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Groundwater level management in a reclamation system

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Abstract: Soil fertility largely depends on the water regime of the territories. Yields on agricultural lands that are subject to flooding and waterlogging are low. On the other hand, lowering the groundwater level also negatively affects soil fertility. The desiccation of the soil leads to the destruction and weathering of the fertile layer. The periodic repetition of the processes of waterlogging, flooding and desiccation of soils leads to soil fusion, that is, the process of degradation of the soil cover does not stop. The reduction of arable land under the influence of various negative factors (deflation, salinization, acidification, desiccation, flooding and waterlogging of lands) reduces the social and economic development of regions. Crop shortages negatively affect the stability of the economy in agriculture. One of the main negative factors of economic destabilization is the degradation of arable land in the south of Russia from flooding.

1 Introduction

The main reason for the flooding of lands in the Dinsky district is the influence of anthropogenic activity in combination with natural factors.

Therefore, it is first necessary to adopt a scheme for the development of measures for the restoration of flooded agricultural landscapes, and then develop a reclamation system for dual regulation of the water-air regime of the soil to obtain high competitive yields.

The ongoing research was devoted to the elimination of flooding and desiccation of agricultural land. Soil and hydrometric studies were performed on an area of 600 hectares in the Dinsky district of the Krasnodar Territory.

One of the important issues of land reclamation and protection is the identification of the stages of degradation of chernozem soils from their periodic flooding and waterlogging. The substantiation of the stages of soil degradation will make it possible to carry out certain reclamation techniques in optimal volumes to protect them from waterlogging and desiccation.

To assess the degree and type of waterlogging of agricultural lands, it is necessary to conduct field studies. The main soils, especially valuable in the production of agricultural products, are chernozem soils [1-8].

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2 Materials and methods

The territory under study is located in the village of Dalny in the Dinsky district of the Krasnodar Territory. The research was carried out on a cluster with an area of 600 hectares.

The stages of degradation of agricultural landscapes were determined by route survey of the territory (Figure 1).

Fig. 1. Flooded areas in the study area

Observations of changes in the level of UGV were carried out. The indicator of excess (lack) of moisture in the field was the UGV, which determined the position of the depression-type UGV in the pits and observation wells. The pits were arranged in winter to a depth of 2.0-2.5 m, in one section perpendicular to the drainage and irrigation canal (ETC). 4 pits were made in the experimental field, the geometric dimensions of which averaged 4.30 × 0.85 m.

Fig. 2. The rise of the groundwater level in the arranged pits

The next step was to investigate the dynamics of soil moisture from the position of the groundwater level in the pits. To do this, soil samples were taken in each of the pits to determine humidity.

Soil moisture was determined by the thermostatic – weight method. Soil samples were placed in buckets.

3 Results and Discussion

To determine the steady-state groundwater level, and the static and dynamic levels of the UGV were determined, the pits had to be slightly deepened (by 0.20 - 0.50 m), and after that the water level was measured every 10 minutes. The level was considered steady when two adjacent measurements gave the same results.

The length of the shaft of the pits is 700 m. Pits 4 are located at a distance of 200 m from each other. The location of the pits was fixed on the google map in the coordinate system and attached to the axis of the DR channel. During the construction of pits, the structure of soils was studied. According to the profile of the pits, soil samples were taken to determine the water-physical properties of the soil. The soil was studied on the site for 3 variants. In the 1st variant, the soil is degraded by flooding (pit 4a), in the second variant, the soil is periodically waterlogged (pit 4b and 4b), in the 3rd variant, the soil is without flooding (pit 4g).

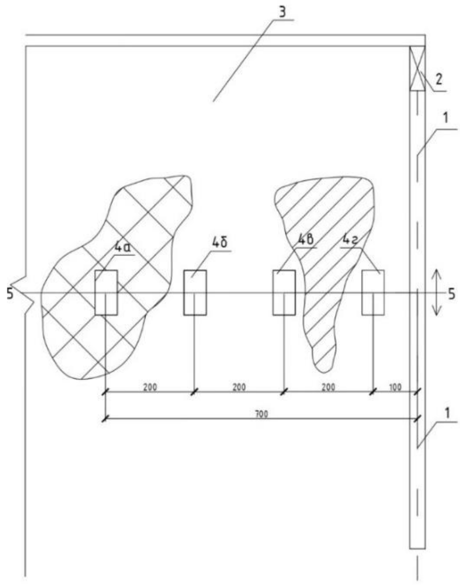

Fig. 3. The scheme of the pilot site. 1 – drainage and irrigation (double regulation) channel; 2- gateway (retaining and regulating structure); 3 - field array under study; 4- (4a–4g) pits; 5 - observation gate; 6 - ditch.

Figure 4 shows the processing of experimental data on changes in humidity according to the soil profile.

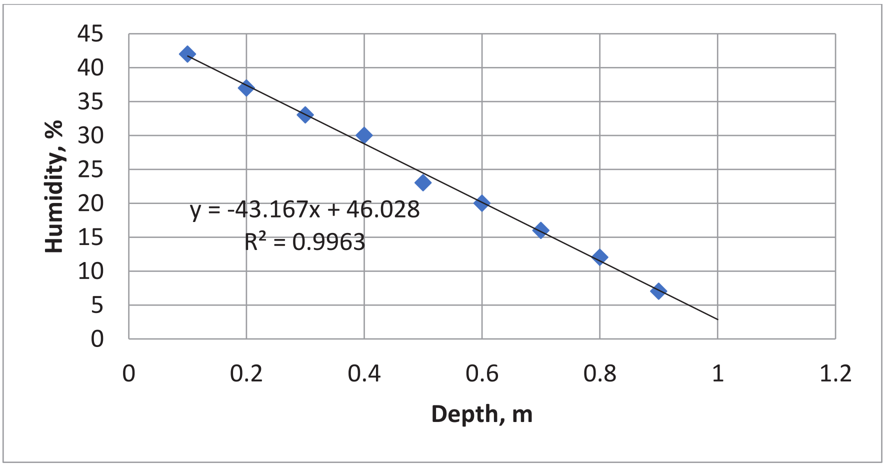

Fig. 4. Changes in soil moisture by depth

The results of the study show the state of the soil, from which it can be seen that with an increase in the depth of the profile, soil moisture decreases from 42% to 0 at a depth of 1 m.

This study allows us to conclude that a merged soil layer has formed at a depth. Filtration at a depth of 0.8-1.0 m is practically absent, and, consequently, there is no vertical outflow of groundwater into the lower layers, as can be seen from the data on the dependence of moisture on soil porosity. Therefore, the upper water is formed on the surface of the fields in low places of relief.

A mathematical model has been obtained that reflects the dynamics of moisture changes in the soil profile:

$$W = 46{,}028 - 43{,}163\ H, \quad (1)$$

where W is soil moisture by profile, %; H is the depth of the profile, m.

Equation (1) expresses the linear dependence of moisture on the depth of sampling of a degraded soil sample. At a depth of 1.0 m, the soil moisture is almost zero. The fusion of soil degraded from waterlogging begins from a depth of 0.8-0.9 m

. For fused chernozems, a dependence is obtained reflecting the linear pattern of an increase in humidity from an increase in the soil porosity coefficient. The graph (Figure 5) shows this pattern in the form of a straight line $n = f(W)$.

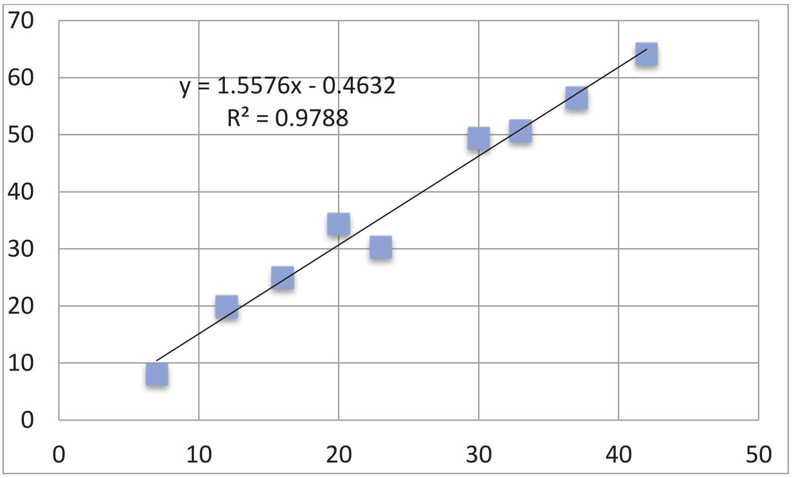

Fig. 5. Changes in soil moisture by depth

The porosity coefficient in the arable horizon has high values of 0.51-0.64, which can be seen from the graph shown in Figure 5. Tillage in spring after autumn plowing on fused chernozems, which undergo freezing and thawing cycles in winter, has a high porosity coefficient, which has a positive effect on the mechanical processing of fields during spring sowing and it does not require significant energy costs, which is confirmed by the natural and climatic factors of the area.

When the groundwater mirror rises to a depth of 2 m from the surface, due to evaporation, the process of secondary salinization of soils begins to develop, sometimes reaching such an extent that the growth of agricultural plants becomes impossible.

To judge the possibility of secondary salinization of the soil, it is necessary to know the critical groundwater level, that is, the depth from which ascending water currents can feed themselves into the upper horizons of the soil, where they are deposited.

Table 1 – The height of the capillary rise of groundwater and the required depth of their occurrence

Soils	The maximum height of the capillary rise, cm	The depth of groundwater occurrence at which the root layer will not be saline, cm
Light clay	150-200	300-350
Medium clay	200-300	350-450
Heavy clay	300-400	450-550

It can be seen from the table that when groundwater is deeper than 6 m, there is no danger of soil salinization, at a depth of 3-4 m it is quite possible; salinization proceeds intensively at a depth of 1.5-2 m from the surface of the groundwater level.

In connection with the above, measures have been identified to prevent the rise of the groundwater level:

1. It is necessary to provide resource-saving types of irrigation - fine sprinkling in the form of "fog";
2. Provide for alfalfa fields in crop rotation, the crops of which reduce the groundwater level and reduce evaporation from the surface;
3. Strictly observe the rules of water use, applying optimal irrigation modes;
4. Leveling of irrigated areas, and later – annual operational leveling in order to prevent an increase in the groundwater level along the "wicks" and reduce evaporation from the soil surface;
5. In order to control the groundwater level at the sites of sowing agricultural crops, provide control wells - 1 well per 100 hectares of crops.

After the work carried out, the design of a dehumidification and humidification system was developed for this area.

Engineering structures are designed as part of the reclamation system, which are designed to increase the water supply of the reclamation system during the growing season and drain the territory of the system in the autumn-winter period.

The double regulation structures of the reclamation system are double regulation channels and a storage pond, which in winter is a water intake, and in the growing season is a water source.

The storage pond is a source of irrigation for agricultural crops. It is located on the Bezymyannaya beam in a natural relief depression and is connected to the Medvedovsky main canal, which feeds the storage pond. At the time of the beginning of the research, the bottom of the pond was silted up, it was in a state of "ecological crisis", the waterway was degraded under the influence of anthropogenic and natural factors. During the hot months, the water level in the pond dropped so much that the water in it bloomed and rotted.

In order to increase the water availability of the reclamation system during the irrigation period and improve the reception of waste water during floods and in winter, reclamation of the storage pond was recommended. The greatest efficiency of pond reclamation is achieved with an integrated approach involving the use of complexes of various types of reclamation with their corresponding intensity and duration of exposure.

After clearing the storage pond, its useful volume of water was increased by 267,500 m^3 (30%). This was achieved by carrying out the following works:

- removal of sediments;
- deepening of shallow water areas;
- construction of collapsed dams;
- drainage device.

Thus, the storage pond is used for reclamation works, is a water regulator for irrigation and collects drainage water during the autumn in order to drain the irrigation area during the off-season. In addition, during the spring flood, the storage pond collects drainage water from open channels.

Channels, therefore, are double-acting structures, when during the vegetative period they are water sources, and in autumn and winter they are water receivers of drainage runoff and its discharge into a storage pond.

During the spring flood, drainage channels are filled with water in a volume of 2280,760 m^3, filling irrigation channels accordingly.

In the autumn – winter period, drainage channels are filled after rains in a volume of 912380 m^3.

Thus, the water supply of the reclamation system is achieved due to the volume of accumulated water in the double regulation channels and the storage pond. The Ponura River will be used only as an additional source of irrigation and can be used in an acutely dry year of the vegetative period in the amount of 2000 thousand m^3 (March, April, May, June).

After the reclamation measures carried out, an analysis of the suitability of water for irrigation was carried out according to qualitative indicators. According to all indicators of the soil reclamation classification, irrigation water belongs to hazard class I - non–hazardous, i.e. irrigation water does not adversely affect soil fertility.

4 Conclusion

1. A drainage and humidification reclamation system with facilities for double regulation of flow and water level in channels has been developed and implemented, which will allow achieving the necessary water availability of the reclamation system due to the volume of accumulated water in structures (double regulation channels, storage pond).

2. The use of this reclamation system makes it possible to increase the yield of agricultural crops of the projected crop rotation (for example, the yield of winter wheat increased by 15 kg / ha).

3. The performed studies indicate that the accumulated water in the storage pond is suitable for all indicators and can be used for irrigation, but for further use of the irrigation system, it is necessary to conduct annual monitoring of the degree of mineralization of wastewater.

4. The introduction of a reclamation system will preserve the biological resources of the Ponura River, since the amount of water taken from the irrigation source will be used only to dilute mineralization in irrigated water.

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