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Environmental Regimes of Drained Soils of the Novgorod Region

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Abstract

Under the influence of drainage, new ecological regimes of groundwater and soil moisture are formed, which in turn form new nutrient regimes. The objects of this study are the ecological regimes of lands reclaimed in different ways: by an open drainage network (with the use of runoff hollows) and a closed drainage network. Experimental plots are located in the Novgorod region on sod-podzolic soil. The efficiency of the reclamation system is determined by the groundwater regime. The results of the research prove that the regime of groundwater in closed drainage systems is more favorable compared to open drainage system. The analysis of the nutrient regime of drained soils showed a decrease in agrochemical indicators due to the removal of minerals by runoff. More mineral salts are washed awayin closed drainage (up to 711 kg/ha).Considering the agrochemical composition of soil, calcium ions are removed most intensively from sod-podzolic soils. The water-physical properties of the drained lands, such as density, porosity and moisture content, have also changed. The study of water-air regimes of reclaimed soils revealed a significant difference in the degree of moisture of the plow and subsurface layers, when implementing either one ordifferent methods of drainage. A more favorable water-air regime is created by closed drainage systems in the subsurface layer, and by open drainage systems -- in the plow layer.

Keywords: Ecological regime, drained lands, groundwater level, moisture reserve.

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1. Introduction

The Novgorod region is located in the North-West of the Russian Plain. The area belongs to the zone of excessive moisture, which causes waterlogging and the growth of swamps in conditions of flat terrain and heavy underlying soils [1]. Currently, waterlogged farmland covers 44%, and wetland 15% of the territory of the region. Therefore, it is impossible to increase farmland fertility and obtain stable yieldswithout carrying out land improvement works [2--4].

The reclamation of agricultural land leads to changes in environmental regimes, which are often irreversible. New environmental regimes, such as the groundwater regime [5], the water-air regime [6], the nutrient regime [7--9], etc., are formed owing to reclamation.

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The change of environmental regimes in turn affects the formation of new water-physical properties of the reclaimed landscapes.

2. Methods and Equipment

The objects of the study are the ecological regimes of runoff hollows reclaimed by open and closed drainage of land. Experimental plots are located in the Novgorod region on sod-podzolic soil.

Groundwater level and soil moisture were determined by the method proposed by Federal State Budgetary Scientific Institution ``All-Russian Scientific Research Institute of Hydraulic Engineering and Land Reclamation named after A. N. Kostyakov [10]. Agrochemical indicators -- according to generally accepted standard methods.

3. Results and discussion

The construction of reclamation facilities (in Novgorod region, these are mainly the drainage systems both open and closed) leads to a violation of the upper root layer, which affects the level of potential fertility.

The agrochemical composition of the soil before drainage, immediately after the commissioning of the facility and 5 years after its development was determined on the experimental site of closed drainage. Prior to drainage, soils were characterized as acidic, medium-humic, medium-phosphorus and poorly provided with potassium (Table1).

TABLE 1: Agrochemical composition of the drained soil.

Period	pH_{KCl}	Humus, %	P_2O_5	K_2O
			mg /100 gsoil	
Prior to drainage	5.2	4.7	5.6	8.5
After drainage	6.5	2.7	24.6	12.4
5 years after drainage	6.0	3.3	22.8	11.2

After the construction of the reclamation system and the introduction of chemical ameliorants, agrochemical indicators of the soil increased significantly, with the exception for humus: its amount decreased by almost 2 times due to the mixing of the ploughing horizon with the excavated soil formed during the construction of channels. After 5 years of growing perennial grasses in this area, the humus content increased 1.2 times, acidity level rose, the content of mobile phosphorus and potassium decreased by 7 and 9 % respectively.

The deterioration of agrochemical indicators is associated with the acceleration of soil and surface runoff. Mineral substances are taken out of the soil together with the runoff. The removal of minerals depends primarily on the amount of runoff and the method of draining. Most of the mineral salts are removed by subsurface drainage (up to 711 kg/ha) due to their higher concentration in the drainage flow compared to the open drainage (Table 2).

TABLE 2: Removal of water-soluble salts with runoff.

Method of land drainage	Volume of annual runoff, mm	Removal of water-soluble salts with runoff, kg/hectare					
		NH_4	K_2O	Ca	Mg	Water-soluble humus	Dry residue in water
Closed drainage	86	1.8	--	36	10	15	172
	180	0.6	--	119	63	40	711
	47	0.1	0.2	40	18	10	235
	26	0.2	0.5	25	9	0	117
Open drainage	175	3.7	--	186	59	16	536
	178	10.3	--	28	9	53	445
	82	0.3	5	9	12	20	164
	9	0.01	0.6	2	2	1	9

Considering the agrochemical composition, calcium ions are taken out of sod-podzolic soils most intensively, which contributes to the enrichment of soils with hydrogen and increasestheir acidity. Therefore, reclaimed excessively moist soil is more demanding for systematic liming.

Along with the removal of nutrients from the soil, the redistribution of mechanical elements is observed in the soil profile, which leads to a change in the physical and water properties of the drained lands.

The observations on the drainage system of closed drainage showed that the density of the solid phase in the ploughing horizon (0--20cm) did not change 5 years laterand increased by an average of 4% in the subsurface layer (20--100 cm). These changes may be associated with an increase in the intensity of organic mineralization in the plow layer and the redistribution of mechanical elements in the soil profile (Table 3).

The density of the soil under the influence of drainage has undergone significant changes. Thus, the upper part of the soil, freed from excessive moisture, has become more accessible to the root system of plants. As a result, the density of the root layer

Table 3: Water-physical properties of soils drained by closed drainage.

Layer, cm	Solid phase density, g/cm^3		Density, g/cm3		Porosity, %		Total moisture content,%	
	Year of operation of the reclamation system							
	1	5	1	5	1	5	1	5
0-10	2.57	2.58	1.16	1.17	55	55	41	36
10-20	2.64	2.61	1.32	1.24	50	52	35	36
20-30	2.52	2.65	1.40	1.30	44	51	32	36
30-40	2.65	2.69	1.54	1.51	42	44	27	26
40-50	2.57	2.70	1.66	1.59	35	41	22	20
50-60	2.57	2.70	1.64	1.67	36	38	23	20

decreased by 0.03 g/cm3, and the porosity increased by 7%. At the same time, the total moisture content decreased by 1%.

Soil density increased by 8% in open drainage systems after 5 years. The maximum increase in density (by 20%) was observed in the ploughing horizon. The total moisture content remained almost unchanged (Table 4).

Table 4: Water-physical properties of soils drained by open drainage.

Layer, cm	Solidphasedensity, g/cm^3		Density, g/cm3		Porosity, %		The total moisture content,%	
	Year of operation of the reclamation system							
	1	5	1	5	1	5	1	5
0-10	2.67	2.67	1.24	1.59	53	40	45	52
10-20	2.65	2.65	1.31	1.47	50	45	54	46
20-30	2.67	2.67	1.39	1.36	47	50	41	40
30-40	2.75	2.75	1.58	1.65	42	40	31	31
40-50	2.84	2.84	1.56	1.61	45	43	35	35
50-60	2.81	2.81	1.52	1.63	45	42	39	37

The changes in water-air properties of drained soils are primarily associated with the groundwater regime. In closed drainage systems, groundwater did not rise above 40 cm from the ground surface throughout 5 years of operation, during which the rainfall in the vegetation period varied from 15% to 60% (Figure 1).

Most often, the highest level of groundwater is observed at the beginning of the vegetation season, due to the spring snowmelt. The steepest rise of groundwater was related to critical periods, when the amount of precipitation was 2 or more times higher than the climatic norm. The level of groundwater on open drainage systems over the 5-year period was observed in the ploughing horizon at the beginning of the vegetation season only once (Figure 2).

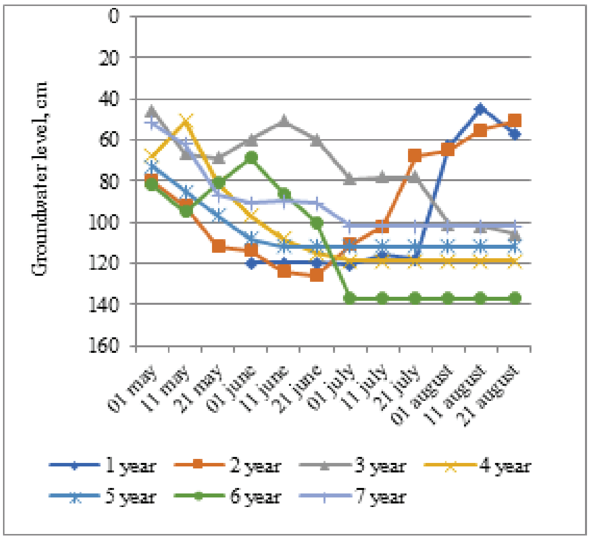

Figure 1: Groundwater regime on drained lands with close drainage.

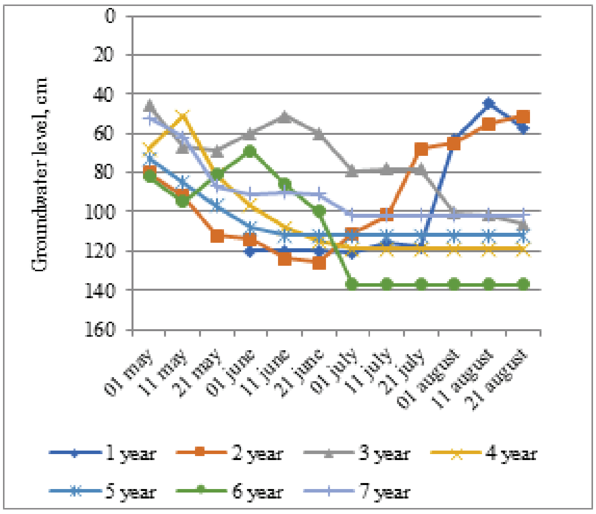

Figure 2: Groundwater regime on drained lands.

In contrast to the closed drainage system, groundwater rose above 40 cm in 7 % of cases in open drainage systems during same period of time.

Groundwater regime affects the water-air regime of the soil, which is one of the main environmental factors of plant growth and development.

The most important parameter is the humidity of the plow layer, because the main mass of roots is concentrated in it. The dynamics of moisture content of the plow layer over a five-year period showed that the plow layer, drained by closed drainage, was most of the time in conditions of insufficient moisture (the optimal moisture limits are shown by a rectanglein Figures 3--6) (Figure 3).

Excessive moisture was observed either at the beginning of the vegetation season after the spring snowmelt, or during critical periods of precipitation. The end of the vegetation period of 2 years with a rainfall of 2% was critical. The second critical period was June of the 3d year of operation, when 55 mm of precipitation fell during the first decade of the month, which amounted to almost a monthly rate (62 mm).

The lack of moisture in the plow layer of the drained soil stimulated the penetration of the roots of the cultivated crops into the subsurface soil horizons, where the moisture reserves were within optimal limits throughout the most part of the vegetation season (Figure 4).

On the lands drained by open drainage, moisture reserves of the ploughing horizon were in conditions of optimal humidityfor a longer period. This horizon, as well as closed drainage systems, was in conditions of excessive moisture either at the beginning of the vegetation season, or in critical periods in terms of precipitation. The period of its exposure to insufficient moisture was 15% shorter than in closed drainage (Figure 5).

Open drainage disposes mainly surface and soil runoff water, as the open dehumidifiers on the experimental system are represented by runoff hollows at the depth of 0.3--0.5 m. Therefore, the subsurface horizon on these systems was in conditions of excessive moisture most of the vegetation period (Figure 6).

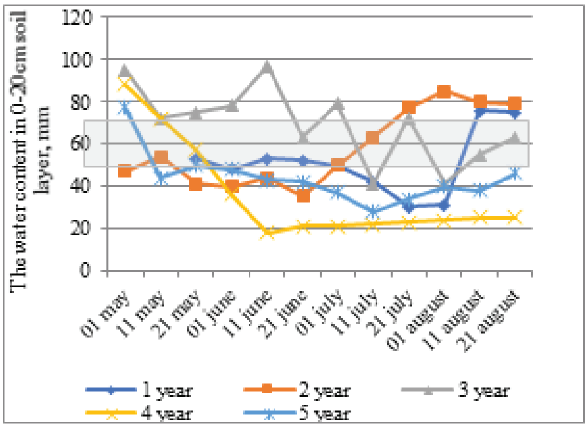

Figure 3: Moisture regime of the arable layer of soil drained by close drainage.

Consequently, open drainage systems form a more favorable water-air regime in the ploughing horizon, which will stimulate the development of a more superficial root system.

4. Conclusion

Under the influence of drainage, new ecological regimes of groundwater and soil moisture are formed, which in turn form new plant nutrition regimes. During the construction of the reclamation system, the nutrient regime of the soil deteriorates due to the mixing

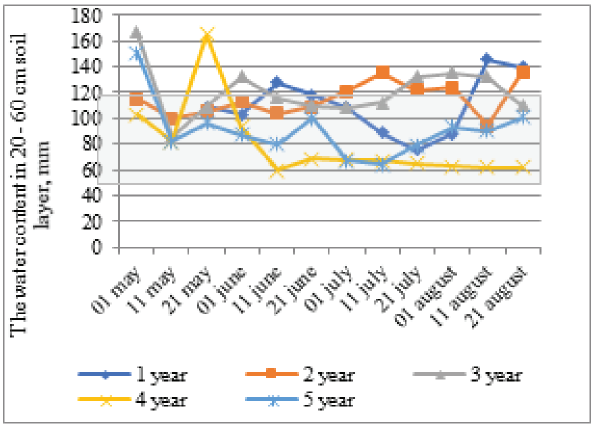

Figure 4: Moisture regime of the subsoil layer of soil drained by closed drainage.

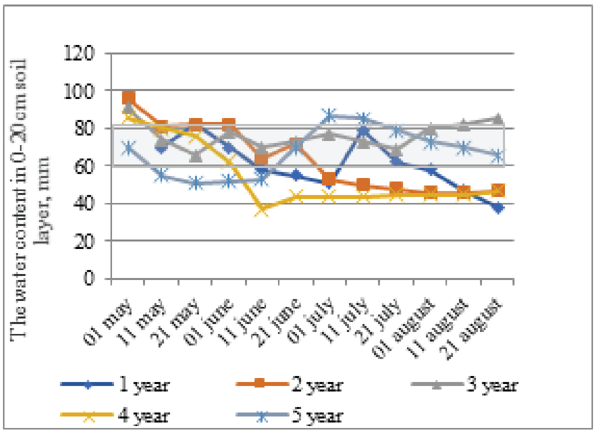

Figure 5: Moisture regime of the arable layer of soil drained by open drainage.

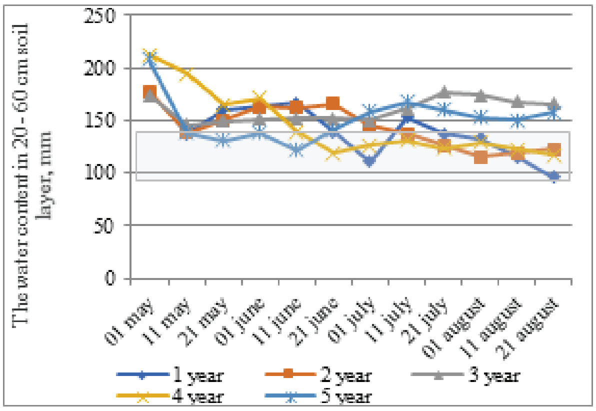

Figure 6: Moisture regime of subsurface soil layer drained by open drainage.

of the subsurface horizons with the plow layer. This especially affects the content of humus. The cultivation of perennial grasses allowed increasing the humus content in the plow soil layer by 0.6% during a 5--year period.

The effectiveness of drainage systems is closely linked with the amount of the runoff water. However together with the runoff, the processes of removal of nutrients and humus from the soil are activated. More intensively, the nutrient substances are washed out by closed drainage systems. The concentration of nutrients in the runoff flow is on average 1.6 times higher than in the surface layer.

It is not uncommon that on drained lands in the Nonblack Soil Zone, represented by the Novgorod region, periods of excessive moisture are replaced by dry periods even within one year.Then the reduction of groundwater contributes to the creation of a more favorable ecological regime of moisture in the deeper soil layer. A more favorable water-air regime is created by closed drainage systems in the subsurface layer, and by open drainage systems -- in the plow layer.

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Conflict of Interest

The authors have no conflict of interest to declare.

References

[1] Balun, O.V., Baiutina, L.A. (2004). Ways to increase the fertility of excessively moist soils. *Plodorodie*, *Fertility*, no. 1, p. 25.

[2] Boitsov, A.S. (2013). The development of reclamation of agricultural land in the Novgorod region for the period of 2014-2020. Achievements of Modern Science to Agricultural Production, in *Proceedings of All-Russian Scientific-Practical Conference Dedicated to the 25th Anniversary of the Novgorod Scientific Research Institute of Agriculture*. State Scientific Establishment Scientific Research Institute of Agriculture Russian Academy of Agriculture. ``Boomerang'' Publ., pp. 44--60.

[3] Povilaytis, A., Lamsodis, R., Bastiyen, N. (2015). Agricultural drainage in Lithuania: overview of practices and environmental impacts. S*oil and Science for Plants*, vol. 65. Special issue: see appendix 1, pp. 14--29: 30 March 2015.

[4] Radu, Oprea, Tsimpeanu, Sorin, Mikhay, Teodoresku, RazvanIonut. (2017). Technical efficiency of subsurface drainage on agricultural lands: meadows and rivers of Moldova *Modern Perspective on Irrigation and Drainage*, pp. 69--81.

[5] Ustinov, M.T., Glistin, M.V. (2018). Critical groundwater level as a criterion of ecological-ameliorative state of soils. *Melioratsiia i vodnoe khoziaistvo*. *Reclamation and Water Management*, no. 3, pp.14--16.

[6] Zinkovskaia, T.S., Kovalev, N.G., Zinkovskii, V.I. (2016). Optimization of soil water regime in potato cultivation on drained lands. *Melioratsiiaivodnoekhoziaistvo. Reclamation and Water Management*, no. 1, pp.40--44.

[7] Booman, Gisel C., Latera, Pedro (2019). The direction of agricultural drainage flows makes it impossible to remove nutrients. *Zhurnal Ekologicheskogo Kachestva -- The Journal of Ecological Quality*, vol. 48, issue 2, pp. 459--468.

[8] Khu, Tsyuli, Yan, Yonkhuey, Khan, Shumin. (2019). Deterioration of the quantity and quality of drainage water in agriculture as a result of the expansion of agricultural land and water-saving operations in arid basins. *Agricultural Water Management*, vol. 213, pp.185--192.

[9] Povilaitis, A., Rudzianskaite, A., Miseviciene. (2018).The efficiency of drainage practices to improve water quality in Lithuania, in*Proceedings of the 10th International Drainage Symposium.* Minneapolis, Minnesota.

[10] Guidelines for the setting up and conducting experiments on drainage systems (1983). Leningrad.