Changes in humus content in forest-steppe soils of Western Siberia

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Abstract. The research is based on the results of local monitoring in 1990-2018 on reference plots of agricultural lands and archival materials of a large-scale agrochemical survey. The purpose of the research is to identify patterns of change in the humus content of arable soils of the forest-steppe in the Omsk region after prolonged use in agriculture. The objects of research were the soils of the forest-steppe zone of the Omsk Region: ordinary chernozem low-power low-humus heavy loamy soil; meadow-chernozem medium-thick medium-humus heavy loamy soil; solonetz meadow chernozemic deep low humus clay soil. The largest area on the last round of agrochemical survey of 1194.3 thousand ha (58.9%) has an average humus content (4.1-6.0%), it increased significantly from 784.5 thousand ha (38.7%). The increased and high (> 6%) humus content significantly decreased over the study period by 416.5 thousand ha from 1118.5 (55.1%) to 702.0 thousand ha (34.6% of the surveyed area). The weighted average humus content over 28 years has changed: from 6.2 to 6.0% in the northern forest-steppe, from 6.0 to 5.3% in the southern forest-steppe, on average it is by 0.5%. A tendency toward a decrease in the humus content of soils remains in the soils of the Omsk Priirtyshye region. The main reason for this is both the ongoing water and wind erosion of soils, and the very low level of organic fertilizers use. The authors revealed the gradual decrease in the content of humus in ordinary chernozems and meadow chernozem soils. There was a stable humus content in the arable horizon of the solonetzes of deep meadow-chernozem soils.

1. Introduction

Soil humus is a complex and relatively dynamic complex of organic compounds formed during the decomposition and humification of organic residues, it is an essential component of fertility. The content of humus in the soil, with the equality of other factors for soils of a particular genetic type, is considered as an integral indicator of its fertility level [1-4]. This has its logic since the soil is the most important property of fertility and differs from soil-forming rock by the presence of humus. The higher content of humus in the soil increases its fertility in the presence of all other factors of plant life.
At the same time, a number of scientists testify to the loss of organic substances in soils [5-7]. Given the importance of humus function in preserving fertility, it is necessary to solve the problems of its optimization in soil. The humus state of soils is in equilibrium with environmental conditions, but the ploughing of soils and their use under crops significantly change these conditions. The soil loses the main features of the humus formation of virgin lands, the mineralization of humus begins to prevail over its formation. Solutions to this problem require information on the dynamics of changes in the content of humus in the soil during its use in agriculture.

The purpose of the research is to identify patterns of change in the humus content of arable soils of the forest-steppe in the Omsk region after prolonged use in agriculture.

2. Conditions, materials and methods
The research is based on the results of local monitoring in 1990-2018 on reference plots of agricultural lands. The objects of research were the soils of the forest-steppe zone of the Omsk Region: ordinary chernozem low-power low-humus heavy loamy soil (JV Druzhba, Gorky district); meadow-chernozem medium-thick medium-humus heavy loamy soil (APC Pushkinsky in the Omsk region); solonetz meadow chernozemic deep low humus clay soil (Yuryevskoye LLC, Kormilovsky district). We also used archival materials of a large-scale agrochemical conducted by the Omsk Agrochemical Service Center and the Tarskaya Agrochemical Service Station. In soil samples, we determined humus according to the Tyurin method in the modification of the Central Research Institute of Agrochemical Services (GOST 26213-91). We performed some research using the equipment of the Collective Use Centre of the Omsk State Agrarian University “Agricultural and technological research.”

3. Results and discussion
Only agrochemical services carry out direct control of the humus content in soils. So, we evaluated the dynamics of humus by a continuous agrochemical survey with the allocation of soil areas by zoning from 1990 to 2018 in the forest-steppe zone of Omsk Priirtyshye. This period covered 3 rounds of continuous agrochemical survey (Table 1, Figure 1).

![Figure 1. Dynamics of soil areas by humus supply groups in the forest-steppe zone of Omsk Priirtyshye (1990-2018)](image)
### Table 1. Dynamics of soil areas by humus supply groups in the forest-steppe zone of Omsk Priirtyshye (1990-2018)

| Natural and agricultural zone | Survey round (years) | very low (\(< 2\)) | low (2.1-4.0) | medium (4.1-6.0) | elevated (6.1-8.0) | high and very high (\(> 8.0\)) | Averag e |
|------------------------------|----------------------|---------------------|--------------|-----------------|-------------------|-----------------------------|----------|
|                              |                      | thous and ha        | %            | thous and ha    | %                 | thous and ha                | %        |
| Northern forest-steppe       | I (1990-2000)        | 30.2                | 3.2          | 70.1            | 7.5               | 280.5                      | 30.0     | 424.1                | 45.4     | 129.6                | 13.9     | 6.2                  |
|                              | II (2000-2012)       | 39.7                | 4.2          | 80.8            | 8.6               | 281.3                      | 30.1     | 413.1                | 44.2     | 119.6                | 12.8     | 6.1                  |
|                              | III (2012-2018)      | 17.3                | 1.9          | 83.6            | 8.9               | 317.8                      | 34.0     | 450.1                | 48.2     | 65.7                 | 7.0      | 6.0                  |
|                              | I (1990-2000)        | 0.70                | 0.1          | 23.9            | 2.2               | 504.0                      | 46.1     | 539.9                | 49.4     | 24.9                 | 2.3      | 6.0                  |
| Southern forest-steppe       | II (2000-2012)       | 2.40                | 0.2          | 47.0            | 4.3               | 666.1                      | 60.9     | 372.3                | 34.0     | 5.6                  | 0.5      | 5.6                  |
|                              | III (2012-2018)      | 1.60                | 0.1          | 29.1            | 2.7               | 876.5                      | 80.2     | 184.1                | 16.8     | 2.1                  | 0.2      | 5.3                  |
|                              | I (1990-2000)        | 30.9                | 1.5          | 94.0            | 4.6               | 784.5                      | 38.7     | 964.0                | 47.5     | 154.5                | 7.6      | 6.1                  |
| Total                        | II (2000-2012)       | 42.1                | 2.1          | 127.8           | 6.3               | 947.4                      | 46.7     | 785.4                | 38.7     | 125.2                | 6.2      | 5.8                  |
|                              | III (2012-2018)      | 18.9                | 0.9          | 112.7           | 5.6               | 1194.3                     | 58.9     | 634.2                | 31.3     | 67.8                 | 3.3      | 5.6                  |

When analysing the areas by the security groups very low and low (<4.0%), we can note that over 28 years the areas in these groups increased by 6.4 thousand ha and makeup 131.6 thousand ha or 6.5% of the surveyed territory. On such lands, crop yields do not exceed 1.0-1.2 tons of grain units per hectare without additional measures aimed at increasing their fertility. The largest area on the last round of agrochemical survey of 1194.3 thousand ha (58.9%) has an average humus content (4.1-6.0%), it increased significantly from 784.5 thousand ha (38.7%). The increased and high (> 6%) humus content significantly decreased over the study period by 416.5 thousand ha from 1118.5 (55.1%) to 702.0 thousand ha (34.6% of the surveyed area). It is due to a sharp drop in the humus content in the southern forest-steppe, from 51.7 to 17.0% of the arable land area of these soil security groups. This zone has more intense deflation, and as a result, the loss of the humus layer [1].

The weighted average humus content over 28 years has changed: from 6.2 to 6.0% in the northern forest-steppe, from 6.0 to 5.3% in the southern forest-steppe that is significant, on average it is 0.5%.

Soils of the Omsk Priirtyshye region have a tendency to a decrease in the humus content of soils, especially in the southern forest-steppe. The main reason for this is both the ongoing water and wind erosion of soils, and the very low level of organic fertilizers use. As a result, annual irreplaceable losses of soil organic matter are 0.3-0.5 t / ha. The rate of intensification of the use of fertilizers in 1984-1990 (application of 40 kg/ha of mineral and 1.8 t/ha of organic) somewhat inhibited this process in the region. The results of scientific observations indicate a certain negative dynamics of the humus
content, however, the loss is much less than the available data in the scientific and agronomic literature [5, 6].

The annual mineralization of humus leads to the loss of its most active part, which mainly determines the favourable properties of the soil. Therefore, there is an annual loss of humus content, but the rate of loss in each case depends on zonal conditions, soil type, particle size distribution, duration and intensity of field use, and, first, on measures taken to maintain soil fertility [5-10].

Since the variegation of soil types in the forest-steppe zone of the Omsk Priartyshye region affects the dynamics of organic matter in the soil, for a long period study we have taken the most common types of arable land in the structure of arable land, namely ordinary chernozem, deep solonetz meadow and chernozemic soil.

The studies of the meter-long soil layer of the reference plots in the forest-steppe zone reflect the general pattern of changes in the humus content depending on the soil depth [5-8]. The main amount of humus in the chernozem soil types, as well as in deep solonetz, accumulates in the 0–40 cm layer; below, there is a sharp decrease in the humus content (Table 2).

**Table 2.** Humus content in a meter soil layer of reference plots in the forest-steppe zone of Omsk Priartyshye, % (2017)

| Depth, cm | Soil type | ordinary low-power low-humus chernozem | meadow-chernozem medium-power medium humus soil | meadow chernozemic deep low humus solonetz |
|----------|-----------|--------------------------------------|------------------------------------------------|------------------------------------------|
| 0-20     |           | 5.50                                 | 5.10                                           | 6.20                                     |
| 20-40    |           | 5.08                                 | 3.62                                           | 4.41                                     |
| 40-60    |           | 1.81                                 | 2.19                                           | 2.00                                     |
| 60-80    |           | 1.30                                 | 1.79                                           | 1.52                                     |
| 80-100   |           | 1.11                                 | 0.81                                           | 1.25                                     |

Considering that the humus content depends on the genesis of soils, we determined the dynamics of humus of soil types common in the arable land of the forest-steppe zone from 1994 to 2018. (Table 3, Figure 2).

**Table 3.** The influence of agricultural activity on the humus content in the arable layer of soils on reference plots in the forest-steppe zone of Omsk Priartyshye, % (1994-2018)

| Soil type                        | The period of the survey, years | Changing the humus content |
|----------------------------------|---------------------------------|-----------------------------|
|                                  | 1994-1998 | 1999-2003 | 2004-2008 | 2009-2013 | 2014-2018 | absolute | relative  |
| Ordinary low-power low-humus chernozem | 5.86     | 5.88     | 5.78     | 5.74     | 5.58     | -0.28 | -4.78     |
| Meadow-chernozem medium-power medium humus soil | 5.36     | 5.26     | 5.20     | 5.12     | 5.10     | -0.26 | -4.85     |
| Meadow chernozemic deep low humus solonetz | 5.98     | 6.08     | 5.98     | 6.00     | 6.18     | 0.20  | 3.34      |
The data obtained allow us to conclude that the humus content in the arable horizon varied in different directions depending on the soil type.

The content of humus decreased by 4.78% and amounted to 5.58% (from 5.86) in the arable horizon of ordinary chernozem. In meadow-Chernozem soils, it also decreased. Every year there was a loss of humus and its reduction on average by 0.20% per year. As a result, the humus content in these soils decreased by 4.85% during the study period and the content changed from 5.36 to 5.10%.

![Figure 2. Dynamics of changes in the humus content in the arable horizon of soils of reference plots in the forest-steppe zone of Omsk Priirtyshe](image)

In the solonetzes of deep meadow chernozem soils, the trend of change is not uniform and constantly varies. So, in the first compared periods of 1994-2003, the humus content increased by 0.20%, in 2004-2013 it decreased slightly and returned to the original (up to 5.98-6.00). Subsequently, the rate of decrease in humus in this soil reduced, which led to an increase in the process of humification and accumulation of humus from 6.00 to 6.18%. This is primarily due to the conditions for the application of these types of soils in this farm (Yuryevskoye LLC in the Kormilovsky district) since in 1990-2013 they were used to growing mainly grain crops and then fodder crops, including perennial grasses.

4. Conclusion

In general, in the forest-steppe of Omsk Priirtyshe zone for the period of research, we revealed that the largest area in the last round of the agrochemical survey has an average humus content, it increased significantly from 38.7 to 58.9% of the surveyed area. The increased and high humus content significantly decreased over the study period from 55.1 to 34.6%. Common chernozems and meadow chernozem soils have a gradual decrease in the content of humus, which means that their fertility decreases; the arable horizon of the solonetzes of deep meadow-chernozem soils have a stable humus content.

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