

Changing in Water-physical Properties of Drained Peat Soils during Extraction and Exploration of Minerals in the Conditions of the Northern Urals

A S Motorin, A V Iglovikov, A V Bukin

Northern Trans-Ural State Agricultural University, Respubliki Str. 7, Tyumen, 625003, Russia

e-mail: a.s.motorin@mail.ru

Abstract. Results of long-term (1976-2016) researches of water-physical properties of long seasonally-permafrost peat soils of Northern Trans-Urals are stated. It is shown that the shrinkage process has a significant impact on the density of peat soil, especially in the first years after drainage. In the Northern Urals, the annual decrease in the size of peat soil is 1.5 cm in the first five years after drainage, 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 0.2 m layer increases by 7.4%, decreasing to 2.1-3.0% in subsequent years. At a depth of 0.6-1.0 m, 5 years after drainage, there are no significant changes in the addition density. A significant increase in the addition density of peaty - gley soil established by plowing the 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 of the average peat soil in the 0.3 m layer increased by 5.4%; low - power for 20 years - increased by 1.2%. The lowest moisture content of the average peat soil for the 35-year period in the root (0.3 m) layer decreased by 11.5%; at a depth of 0.6 – 1.0 m – by 3.7%. In low-power peat soil reduction of moisture capacity in the 0.3 m layer for 20 years was 6.4%; in peat (0.2 m) layer of peaty - gley soil for the same period – by 10.2%.

1. Introduction

Important indicators of effective fertility of peat soils are water-physical properties [1-3]. Studies on meliorative systems of Belarus [4], non-black earth zone of Russia [5, 6], the Republic of Komi [7], Karelia [8], Barabinskaya lowland [9], Western Siberia [10, 11] were of great importance for establishing the consequences of drainage and agricultural use on the composition and properties of peat soils.

Drainage is the main primary factor that leads to changes in all soil processes occurring in the peat deposit [12]. Cultivation of crops and associated periodic loosening of the soil (plowing, disking, etc.), the use of mineral soil additives and fertilizers are secondary factors that have a significant impact on changes in the water-physical and physico-chemical properties occurring in the developed peat soil [13]. The intensity and direction of changes in the properties and regimes involved in the culture of peat soil depends on the optimal combination of primary and secondary factors [14]. Many aspects of this problem in the peculiar climatic conditions of the forest-steppe zone of the Northern Trans-Urals have not been studied enough. Even less attention is paid to agromeliorative methods of their regulation. All this hinders the development of techniques aimed at optimizing the water-physical



properties of drained peat soils.

The purpose of the research is to study the features of water – physical properties of drained long seasonal-permafrost peat soils of the Northern Trans-Urals.

2. Subjects and Methods

Studies were conducted from 1976 to 2016 on the Reshetnikovo experimental system, located in the Tyumen region in the Central part of the Tarman swamp, occupying an area of 125.8 thousand hectares on the second floodplain of the lake-alluvial terrace of the Tura River.

Water-physical properties of peaty-gley (a 0.2 m layer of peat), low-power (a 0.7 m layer of peat) and medium (a 1.5 m layer of peat) peat soil were studied at the object Reshetnikovo. Peat-forming plants were sedge, cane, hypnum, etc. The decomposition degree of peat varied from 20 to 45%. Its maximum value was in peaty-gley soil (more than 50%).

Initial water-physical properties of peat were determined before drainage. Water-physical properties of peat were studied by methods commonly used in soil science [15], [16]. To select soil samples, soil sections were laid on permanent (fixed) sites.

3. Results

Studies have found that the changes in the water-physical properties are functional and mainly due to the economic use of the soil and the state of its surface. The evidence of this is the density of medium-lying peat soil. The density of the soil composition of atmospheric-alluvial type of water supply varies significantly along the profile (table. 1).

Table 1. The composition density of dried peat soils under perennial grasses, g/cm³

Time of determination after drying	Depth, m					0.6-1.0
	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Prior to drainage	Medium-power peat soil					
	0.126	0.122	0.131	0.123	0.126	0.114
After 5 years	0.187	0.154	0.151	0.133	0.135	0.150
After 9 years	0.188	0.180	0.156	0.165	0.154	0.152
After 13 years	0.193	0.215	0.157	0.159	0.153	0.156
After 23 years	0.227	0.193	0.152	0.154	0.155	0.159
After 35 years	0.230	0.200	0.160	0.159	0.160	0.155
After 5 years	Low-power peat soil					
	0.181	0.175	0.176	0.156	0.151	0.96
After 9 years	0.194	0.185	0.172	0.158	0.160	0.94
After 20 years	0.200	0.190	0.182	0.158	0.158	0.97
After 5 years	Peaty-gley soil					
	0.310	0.320	1.63	1.62	1.61	1.59
After 20 years	0.315	0.325	1.65	1.55	1.62	1.60

This is explained by the fact that the very heterogeneous decomposition degree peatland was formed as a result of dying vegetation: weakly decomposed layers (15-20%) alternate with medium decomposed (30-45%). Differences in the addition density to the profile of peat soils remain after a long (35 years) agricultural use.

The process of compaction (shrinkage) has a significant impact on the density of peat soil addition, especially in the first years after drainage. Shrinkage of peat in the process of use is mainly due to the reduction of large pores. Therefore, the most intensive shrinkage processes occur in weakly decomposed peat, where large pores prevail [1].

One of the indirect indicators of compaction is a decrease in the size of the peat layer. The decrease in peat soil by 86% caused by the seal, not the mineralization of organic matter. In the conditions of

the Northern Trans-Urals we have established an annual decrease in the size 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, during the 40-year period peat soil decreased from 1.5 to 0.9-1.0 m.

The data obtained in Belarus [17] deserve attention with regard to the dynamics of changes in the density of addition to agricultural use of peat soils. Significant changes in peat soils occur here in the first 18-25 years. We have established a similar pattern in the Northern Trans-Urals. The density of addition in the arable layer (0.2 m) of soil in the first five years after drainage increased by 37.1%, 9 years – by 48.4, 13 years – by 64.5, 23 years – by 69.3 and 35 years – by 73.4%. The above data show that the annual increase in the addition density decreases from 7.4% in the first five years after drainage to 2.1-3.0% in subsequent years. In the sub-arable 0.3-0.5 m layer, a significant increase in the addition density occurs only the first 9 years. The obtained results confirm the leading role of groundwater level in increasing the density of peat soil formation. The influence of peat mineralization is manifested in the arable layer. At a depth of 0.6-1.0 m 5 years after drainage, significant changes in the addition density do not occur.

In Baraba conditions, for 32 years, the addition density increases only in the 0.3-meter layer, and at a depth of 0.3-1.14 m, it remained unchanged. In the first 18 years, the addition density of a 0.3-meter layer increased by 46%, and in the next 15 years – by only 5%. The increase in the mass of the arable layer is mainly due to the compaction of peat during planting. Biochemical actuation of peat is insignificant. For 32 years, in the meter layer it was 70 t/ha, which is equal to 2.2 t/ha per year, or 0.1% of the total reserve of peat [9]. Significant differences in the dynamics of increasing the density of addition, obtained in our experiments and in the conditions of the Central Baraba, are due primarily to the depth of groundwater. The deeper the ground water table is, the higher the rates of decomposition of peat organic matter are. For 40 years, the biochemical triggers for deep peat drainage (1.2 to 1.6 m in the vegetation period) in the one-meter layer were 138 t/ha; small (0.6-0.7 m) – 57,3 t/ha. This is 3.5 and 1.4 t/ha per year respectively or 6.1 and 2.3% of the total reserve of peat.

Density determination of low-power peat soil on the experimental site near the Medium-power peat soil confirmed the results. The main increase in the addition density occurs in the 0.3 m layer in the first years after drainage. In the future, this process slows down by 1.6 times. The addition density of low-power peat soil differs slightly from the similar value of medium-power soil. This is probably due to the fact that the decomposition degree of peat was almost the same (25-35%).

The decomposition degree of peat from peaty-gley the soil is much higher (>50%). This is reflected in the magnitude of the addition density. During the 20-year period after drainage, the density of peaty-gley soil addition increased slightly, being under perennial grasses. The trigger of the peat was minimal, which is very important, because complete loss of organic matter will inevitably lead to a significant decline in fertility.

In contrast to the density of addition, a relatively stable indicator is the density of the solid phase of the soil. To a large extent, it is determined by the soil composition and does not depend on the addition. At the Reshetnikovo site for 35 years, the density of the solid phase of the medium-power soil increased in a layer of 0.3 m by 5.4%, 0.5 m - by 2.9% (table. 2). 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. Thus, after 9 years in the layer of 0.3 m, its value increased by 2.6%, after 23 years – by 5.2%, 35 years – by 5.4%.

Table 2. Density of solid phase of drained peat soils under perennial grasses, g/cm³

Time of determination after drying	Depth, m					
	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.6-1.0
Medium-power 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-power 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

Close to these data, the results were obtained during field studies on low-power peat soil. The density of the solid phase of the soil practically remained at the initial level. For perennial grasses, the mineralization of peat is very slow. This fact explains the stability of the solid phase of low-power peat soil. From a practical point of view, this is very good, because it confirms a very low actuation of peat. Long-term preservation of peat organic matter is the key to future high yields and fertility.

The problem of preserving the peat layer is even more acute in drained peatland soils. On the experimental plot, the active trigger of the 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 obtained results give the basis for the conclusion that the drainage regime of low-power and especially peaty-gley soils should significantly differ from the level of groundwater occurrence in medium-power soils. This approach will ensure not only economic, but also environmental impact.

The increase in the density of the addition and the solid phase of the soil in agricultural use leads to a decrease in the lowest moisture capacity (table 3).

Table 3. The lowest moisture content of drained peat soils under perennial grasses, mm

Time of determination after drying	Depth, m					
	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.6-1.0
After 5 years After 23 years After 35 years	Medium-power peat soil					
	62.5	56.1	60.6	60.0	69.3	341.1
	60.0	52.9	57.9	57.4	68.8	331.2
	53.5	50.5	56.7	57.1	66.5	328.8
After 5 years After 9 years After 20 years	Low-power peat soil					
	60.2	58.5	60.5	60.5	63.8	303.5
	58.2	60.5	59.9	56.7	61.2	296.5
	54.7	54.3	58.8	60.3	62.4	290.1
After 5 years After 20 years	Peaty-gley soil					
	59.4	61.2	34.6	37.3	35.4	192.0
	50.7	53.4	35.0	33.0	31.1	186.2

At the field experimental site at the level of groundwater 1.2-1.6 m, the moisture content of the medium-power peat soil for the 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 sub-arable (0.3-0.5 m) is 2.5 times less. The most insignificant decrease in the lowest moisture capacity occurred in the layer of 0.6-1.0 m, which for the 35-year period amounted to 3.7%. The decrease in water intensity is due to the reduction of water-retaining capacity of peat colloids.

Field studies have also confirmed a decrease in the lowest moisture capacity in low-power peat soils. 9 years after drainage, the lowest moisture capacity in the 0.5 m layer was reduced by 7 mm (2.4%), 20 years - 13.4 mm (4.6 per cent). In the root (0.3 m) layer, the decrease in moisture capacity has a maximum value of 3.2 and 6.4%, respectively. Mineralization of peat organic matter is the

reason of the decrease of its water-retaining ability. The obtained results give the basis for the assumption of the further reduction of moisture capacity.

The lowest moisture content of peaty-gley soil under perennial grasses in the layer of 0.5 m decreased by 24.7 mm (10.2%) during the 20-year period. The main reduction in soil moisture capacity occurred in the peat 0.2-meter layer (16.5 mm – 13.7%). Data by determining the density of addition and a solid soil phase confirm the process of mineralization of peat that leads to a decrease in the smallest moisture capacity. Peaty-gley soils must only be used for the cultivation of perennial grasses for conservation of peat. At the same time, it is necessary to maintain the "meadow" type of water regime (groundwater level at a depth of 0.7-0.9 m).

4. Conclusion

1. Changes in water-physical properties are functional and mainly due to economic use of the soil and the state of its surface. The initial water-physical properties of drained peat soils vary in profile due to the varying degree of decomposition (20-45% or more) of peat plants. The differences persist after long-term (35 years) of agricultural use.

2. The composition density of the medium-power soil after drainage increases mainly due to shrinkage. The decrease in peat soil by 86% caused by the seal, not the mineralization of organic matter. In the conditions of the Northern Trans-Urals, we have established an annual decrease in the size of peat soil of 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, during the 40-year period peat soil decreased from 1.5 to 0.9-1.0 m.

3. In the first five years after drainage, the density of the 0.2 m layer increases by 7.4%, decreasing to 2.1-3.0% in subsequent years. In the sub-arable layer (0.3-0.5 m), the density of the addition increases over 9 years. A significant increase in the addition density of peaty - gley soil established by plowing the 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 of the average peat soil in the 0.3 m layer increased by 5.4%; low-power for 20 years - increased by 1.2%. The lowest moisture content of the average peat soil for the 35-year period in the root (0.3 m) layer decreased by 11.5%; at a depth of 0.6-1.0 m – by 3.7%. In low-power peat soil, the reduction of moisture capacity in the 0.3 m layer for 20 years was 6.4%; in the peat (0.2 m) layer of peaty-gley soil for the same period – by 10.2%.

4. A relatively stable indicator is the density of the solid phase of the soil. To a large extent, it is determined by the soil composition and does not depend on the addition. At the Reshetnikovo site, for 35 years, the density of the solid phase of the medium-power soil increased in a 0.3 m layer by 5.4%, 0.5 m - by 2.9%. At a depth of 0.6-1.0 m, it remained almost at the initial level. Similar results were obtained in low-power and peaty-gley soils.

5. The increase in the density of the addition and the solid phase of the soil during agricultural use leads to a decrease in the lowest moisture capacity. The lowest moisture capacity of the medium-power peat soil in the 35-year period in the layer of 0.5 m decreased by 24.2 mm (8.5%), 0.3 m – by 11.5%. The moisture capacity of low-power peat soil decreased by 13.4 mm (4.6%) in a half-meter layer over a 20-year period. In the peat layer (0.2 m) of peaty-gley soil, moisture capacity decreased by 16.5 mm (13.7%) in 20 years.

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