humus condition of soils under control (without fertilizers) and in variants of the experiment with fertilizers, and the calculation of the energy potential of organic substances was carried out. The content of humus in the soil was determined by I.V. Tyurin in the modification of Simakov, the group and fractional composition of it - according to the method of B. B. Ponomareva and Plotnikova. Evaluation of the energy potential of organic substances in agroseric soil was conducted by the method of Volodin V.M. and Vasyutenko N.P. (2005), using the data on humus content, soil density and crop yields.

3. Results and discussion

The generalization and statistical evaluation of soil and agrochemical survey data on the Prekamje region of the Republic of Tatarstan showed a decrease of humus content and reserves in gray forest soils in recent years. The obtained factual material in the field experiment indicates significant changes in the humus state of the soil as a result of prolonged application of fertilizers [6,7].

Calculations of the humus balance in the soil of various variants of the experiment with fertilizers have shown that over 20 years of use, a negative balance of humus is formed in it, both while using fertilizers and without them.

Mineral fertilizers contributed to the enhancement of mineralization of humus. The change in the parameters of the qualitative composition of humus is shown in table 1, from which it can be seen that the soil before the experiment was characterized by the predominance of humic acids over fulvic acids, while the ratio of GK to FK is 1.2, which is typical for arable gray forest soils in the republic [8].

Long-term use of soil (for 20 years) without using fertilizers (control) leads to a decrease in the content of humic acids and fulvic acids relative to the initial soil, which indicates an increase in mineralization of soil humus. The type of humus at the same time remains the same (fulvate-humate), but with depth the content of fulvic acids increases, and humic - decreases.

In the experiment with fertilizers, 1000 kg of nitrogen, 1000 kg of phosphorus and 2000 kg of potassium were applied to the soil over 20 years of experience. Such a high saturation of the crop rotation with mineral fertilizers contributed to a decrease in the content of GK in humus and an increase in the content of FA.

- **Table 1.** Dynamics of group and fractional composition of humus in agroserous soil under the influence of intensive application of fertilizers (% of C_{org}).

Horizon	Humic acids				Fulvic acids					The sum of acids	CGK/CFK	Humin
	GK*-1	GK -2	GK -3	Total	FK* - 1a	FK -1	FK -2	FK -3	Total			
Initial Soil												
PY	3.4	29.5	7.1	40.0	4.2	10.4	11.7	7.2	33.5	73.5	1.2	26.5
ELB	2.2	27.5	5.2	34.9	6.9	8.5	10.3	9.8	35.5	70.4	1.0	29.6
B1	1.3	24.7	8.7	34.7	9.5	9.9	9.0	11.2	39.6	74.3	0.9	25.7
Control (without fertilizer)												
PY	1.4	26.5	10.1	38.0	4.0	8.4	10.9	7.0	31.3	69.3	1.2	30.7
ELB	1.2	24.6	4.2	32.0	8.0	13.0	9.4	5.6	35.0	67.0	0.9	33.0
B1	1.7	23.0	6.0	31.7	7.2	10.9	9.0	11.5	38.6	70.3	0.8	29.7
Long-fertilized soil (Variant N ₆₀ P ₆₀ K ₁₂₀)												
PY	8.0	22.5	5.0	35.5	9.0	15.0	7.0	4.5	35.5	71.0	1.0	29.0
ELB	9.0	16.0	3.0	28.0	10.0	16.0	6.0	3.0	35.0	63.0	0.8	37.0
B1	11.0	12.0	3.0	26.0	11.0	10.0	5.0	12.0	38.0	64.0	0.7	36.0

Note. * GK -humic acids, FK -fulvic acids

The ratio of GK to FK was reduced from 1.2 in the initial soil to 1.0, which indicates that under the influence of fertilizers more acidic humus is formed in the plow layer. Changes in the quality of humus are associated with an increase in mobile first fractions of GK and FK, as well as a decrease in the content of the most agronomically valuable fraction associated with calcium (GK-2).

Our studies show a decrease in the content and reserves of humus in the soil under the effect of prolonged use of mineral fertilizers in the crop rotation, which undoubtedly leads to structural changes in energy and mass content.

The energy potential of soil organic matter is represented by the energy potential of humus, which is characterized by the parameters of the energy potential of inert and labile humus, the energy reserve of unguilified organic substances and an additional energy reserve in the form of microbial bodies and the energy of soil reactions.

The calculation of the dynamics of the energy potential of organic substances in gray forest soils used in grain-crop rotation for 20 years shows (table 2) that both in control and in experiments with fertilizers, as humus stocks decrease, structural changes occur in the energy potential of organic soil substances.

Table 2. Structure of the loss of the energy potential of organic substances in the agro-soil of agrocenoses under the influence of fertilizers over 20 years, GJ/ha.

Options	The loss of energy reserves in humic substances	The loss of energy reserves in inert humus	Loss of energy reserve labile humus	The loss of energy in non-humified organic substances	Additional energy losses	Total loss of energy potential of soil organic matter
Control	54.1	50.9	3.24	1.3	4.8	60.3
N ₆₀ P ₆₀ + K ₄₀	90.9	85.5	5.45	2.3	6.8	100.3
N ₆₀ P ₆₀ + K ₁₂₀	174.8	163.7	10.5	4.3	13.1	191.5
N ₆₀ P ₆₀ + K ₂₀₀	193.0	181.5	11.6	4.8	19.3	217.7

On the control, the total energy potential of all structural constituents of organic substances decreased by 60.3 GJ / ha over 20 years, and in the variants with mineral fertilizers - by 100-218 GJ /

ha. In this case, increasing doses of potassium (K120-200) against the background of $N_{60}P_{60}$ contributed to an increase in the loss of energy potential of organic substances almost twice.

Acknowledgement

Generalization and statistical evaluation of soil and agrochemical survey data on the Predkamje region of the Republic of Tatarstan showed a decrease in humus content and reserves in agroforest soils.

Calculations of the humus balance in the soil of various variants of the experiment with fertilizers have shown that over 20 years of use, a negative balance of humus is formed in it, both with fertilizers and without them. Mineral fertilizers contributed to the enhancement of mineralization of humus.

Due to the long application of fertilizers, a more acidic humus is formed in the plow layer. Changes in the quality of humus are associated with an increase in mobile first fractions of GK and FK, as well as a decrease in the content of the most agronomically valuable fraction associated with calcium (GK-2).

In systems of agriculture that are not balanced by organic matter, which are predominant in most farms of the Republic of Tatarstan, the use of very high doses of potassium fertilizers is not justified energetically.

To compensate for losses of humus and its energy potential in calculating organic fertilizers on backgrounds with high doses of mineral fertilizers, the humification coefficients of organic residues should be increased by 30-40% during the rotational rotation period of 5-6 years, which will reduce the loss of energy reserves and thereby improve the ecological stability of soils and stability of agrological landscapes.

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