Influence of anthropogenic activities on changes in the chemical and biological properties of the soil

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Abstract. The article investigates the influence of anthropogenic activity on the change in the chemical and biological properties of soils during agricultural use. The work was carried out in long-term stationary experiments laid down in 1963–1965. in the Khabarovsk Territory. The soil is meadow-brown, heavy loamy with an acidic reaction of the environment and low natural fertility. In the studied soils, the phosphorus supply varied from average in natural ecosystems to low in the variants with mineral fertilizers and very low in the variant without fertilizers. Potassium supply from high to high and medium, respectively. A decrease in acidity (pH 4.3) with an increase in anthropogenic load negatively affected the availability of chemical elements to plants and the number of microorganisms. Long-term agricultural use had a negative impact on the number of microorganisms inhabiting the soil of the agrocenosis: the content of ammonifiers decreased on average 9.7 times, amylolytics - 4.2 times. The use of mineral fertilizers contributes to some restoration of the biological activity of the soil, in comparison with the control option without their use.

1. Introduction

An increase in the variety of anthropogenic impacts on the soil, an increase in their intensity necessitate deepening research to clarify the mechanisms leading to a change in the initial properties and structure of the soil [1]. Depending on the type of processing in the soil, various conditions of density, aeration, and moisture can form, which affect the activity of microbiological processes [2].

The dynamics of changes in the content of agrochemical indicators within one soil difference can lead to significant fluctuations in crop yields and the quality of products obtained. An increase in productivity leads to an increase in the removal of nutrients from the soil, and, as a consequence, to their negative balance in the crop rotation [3]. The introduction of high doses of mineral fertilizers contributes to a significant increase in crop yields, but at the same time leads to deterioration in soil quality, which manifests itself in significant changes in the number of microorganisms that, participating in many soil processes, affect fertility. The number of denitrifiers, saprophytic fungi, actinomycetes increases, the number of nitrogen fixers and ammonifiers decreases, and the species composition of micromycetes changes [4-5].

The state of the microbial community of the soil depends on the agricultural techniques used (application of fertilizers, cultivation of soil-protective crops, the type of crop rotation, the technique of incorporating plant residues) [6]. The main components of soil microbocenosis are successfully used as test systems for assessing the ecological state of soils. Numerous studies point out the role of
microorganisms in the stability of agroecosystems and in increasing the productivity of agricultural crops [7-8]. Physical, chemical and biological properties are important in assessing health status [9].

2. Materials and methods
The studies were carried out in 2019–2020. in the long-term stationary experience of the Far Eastern Scientific Research Institute of Agriculture (Khabarovsk Territory), laid down sequentially on three fields of field crop rotation in 1963-1965. in the 8th rotation of the crop rotation in the cultivation of oats and corn. A meadow was chosen as an ecosystem that has never been subjected to anthropogenic impact. The soil cover in the study area is represented by meadow-brown heavy loamy soils with an acidic reaction of the environment and low natural fertility, which is due to the low content of nutrients and humus, and weak biological activity.

The experimental scheme included the following options: without fertilizers since 1963 - control; aftereffect of liming, carried out during six rotations of the crop rotation (32 t / ha of lime flour), bringing the total Ca dose to 2.25 g.c. (lime 2.25 g.c, aftereffect) - background; introduction against the specified background of increasing doses of mineral fertilizers - N\textsubscript{1}P\textsubscript{1}K\textsubscript{1}, N\textsubscript{3}P\textsubscript{3}K\textsubscript{3}, (respectively background +N\textsubscript{1}P\textsubscript{1}K\textsubscript{1}, background +N\textsubscript{3}P\textsubscript{3}K\textsubscript{3}). A single dose of mineral fertilizers (N\textsubscript{1}P\textsubscript{1}K\textsubscript{1}) for oats was N\textsubscript{16}P\textsubscript{16}K\textsubscript{16}, for maize - N\textsubscript{48}P\textsubscript{48}K\textsubscript{48}, the increment of increasing doses of all elements was 32 kg ai / ha. The area of the plots is 170 m\textsuperscript{2}, the replication is 4-fold. The work compares the agrochemical and microbiological indicators of the soil of the agro ecosystem and the natural ecosystem (meadow) for 2019-2020.

The samples were taken in the phase of flowering of cereals and maize, which, under the hydrothermal conditions of the region, coincides with the maximum intensity of the processes of mineralization of soil organic matter. The content was determined by the colorimetric method with Nessler's reagent; nitrates - according to GOST 26951-86; mobile phosphorus and potassium - according to GOST 26207-91; pH - according to GOST 2648385.

The measurements were carried out in triplicate for further calculation, the average value was used. Samples for microbiological analysis were taken aseptically. The total number, as well as the quantitative characteristics of the main groups (ammonifying, amylolytic) microorganisms were determined by sowing on solid nutrient media with a series of successive dilutions of the soil suspension, according to the current methods [10].

To account for the ammonifying microorganisms that decompose nitrogen-containing organic matter in the soil, we used mesopotamia agar (MPA); amylolytic microflora, capable of destruction of oligo- and polysaccharides, immobilization of nitrogen, as well as actinomycetes - starch-ammonia agar (SAA). After inoculation, the dishes were incubated in a thermostat at +27 °C. Counting of the colonies grown on the MPA was carried out on the 2nd ... 4th day of incubation, on the SAA - starting from the 4th day and as the colonies grew. The number of colonies in Petri dishes per 1 g of soil (soil) was recalculated according to the current method [11].

The coefficient of mineralization according to Mishustin was determined by the ratio of the number of microorganisms taken into account by sowing on the SAA to the number of microbes counted on the MPA, which characterize the transformation of soil protein substances [10].

The hydrothermal conditions of the growing season during the years of research differed in the amount of heat and precipitation, as evidenced by the values of the hydrothermal coefficient: in 2019 - 3.3, in 2020 - 2.6. The amount of precipitation was 804.4 and 582.8 mm, respectively, and active temperatures were 2578.2 and 2210.7 °C.

3. Results and Discussion
With an increase in anthropogenic load, the zonal properties of the soil change. All combinations of mineral fertilizers at the beginning of the growing season of the studied crops changed the nutritional regime of the soil in comparison with the control variant. The reaction of the environment is the main factor limiting the growth and development of plants on meadow brown soils. Increased acidity has an adverse effect on the mobility and availability of phosphorus and potassium, important nutrients for
plants. In acidic soils (at pH below 4.5–4.6), iron and aluminum hydroxides interact with soil phosphorus and convert them into compounds inaccessible to plants. In the soils of natural ecosystems, acidity varies from 4.4 to 4.7, which leads to a decrease in the phosphorus content, but the potassium content is insignificantly affected (table 1). In the soils of agro ecosystems, the acidity of soils is in the range of strongly acidic and acidic levels (pH 4.3-4.7) and depends on the dose of mineral fertilizers and the cultivated crop.

Table 1. Changes in the dietary regime of the soil 2019-2020.

| Options                | pH, сол       | P₂O₅  | K₂O |
|------------------------|---------------|-------|-----|
|                        | 2019 oats     | 2020  | 2019 oats | 2020  | 2019 oats | 2020  |
| Crop rotation culture  |               |       |       |       |       |       |
| Ecosystem (meadow)     | 4.4           | 4.7   | 8.5   | 13.9  | 23.3   | 24.0  |
| Control - used         | 4.3           | 4.3   | 1.5   | 0.9   | 13.9   | 12.0  |
| Ground + N₁P₁K₁        | 4.7           | 4.4   | 3.4   | 2.8   | 16.5   | 19.8  |
| Ground + N₂P₂K₂        | 4.6           | 4.4   | 5.0   | 3.1   | 17.9   | 20.2  |
| HCP₉₅                  | 0.3           | 0.2   | 1.1   | 1.0   | 1.9    | 2.1   |

With the introduction of mineral fertilizers, the acidity of the soil in oat crops in the flowering phase increased, both in comparison with the control option and in comparison with natural ecosystems (pH 4.6-4.7), the content of mobile phosphorus and exchangeable potassium increased in comparison with the control option in 2.3 -3.3 and 1.2-1.3 times, respectively, but in comparison with the natural ecosystem, we observe a decrease by 1.7-2.5 and 1.3-1.4 times. The use of mineral fertilizers in the cultivation of corn led to a decrease in soil acidity (pH 4.4), which negatively affected the content of mobile phosphorus; in comparison with the soils of natural ecosystems, its content decreased 4.5-5.0 times. The content of exchangeable potassium in the flowering phase in maize crops was determined by both the reaction of the environment and the dose of mineral fertilizers, and the consumption of the crop, in comparison with the control variant without the use of fertilizers, the content of exchangeable potassium increased 1.7 times, but in comparison with the natural ecosystem it decreased by 1.2 times (table 1). Thus, with a lack of nutrients in the soil, a community of microorganisms is formed, which not only does not contribute to the improvement of conditions for plants, but, as it were, enters into a competitor for plants, especially in the struggle for phosphorus.

With prolonged anthropogenic impact on agricultural soils, the conditions for the existence of soil microorganisms [12] change significantly, their composition and number, the course of microbial transformation processes may be disrupted. According to the research results, the microbocenosis of the areas involved in agricultural use differs significantly from the natural ecosystem in terms of the number of microorganisms. In soils not exposed to anthropogenic impact, the number of ammonifying micro flora is on average 9.7 times, and amylolytic - 4.2 times higher than in the agro ecosystem (Table 2). In the control variant, under conditions of a very acidic reaction of the medium (pH 4.3 units) and a low content of mobile phosphorus (0.9-1.5 mg / 100 g of soil), the suppression of the vital activity of microorganisms, especially of the ammonifying micro flora, was noted. The use of mineral nutrients and an improvement in soil pH in oat crops had a positive effect on the microbiological pool of the soil, the amount of ammonifying microflora increased in comparison with the control variant by 1.9-3.9 times, amylolytic - by 4.1-4.5 times. With a decrease in the content of mobile phosphorus and soil acidity in corn crops, the content of microorganisms of both groups decreased compared to the previous year, the amount of ammonifying micro flora decreased by 1.24 times, amylolytic - by 2.35 times (table 2).

The number of microorganisms amylolytics is much higher than that of ammonifiers, which has a significant effect on the development of organic matter mineralization processes. The value of the coefficient of mineralization indicates that the rate of transformation of organic matter in the soil
increases with the involvement of land in agricultural use. In the soils of natural ecosystems, humus components decompose more slowly than under agricultural crops, therefore the mineralization coefficient (1.76-2.15) is lower than in corn (2.25-6.33) and oats (3.73-9.16) (table 3).

**Table 2.** Influence of mineral fertilizers on the number of soil microbiome in crops 2019-2020.

| Options             | CFU per 1 g absolute dry. soil, million units |
|---------------------|-----------------------------------------------|
|                     | Ammonifiers MPA  | Amylolytics SAA  |
|                     | oats  | corn  | oats  | corn  |
| Crop rotation culture | 2019 | 2020 | 2019 | 2020 |
| Ecosystem (meadow)  | 2.10  | 3.72  | 4.51  | 6.55  |
| Control - used      | 0.15  | 0.10  | 0.56  | 0.63  |
| Ground + N₃P₃K₃    | 0.28  | 0.22  | 2.52  | 0.85  |
| Ground + N₁P₁K₁    | 0.59  | 0.48  | 2.29  | 1.08  |
| НСР₉₅            | 0.45  | 0.51  | 2.15  | 1.87  |

**Table 3.** Coefficient of mineralization of the studied soils.

| Options             | Mineralization coefficient * |
|---------------------|------------------------------|
|                     | 2019 | 2020 |
| Crop rotation culture | oats  | corn  |
| Ecosystem (meadow)  | 2.15  | 1.76  |
| Control - used      | 3.73  | 6.33  |
| Ground + N₁P₁K₁    | 9.16  | 3.86  |
| Ground + N₁P₁K₃    | 3.89  | 2.25  |

Mineralization coefficient * - ratio of bacteria SAA / MPA

**4. Conclusion**

The anthropogenic impact on meadow-brown soils used in field crop rotation led to the leveling of zonal properties with respect to mobile phosphorus and exchangeable potassium. The content of mobile phosphorus decreased by 5.7 times, exchangeable potassium by 1.4 times. Because of the research, it was found that the number of microorganisms changes significantly in the gradient of ecosystems from natural to anthropogenic ally transformed, depending on the application of mineral fertilizers and the acidity of the environment. The total number of components of the microbial cenosis of the sites involved in agricultural activity decreased 5.2 times compared to the natural ecosystem.

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