Water-physical properties of drained peat soils of Northern Trans-Ural forest-steppe zone

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Abstract. The results of long-term studies (1976-2016) of water-physical properties of long-seasonally-frozen peat soils of Northern Trans-Ural are set out. It is shown that the changes in water-physical properties are functional in nature and primarily due to economic use of soil and the condition of its surface. A significant influence on the composition density of peat soils, especially in the first years after drainage, has the process of shrinking. In the conditions of Northern Trans-Ural annual reduction in the value of peat soils is 1.5 cm in the first five years after drainage, 1.1-1.2 cm for 15 years and 0.6-0.7 cm in subsequent years. In the first five years after drainage, the density of the composition in the layer 0.2 m increased by 7.4%, declining to 2.1-3.0% in subsequent years. At a depth of 0.6-1.0 m in 5 years after drainage there is no significant change of addition density. A significant increase in the density of the addition of peat-gley soil established by plowing underlying mineral soil. A relatively stable indicator is the density of the solid phase of the soil. For 35 years, the density of the solid phase medium peat soil layer of 0.3 m increased by 5.4%; low power over a 20 year period by 1.2%. The least moisture capacity medium peat soil over a 35-year period in the rooting zone (0.3 m) layer was reduced by 11.5%; at a depth of 0.6-1.0 m - by 3.7%. In thin peat soil reduction of water capacity in the layer of 0.3 m in 20 years was 6.4%; in peat (0.2 m) layer of peaty gley soil during the same period - by 10.2%.

1. Introduction
Long-term use and preservation of fertility of peat soils is possible only with full consideration of their peculiarities and changes, both positive and negative that accompany the processes of drainage and cultivation of agricultural crops [1]. After studying the processes that occur on peat soils in agricultural use, it is possible to prevent the mistakes that were typical reclamation practices of past years [2, 3].

Important indicators of effective fertility of peat soils are water-physical properties. Of great importance to establish the effects of drainage and agricultural utilization on the composition and properties of peat soils were the study at the reclamation system of Belarus [4], the non-Chernozem zone of Russia [5,6], the Komi Republic [7], Karelia [8], the Baraba lowland [9], Western Siberia [10,11].

The main primary factor which affects all soil processes in peat deposits is the drainage [12]. The cultivation of crops and periodic tilling of the soil (plowing, disking, etc.), the use of additives of mineral soil and fertilizers are the secondary factors that have a significant impact on the change of water-physical and physico-chemical properties, occurring in the developed peat soil [13]. The intensity and direction of the change of properties and behaviors involved in the culture of peat soil depends on the optimal combination of primary and secondary factors [14]. Many parties of this problem in the peculiar climatic conditions of forest-steppe zone of Northern Trans-Ural have not been studied. Even less
attention is paid to agroforestry techniques for their regulation. All this hinders the development of techniques aimed at optimization of water-physical properties of drained peat soils.

The purpose of the research is to study the characteristics of water-physical properties of drained long-seasonally-frozen peat soils of Northern Trans-Ural in the cultivation of perennial grasses.

2. Methods.
The study was carried out from 1976 to 2016 for an experimental Reshetnikovo system, located in the Tyumen region in the Central part of the Tarmanskiy bog, covering an area of 125, 8 thousand ha in the second above flood-plain lacustrine-alluvial terrace of the river Tour. The total area of the system is 278 hectares, of which 60 hectares are drained drainage of the pottery with different parameters of laying: depth from 0.9 to 1.8 m, the distance between the drains is from 8 to 40 m. The other part is dries with open channels with a distance between 100-250 m and a depth of 1.5-1.7 m.

On the object Reshetnikovo studied water-physical properties of peat-gleevac (a layer of peat 0.2 m), thin (layer of peat of 0.7 m) and medium (a layer of peat 1.5 m) peat soils. Peat-forming plants here were sedge, reed, gypnum etc. The degree of peat decomposition varied from 20 to 45%. Peaty-gley soil had the maximum value (50%).

Primary treatment in the test area held with a machine MTP – 42. Preplant tillage included two - triple disking and rolling. Before grassing with perennial grasses (awnless brome and fescue) on the experimental plot were cultivated annual crops (oats and winter rye) for green fodder. For the past 20 years on the experimental plot re-grassing of perennial grasses were not conducted. Fescue in the stand represented by single, awnless brome is dominated. The proportion of wild species herbaceous vegetation is about 2-3%.

Source water physical properties of peat were determined before drying. Water-physical properties of peat were studied by methods generally accepted in soil science [15, 16]. Soil cuts on permanent (fixed) platforms laid for selection of soil samples.

3. Results
Studies found that the changes in water-physical properties are functional in nature and primarily due to economic use of soil and the condition of its surface. Evidence of this is the density of the addition of medium peat soil. The density of the soils composition at atmospheric-alluvial type of water supply varies significantly along the profile (table. 1).

| Table 1. The density of the composition of drained peat soils under perennial grasses, g/cm³ |
|---------------------------------------------------------------|
| Determining after drying | Depth, m | Medium-powered peat soil |
|--------------------------|----------|--------------------------|
| Prior to drainage        | 0-0.1    | 0.126                    |
|                          | 0.1-0.2  | 0.122                    |
|                          | 0.2-0.3  | 0.131                    |
|                          | 0.3-0.4  | 0.123                    |
|                          | 0.4-0.5  | 0.126                    |
|                          | 0.6-1.0  | 0.114                    |
| After 5 years            |          |                          |
| After 9 years            |          |                          |
| After 13 years           |          |                          |
| After 23 years           |          |                          |
| After 35 years           |          |                          |
| After 5 years            | 0.181    | 0.175                    |
| After 9 years            | 0.194    | 0.185                    |
| After 20 years           | 0.200    | 0.190                    |

Low-powered peat soil
The reason is that very heterogeneous peat, according to the degree of decomposition, formed by the decay of vegetation; poorly decomposed layers (15-20%) alternate with medium decomposed layers (30-45%). Density differences addition on the profile of peat soils remain after a long (35 years) agricultural use.

The process of compaction (shrinkage), especially in the first years after drainage, has a significant impact on the density of the composition of peat soil. Shrinkage of peat in use is mainly due to the reduction of the volume of large pores. Therefore, the most intensive processes of shrinkage are in poorly decomposed peat, dominated by large pores [1].

One of the indirect indicators of compaction is the reduction of the peat layer. The decrease in peat soil by 86% due to the seal, not the mineralization of organic matter. In the conditions of Northern Trans-Ural, we have established an annual reduction in the value of peat soil 1.5 cm in the first five years, 1-1.2 cm for 15 years and 0.6-0.7 cm in subsequent years. In general, over the 40-year period, peat soil decreased from 1.5 to 0.9-1.0 m.

In relation to the dynamics of change of density addition at agricultural use of peat soils, the data obtained in Belarus, deserve attention [17]. Significant changes in the peat soil here occur in the first 18-25 years. A similar pattern we set in the Northern Trans-Ural. The density of the composition in the topsoil (0.2 m) of soil in the first five years after drainage has increased by 37.1%, 9 years – 48.4, 13 years old – 64.5, 23 years – 69.3 and 35 years at 73.4%. The data show that the annual increase in the density of the addition is reduced from 7.4% in the first five years after drainage to 2.1-3.0% in subsequent years. In the subsurface layer of 0.3-0.5 m, a significant increase in the density summation only occurs the first 9 years. The obtained results confirm the leading role of the level of groundwater in increasing the density of the addition of peat soils. The influence of mineralization of the peat is evident in the topsoil. At a depth of 0.6-1.0 m in 5 years after drainage of significant changes of density of addition is not happening.

In terms of Baraba in 32 years, the density of the composition is increased only in the 0.3 – m layer, but at the depth of 0.3-1.14 m it remained unchanged. In the first 18 years, the density of the composition at 0.3 – m layer increased by 46%, and in the next 15 years – just 5%. The increase in the mass of the plow layer mainly occurs due to compaction of peat in the sediment. A biochemical trigger of peat is insignificant. For 32 years it was 70 t/ha in the meter layer, which is equal to 2.2 t/ha per year, or 0.1% of the total reserves of peat [9]. Significant differences in the dynamics of increasing the density of the addition obtained in our experiments and in the context of Central Baraba, primarily due to the depth of groundwater. The deeper ground water table, the higher the rate of decomposition of peat organic matter. For 40 years the biochemical triggers for deep peat drainage (1.2 to 1.6 m in the vegetation period) in the one-metre layer was 138 t/ha; small (0.6-0.7 m) – 57.3 t/ha. This is respectively 3.5 and 1.4 t/ha / year or 6.1 and 2.3% of the total reserve of peat.

Determination of the density of the addition of low-powered peat soil on the experimental plot near medium confirmed the obtained results. The main increase in the density of the addition occurs in the layer of 0.3 m in the first years after drainage. Further, this process slows down to 1.6 times. Noteworthy is the fact that the density of the addition of low-powered peat soil differs slightly from the similar magnitude of medium of the soil. This is probably due to the fact that the degree of peat decomposition was similar (25-35%).

The degree of decomposition of peat from peat-gley the soil is much higher (>50%). This is reflected in the value of the density addition. Over a period of 20 years after drainage the density of the composition of peat-gley soil slightly increased under perennial grasses. The drawdown of the peat was minimal, which is very important, because complete loss of organic matter will inevitably lead to a significant decline in fertility.
A significant increase in the density structure in the arable layer of peat-gley soil is due to plowing the underlying mineral soil (tab. 2).

**Table 2.** The density of the composition of peat-gley soil depending on the depth of plowing, g/cm³

| Option experience | 0-0.1 | 0.1-0.2 | 0.2-0.3 | 0.3-0.4 | 0.4-0.5 | 0.6-1.0 |
|-------------------|-------|---------|---------|---------|---------|---------|
| Plowing: 0.22 m   | 0.294 | 0.282   | 1.622   | 1.630   | 1.608   | 1.59    |
| 0.27 m            | 0.295 | 0.298   | 1.520   | 1.620   | 1.595   | 1.59    |
| 0.32 m            | 0.415 | 0.450   | 1.370   | 1.595   | 1.590   | 1.60    |
| 0.37 m            | 0.482 | 0.459   | 0.820   | 1.582   | 1.605   | 1.60    |

Increasing the density of the addition of the peat layer (0.2 m) is due to its seal due to plowing mineral soil and change the structure of the pores. On the contrary, in the layer 0.2-0.3 m and partly at the depth of 0.3-0.4 m there is a decrease in density of the addition of the underlying mineral soil due to the enrichment of organic matter in result of plowing. Consequently, plowing mineral soil allows to optimize the density of the composition 0.3 m layer of soil. Essentially it is about creating a plow layer with new water-physical properties.

Unlike density addition, a relatively stable indicator is the density of the solid phase of the soil. Largely it is determined by the soil composition and does not depend on the addition. On the Reshetnikovo object for 35 years, the density of the solid phase of medium soil increased in the layer of 0.3 m of 5.4%, 0.5 m – 2.9% (table. 3). At a depth of 0.6-1.0 m, it remained almost at the initial level. The change in the density of the solid phase occurred gradually. So, after 9 years in the layer is 0.3 m, its value increased by 2.6%, in 23 years – 5.2% 35.54%.

Similar to these data the results obtained during the field research on shallow peat soil. The density of the solid phase of the soil remained at the original level. For perennial grasses, the mineralization of peat is very slow. This fact explains the stability of the solid phase low-powered peat soil. A practical point of view it is very good, as evidenced by the very low drawdown of the peat. Long-term preservation of peat organic matter is the key to future harvests and fertility.

**Table 3.** The density of the solid phase drained peat soils under perennial grasses, g/cm³

| Determining after drying | 0-0.1 | 0.1-0.2 | 0.2-0.3 | 0.3-0.4 | 0.4-0.5 | 0.6-1.0 |
|--------------------------|-------|---------|---------|---------|---------|---------|
| Medium-powered peat soil |       |         |         |         |         |         |
| After 5 years            | 1.60  | 1.53    | 1.47    | 1.54    | 1.54    | 1.52    |
| After 9 years            | 1.65  | 1.55    | 1.50    | 1.52    | 1.56    | 1.51    |
| After 23 years           | 1.70  | 1.54    | 1.59    | 1.53    | 1.59    | 1.52    |
| After 35 years           | 1.74  | 1.53    | 1.57    | 1.52    | 1.54    | 1.53    |
| Low-powered peat soil    |       |         |         |         |         |         |
| After 5 years            | 1.65  | 1.57    | 1.60    | 1.52    | 1.52    | 2.23    |
| After 9 years            | 1.66  | 1.55    | 1.57    | 1.54    | 1.54    | 2.20    |
| After 20 years           | 1.68  | 1.60    | 1.62    | 1.57    | 1.53    | 2.26    |
| Peaty – gley soil        |       |         |         |         |         |         |
| After 5 years            | 1.72  | 1.62    | 2.60    | 2.63    | 2.68    | 2.70    |
| After 9 years            | 1.70  | 1.69    | 2.63    | 2.73    | 2.70    | 2.69    |
| After 20 years           | 1.79  | 1.73    | 2.69    | 2.63    | 2.73    | 2.68    |

The problem of preservation of the peat layer is even more pronounced at the drained peat-gley soils. In the test area active processing of peat was able to prevent by maintaining the groundwater level at a depth of 0.6-0.8 m. the density of the solid phase of 0.2 - meter layer over the 20 – year period increased by only 5.4%.
The results provide a basis for concluding that the dry mode of low-power and especially peaty-gley soils must be significantly different from the level of the groundwater table at medium-powered soils. This approach will provide not only economic but also environmental benefits. Increasing the density of the addition and the solid phase of the soil in agricultural use leads to a decrease of the smallest moisture capacity (table 4).

**Table 4.** The minimum moisture content of drained peat soils under perennial grasses, mm

| Determining after drying | Depth, m | Medium-powered peat soil | Low-powered peat soil |
|--------------------------|---------|--------------------------|-----------------------|
|                          | 0-0.1   | 0.1-0.2                  | 0.2-0.3               |
| After 5 years            | 62.5    | 56.1                     | 60.0                  |
| After 23 years           | 60.0    | 52.9                     | 57.9                  |
| After 35 years           | 53.5    | 50.5                     | 56.7                  |
|                          | 0.4-0.5 | 0.6-1.0                  |                       |
| After 5 years            | 60.2    | 58.5                     | 60.5                  |
| After 9 years            | 58.2    | 60.5                     | 59.9                  |
| After 20 years           | 54.7    | 54.3                     | 58.8                  |
|                          | 0.3 m   | 0.4 m                    | 0.5 m                 |
| After 5 years            | 59.4    | 61.2                     | 34.6                  |
| After 20 years           | 50.7    | 53.4                     | 35.0                  |

At the field experimental plot in the ground water level of 1.2-1.6 m medium water-holding capacity of peat soil over a 35 – year period in the layer of 0.5 m decreased by 24.2 mm (8.5%). Thus in the rooting zone (0.3 m) water capacity was reduced by 11.5%, in the subsurface (0.3-0.5 m) is 2.5 times less. The slight decrease in the smallest moisture capacity occurred in the layer of 0.6-1.0 m, which in 35 - year period was 3.7%. The reduction in capacity due to reduced water-holding capacity of peat colloids.

Field studies also confirmed the reduction in the smallest capacity of low-powered peat soil. 9 years after draining the lowest water-holding capacity in the 0.5 m layer was reduced by 7 mm (2.4%), 20 years is 13.4 mm (4.6 per cent). In the rooting zone (0.3 m) layer of the reduction capacity has a maximum value of, respectively, 3.2 and 6.4%. Mineralization of peat organic matter is the cause of the decline in its water-holding capacity. The obtained results provide a basis for assumptions further reduce capacity.

The least water-holding capacity of peat-gley soil under perennial grasses over a 20 year period in the layer of 0.5 m decreased by 24.7 mm (10.2 percent). Most of the reduction in soil water content occurred in the peat of 0.2 – m layer (16.5 mm – 13.7%). Data for determining the density of addition and the solid phase of the soil confirm the mineralization of peat that leads to a decrease in the smallest capacity. To save peaty – gley soils must only be used for the cultivation of perennial grasses. To support a "meadow" type of the water regime (groundwater level at a depth of 0.7-0.9 m).

**Conclusion.**
1. The change of water-physical properties are functional in nature and primarily due to economic use of soil and the condition of its surface. The original water-physical properties of drained peat soils change the profile in connection with different degree of decomposition (20-45% or more) plants of the peat-forming plants. The differences persist after long-term (35 years) agricultural use.
2. The density of the medium soil composition after drainage is increased mainly due to shrinkage. The decrease in peat soil by 86% due to the seal, not the mineralization of organic matter. The annual reduction in the value of peat soils is 1.5 cm in the first five years after drainage, of 1.0-1.2 cm for 15 years and 0.6-0.7 cm in the next 20 years. In general, over the 40 – year period peat soil decreased from 1.5 to 0.9-1.0 m.
3. In the first five years after drainage, increasing the density structure in the layer of 0.2 m is 7.4%, in subsequent years, dropping to 2.1 and 3.0%. In the subsurface layer (0.3-0.5 m) the density of the composition increases during the 9 years. At a depth of 0.6-1.0 m the density of the composition remains fairly stable. In thin peat soil of the dynamics of change in density of the addition is similar to medium grounds. A significant increase in the density of addition is due to plowing (10-15 cm) of the underlying mineral soil.

4. The density of the soil solid phase is a relatively stable rate and determined by its composition and does not depend on the addition. For 35 years, the density of the solid phase medium of peat soil has increased in the layer of 0.3 m of 5.4%, 0.5 m, 2.9%. At a depth of 0.6-1.0 m, it remained at the initial level. Similar results were obtained from thin and peaty-gley soil.

5. Increasing the density of the addition and the solid phase of the soil in agricultural use leads to a decrease in the smallest capacity. The least moisture capacity of medium peat soil over a 35 – year period in the layer of 0.5 m decreased by 24.2 mm (8.5%), 0.3 m to 11.5%. Moisture content in the thin peat soils over a 20 year period reduced in half-meter layer of 13.4 mm (4.6 per cent). In the peat layer (0.2 m) peat-gley the soil moisture content in 20 years has decreased by 16.5 mm (13.7 per cent).

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