Influence of Hydrological Conditions on the Meliorative Features of the Soils of the Novgorod Region

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Abstract. The article is devoted to the problem of drainage and conditions of soil moisture in the Novgorod region; the solution of this problem is associated with the definition of reclamation measures in agricultural land use. The article gives a characteristic of drained areas, identified based on the conditions of their moisture, type of nutrition, depth of groundwater, granulometric composition and filtration coefficient of rocks, height of the terrain and, accordingly, the degree of soil moisture, and proposed reclamation measures aimed at increasing their fertility.

1. Introduction
The natural conditions of the Novgorod region are not homogeneous, which affects the degree of soil drainage and, accordingly, determines the level of moisture in agricultural lands and directly affects the agricultural technology of using the land fund and growing agricultural crops.

2. Objects and methods of research
The object of the study was the territory of the Novgorod region. The research was carried out in the course of fieldwork and educational practices of students. The research methods were the analysis of cartographic materials, the construction of hypsometric profiles, the leveling of slopes, the study of geological and soil sections, soil profiles.

3. Results and discussion
The highest and most dissected parts of the region are tied to the Valdai Upland. It is possible to distinguish an area of intensively drained hilly-ridged and hilly-hollow formations of the regional glacial complex with atmospheric water supply. The region is distinguished with the maximum heights for the region from 150 to 280 meters, significant slopes of the surface, various combinations of hills and depressions. A characteristic hilly-moraine landscape, groups of kams, kama-deltaic forms, ozas, bells form elevations of up to 30 meters or more. Interhill depressions in the area are often lakeside, the spread of bogs is insignificant. The area is confined to the Carboniferous plateau; therefore, the Quaternary deposits at the margins of the zone lie on the sandy-argillaceous sediments of the Upper Devonian and Carbon, but mainly on the calcareous rocks of the Carbon. Quaternary deposits form a stratum 30–60 meters thick, consisting of glacial and water-glacial deposits – boulder loams and sandy loams, clays and sands of various grain sizes, gravel-pebble deposits. This complex of sediments with different filtration properties is generally dominated with boulder loams and sandy loams. For areas of development of hilly-moraine relief, these lithological differences are dominant [1]. Kams are composed of fine-grained and fine-grained sands, and ozas are composed of sands of various grain sizes. The
filtration coefficient varies on average from 0.36 to 7 m / day, but can reach tens of meters per day. In interlayers of different-grained sands and in gravel-pebble deposits, the filtration coefficient is 9.15 and 66.25 m / day, respectively. Fluvioglacial deltas are composed of different-grained sands (2.8-21.3 m / day), gravel-pebble deposits with interlayers of fine and fine-grained sands and sandy loams, the filtration coefficient of which does not exceed 0.45 m per day. Groundwater occurs at a depth of 3–5-10 meters, which is associated with a highly dissected topography and confinement to sandy surface formations, or to lenses and sand interlayers in a loamy moraine. The amplitude of the water level fluctuations is 0.5–4.0 m. The water supply of the zone is carried out due to atmospheric precipitation, the amount of which ranges from 600 to 800 mm / year and more. [2]. In some places, at the foot of the hills and along the slopes of river valleys, groundwater comes to the surface, forming springs. Intensive discharge of groundwater is carried out into the river network and lakes. In the southern part of the Valdai Upland, which has incisions in river valleys with a depth of more than 50 m, the unloading is most intense. Karst processes are also widespread in the region, melt and rainwater is absorbed in karst sinkholes and cracks. In such conditions, to drain the depressions, it is possible to recommend an accelerated discharge of surface water with building branch channels into the existing river network.

Within the Valdai scarp, bordering the highest areas of the upland and exceeding 80-120 meters, an area of well-drained moraine and water-glacial plains, hilly-moraine and kame formations of atmospheric and groundwater supply should be distinguished. This should include the slopes of the Mstinskaya depression, Tikhvin ridge, Ostashkovskaya ridge. The slopes of the surface here are less than in the first region and fluctuate in the range of 0.01–0.02. The area is characterized with a large swumpiness, but it is usually within 10%, rarely up to 15–20%. The density of the river network reaches 20%-30%, the depth of the preglacial valleys is 40–60 m, and the depth of other 10–20 m. In a number of river channels, rapids and rifts, significant flow rates are observed. Karst phenomena are less developed. The area is dominated with moraine and outwash plains, hilly-moraine formations, kama and kama-delta forms do not exceed 15% of the area. Moraine plains on the Valdai scarp are expressed in the form of inclined terraces, lowering to the west. The general slope of the outwash plains is directed to the east, towards the Molo-Sheksninskaya lowland. As usual, moraine plains are composed of boulder loams and sandy loams, contain interlayers and lenses of sands of various grain sizes. The thickness of the moraine reaches 18 m, the thickness of the interlayers is 4 m. The filtration coefficient of the moraine is 0.003–0.3 m / day, in the interlayers of sands of varying granularity, it is 0.02–4.5 m / day. Fluvioglacial plains are composed of sands of varying granularity with a predominance of medium- and coarse-grained varieties, with interlayers of gravel-pebble deposits. The thickness of sands is up to 15 m, of gravel-pebble formations up to 6 m. The filtration properties of outwash sand deposits are characterized with a range of 1.0–13 m / day. The Quaternary strata of the zone is confined to the slope of the Carboniferous plateau, composed of sandy-clayey sediments of the Upper Devonian and Carboniferous with interlayers of calcareous rocks. Some areas are composed of calcareous rocks [3]. The depth of groundwater most often exceeds 1.5 m; in many it reaches 3 or more meters. During spring floods, groundwater levels rise to 0.5–1 m, contributing to a short-term excess moisture in outwash and moraine plains. The slopes of the groundwater surface are 0.002–0.2. Long-term waterlogging is characteristic of depressions, sometimes occupied by swamps, where water-resistant rocks are developed. The amount of precipitation within this territory is 700–800 mm. Part of the district is characterized with waterlogged lands, the water supply of which is carried out at the expense of precipitation and groundwater runoff. Unloading of water takes place on the slopes of sandy hills and in river valleys. To regulate the water balance (surface runoff, groundwater and pressure water) in the described area, open water canals can be used to discharge surface water, horizontal drainage, trapping canals can be used to lower the groundwater level, and in some areas, vertical drainage can be used to drain groundwater into the underlying aquifers [4].

The largest area in the region is occupied with the area of poorly drained moraine, fluvi-glacial, lacustrine-glacial and bog plains of atmospheric, ground and ground-pressure feeding. In the Priilmenskaya lowland, the absolute heights of the plains of this region are 35–80 m, in the Mologa river basin, in the east of the region; they reach 150 m and more. There are small slopes of the surface (less
Areas with steeper slopes occur at the transitions from moraine plains to lower lacustrine-glacial ones. Here the slopes reach 0.01. The degree of waterlogging of the area in some places is more than 50%, usually about 25%. The density of watercourses is relatively high within the Polistovskaya moraine and Kholmsk lacustrine-glacial plain (30–50%), in other areas of the zone the slopes of the rivers are small, no more than 0.002. Moraine and fluvioglacial plains in composition and thickness of sediments, their properties, including filtration, are close to similar morphogenic types of the second region. Lacustrine-glacial sediments are represented with fine and fine-grained sands, often silty and clayey sandy loams, band clays and loams. The thickness of sands sometimes reaches 10 m, sandy loam – 4 m, clay – 10 m. They are underlain mainly with loamy moraine, less often with sandy sediments of various grains. The filtration coefficient for fine and fine-grained sands ranges from 0.5 to 3.5 m / day, for sandy loams – 0.15 – 0.86 m / day, for loams up to 0.08 m / day, for band clays up to 0.002 m / day. Long-term excessive and constant waterlogging is typical for most of the territory. The depth of the groundwater most often does not exceed 1.5 m. Only along the deep valleys of large rivers inhabiting ancient preglacial valleys in a number of areas, the drainage effect of these waterways affects, and the groundwater levels drop to 3.0 m. The slopes of the surface of the groundwater table are 0.0002–0.003. Large raised and transitional peat bogs, most often occurring on the moraine, are especially developed in the region. In addition, the zone has a large number of small-sized lowland bogs of ground, sometimes ground-pressure recharge. Quite large rivers originate from these swamps – Polomet, Redya, Robya and others. Bog massifs play the role of accumulators of moisture, which they give to rivers in dry years, playing the role of a kind of regulators of the water balance of the territory [5]. In the area, extensive waterlogged lands and small low-lying peatlands require draining, since surface runoff should be regulated on moraine plains. To accelerate this process, open drainage canals and hollows with profiling and leveling of the surface can be built. Closed collectors, mole ploughing and deep plowing will be helpful. To regulate groundwater supply with accelerating groundwater flow and lowering groundwater levels, horizontal drainage, absorption wells, and trapping canals are advisable [6].

A small area has a region of drained lacustrine-glacial and bog plains of atmospheric, ground and ground-pressure feeding. These are plains with a flat surface relief in the lowest areas in the lower reaches of the rivers flowing into Ilmen and along the upper reaches of the Volkov. The absolute heights of the surface decrease to the northeast from 35 to 20 m. Highland peat bogs are developed within the zone. Surface slopes are close to zero. Band clays, which lie here at a depth of 5 m or more, are usually underlain with moraine, sandy at the contact with clays. The clay thickness is a good aquiclute, but it contributes to the stagnation of melt and rainwater, which, in conditions of flat relief and small slopes, create conditions for prolonged and constant waterlogging of lands [7]. Pressure and ground-pressure feeding is carried out in a number of areas where the thickness of moraine and clays is low; pressure water comes from sandy and limestone layers of Devonian rocks underlying Quaternary formations. The river network of the zone is unevenly developed, the density of watercourses does not exceed 20%. The depths of the groundwater are relatively large here – more than 3–5 m, depending on the thickness of the clay layer from the surface, as well as on the thickness of the underlying loamy moraine. Drainage consists in the creation of systems, preferably closed collectors for the timely removal of excess surface water from the surface and from the arable layer [8]. Pressure water in the zone does not pose a great danger. They are discharged into rivers without affecting the surface band of clay.

The area of alluvial-lacustrine plains with stagnant alluvial and pressure feeding combines territories in the Lovati, Msta deltas and on the Volkov River at its outlet to the Georgian Basin, where alluvial-lacustrine deposits are developed, represented with sands of various grain sizes, sandy loams and clays containing humified interlayers. The thickness of this stratum is up to 10 m. In the delta of the Msta River and on the Volkov River, the material is more clayey, in the delta of the Lovati River, it is more sandy. The stratum of alluvial-lacustrine formations lies on moraine and lacustrine-glacial clays, as well as on sandy-clayey sediments of the Upper Devonian. The alluvial-lacustrine plain of the coast of Lake Ilmen has an absolute surface height of 18–23 m. The deltas are confined to the intertwining of complex systems of ancient preglacial valleys, exposing pre-Quaternary rocks to a depth of several tens of meters. The ancient valleys are filled with complex interlayering of sandy and clayey interlayers, contributing.
to the pressure water supply of the territory. However, not only pressure feeding creates long-term and permanent stagnant conditions in deltas [9]. The main role in the waterlogging of these lands is played with the floods of rivers and Lake Ilmen, which keep these formations under water for several months. The groundwater levels here usually do not drop below 0.7 m, and the huge number of branches at high levels of the groundwater table does not contribute to the drainage of this difficult territory for reclamation [10].

4. Conclusion

The filtration capacity of various areas of the Novgorod region is largely determined with the nature of the relief, absolute heights, characteristic features of the geological structure of the territory and the granulometric composition of rocks. Waterlogged lands include those where the groundwater level does not fall below 1.5 m, as well as land plots within which the waterproof layers lie at a depth of 1–2 m. In the Novgorod region, more than 70–75% of the land is waterlogged. Batetskii, Volotovskiy, Novgorodskiy, Parfinskiy, Soletskiy, Starorusskiy and Chudovskiy are among the districts with 100% or close to it waterlogging. In Poddorky, Kholmsky and Malovishersky districts, more than 65% of farmland is waterlogged. About half of agricultural land is waterlogged in Borovichi, Demyansky, Lyubytinsky, Krestetsky, Marevsky and Moshensky districts. The percentage of waterlogged agricultural land is less than 40% in Valdai, Okulovsky and Pestovsky districts, significant areas of which are within the first and second designated districts.

Analysis of the data obtained showed the leading role of the hypsometric factor, with which the degree of drainage is closely related, characterized with certain relationships between morphometric and hydrological-climatic indicators. The second place in terms of influence on waterlogging is taken by hydrogeological signs – the hypsometric position of the ground and pressure water levels, their ratio. In third place in importance are morphogenetic types of relief, characterized with different lithological composition and different depths of groundwater levels. The lithological factor is important in relation to the ratio of impermeable and permeable layers. The greatest waterlogging is created in conditions of occurrence of water-resistant rocks from the surface, or at shallow depths.

References

[1] Ovchinnikov A Yu, Alifanov V M and Gugalinskaya L A 2021 Paleocryogenesis in the soils of the periglacial zone of the Valdai glaciation Bulletin of Moscow University Series 5 Geography 244–53

[2] Dmitruk N G and Stepanova A A 2020 Glimatic characteristic changes analysis of the agroclimatic Novgorod regions IOP Conference Series: Earth and Environmental Science 012024

[3] Druzhnova M P and Davydoval S G 2020 The role of the Valdai Glaciation in the formation of quaternary deposits of the Novgorod region IOP Conference Series: Earth and Environmental Science 012028

[4] Pokrovsky V, Pokrovsky D, Dutova E, Nikitenkov A and Nazarov A 2014 Degree of areal drainage assessment using digital elevation models IOP Conference Series: Earth and Environmental Science 012018

[5] Mitrofanov Yu I, Antisferova O N and Petrov L I 2016 Features of regulation of fertility of waterlogged soils of reclamation-geographical views Bulletin of Russian agricultural science 5 35–39

[6] Ovchinnikova M F 2018 Changes in the content, composition, and proprieties of humic substances in particle-size fractions of soddy-podzolic soils under the impact of long-term drainage Eurasian soil science Vol. 51 (6) 647–57

[7] Muromtsev N A and Anisimov K B 2015 The peculiar formation of the water regime in soddy-podzolic soil in different positions of soil catena Dokuchaev Soil Bulletin 77 78–93

[8] Sukhacheva E U and Aparin B F 2019 Soil cover patterns in anthropogenically transformed landscapes of Leningrad oblast Eurasian soil science Vol. 52 9 1146–58
[9] Muromtsev N A, Anisimov K B, Semenov N A and Gribov V V 2017 Moisture potential under the conditions of the phase transition of the soil solution and during the year in sod-podzolic soil *Bulletin of the Soil Institute im. V.V. Dokuchayeva* **87** 114–27

[10] Nekhaichik V P, Barysheva A A and Zhekulin V 1975 Development and transformation of the geographical environment Leningrad State Pedagogical Institute named after A.I. Herzen 161 p