Ways to save water resources in rice systems in dry years

M A Bandurin¹, I P Bandurina¹ and A P Bandurin²

¹Kuban State Agrarian University named after IT Trubilin, Kalinin st., 13, Krasnodar, 350044, Russia
²Novocherkassk Engineering and Reclamation Institute named after AK Kortunov, Don State Agrarian University, Pushkinskaya st., 111, Novocherkassk, 346400, Russia
E-mail: bandurin.m@edu.kubsau.ru

Abstract. The article describes methods of improving the regime for saving water resources in rice systems in dry years. The greatest impact on the volume of water supply and runoff is exerted by the spring flooding of rice fields in May-June. Filtration from the canals has a great effect on the groundwater regime, rises the level of groundwater in the canal zone, causing flooding, waterlogging and salinization of territories adjacent to the canals, up to their withdrawal from the agricultural use. Filtration losses from the interfarm and on-farm networks depend on the frequency of works, the type of soil, and the degree of turbidity of the irrigation water. The study substantiates the methods of improving the regime of saving drainage and discharge runoff in rice systems in dry years. The irrigation methods remove salts from the upper soil profile layers during groundwater mineralization up to 5 g/l, and irrigation is of a desalination nature.

1. Introduction
Rice, being a hygrophyte, requires special water regimes. The best conditions are created when there is a water layer on the soil surface. Due to the water layer and its regulation on the lands of rice systems, an optimal melioration state can be maintained. The volumes of water supplied and withdrawn from the rice systems depend on relief, hydrogeological and hydrological conditions.

The volume of drainage and discharge runoff of the rice irrigation systems of the North Caucasus is 20-75 % of the water supply. For rice systems located in closed and weakly drained zones of the Volga delta, this volume is much larger and reaches 120% of the water supply [1].

Water supply to rice systems and removal of surface and drainage waters depend on the hydrological regime of the Volga River. The water content of the Volga river is subject to long-term seasonal and periodic fluctuations. Long-term fluctuations create long-term (4 ... 5 years) high and low levels in the river delta, against the background of which fluctuations are caused by seasonal changes in the river water content [2]. The greatest impact on the volume of water supply and runoff is exerted by the spring flood in May - June, which causes flooding of rice fields.

Filtration from the canals has a great effect on the groundwater regime, rises the level of groundwater in the canal zone, causing flooding, waterlogging and salinization of territories adjacent to the canals, up to their withdrawal from the agricultural use.

Large canals are a source of groundwater and “local pressure” [3], as they maintain their level at high elevations. Due to these two reasons, amplitudes of the groundwater level fluctuations in the canal zone are significant. With the initial deep bedding of groundwater, the level increases in the zone...
of influence of canals. It is 2.5-3 m and more per year.

In the canal zone, the technogenic (irrigation) regime of groundwater is formed. If required reclamation measures are not taken, the processes of waterlogging and salinization occur.

Losses for filtration from the interfarm and on-farm networks depend on the frequency of works, the type of soil, and the degree of turbidity of the irrigation water. Depending on different combinations of these factors, the efficiency varies from 0.40 to 0.97 [4], determining a wide range of losses for filtration and groundwater recharge.

S.F. Averyanov [5, 6, 7] identified the following stages of filtration from the canals: soil wetting is characterized by the absorption of water from the canal into dry soil and the absence of a connection between the filtration flow from the canal and the groundwater basin. The movement of the filtration flow from the channel is observed in the vertical direction under the gravity and surface forces at the water-air interface until the front of seepage waters of their channel reaches the capillary border of the groundwater basin [8];

- formation of a capillary-groundwater flow begins when the filtration flow front closes with the capillary border of groundwater. The second stage is characterized by the presence of a zone of incomplete saturation; in the area between the channel and the groundwater surface, the water pressure is less than the atmospheric one;
- the continuous flow of groundwater when there are three main ways of using groundwater: to raise the level of groundwater; to underground outflow; for evaporation and transpiration [9].

The processes of filtration and transition from one stage to the next one depend on the canal size, physical soil properties, conditions of the underground outflow, the natural location of the groundwater level, and canal operation duration.

The practice of using irrigation systems has shown that irrigation without anti-seepage measures and drainage cause flooding. Irrigation causes a sharp disruption of the water balance, contributes to a more intensive penetration of atmospheric precipitation, i.e. on irrigated lands, the natural infiltration nutrition increases. At the same time, the evaporation level decreases, the nutrition level increases, which increases the water-regulating capacity of the "aeration zone - groundwater" system, i.e. the permissible environmental load [10].

The filtration from canals cannot be regarded as a target for increasing the flow of the river network. It is an inevitable process when transferring large volumes of water. At the same time, in order to reduce or eliminate the negative effects of filtration, it is necessary to implement measures and use special waterproof coatings in highly permeable base soils. The feasibility of using anti-seepage linings in canals should be assessed taking into account the hydrogeological zones. In some cases, their arrangement is even unacceptable, since it can have a negative effect on the land reclamation state [11].

2. Materials and methods

It is necessary to improve methods of reducing the share of irrigation water in the volume of drainage and discharge runoff in dry years due to their significant expenditure on replenishment of groundwater, since in these years the reverse process is observed: the outflow of groundwater into watercourses. In high-water years, there is a significant rise in the water level, which is accompanied by an increase in the level of groundwater in the rice system and an increase in the inflow of groundwater and river water into the collector-drainage network (especially in the contour drains of collectors), and a decrease in the flow of infiltration irrigation water [12].

In Russia, the area of possible rice cultivation is very extensive and located south of the 49th parallel north latitude. Rice is cultivated on unproductive, saline and saline-prone lands, with complex soil hydrogeological conditions, located in the basins and lower reaches of southern rivers whose development is difficult and takes a long time. Due to the water layer on the surface of saline lands and the presence of infiltration, there is a gradual desalinization of the soil layer, desalination of groundwater; barren, lands become suitable for agricultural development. With the help of rice, a significant part of the lands of Central Asia, Azerbaijan, Ukraine, Krasnodar Territory, Rostov and
Astrakhan regions have been developed [13, 14]. One of the main factors affecting the efficiency of leaching of saline lands is the drainage of territories.

The saline lands in combination with the cultivation of rice in rice irrigation systems located in closed and weakly drained zones can be leached only if there is a drainage network. Desalinization of soils is intense and irreversible. The efficiency of soil leaching is affected by the degree of drainage of rice irrigation systems. Studies by S. Stas, T.P. Lapteva, V.N. Laptev, and I.N. Subbotin [15, 16] show that in the difficult natural conditions of the Volga delta, it is possible to use rice for washing saline soils if there is a well-developed drainage network.

A meter layer of moderately saline soils in elevated areas is desalinized within a year at a drain depth of 0.8-1.2 m and a drain distance of 120 m. On highly saline soils of low areas, desalinization is achieved within two years at a distance between drains of 240-300 m and a depth of 2.0 m [17].

According to T.P. Lapteva on the "Sultanov" rice plot with an open drainage network with a drainage depth of 2.0-3.0 m and a distance between drains of 233 m and a closed network with a depth of 105-202 m and an interdrain distance of 30.60 and 90 m, the degree of soil desalinization does not have a pronounced dependence on the drainage design.

The reclamation value of rice depends on the design of the irrigation system, the type of soils, the degree of their salinity and irrigation regimes. It is very difficult to achieve an optimal combination of all these conditions, especially for rice systems located in floodplains and river deltas characterized by good water supply, drainlessness, close location of saline ground waters, and complex soil and hydrogeological conditions [18].

Russia has gained experience in the development of floodplain delta territories for rice cultivation. However, underestimation of peculiarities of the water-salt regime of rice fields, shortcomings in the design, construction and operation of rice systems decrease the reclamation efficiency of rice.

Studies that were being conducted on the lands of the Kommunar rice irrigation system of Kamyzyak district (Astrakhan region) for 14 years have shown that the salt regime depends on the type of desalinization, as evidenced from the salt survey on an area of 1038.6 hectares. Compared to the initial state, the area of highly saline lands decreased from 226.5 hectares to 9.2 hectares, which is 1 % of the surveyed area. The area of moderately saline lands decreased from 533.2 hectares to 338.9 hectares, while the area of slightly saline lands increased from 57.4 hectares to 323.4 hectares. The area of non-saline lands amounted to 367.1 hectares against 221.5 hectares, which amounted to 35.3 %. The type of salinization remained the same: chloride - sulfate, sulfate [19].

The data indicate that in rice systems located in difficult climatic, soil and hydrogeological conditions, the drainage network cannot eliminate local ascending pressure currents of groundwater, causing partial patchy soil salinization of rice maps located in the zone of influence of large distribution channels.

At the first stage, studies conducted on the Kommunar rice system in Astrakhan region have shown that irrigation river waters play a decisive role in the runoff volume. Moreover, their role in the years of different water supply of watercourses is not the same [20]. When the supply of watercourses is more than 24 % and less than 90 %, irrigation waters affect the drainage and discharge runoff development. Their share in the volume of annual runoff reaches 81 %, and the linear regression equation describes it at a correlation coefficient of 0.9. Taking into account the availability of watercourses less than 24 % and more than 90 %, the share of irrigation water in the runoff volume sharply decreases and amounts to 37 – 42 %.

In order to optimize the irrigation regime, four combinations of irrigation regimes and methods were studied: without irrigation, irrigation flooding, sprinkler irrigation with and without water charging irrigation, irrigation with waste water. The experiments were conducted on the Kommunar rice system in Astrakhan region [21].

In all variants, except for the control one, soil moisture in the zone of active water consumption of alfalfa (0.6 m) was 70-75 % of the water recharge irrigation rate. Irrigation at a rate of 500-600 m$^3$/ha with a sprinkler irrigation rate of 950 - 1100 m$^3$/ha was performed after each cut. The rate of water
Recharge irrigation was 1500 m$^3$/ha. During the growing season of alfalfa, depending on the amount of precipitation and temperature regimes, there were 3-4 waterings [22]. The irrigation rate for sprinkling irrigation without water-charging irrigation ranged from 1850-2420 m$^3$/ha, for water-charging irrigation - 320-3950 m$^3$/ha, for flooding irrigation - 3050 - 4100 m$^3$/ha. In the control variant, the moisture content in the active zone of water consumption varied within 60 – 85 % of the rate of water charging irrigation [23].

In the control yield, the alfalfa yield was 3.45-6.42 t/ha; when using the irrigation method - 7.05-14.58 t/ha. In all variants, despite the different yields of alfalfa, the irrigation method increased the yield. The largest increase in the yield was obtained when using the sprinkler irrigation method in combination with the water-charging irrigation method (6.74 t/ha over 4 years). When using the sprinkling irrigation method without water-charging irrigation, an increase in the yield was 5.63-5.72 t/ha. The absence of a difference in an increase in the yield with the sprinkling irrigation method indicates the equivalence of effectiveness of these variants. The smallest average increase of 4.47 t/ha was achieved with the flooding irrigation method. A decrease in the alfalfa yield with the flooding irrigation method was caused by an overestimation of the irrigation rates and uneven soil moisture. In the delta conditions, the irregularity of soil moisture is caused by the alternation of poorly and well-permeable soils. Heavy soils prevent the penetration of roots, and limit the infiltration of irrigation water, causing temporary waterlogging. Light soils are subject to rapid drying out due to the insufficient water-holding capacity and high rates of infiltration. The difference in soil moisture rates was 220 - 310 m$^3$/ha.

Changes in the soil salinity were studied. Despite the fact that soils of the experimental plots were washed out during the rice cultivation, the salt content was significant. According to the degree of salinity, the soils were categorized as moderately saline with the salt content of 0.219-0.454 % [24]. The type of salinity is chloride-sulphate.

The salt survey showed that the flood irrigation and sprinkler irrigation methods with water-charging irrigation improved the salt regime. The rates of salt removal from the meter layer were 2.86-7.35 t/ha and 1.77-4.26 t/ha. With the sprinkling irrigation method without water-charging irrigation, irrigation and waste waters, an increase in the salt content was 4.15-10.87 t/ha. However, their number did not reach the toxic limits for alfalfa and did not affect its development.

3. Conclusion
When rice is cultivated by flooding, crop rotation is the basis for maintaining a high ameliorative state of irrigated lands, preserving soil fertility. Crops cultivated without flooding play a crucial role. When choosing such crops, their ability to improve the land reclamation state is taken into account. Alfalfa is universal. Developing a deep powerful root system and having a high transpiration and shading ability, it reduces the capillary level of groundwater, reduces the rate of removal of salts into the surface soil horizons. This crop is responsive to irrigation, durable, and capable of producing high and stable yields. For irrigation of alfalfa in rice crop rotations, various irrigation methods are used in combination with the irrigation regime options.

The methods of improving the drainage and discharge runoff regimes for rice systems have been substantiated. The use of various irrigation methods contributes to the removal of salts from the upper soil layers during groundwater mineralization up to 5 g/l, and irrigation is of a desalination nature. Sprinkling irrigation without water-charging irrigation does not prevent the process of secondary soil salinization, but reduces its intensity.

References
[1] Yurchenko I F 2018 Information support system designed for technical operation planning of reclamative facilities *Journal of Theoretical and Applied Information Technology* 96(5) 1253-1265
[2] Kireicheva L V and Zakharova O A 2002 The effect of cyclic irrigation with wastewater on the properties of gray forest soils *Eurasian Soil Science* 35(9) 990-995
[3] Yurchenko I F 2017 Automatization of water distribution control for irrigation International Journal of Advanced and Applied Sciences 4(2) 72-77
[4] Olgarenko V I, Olgarenko G V and Olgarenko I V 2018 A method of integral efficiency evaluation of water use on irrigation systems International Multidisciplinary Scientific GeoConference SGEM. 18(3.1) 3-9
[5] Abdrazakov F K, Orlova S S, Pankova T A, Mirkina E N and Mikheeva O V 2018 Risk assessment and the prediction of breakthrough wave during a dam accident Journal of Interdisciplinary Research 8(1) 154-161
[6] Yurchenko I F 2018 Information support for decision making on dispatching control of water distribution in irrigation Journal of Physics: Conference Series 1015 042063.
[7] Kireicheva L V and Khokhlova O B 2000 Elemental composition of different fractions from the sapropel organic matter Eurasian Soil Science 33(9) 947-949
[8] Vladimirov S, Prikhodko I, Safronova T and Chebanova E 2020 Water regime formation of river basins in the delta zone on the example of the Azov region E3S Web of Conferences 175 12010
[9] Olgarenko G, Olgarenko V, Olgarenko I and Olgarenko V I 2019 Justification of methodological approaches to standardisation of irrigation as an element of resource saving and minimization of the anthropogenic load on agrobioncosis IOP Conference Series: Earth and Environmental Science 337 (1) 012027
[10] Bandurin M A, Yurchenko I F and Bandurina I P 2019 Computer technology to assess the capacity reserve of the irrigation facilities of the agro-industrial complex International Conference on Industrial Engineering and Modern Technologies, FarEastCon 2019 8933970
[11] Degtyareva O G, Degtyarev G V, Togo I A, Terleev V V, Nikonorov A O and Volkova Yu V 2016 Analysis of stress-strain state rainfall runoff control system – buttress dam Procedia Engineering 165 1619-1628
[12] Bandurin M A, Volosukhin V A, Mikheev A V, Volosukhin Y V and Bandurina I P 2018 Finite element simulation of cracks formation in parabolic flume above fixed service live IOP Conference Series: Materials Science and Engineering 327(2) 022010
[13] Abdrazakov F K, Pankova T A, Zatintsksy S V, Orlova S S and Trushin Yu E 2017 Increasing efficiency of water resources use in forage crops irrigation International Journal of Advanced Biotechnology and Research 8 283-293
[14] Yurchenko I F 2017 Methodological foundations for the creation of an information management system for water use in irrigation Bulletin of Russian Agricultural Science 1 13-17
[15] Degtyarev G V, Belokur K A and Sokolova I V 2018 Modeling of the building by numerical methods at assessment of the technical condition of structures Materials Science Forum 2018 931 141-147
[16] Bandurin M A, Vanzha V V, Volosukhin V A, Volosukhin Y V and Bandurina I P 2018 Finite-element simulation of permissible load on gate elements of water-conveying structures to assess risks of anthropogenic accidents Journal of Physics: Conference Series 1118(1) 012005
[17] Kuznetsov E V, Khadzhiadi A E, Kilidi K I and Kurtnezirov A N 2018 Management of agro-resource potential for agricultural landscape stability increase Plant Archives 18(2) 2151-2158
[18] Degtyareva O G, Degtyarev G V, Lavrov N L and Aliev D U 2018 Constructive-technological decisions in regulating the flow of atmospheric precipitation. Magazine of Civil Engineering 82(6) 32-48
[19] Olgarenko V I, Olgarenko I V and Olgarenko V I 2019 Technical condition diagnostics of the water supply facilities in the irrigation systems IOP Conference Series: Materials Science and Engineering 698 (2) 022060
[20] Chesnokov B P, Abdrazakov F K, Naumova O V, Krivoschagov D S and Strelnikov V A 2017 The use of ionizing radiation for the tungsten preparation Journal of Industrial PollutionControl 1-12
[21] Safronova T, Vladimirov S, Prikhodko I and Sergeyev A 2020 Optimization problem in
mathematical modeling of technological processes of economic activity on rice irrigation systems *E3S Web of Conferences* **210** 05014

[22] Ovchinnikov A S, Bocharnikov V S, Skorobogatchenko D A, Borisenko I B, Chernyavsky A N, Abezin V G, Ryadnov A I, Shaprov M N, Kuznetsov N G, Nekhoroshev D A, Sedov A V, Grigorov S M, Fomin S D and Ol'garenko V I 2018 The optimum geometrical form modeling of the "striegel" type harrow *ARPN Journal of Engineering and Applied Sciences* **13**(23) 9138-9144

[23] Kuznetsov E V, Khadzhidi A E, Poltorak Y A and Kuznetsova M 2019 Operator model to control process of obtaining vermicompost *EurAsian J. of BioSciences* **13**(1) 315-321

[24] Degtyarev G V, Belokur K A and Sokolova I V 2018 Modeling of the building by numerical methods at assessment of the technical condition of structures *Mater. Sci. Forum* **931** 141-147