Parallel successions of microbiomass and oribatid mites in the soil during the transformation of the forest ecosystem into an agrocenosis in the south of Western Siberia

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Abstract. The analysis of the state of the destructive block in gray forest soils in the Novosibirsk region was carried out. Forest, meadow under pasture and vegetable agrocenosis were selected as the objects of the study. Soil-zoological and soil-microbiological methods were used in the work. The biomass of soil microorganisms, basal respiration, metabolic coefficient, species richness and the total numbers of oribatid mites in soils were studied. Strong changes in the studied parameters in soils with different agricultural uses, compared with the soil under the forest, are demonstrated. With the deforestation and the transformation of the formed grass ecosystem to pasture, all the studied indicators decrease. When the grass ecosystem is plowed and the soil is used for a long time as an agrocenosis, a further decrease in microbiological and zoological indexes is observed. The conclusion is made about the possibility of applying the methods used in the practice of ecological monitoring of gray forest soils is made.

1 Introduction

The soil and climatic conditions of the Novosibirsk region are favorable for the development of highly productive agriculture. 10,649 million hectares are occupied under agricultural land, of which 6,011 million hectares are under arable land and under hayfields and pastures 4,637 million hectares, i.e. about 60% of the territory of the region [1-2]. Gray forest soils, according to the totality of morphological features and properties, occupy a transitional position from sod-podzolic soils of the south taiga subzone to chernozem soils of the forest-steppe [3].

The area of gray forest soils of the Novosibirsk region is 1253,4 thousand hectares. This is 7,4% of the entire territory of the region (without the area of rivers and lakes). These soils are formed under the influence of small-leaved woody and herbaceous vegetation. Gray forest soils are characterized by the presence of two leading processes of soil formation, which determine their morphological features and basic properties: podzolic and

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turf. Depending on the degree of participation and duration of exposure in virgin conditions of woody and herbaceous plant formations and the degree of cultivation in conditions of agricultural development, more or less humusized gray forest soils are formed. Currently, a significant part of the gray forest soils of the Novosibirsk region has been plowed. The untilled plots are mainly either forests of local importance that are under protection, or slopes of hollows and gullies that are difficult for agricultural development [1;4].

The high degree of agricultural development of the territory of the distribution of gray forest soils makes it urgent to search for simple and reliable methods of environmental monitoring. Monitoring using botanical methods in this case turns out to be ineffective due to the high degree of plowing of these soils. Microbiological and zoological monitoring methods are currently not widely used in the Novosibirsk Region. At the same time, it is shown that soil microorganisms and small soil animals are subtle indicators of the state of the soil and the ecosystem as a whole [5].

The main distinction of instrumental soil-microbiological methods of environmental monitoring is the simplicity and speed of execution, the possibility of parallel analysis of a large number of samples [6-8]. Thus, the purpose of this study was to assess the applicability of soil-microbiological and soil-zoological methods for the purposes of ecological monitoring of agroecosystems on gray forest soils.

2 Materials and methods

Three ecosystems on gray forest soils were selected as objects of research. All of them are located in the vicinity of the Talmenka village in the Iskitimsky district of the Novosibirsk region on a large array of gray forest soils, formerly covered with deciduous and mixed birch-pine forests. Ecosystem 1 is a mixed pine-birch forest. Ecosystem 2 is a grassland used as a pasture. Ecosystem 3 is an arable land used for sowing vegetable crops.

Samples for microbiological analysis were taken in August from layers 0-10 and 10-20 cm in all studied ecosystems. For the analysis of microbiological characteristics, samples were taken in fourfold repetition according to the generally accepted method. The carbon content in the biomass of soil microorganisms (C-biomass) was determined in soil samples by the method of fumigation- is incubation, and basal respiration. The metabolic coefficient was calculated as indicator of the specific metabolic activity of soil microbial biomass (qCO2), as the release of C-CO2 per unit of C-biomass per hour [9].

To analyze the population of oribatid mites in August, soil samples were taken in all the studied ecosystems with a standard cylindrical sampler in layers, 5 cm deep in 10-fold repetition in each ecosystem. The extraction of mites from the soil was carried out by the method of Tullgren-Berlese thermo-eclection generally accepted for microarthropods [10]. Statistical treatment of the results was carried out by methods of variance analysis [11].

3 Results and Discussion

The result of forest cutting and transformation of the forest ecosystem into a meadow one, which has been used as pasture for a long time, is a decrease in the biomass of soil microorganisms by 1.8 times in the 0-10 cm layer and 3.2 times in the 10-20 cm layer (figure 1). When plowing gray forest soil, a further sharp decrease in the biomass of microorganisms by 4.4 times in the 0-10 cm layer and 2.1 times in a layer of 10-20 cm.

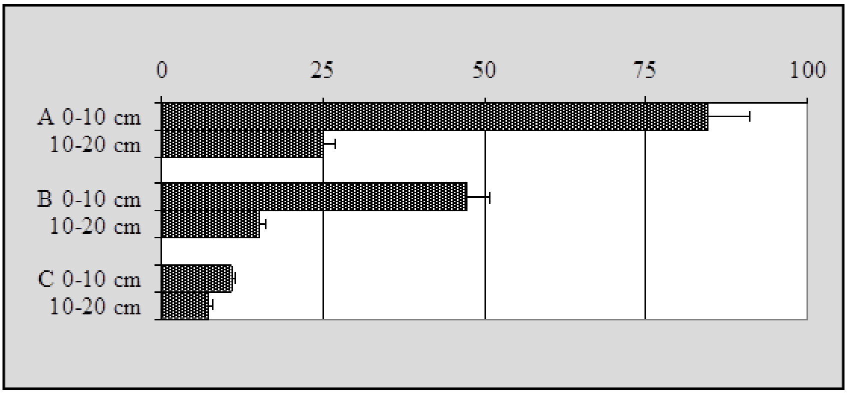

Fig. 1. C-biomass (mg C / 100 g of soil) in the soil under forest (A), under meadow (B) and under agrocenosis (C). SSD(5%)=23.9.

Similar trends have been revealed in the study of basal respiration. During the transition from the forest ecosystem to the meadow one, this indicator decreases by 1.9 times in the 0-10 cm layer and 2.5 times in the 10-20 cm layer (figure 2). During the transition from the meadow ecosystem to the agrocenosis, basal respiration decreases by 4.8 times in the 0-10 cm layer, and in the 10-20 cm layer, this indicator practically does not change.

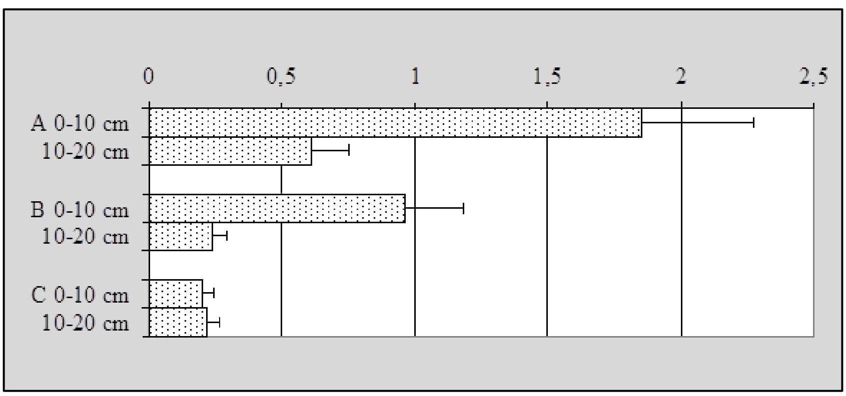

Fig. 2. Basal respiration (mcg C–CO2 /g of soil per hour) in Figure 2. Basal respiration (mcg C–CO2 /g of soil per hour) in the soil under forest (A), under meadow (B) and under agrocenosis (C). SSD(5%)=0.31.

The level of specific metabolic activity of microbiomass (qCO2) in the studied soils in the 0-10 cm layer varied from 1.8 to 2.2, and in the 10-20 cm layer changed slightly during the transition from the forest ecosystem to the meadow one (from 1.3 to 1.6) and sharply increased (by 1.9 times) during the transition from the meadow ecosystem to the agrocenosis (figure 3).

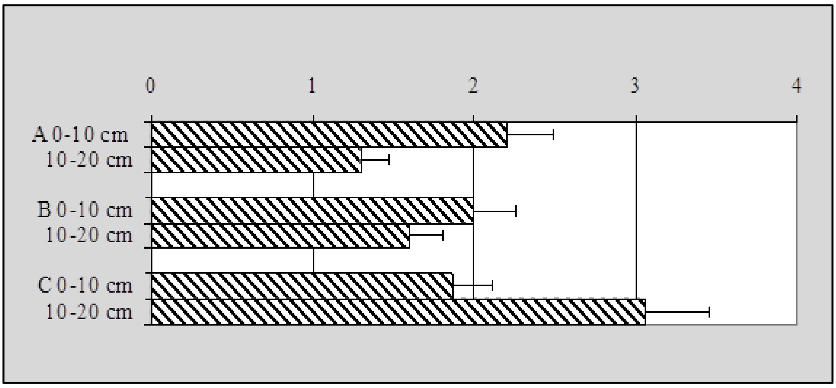

Fig. 3. Metabolic coefficient (mcg of C-CO2 / mg of C-biomass per hour) in soil under forest (A), under meadow (B) and under agrocenosis (C). SSD(5%)=0.35. . 4. Caption of the Figure 1. Below the figure.

Thus, when a mixed forest on gray forest soil is cut down and the forest ecosystem is transformed into a meadow one, there is a sharp decrease in the biomass of microorganisms and basal respiration of this biomass. When plowing gray forest soil, an even sharper decrease in these indicators occurs in the 0-10 cm layer. In a layer of 10-20 cm on arable land, the decrease in microbial biomass and basal respiration compared to pasture is not so sharp. Similar patterns were revealed during the transition of the grass ecosystem to the agrocenosis by other researchers [12].

The pine-birch forest, the control biotope in the studied series of ecosystems, has a very high index of oribatid mites abundance – 70.2 thousand specimen / m2. This number is typical for the most populated forest ecosystems of the Palearctic region with oribatids, and is noted, for example, in a floodplain mixed forest on turf soil in the northern taiga of the Tyumen region. Also, 31 species of oribatid mites were recorded in the studied forest biotope. This indicates a high level of species richness in comparison with other forest ecosystems of the Palearctic (figures 4 and 5) [13].

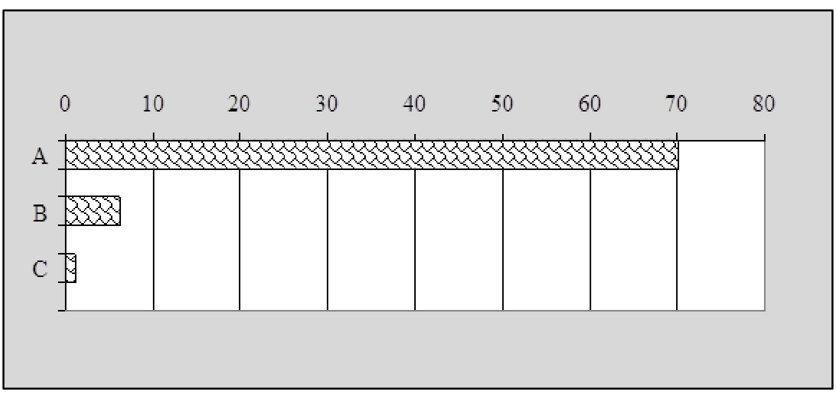

Fig. 4. The total numbers of oribatid mites (thousand specimen / m2) in the soil under forest (A), under meadow (B) and under agrocenosis (C).

The community of oribatid mites in the ecosystem of a grass meadow in the studied series of biotopes is depleted by 11 times compared to the forest grouping. This indicator is 6 times inferior to the similar one in the ecosystem of a settled meadow on meadow-chernozem soil (40,2 thousand numbers/m2 were noted there), and 2 times to the indicator of a mesophytic grass meadow on chernozem-meadow soil (11,9 thousand numbers/m2) in the forest-steppe of the Krasnoyarsk Territory [14]. The large difference in the first case can be explained by the absence of anthropogenic influence in the settled meadow of the Krasnoyarsk forest–steppe (this ecosystem has been in a protected regime for about 5 years), whereas in the second case, a much smaller difference with the mesophytic meadow of this territory is a consequence of the presence of pasture pressure in both compared biotopes.

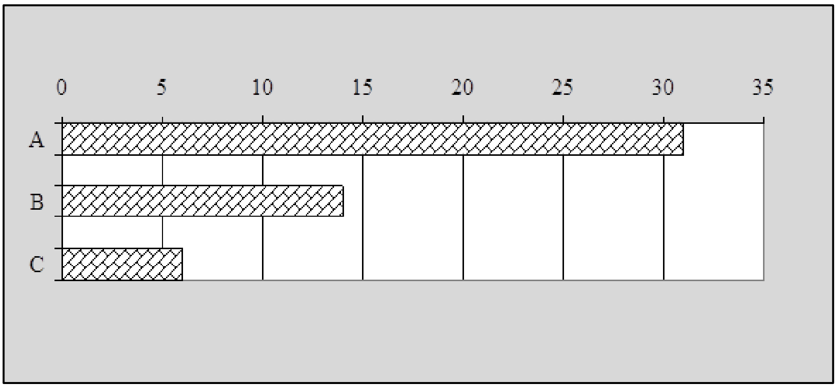

Fig. 5. The number of oribatid mites species in the soil under forest (A), under meadow (B) and under agrocenosis (C).

The community of oribatid mites in the agrocenosis soil is significantly depleted in comparison with the groupings of forest and meadow ecosystems. In terms of numbers, this community is 59 times inferior to the control forest community, and to the meadow community is 5.3 times. The indicator of the species richness of the oribatids of the studied agrocenosis is 5 times inferior to that of the forest biotope and the meadow biotope – 2 times. A sharp depletion of the oribatid mites population in agrocenoses compared with undisturbed ecosystems is shown for different natural zones and regions [15-17].

4 Conclusion

Thus, the transformation of a forest ecosystem into a meadow one after the deforestation leads to a significant restructuring of the destructive link of the biological cycle in the underground block of the ecosystem. There is a sharp decrease in the biomass of microorganisms and basal respiration, the indexes of species richness and abundance of oribatid mites. These abrupt changes in the parameters of the functioning of the destructive block can be explained by a change in the nature and quantity of plant litter entering decomposition. A slight change in the specific metabolic activity of microbial biomass (QCO2) during the transition from the forest ecosystem to the meadow one indicates a stable state of microbocenosis in the formed grass ecosystem.

The plowing of the meadow ecosystem with the subsequent formation of agrocenosis has a powerful depressing effect on the entire complex of destructors. There is a sharp decrease in the biomass of soil microorganisms, basal respiration, the total numbers and species richness of oribatid mites. At the same time, there is a general increase in the level of metabolic activity of the soil microbiocenosis, which indicates a decrease in its stability.

The study demonstrated that the revealed features of the studied soil-biological indicators (C-microbiomass, basal respiration, abundance and species richness of oribatid mites) can be successfully used in the practice of environmental monitoring in agro-landscapes on gray forest soils of the forest-steppe zone of Western Siberia.

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