

# Studying soil-reclamation state of rice agricultural landscapes

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**Abstract.** The article presents studies of the soil-reclamation state of rice agricultural landscapes of Krasnodar Territory using the example of the Chernoyevovskaya irrigation system. The direction of changes in soil salinity over a long-term period was revealed. In the framework of monitoring the state of rice soils, salt survey was carried out. The degree, type and causes of their salinization have been determined, the relationship between the salt regime of soils and the regime of the level and chemical composition of groundwater has been established. Recommendations for managing the fertility of rice agricultural landscapes are given.

## 1 Introduction

The reclamation complex of Kuban is represented by twelve rice irrigation systems with the total area of 234.4 thousand hectares, which are used in crop production and are integral part of the agro-industrial complex of the Krasnodar Territory [1].

The rice irrigation systems of Krasnodar Territory are located mainly in the places of the former floodplains of Lower Kuban, which were not previously used for the cultivation of crops. These were large land tracts with marsh soils, that were heavy in texture, often mineralized with high salt content, unsuitable for agricultural production. The indicated areas represented certain landscapes formed under the influence of natural factors. [2].

The construction of irrigation systems with the movement of large soil volumes, agricultural activities, and especially rice cultivation, where rice cultivation technology is associated with the presence of water layer in the field for three months a year, transformed natural landscapes into agricultural landscapes, characterized by fairly large variety of soils, mesorelief forms, geochemical, hydrochemical and other indicators [3-4].

In Lower Kuban, the main subtypes of rice soils are meadow-chernozemic, meadow, alluvial meadow-marshy, characteristic feature of which is compaction, merging and salinity [5, 6]. Some of these soils (about 15%) are saline, which is associated with the hydrological regime during the growing season, the close occurrence of groundwater and

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their high mineralization due to the proximity of the Azov Sea. Rice cultivation on such soils contributes to their stratification and involvement in agricultural circulation [7].

At present, despite the intensification of agricultural production and the successful cultivation of rice and rice crop rotation in the irrigation systems of the region, the problem of soil salinization in rice agricultural landscapes, caused by groundwater salinity, remains relevant, which requires the development of measures that contribute to the management of soil fertility in order to increase productivity and of gross harvest of rice grain.

Therefore, the main purpose of these studies is to investigate the soil-reclamation state of irrigated lands using the example of Chernookovsk irrigation system, located in the Slavyansky district of Krasnodar Territory, to ensure the food security of the region, as well as to develop set of measures to prevent soil degradation and their removal them from agricultural circulation. The achievement of this goal is ensured by solving the problems of assessing the hydrogeological-reclamation situation with the establishment of stationary wells to study the groundwater depth, conduct their chemical analysis, determine the degree of salinity and alkalinity of soils, and develop recommendations for regulating the soil fertility of rice agricultural landscapes.

## **2 Material and methods**

To study changes in soil salinity over a long-term period (1977-2019) on Chernookovskaya irrigation system, cameral work was carried out on retrospective analysis of indicators of groundwater occurrence depth and mineralization. There were used materials of the annual technical reports of the "Management of land reclamation and agricultural water supply on Krasnodar Territory" organization that is operating melioration systems.

To monitor hydrological and reclamation state of irrigated lands before the beginning of the irrigation period (April-May) and after its end (September-November), temporary wells were drilled up to 1 m deep (one well per 150 hectares of irrigated land) on Chernookovsk irrigation system. The selection of soil samples was carried out at intervals of 0-25 cm, 25-50 cm. Drilling of wells was accompanied by hydrogeological observations of the salt regime of soils. Salt sampling and determination of the soil salinity degree in the surveyed massif were carried out according to the standards [8]. In the selected patterns and samples, the following analyzes were performed: water extract; the absorbed sodium and the absorbed bases are determined. The method is based on the extraction of soluble salts from the soil by water at soil:water ratio of 1:5, followed by determination of CO<sub>3</sub>, HCO<sub>3</sub>, Cl, Ca, Mg, Na, SO<sub>4</sub> ions in the studied aqueous extract [9]. Determination of sodium is carried out on flame photometer (Figure 10), spraying the analyzed extracts into the flame. The sodium content in the analyzed soils is found on the working scale of standard solutions in mg-eq per 100 g of soil.

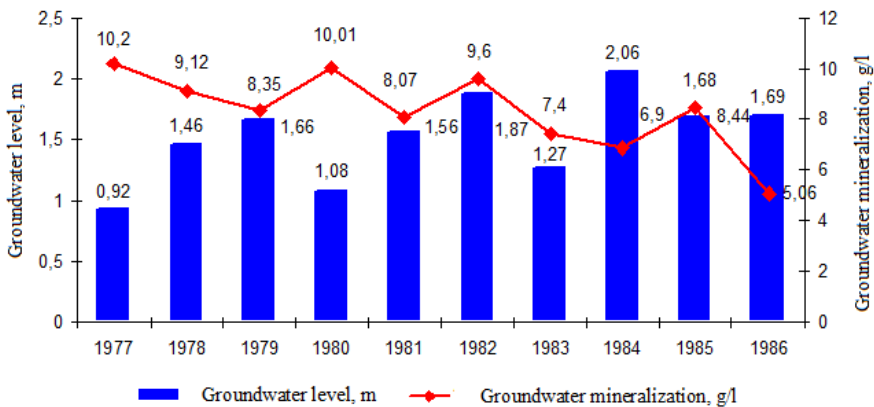
After finishing laboratory work, all identified saline soils were systematized according to depth intervals, salt accumulation intervals, and type and degree of salinity.

## **3 Results and discussion**

The Chernookovskaya irrigation system has been exploited since 1977, at present it is located on total area of 33.2 thousand hectares, and is the most typical in terms of soil conditions for the western natural and climatic zone of Krasnodar Territory. In terms of geomorphological zoning, it is part of the Kuban delta-flooded region, and its northern part is located on the territory of the Azov Plains subdistrict, and its large southern part is located on the territory of the transitional region to Old Delta. On Chernookovskaya rice

irrigation system, humus-gley, peat-gley and meadow-bog soils with close occurrence of groundwater and their high mineralization are widespread, which have undergone significant changes since 1997 under the influence of constant flooding during the growing season of rice [10].

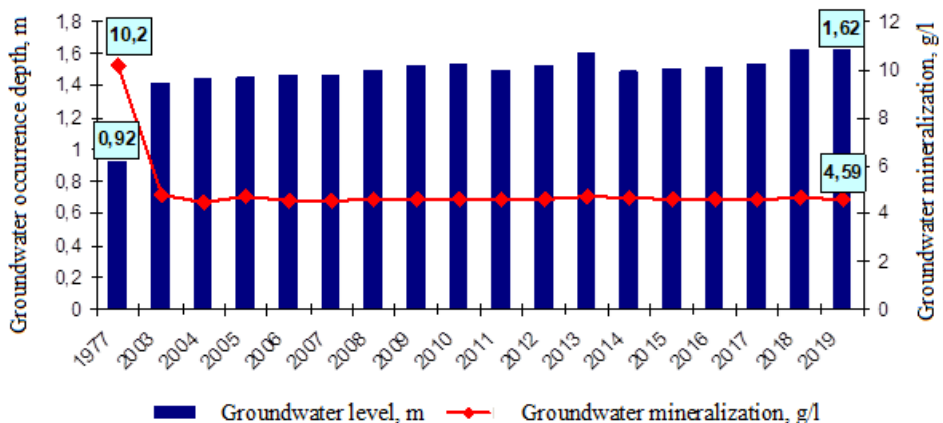
Retrospective analysis revealed that decrease in the groundwater salinity and downgrade in its level occurred gradually, which was facilitated by the percolative regime of soils under the rice crop and the year-round operation of the collector-drainage network. So, at the beginning of exploitation in 1997, the groundwater occurrence of 0.92 m that is very close to the soil surface, was observed, and their mineralization was 10.2 g/l. With further operation, significant decrease in the above indicators was observed only after 10 years by 1986 (Fig.1).



**Fig. 1.** Groundwater level and mineralization on the Chernookovskaya irrigation system, 1977-1986

From 1986 to 2001, groundwater was at 1.49 m, and their salinity averaged 5.02 g / l for the indicated period.

A further decrease and stabilization of the groundwater level at elevations of 1.41-1.62 m was observed from 2002 to the present. At the same time, the indicators of groundwater salinity were lower than in the previous period and amounted to about 4.46-4.76 g / l (Fig. 2).



**Fig. 2.** Groundwater level and mineralization in the Chernookovsk irrigation system, 2003-2019 in comparison with 1977

Thus, retrospective analysis of the indicators of groundwater mineralization revealed their significant salinity since the beginning of the operation at Chernookovsk irrigation system (1977), which equaled to 10.2 g/l. Over the course of 42 years of land exploitation for growing rice and related crops of crop rotation, this indicator has stabilized since 2002 at 4.46 g/l-4.76 g/l, which is caused by the percolative regime of soils and proves once again the need to grow rice in the crop rotation system as ameliorant.

In order to monitor the hydrological and reclamation state of Chernookovsk irrigation system in the period of 2017-2019 salt survey was carried out. It was found that the groundwater opening at Chernookovsk irrigation system on average over the past three years (2017-2019) was within 1.62 m and ranged from 0.93 m (well no. 75) to 2.77 m (well no. 42, 48). By the occurrence depth of groundwater in 2019, the system areas were distributed in the following order: less than 1.0 m - 378 hectares (1% of the total area of the system); from 1.0 m to 1.5 m - 11187 ha (34%); from 1.5 m to 2.0 m - 18,079 ha (54%); from 2.0 m to 3.0 m - 3194 ha (9%); from 3.0 m and more - 362 hectares (1%) (Table 1).

**Table 1.** Occurrence depth of groundwater on the irrigated lands of Chernookovsk irrigation system, 2019

Determination place of groundwater level	Suspended area, ha	Occurrence depth of groundwater, m				
		less than 1.0 m	1.0-1.5	1.5-2.0	2.0-3.0	3.0-5.0
well no. 7	538	44	376	57	61	-
well no. 8-15	14200	155	4238	8951	774	82
well no. 16-18	5594	115	2394	2590	279	216
well no. 19-20	1239	-	-	820	355	64
well no. 21	664	-	-	409	255	-
well no. 22	701	-	206	250	245	-
well no. 26-28	2694	64	634	1801	195	-
well no. 29	854	-	150	601	103	-
well no. 30-34	4282	-	2274	1543	465	-
well no. 35	96	-	18	54	24	-
well no.38-45	2324	-	897	1003	424	-
well no.48	14				14	-
Bcero	33200	378	11187	18079	3194	362

According to the chemical analysis results of ground waters, it was revealed that their average mineralization for the above period is 4.6 g/l. The area of surveyed irrigated land in 2019 with groundwater mineralization above 3 g/l is 18.34 thousand hectares or 56% of the surveyed land, which characterizes them as highly salsuginous. On the rest of the area of 14.86 thousand hectares, the groundwater is salsuginous with mineralization of 1 g/l to 3 g/l. Fresh waters with mineralization less than 1 g/l were not found.[17-18]

The chemical composition of groundwater is diverse. Sulphate and sulphate-chloride waters are predominant.

Chloride-hydrocarbonate, chloride-sulphate, chloride, sulphate-hydrocarbonate, hydrocarbonate-sulphate, hydrocarbonate-chloride, hydrocarbonate ones are less developed (Table 2).

**Table 2.** Anionic-cationic composition of the water extract of the soils of Chernookovsk irrigation system, 2019

Sampling location	Sampling interval. cm	Anions				Cations		general % of salts
		HCO <sub>3</sub>	Cl	SO <sub>4</sub>	Ca	Mg	Na	
well no. 38	0-25	0.850	0.192	0.748	0.450	0.700	0.640	0.127
		0.052	0.007	0.036	0.009	0.009	0.015	
	25-50	0.600	0.192	0.733	0.250	0.600	0.675	0.106
		0.037	0.007	0.035	0.005	0.007	0.016	
well no. 42	0-25	0.800	0.240	1.310	0.500	0.550	1.300	0.167
		0.049	0.009	0.063	0.010	0.007	0.030	
	25-50	1.000	0.192	1.358	0.400	0.450	1.700	0.186
		0.061	0.007	0.065	0.008	0.005	0.039	
well no. 34	0-25	1.050	0.144	0.656	0.300	0.550	1.000	0.136
		0.064	0.005	0.031	0.006	0.007	0.023	
	25-50	1.250	0.144	0.706	0.200	0.400	1.500	0.159
		0.076	0.005	0.034	0.004	0.005	0.035	
ckb no. 48	0-25	1.000	0.240	0.910	0.350	0.650	1.150	0.155
		0.061	0.009	0.044	0.007	0.008	0.026	
	25-50	1.450	0.192	0.858	0.250	0.450	1.800	0.188
		0.088	0.007	0.041	0.005	0.005	0.041	
well no. 20	0-25	0.150	0.192	0.338	0.150	0.350	0.180	0.044
		0.009	0.007	0.016	0.003	0.004	0.004	
	25-50	0.200	0.096	0.294	0.150	0.300	0.140	0.040
		0.012	0.003	0.014	0.003	0.004	0.003	
well no. 27	0-25	0.300	0.192	0.418	0.200	0.350	0.360	0.062
		0.018	0.007	0.020	0.004	0.004	0.008	
	25-50	0.300	0.144	0.756	0.200	0.500	0.500	0.081
		0.018	0.005	0.036	0.004	0.006	0.012	

Analysis of Table 2 shows that, in terms of cationic composition, sodium and sodium-magnesium ground waters are mainly developed.

According to the results of the survey in 2019, it was revealed that soils on Chernookovsk irrigation system have different salinity degrees: there are 837 hectares of highly and very saline soils (2%), 8742 hectares of moderately saline soils (26%), 10,093 hectares of slightly saline soils (37%), 11528 ha of non-saline soils (35%).

According to the solonetzic content, the soils of the studied system are subdivided into non-solonetzic soils - 32120 ha (97%) and weakly solonetzic soils - 1082 ha (3%). No medium and strongly solonetzic soils were found. Summarizing the results of the comprehensive survey, it is possible to characterize the reclamation state of irrigated lands on Chernookovsk irrigation system. Out of the surveyed 33,200 ha, 7413 ha are in good condition, 8448 ha are in satisfactory ones. Areas with unsatisfactory condition amount to 17339 hectares, including 7760 hectares of unacceptable groundwater level, 5570 hectares of under salinization, 3709 hectares with unacceptable groundwater level. [19-20]

To improve hydrological and reclamation state of soils on the irrigated lands of Chernookovsk irrigation system, especially in areas with unsatisfactory indicators of reclamation status, to regulate their soil fertility, the following measures are required: repair planning of checks; arrangement of mole drainage and cutting of drainage furrows. For the cultivation of salt licks, it is recommended to carry out chemical reclamation in combination with organic fertilizer. On weakly and medium-solonetzic soils, it is recommended to apply gypsum: on slightly solonetzic soils it is 3-5 t/ha, on medium-alkaline soils it is 5-9 t/ha. In the absence of gypsum, it is recommended to use phosphogypsum in amount of 3 - 8 t/ha. On salt licks of heavy texture, in order to improve the water-air regime and wash out the salts, it is necessary to arrange mole draining or in-line ripping.

Along with the introduction of chemical ameliorants, deep soil cultivation is required in order to use calcium carbonates or gypsum of the soil itself (soil self-reclamation), the

introduction of organic and mineral fertilizers, as well as grass sowing against the background of irrigation.

Crop rotation is one of the effective ways of soil desalinization and soil fertility management in rice agricultural landscapes.

As a result of widespread non-observance of scientifically grounded crop rotation in rice crop rotation (refusal to grow perennial grasses (lucerne), which is consequence of reducing livestock production at rice-growing enterprises. Economically viable alternative to lucerne in rice crop rotations is soybeans, whose plants have the ability to assimilate atmospheric nitrogen through symbiosis with nodule bacteria, i.e. increase soil fertility. During the growing season, under soybeans, biological nitrogen of up to 100 kg/ha is accumulated in the soil. Soybeans are placed in those checks where the groundwater level is not higher than 40-50 cm from the soil surface and there is no flooding. In rotation, soybeans can withstand saturation up to 50% alternating with rice, i.e. it can be successfully cultivated in specialized short-rotation (4-field) crop rotations.

In the first year after soybeans, rice yields are 5.3% lower than that of lucerne, and in the second year, these differences can be 10-15%. The reason for the lower rice yields caused by the fact that, in comparison with lucerne soybeans, firstly, leaves less nutrients in the soil in the form of roots and crop residues and, secondly, having less developed root system, does not provide adequate improvement in aquatic-physical properties of the soil. This problem can be solved by phytomelioration and replacing soybeans in the second field with colza (Table 3). [25]

**Table 3.** Prospective schemes for 8-field rice crop rotations

Field number	Base crop rotation	Promising crop rotations		
		at 62.5 % saturation with rice		at 50 % saturation with rice
1	Lucerne	Soybean	Soybean	Soybean
2	Lucerne	Soybean	Rice	Soybean
3	Rice	Rice	Rice	Rice
4	Rice	Rice	Rice	Rice
5	Rice	Rice	Rice	Soybean
6	Agro-reclamation field	Occupied fallow (50% soybean, 50% colza)	Occupied fallow (50% soybean)	Occupied fallow (50% soybean, 50% colza)
7	Rice	Rice	Rice	Rice
8	Rice	Rice	Rice	Rice

When cultivated for grain or as green manure, winter colza acts as phytomeliorant. It develops powerful, deeply penetrating into the soil (up to 3 m) tap root system, which piercing the soil improves its water and air permeability. It helps to improve the structure of soils, increases their fertility, clears weeds, significantly improves the phytosanitary state of the field. For 1 ha, winter colza leaves about 60 centners of root residues - more than winter wheat. The root secretions of colza are capable of converting phosphorus from hard-to-reach forms into available ones for rice plants. Colza is the only crop that "pulls" potassium from the lower soil layers to the upper fertile one and transforms it into a form that is available for rice. With the observance of agricultural technology in rice crop rotations, it is possible to obtain colza yields up to 50 and more c/ha.

Winter colza can be used as green manure crop. In terms of fertilizing ability, the green mass of colza is close to manure. At the same time, growing it for green manure is much more economical and efficient. Plowing the green mass of colza at the rice-sowing farm on Chernoerkovskaya irrigation system in 2018 made it possible to obtain increase in the rice grain yield of 18.5 c/ha. In the case when the green mass was used for fodder (200 c/ha),

and the crop residues were plowed, the increase in the rice grain yield was only 8 c/ha [23-24].

Colza is alternative source of organic fertilizers. 10-15 t/ha of dry matter of roots, leaves, straw returns to the soil, and another 10-20 tons of green biomass grows from self-seeding. After harvesting winter colza for seeds, 6-7 times more root residues remain in the soil than after grain crops. With them, up to 10 kg/ha of nitrogen, phosphorus and potassium enter the soil. One ton of colza root residues in terms of their nutrient content is equivalent to 3.75 tonnes of manure.

Research shows that the use of colza as green manure is equivalent to the manure introduction, and the costs are 1.5-2 times lower. The biological activity of the soil increases by 10-15%, the rice yield rises by 20%. [21-22]

Colza, due to the content of allyl mustard oils in its biomass, has positive phytosanitary effect on the soil, reduces the incidence of root rot and other diseases in cereals.

Soybeans and colza, as intercrops of the rice crop rotation, are not only good precursors for the main crop, rice, but also contribute to increase in soil fertility.

## 4 Conclusion

Thus, the results of the survey of agricultural lands of Chernookovsk irrigation system have scientific and practical importance and allow differentiated approach to their use in the formation of measures that contribute to the soil fertility management at rice agricultural landscapes. The results of the study of the soil-reclamation state of rice agricultural landscapes showed that during the exploitation of Chernookovskaya rice irrigation system, their desalinization was observed, which was facilitated by percolative regime of rice fields under rice.

Monitoring of the hydrological and reclamation state made it possible to differentiate the exploited lands by salinity. The degree, type and causes of their salinity have been determined, the relationship between the salt regime of soils and the regime of the level and chemical composition of groundwater has been established; recommendations for managing the fertility of rice agricultural landscapes are given.

In addition, the proposed eight-field crop rotation for modern economic conditions with its saturation with colza and soybean crops will contribute to the creation of favorable conditions for microbiological processes in the soil, mineralization of organic substances, and improvement of the phytosanitary situation in rice agrobiocenoses.

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