The water regime of the long-seasonally-frozen peat soils of the Northern Trans-Ural

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Abstract. The results of many-years research of the water regime of the long-seasonally-frozen peat soils of the Northern Trans-Uralare described. It is shown that the fluctuation of groundwater in the Tarmanskoe swamp before drying is characterized by a sharp increase in levels during the spring snowmelt, then – a minimal level in summer, increase in levels in autumn, and winter minimum. The intensity of the decline in groundwater depends on precipitation (r=0.83) and evaporation. The change of groundwater level in winter is significantly affected by the progress of freezing of the upper layer and thaw. After drying at atmospheric-alluvial type of water supply of the swamp, the groundwater level during the vegetation period is determined mainly by the amount of rainfall (r=0.76). The deepest groundwater table (1.97 m) on average during the growing season set in 2012, when 56.7% of the average annual norm of precipitation fell. On the dried potter`s drainage (To=24 m, H=1.5 m) land there is no increase of the groundwater in the autumn. The lowest possible (2.5 m and more) level of the groundwater table reaches in the beginning of snowmelt in late March - early April. The magnitude of the spring rise is 1-1.5 m and depends on winter moisture (r=0.65), the snow cover and the intensity of the melting of solid precipitation. The humidity of the root layer (0.3 m) medium peat soil with a deep groundwater table (1.3 to 1.9 m) under perennial grasses is in the range of 0.5-0.6 LMC (the least moisture capacity). In the formation of the first mowing of perennial grasses, soil moisture is in the optimum range (0.6-0.85 LMC); in the high-draught years for a full second mowing has a deficit. On the boundary of the thawed and frozen layers, soil moisture is always at the upper limit of the optimum (0.85-0.95 LMC). During the winter period, the moisture reserves in the upper layer 0.5 m up to 20% due to the underlying horizons.

1 Introduction

The method of water regime regulation of drained peat soils is a change in position of the groundwater [1,2]. The lowering of the groundwater level during the growing season below the depth distribution of roots is necessary for normal plant growth [3,4]. The draining of the marshes under the most demanding normal drainage leading culture should be considered correct [5,6]. The most rational is to create a "meadow" type of water regime in peat soils, in which the capillary fringe is not divorced from the root layer [7,8]. Normal

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drainage shall be adopted in accordance with the requirements of SNiP 2.06.85. Average values for meadows on fens are 0.6 m [9]. At a deeper draining the humidity of topsoil is greatly reduced due to the fact that evaporation and transpiration of moisture occur more intense than the capillary rise of groundwater. In addition, deep groundwater table reduces the minimum moisture content in the layer 0.5 m [10].

In the conditions of long-seasonally – frozen soils the determination of the optimal depth of groundwater (normal drainage) is especially important [11,12]. Vague questions arise about regulation of drainage in the period of the presence of permafrost in the soil and about the role of the winter position of groundwater in the water regime of the vegetation period [13]. A powerful natural factor, opposing early-summer arid period, is seasonal permafrost [14]. The purpose of the research is to study the characteristics of the water regime long-seasonally-frozen peat soils of Northern Trans-Ural in the cultivation of perennial grasses.

2 Subjects and Methods

Studies were conducted in the experimental drainage station Reshetnikovo, dried by pottery drainage with a distance of 24 m and a depth of 1.5 m.Experienced reclamation Reshetnikovo system located in Tyumen district, in the Central part of the bog Tarmanskoe, covering an area of 125.8 thousand ha in the second lacustrine-alluvial terraces of the river Tura.

The soil of experimental plot is presented of low-ash (4.7-6.5%) sedge-reed medium peat bog (150 cm) with the degree of decomposition of 20-45%.

The first 2 years after drainage and initial processing of peat with machines MTP-42 at the depth of 0.25-0.27 m oats cultivated for green fodder. After that, the grassing of the area by perennial grasses for hay was conducted.

The well depth of 2.7 m was drilled for observation of the groundwater level at the experimental site. The level of groundwater was measured by a "cracker" every ten days throughout the year. Soil moisture was determined by thermostat-weight method in 10-15 days during the warm period. The accumulation of moisture in the soil during the cold period studied its definition before freezing at the end of October and before the snowmelt. The influence of winter precipitation on soil moisture for early growing season of perennial grasses – in 2-3 days after snowmelt.

3 Results

Analysis of groundwater regime on the Tarmanskoe swamp before drying carried out on the basis of observations of the Tyumen marsh station, which operated from 1959.

The beginning of the spring levels rising of drainage on Tarmanskoe array refers to 13-16 April. The intensity of the rise is different, in flooded areas it is 7-10 cm per day, the other areas - 1-2 cm. The occurrence of the maximum level occurs in the first decade of May. In some years, due to weather conditions, there may be significant deviation from the average date up to 30-40 days. Air temperature and precipitation have an impact on the reduction date of the maximum. As a rule, the natural state of the high level is above the surface of the swamp. However, in some years it is marked by 0.1-0.2 m below the surface. The maximum level is characterized by great variability. The coefficient of variation is greater than 1.

Duration of lifting the entire array is 28-35 days. Sometimes, depending on the distribution of air temperature and precipitation, it varies from 3 to 70 days.

The decline in levels lasts 2-3 months. In the grass-moss group the average duration of recession is 100-110 days, in shrub is 50-75 days. The intensity of the decay depends on precipitation and evaporation, the correlation coefficient of these connections is 0.83.

Summer low-water period occurs after recession levels. The average duration of this period is 100-130 days. In summer the position of the levels depends mainly on precipitation and evaporation.

The analysis showed that there is no direct relationship between these variables. The correlation coefficient is 0.49. Upgrades levels observed during extended precipitation, average on the studied array reach 0.2-0.3 m, and in some years – 0.6 m.

Periodic oscillations of the levels are typical for the Tarmanskoe array marsh waters during the whole summer period. The magnitude of the rise depends on the relief and height of standing levels by the time of the rainfall. Analysis of long-term data showed that the lower was the level of bog water from the bog surface to the point of precipitation, the more and the closer the relationship of the studied variables. The scatter of the points depends on the micro relief of the bog. The increase in the magnitude of response as the level decreases due to a decrease in the yield of peat deposits with a depth level and a different magnitude of seepage flow from the top and bottom horizons of the peat deposit.

The minimum level in the summer period is observed in different months depending on weather conditions. The average minimum level in the grass-moss group is about 0.44-0.60 m, in shrub – 0.21-0.37 m from the surface of the swamp. In dry years, the minimum level is lowered to 1 m below the surface of the swamp.

Since the beginning of the freezing marshes (mid-October) comes the winter season, which characteristic feature is the lack of groundwater evaporation. Therefore, the change in groundwater levels in the marshes occurs mainly under the influence of seepage flowing in the active layer. To change the level in the winter is significantly affected by the progress of freezing of the upper layer and thaw.

The minimum winter level on the Tarmanskoe swamp is observed in February – March, the average duration of the winter low water period is 150-170 days.

The draining of swamps for agricultural use causes a sharp decline in groundwater levels. For many years (1980-2016), on the Reshetnikovo object, we have conducted studies on the mode of occurrence of groundwater at the site, dried by the pottery drainage with a depth of 1.5 m and a distance of 24 m. Obtained results have a great practical value, as they allow you to set the amount of moisture with a deep groundwater table during the vegetation period. Consider the example of recent years research (2011-2015). At atmospheric-alluvial type of water supply swamps the level of groundwater during the vegetation period is determined mainly by the amount of rainfall ($r=0.76$). Over the past years of research, the deepest groundwater table (1.97 m) recorded in 2012, when during May – September only dropped 159.4 mm (56.7%) of precipitation instead of 281 mm average long-term norm. In the first half of the vegetation period the groundwater was at the depth of 1.4-1.62 m. By mid-September they dropped to 2.42 m, which is more than twice the optimal level of drainage.

It should be noted that a similar situation existed in the summer of 2011, despite the fact that fell 97.9 mm more precipitation. The reason for this is the drought of 2010, when during the warm period has dropped only 211 mm. soil Moisture dropped to 0.4 LMC. Resulting in half-meter layer of soil there was a considerable regulating capacity. The drop-down precipitation the following year was to replenish the moisture of upper soil layer did not reach the level of groundwater.

Heavy autumn and winter precipitation of 2012 was provided in the spring 2013 the rise of groundwater to the end of April to 1 M. in addition, in May fell to 63.9 mm of rain while the norm is 38 mm. In the result until the end of June the ground water did not fall below 1.07 m - were in the optimal range. In the second half of the vegetation period ground water activity is reduced and by mid-September had reached a depth of 1.96 m. During this period, rain fell 120.3 mm instead of 180 mm according to the norm.

In May-June 2014, the level of groundwater was also at the optimal depth (0.8-1.1 m). During the formation of the second mowing of perennial grasses decreased to 1.54 m. Especially active reduction of groundwater occurred in August.

Studies found that the level of groundwater is determined not only by rainfall but also its timing. So, during the vegetation period of 2013 fell 297.1 mm of rain in 2014 was 271.7 mm; in May-June 2013, the amount of precipitation was 97.8 mm, 2014 – 91.0 mm; July-September, respectively, 199.3 mm and 180,7. While in both years until the end of June the level of groundwater was almost the same (0.88-1.07 and 0.84-1.1 m). By mid-September 2014, they were at a depth of 1.54 m, while at the same date in 2013 below is 0.42 m. This circumstance is explained by the peculiarities of rainfall. In July 2014, heavy rainfall (117.9 mm 196.5% of normal) fell over two decades. Regulating capacity of the soil was low and precipitation was actively replenishing groundwater.

The level of groundwater during the vegetation period 2015 was close to the previous year. During the summer season his position was changed only slightly, helped by relatively uniform rainfall.

In all years of study in the autumn period, there was no rise of the groundwater level. They slowly decreased and reached its lowest possible position by the end of March (2.5 m or more), by early snowmelt. The magnitude of the spring rise was 1-1. 5 m and depended on the pre-winter soil moisture (r = 0.69),the snow depth, the intensity of the melting of solid precipitation and air temperature.

Deep occurrence of groundwater in all years of research was the main reason for low humidity peaty soil in half-meter layer (tab.1).

On average over the five years of research, the humidity of 0.1 m amounted to 125.9% 0.57 in (LMC), with an interval of 112.4-151.1% (0,5-0,68 LMC). A similar situation existed in the rooting zone of 0.3 m. In this layer, the soil moisture was kept during the vegetation period in the range of 129.7-166.3% (0.47-0.60 LMC).

Table 1. Humidity of the medium peat soils under perennial grasses during the vegetation period (average terms), %.

Years	Humidity in the layer, m				
	0-0.1	0-0.3	0-0.5	0.6-1.0	0-1.0
2011	151.1	166.3	174.8	376.4	275.6
2012	130.9	131.3	137.9	346.6	242.3
2013	121.5	129.7	155.8	311.0	233.4
2014	112.4	144.1	164.7	351.2	257.9
2015	113.8	134.2	178.3	368.3	273.3
The least moisture capacity (LMC)	223.1	276.8	334.6	400.2	367.4

In general, upper layer 0.5 m, the soil moisture amounted to 137.9-178.3% (0.41-0.53 LMC). The obtained results provide a basis for practical conclusions: deep drainage leads to a deficiency of moisture for growing crops, especially the formation of the second mowing of perennial grasses. It must be stressed that in May and June, when forming the first mowing of perennial grasses, soil moisture deficit in the medium peat soil are not present absolutely, or it is minimal. The average for the study years the soil moisture in the layer of 0.3 m in May-June was 167.1% (0.6 LMC). In May, when the active growing season of perennial grasses was begun, the soil moisture was always optimum (0.7-0.85 LMC). In the second half of the vegetation period, the humidity of the root layer decreased to 107.7-152.2% (0.39-0.55 LMC).

As a preventive measure can be used the spring water saturation to full capacity by the beginning of active growth of grasses. Then (in 3-6 days) required water discharge to the level of 0.5 m. After that set the level of groundwater is set to (0.8-1.0 m) [15].

Studies have shown that soil moisture half-meter layer depended mainly on rainfall. Low soil moisture observed in 2012, when they dropped slightly more than half of the mean annual rainfall. The height of capillary rise of moisture from the medium peat soil is only 0.75 m. Therefore, groundwater at the level of occurrence of 1.5 m or more did not affect the humidity of the root layer into the second half of the growing season.

In the early spring (until late may) ground water was under a layer of permafrost. So they in this period have no effect on soil moisture. In open areas the permafrost disappears 2-3 weeks earlier than in the occupied vegetation because perennial grasses cover the soil surface and thereby reduces the amount of heat flow [16]. During the research years at the Reshetnikovo object there was no flooding of top soil during periods of precipitation, including intensity of more than 10-15 mm per day. Permafrost with low humidity of the soil is "loose" and is not a waterproof monolith. The moisture produced by the melting of solid precipitation, relatively easy to move down the soil profile to groundwater.

In addition to precipitation, soil moisture is significantly affected by permafrost. This is particularly noticeable in dry periods. On the boundary of the thawed and frozen layers, the difference in the moisture content reaches 50 to 120% and more. The rational use of moisture is due to slow defrosting of the soil. As it is earlier noted, during the research, the depth of frost penetration changed slightly. The reason is a deep groundwater table. Our study confirmed the data [17], that the depth of frost penetration depends on the position of groundwater in the autumn and winter to a certain depth. The amount of freezing of the soil not depends on the level of standing groundwater at depth greater than 1.5 m. In this regard, the thawing of the soil occurred approximately during the same dates that had an impact on its moisture content.

Reduced soil moisture in summer is temporary. During the cold period and during snowmelt moisture reserves are replenished again (Table 2).

Table 2. Moisture accumulation in a medium peat soil during the autumn-winter period, %.

Thedateofdetermination	Depthdefinitions, m				
	0-0.1	0-0.3	0-0.5	0.6-1.0	0-1.0
7.10.2010	88.5	111.0	149.2	368.2	258.7
5.04.2011	156.9	129.7	153.8	309.2	236.5
23.10.2011	184.2	156.6	145.4	393.6	269.5
27.05.2012	191.6	237.9	294.1	410.0	352.0
26.10.2013	154.4	180.7	166.6	393.1	250.2
26.03.2014	250.6	246.4	241.4	333.7	317.3
30.10.2014	220.3	227.4	188.1	366.2	277.2
19.03.2015	239.2	233.5	199.5	345.5	278.5

In half-meter layer soil moisture increased on average for the three winters study period from 0.5 to 0.6 LMC (20%). Main replenishment of soil moisture occurred during the period of snowmelt. So, if due to winter distillation of moisture in frozen soil, it increases by 20% compared to pre-winter value, then after the snow has melted by 80%. Added to this, is that the results are correct for the conditions of deep winter levels of groundwater. The increase of moisture in the frozen layer is associated with its movement, mostly in the form of liquid water. The role of vapor condensation is small at 4-7% of the total amount of water moved in the frozen layers of soil for the season [18,19]. At a depth of 0.6-1.0 m decrease in soil moisture occurs. This means that the accumulation of moisture in the upper soil layer compensate due to its underlying horizons. Ground water plays a minor role [20,21].

The result of years research found that even with a deep groundwater table during the vegetation period, a significant humidity change is limited to the top layer of 0.5 m. At a depth of 0.6-1.0 m soil moisture on average over the five years was 0.88 LMC, that was at the upper limit of optimality. Low soil moisture during these years at a depth of 0.6-1.0 m was 0.78 LMC, and the maximum is 0.94. There has not been a single time excess humidity higher than the smallest capacity around the meter layer of peat soil.

4 Conclusion

1. The fluctuation of groundwater in the Tarmanskoe swamp before drying is characterized by a sharp increase in levels during the spring snowmelt, then – a minimal level in summer, increase in levels in autumn, and winter minimum. The intensity of the decline in groundwater depends on precipitation (r=0.83) and evaporation. The change of groundwater level in winter is significantly affected by the progress of freezing of the upper layer and thaw.
2. After drying at atmospheric-alluvial type of water supply of the swamp, the groundwater level during the vegetation period is determined mainly by the amount of rainfall (r=0.76). The deepest groundwater table (1.97 m) on average during the growing season set in 2012, when 56.7% of the average annual norm of precipitation fell.
3. The level of groundwater is determined not only by amount of precipitation during the vegetation period, but also their distribution. Heavy precipitation (117.9 mm; 196.5% of normal) during the second and third decade in July 2014, provided the rise of groundwater of 0.42 m compared to 2013, despite almost the same amount on average during the growing season, respectively 297.1 and 271.7 mm.
4. In the autumn period, there was no rise of the groundwater level. They slowly decreased and reached its lowest possible position by the end of March (2.5 m or more), by early snowmelt. The magnitude of the spring rise was 1-1.5 m and depended on the pre-winter soil moisture (r = 0.69),the snow depth, the intensity of the melting of solid precipitation.
5. The humidity of the root layer (0.3 m) medium peat soil with a deep groundwater table (1.3 to 1.9 m) under perennial grasses is in the range of 0.5-0.6 LMC (the least moisture capacity). In the formation of the first mowing of perennial grasses, soil moisture is in the optimum range (0.6-0.85 LMC); in the high-draught years for a full second mowing has a deficit (0.4-0.5 LMC).
6. Permafrost with low humidity of the soil is "loose" and is not a waterproof monolith. The moisture produced by the melting of solid precipitation, relatively easy to move down the soil profile to groundwater. On the boundary of the thawed and frozen layers, the difference in moisture content is 50-120 %.
7. Reduced soil moisture in summer is temporary. During the cold period the water reserves in half-meter layer is replenished by 20% (from 0.5 to 0.6 LMC). The accumulation of moisture in the upper soil layer compensate due to its underlying horizons. Ground water plays a minor role. Main replenishment of soil moisture with a deep groundwater table occurs within the period of snowmelt.

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