Quantitative and Qualitative Characteristics of Organic Matter Under Long-Term Exposure to Natural and Anthropogenic Factors

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Abstract. Studies have found that the increase in differences between the amount of energy subsidies invested in agrobiocenoses and alienated from them over a 105-year period changes the direction of biochemical processes of organic matter transformation, which leads to significant losses of organic carbon reserves, which amount to 17.5 t/ha in highly degraded soils, 7.3 t/ha in poorly cultivated soils, and in highly cultivated - increases them by 2.8 t /ha, respectively, compared with the initial content. Long-term use of arable land affects the qualitative characteristics of the state of organic matter of sod-podzolic soil, which are expressed in a change in the ratio of the peripheral and central parts, the enrichment of humus with nitrogen. The humus substances of medium (57%) and highly cultivated soils (54%) are characterized by the highest degree of participation of peripheral groupings in the construction, and the least - highly degraded (29%).
Keywords: Agrobiocenoses, organic carbon, permanent crops, crop rotation, long-term field experiment.

1 Introduction

In 2022, the 110th anniversary of the long-term experience of the RGAU-MSHA named after K.A. Timiryazev, known in foreign literature under the name "Moscow Station", will be celebrated. In terms of the volume and depth of the research, it is one of the unique experiments of global importance for agronomic science. The value of the results of scientific research in such experiments is proportional to the duration of the station and increases as the experimental site approaches a stable eco-phytocenotic equilibrium.

Under conditions of a long-term hospital, the action, interaction and aftereffect of anthropogenic impact of varying degrees of intensity accumulate over time against the background of changes in environmental factors, which makes it possible to monitor the quantitative and qualitative changes in the state of organic matter, the content and

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circulation of biophilic elements, as well as the dynamics of soil cover contamination with various toxicants [1].

The ecological functions of the soil are realized through its ability to form a crop of agricultural crops, accumulate solar energy in the form of humus, and provide biochemical cycles for the transformation of biophilic elements. If these functions are violated due to excessive anthropogenic interference, the soil cover undergoes degradation [2]. The study of quantitative and qualitative parameters of the transformation of soil organic matter seems to be very relevant. The rational use of various methods slows down and completely prevents degradation processes, ensures an increase in the energy intensity of agroecosystems, and increases their resistance to stress factors. Fundamental importance in the formation of agroecosystems is given to assessing their ability to maintain and maintain their parameters and structure in space and time without changing the balance of the biochemical cycle of energy flows [3]. The dissertation research under consideration, the value of which is enhanced by a long, more than 100 years, observation period. Dehumidification of soils, which is determined by the intensity of organic matter mineralization processes, causes damage to agroecosystems that is difficult to repair. A decrease in the content of humus in soils not only significantly reduces their fertility, but also negatively affects the global ecological functions of soils, their ability to serve as a barrier to the effects of adverse environmental stress factors. Excessive intensification of agricultural production by increasing the share of tilled and industrial crops in agroecosystems, with insufficient application of organic fertilizers, contributes to the widespread decrease in the humus content in the arable soil layer. The quantitative and qualitative state of organic matter is one of the central blocks in soil monitoring. These indicators determine the functioning of the main properties and regimes of soils. The creation of sustainable agroecosystems is primarily associated with the implementation of complex measures to create conditions not only for a deficit-free, but also a positive balance of organic matter.

The quantity, rate, and completeness of the transformation of organic matter by microbial biota determine the nature of the formation of the soil profile in a particular ecosystem. Annual fluctuations of natural factors determine minor fluctuations in ecosystem parameters (fluctuations) within the “norm” [4].

2 Materials and methods

The aim of the research was to study the dynamics of changes in the quantitative and qualitative characteristics of the humus state of soddy-podzolic soil in the southern part of the taiga-forest zone of Russia under long-term (more than 105 years) exposure to natural and anthropogenic factors of varying intensity.

In the Long-term field stationary experiment of the RGAU-MSHA named after K.A. Timiryazev, founded in 1912 by Professor A.G. Doyarenko. The objects of research were soddy-podzolic soils (according to the FAO classification - Podsolluvisol) of various degrees of cultivation and agrophytocenoses of field crops cultivated on various backgrounds of nutrition [5]:

- highly degraded - a field of 105-year-old pure fallow without fertilizers and lime with an organic carbon content at the level of a quasi-equilibrium state, provided with a granulometric composition (0.5 - 0.6% C_{org}) and very low humus reserves (36.6 t/ha) ;
- poorly cultivated - potato monoculture against the background without fertilizers and lime with a C_{org} content of 0.8-0.9% and humus reserves of 56.2 t/ha
- medium cultivated - crop rotation plots with the biodiversity of agricultural plants since 1912. (pure fallow-winter rye-potato - barley with clover undersowing - clover - flax)

against the background of applying $N_{100}P_{150}K_{120}$ and 20 t/ha of manure annually with a C_{org} content of 1.2-1.3%, and humus reserves in the arable layer of 55.7 t/ha

- highly cultivated - monoculture of winter rye against the background of applying $N_{100}P_{150}K_{120}$ and 20 t/ha of manure annually with a C_{org} content of 1.4-1.5%, and humus reserves - 69.8 t/ha) in the arable soil layer.

Doses of application of mineral, organic fertilizers and lime for the periods of operation of the "Moscow Station" are presented in Table 1.

Determination of humus content in the arable soil layer was carried out according to the Tyurin method modified by TsINAO (GOST 26213). To study the qualitative and quantitative composition of soils, a modernized thermoanalytical complex based on the Q-1500 Derivatograph was used, which makes it possible to calculate the percentage of adsorption and constitutional water, organic matter, primary and secondary minerals. Statistical data processing was performed using the program "Statistika" [6].

Table 1. Periodic norms and the total amount of mineral nutrients and manure introduced over periods of long-term experience of the ICCA.

Experience options	N	P_2O_5	K_2O	Manure, t/ha	Total			
	kg/ha				kg/ha			t/ha
					N	P_2O_5	K_2O	навоз
1 period 1912-1938	7,5	15	22,5	18	195	390	586	468
2 period 1939-1954	75	60	90	20	1125	900	1350	300
3 period 1955-1972	50	75	60	10	900	1350	1080	180
4 period 1973-2022	100	150	120	20	4900	7300	5260	980
Only for 1912-2022	-	-	-	-	7120	9940	8276	1926
Average for one year	-	-	-	-	64,8	90,4	75,2	17,5

3 Results and discussion

The involvement of virgin soddy-podzolic soils in agricultural circulation causes a gradual process of their cultivation, which is accompanied by a significant leveling of the heterogeneity of the properties of elementary soil areas, a change in the morphological features and qualitative composition of the soil horizons involved in this process [7]. The speed and direction of these processes depends on soil and climatic conditions, duration and intensity.

Soil fertility mainly depends on the content of organic matter, and under optimal conditions, the process of organic synthesis and mineralization is maintained at a certain balanced level characteristic of this soil.

Our studies in agrobiocenoses of different intensity of Long-term experience showed that long-term (more than 105 years) exposure to natural and anthropogenic factors led to a change in the direction of biochemical processes of organic matter transformation towards its mineralization, which led to a decrease in organic carbon reserves depending on the method of arable land use by 17 .5 t/ha in highly degraded soils, by 7.3 - in poorly cultivated and 3.6 t/ha - in medium cultivated. The greatest losses of carbon (4.5 t/ha) were noted in the field of pure fallow in the first two decades after the start of the experiment [8].

Subsequently, humus mineralization slowed down with annual losses of 1.2-3.0 t/ha Corg, tending to Cmin (0.70% Corg), provided by light loamy granulometric composition (Fig. 1).

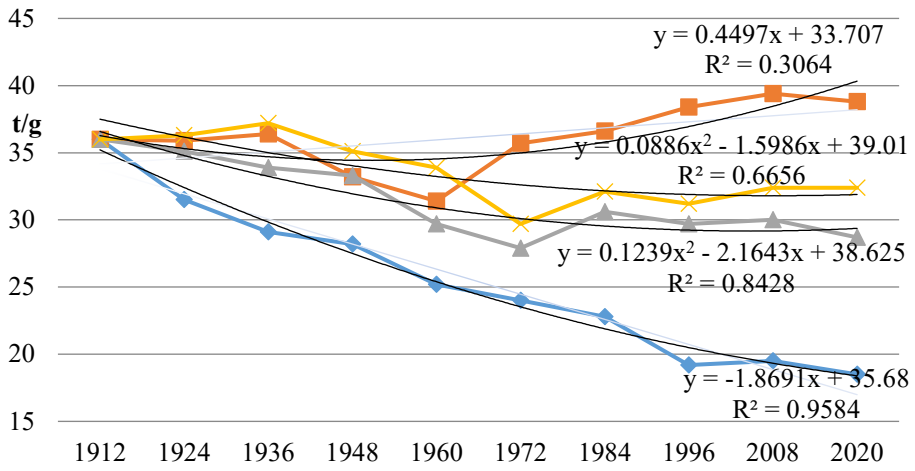

Fig. 1. Dynamics of organic carbon content (t/ha) at different intensity of arable land use

Long-term (more than 105 years) permanent cultivation of potatoes without fertilizers in combination with intensive mechanical processing increased the rate of mineralization of organic matter, which led to significant losses of organic carbon reserves (7.3 t/ha), while winter rye, on the contrary, supported them. at the initial level with seasonal fluctuations depending on the level of yield provided by the weather conditions of the growing season [9].

The intensity of the impact on the soil cover of soddy-podzolic light loamy soil by various technological methods (single-component, two-component and, complete mineral fertilizer and its combination with manure, the method of crop placement) was also manifested in changes in organic carbon reserves (Fig. 2).

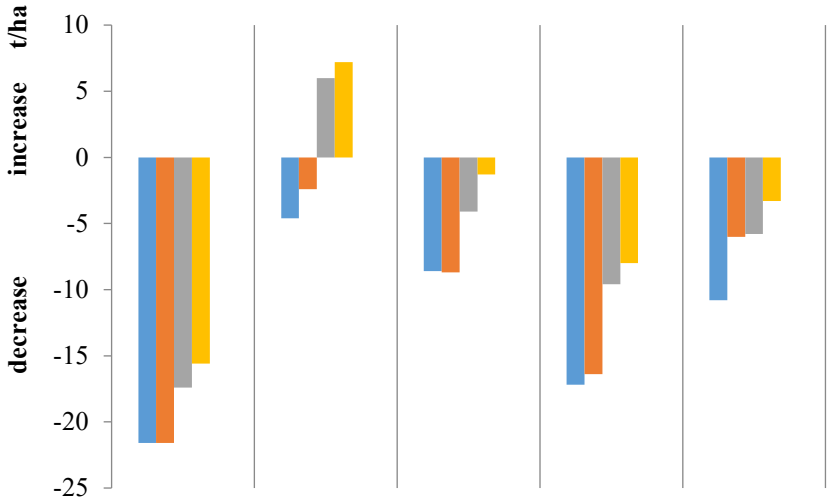

Fig. 2. Change in organic carbon stocks in the arable soil layer from the initial content (36 t/ha)

Our studies have shown that in the absence of sources of anthropogenic energy subsidies to agrobiocenoses, all cultivated crops caused a decrease in carbon stocks, the numerical values of which correlated with the intensity of the impact of anthropogenic factors on them.

The greatest losses (21.6 t/ha) were noted in the field of bare fallow and potatoes (17.2 t/ha), and the smallest (4.6 t/ha) under permanent crops of winter rye. The introduction of complete mineral fertilizer at a dose of $N_{65}P_{90}K_{75}$ annually on average over the period of operation of the experiment and its combination with 17.5 t/ha of manure caused the stabilization of humus reserves in the cultivation of barley and potatoes. And with the permanent cultivation of winter rye - their increase by 6.0 - 7.2 t / ha compared to the initial state of super-intensive with an annual intake of about 20 t / ha of organic matter in the form of manure and crop and root residues [10].

The intensity of the use of arable land, the amount of anthropogenic energy subsidies introduced changes not only the quantitative but also the qualitative state of organic matter. Our studies have shown that the determination of its content by the thermoanalytical method makes it possible to conditionally distinguish the central and peripheral parts according to the ability to decompose in different temperature ranges.

It has been established that the lowest content of peripheral components (19.9%) is characteristic of highly degraded fallow soils. On the other hand, the organic matter of the soils of these agroecosystems contains the largest amount of components of the central part. At the same time, the maximum temperature of destruction of these components of organic matter is the lowest in comparison with the organic matter of soils of more intense agrobiocenoses.

On the differential thermal (DTA) and differential thermogravimetric (DTG) curves, reflecting the physicochemical transformation of organic compounds, endothermic and exothermic effects are clearly expressed, which can be divided into three areas. One endothermic effect at 115-130 0C (dehydration reaction), i.e. removal of adsorption moisture; the second effect is extended in the temperature range and is divided into two components: low-temperature (280-300 0C), in which individual aliphatic and alicyclic groups are destroyed, and high-temperature (450-550 0C), in which the stable part of macromolecules of organic acids is destroyed (Table 2) [11].

Table 2. Thermal characterization of organic matter

The degree of cultivation of the soil	Removal of adsorbents. moisture	Destruction of the peripheral part	Destruction of the central part	Ratio P:C
Severely degraded	127 11,1	350 19,9	451 69,0	0,29
Weakly cultivated	92 9,4	340 24,4	450 66,2	0,37
Medium Cultivated	104 13,7	350 26,0	465 60,3	0,43
Highly cultivated	107 11,2	370 28,0	445 60,8	0,46

Note: in the numerator - the maximum temperature of the effects, ^{0}C; in the denominator - weight loss, % of the total

According to the indicator of the ratio of the peripheral and central parts, it follows that the highest degree of participation of the central groups in the formation is characterized by the organic matter of the highly degraded soil of perpetual fallow (71%), and the least (38%) is the highly cultivated soil with permanent cultivation of winter rye. As the mass of energy subsidies received by various agroecosystems in the form of crop and root residues, mineral and organic fertilizers, as well as microbial biomass carbon, the share of the

peripheral part increases, which amounted to 37% in soils under potatoes, 43% in crop rotation and 46 % under winter rye, but it remains much less.

4 Conclusion

1. The impact on agricultural landscapes by anthropogenic factors of varying intensity over a long period of their functioning has a significant impact on the content and quality of organic matter, changing the direction of biochemical processes of its transformation towards mineralization in the field of pure fallow and, when growing potatoes in variants without fertilizer, towards humus accumulation - with the permanent cultivation of winter rye, as well as the ratio of the central and peripheral parts of humic acids.

2. Increasing differences between the value of the energy subsidy invested in agrobiocenoses and alienated from them over a 105-year period changes the direction of biochemical processes of organic matter transformation, which leads to significant losses of organic carbon reserves, which in highly degraded soils amount to 17.5 t/ha, poorly cultivated - 7.3 t/ha, and in highly cultivated - increases them by 2.8 t/ha, respectively, compared with the original content.

3. Long-term use of arable land affects the qualitative characteristics of the state of organic matter in soddy-podzolic soil, which are expressed in a change in the ratio of the peripheral and central parts, the enrichment of humus with nitrogen. The highest degree of participation of peripheral (accessible to plants) groups in the formation is characterized by humic substances of medium (57%) and highly cultivated soils (54%), and the lowest degree is strongly degraded (29%).

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