Organization of water accounting and water saving of irrigation water based on world experience in the conditions of changing climate

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Abstract. Research allowed to determine that value of water resources and competition for access to them would increase due to climate change. That is why role of fair and accurate water distribution to consumers both between different sectors of the economy and within them will increase (for example agricultural industry). Modern examples of water metering automation in irrigation systems demonstrate that partial automation is most often used, which uses SCADA technologies. It is still important to create a system for accounting for water consumption and distribution, consisting of several levels with the use of modern technological solutions, including SCADA technology, in the region or at the level of the water supply reclamation organization. No less important is the question of correlation of modern irrigation technology with the possibilities of irrigation systems.

1. Introduction
The problem of climate change is becoming more and more actual in the context of a green economy [1]. Among the most likely changes, scientists on a global scale highlight: an increase in temperature over a larger area of land, including an increase in the frequency and duration of periods with extremely high temperatures; an increase in the intensity of precipitation and areas affected by drought. By the end of the 21st century, the projected increase in global temperature may be between 1.1 and 6.4 °C compared to the values observed at the end of the 20th century [2].

Global warming, which researchers are currently studying, could lead to heat stress by 2100. According to expert view this could affect 1.2 billion people [3]. Previous research has focused on extreme temperatures, but has not looked at the role of humidity, that is another key factor. Robert E. Kapp, Director of the Rutgers Institute of Earth, Ocean and Atmospheric Science, thinks [3] that global warming provokes an increase in hot and humid days [4]. Researchers from Australia have found that the most important climatic factors for yield anomalies are associated with the average temperature of the growing season and temperature extremes. They play a dominant role in predicting crop yields, rather than the amount of precipitation [5].
According to the FGBNU Institute of agricultural Economics [6] in 2010, due to the drought, the total area of loss of crops was 13.3 million hectares. The drought in 43 regions of Russia, where 60% of the acreage is concentrated, has seriously undermined the potential of the agro-industrial complex. As a result of the drought, arable crops on an area of 13.2 million hectares were lost, which is 29% of the total area sown. As a result of natural disasters and emergencies, agriculture was damaged in the amount of 41.8 billion rubles [6].

In the early 2000s, 40% of the world’s agricultural production was produced on irrigated land, which accounted for 18% of the total area of agricultural land, and this consumes 70% of the total amount of water consumed globally [7].

Agriculture is one of the main consumers of water resources. According to AQUASTAT data [8] in Russia, the water intake in 2017 for agricultural needs was 18.66 km³ from 64.41 km³; in the USA (2010) 175.1 from 485.6 km³; Ukraine (2010) 4.454 km³ from 14.85 km³; Uzbekistan (2005) 50.4 km³ from 56 km³. According to a special research that collected data on irrigation in the United States [9] in 2018, an irrigated area of 22,638,430 ha (55,938,795 acres) from all sources of irrigation contributed about 102.8 km³ of water, with 50.2% from surface water sources. According to a special study that collected data, it is predicted that by the end of the 21st century, the total water consumption of agricultural crops will increase by 40-250%, mainly due to a decrease in water availability during the growing season, an increase in evapotranspiration and changes in the phenology of agricultural crops [10]. In other words, the need for irrigation will increase in the future due to climate change, but the availability of water resources due to the increase in the number and duration of droughts may significantly decrease in many regions of the world. Therefore, the problem of water conservation and regulation of water consumption is becoming more actual than ever [11].

The main directions of water saving include agrotechnical, hydrotechnical and organizational methods [12]. Agrotechnical methods are aimed at improving soil cultivation techniques, increasing soil fertility, developing the structure of acreage, creating plantations, fighting unproductive water losses, including reducing water losses to runoff, unproductive evaporation of moisture, transpiration and infiltration, snow accumulation. Hydrotechnical methods consider the problems of water accounting; water turnover; irrigation techniques and modes; reuse of waste water; regulation of runoff. Organizational methods provide irrigation through a system of decisions: the adoption of laws, regulations, organization of water conservation and paid water use.

In the Russian Federation, water distribution is becoming more complicated due to the deterioration of the technical condition of irrigation networks [11]; an increase in the number of small water consumers [13]. Water supply must be provided to consumers in a timely manner, otherwise lack of water, especially during critical phases of plant development, can reduce the productivity of irrigated crops and the income of agricultural producers. This type of development can lead to a decrease in the confidence of land users in the use of irrigation in agricultural production. The development of organizational steps and technical devices that allow flexible consideration of various interests of agricultural producers in the use of water resources is one of the urgent tasks. The purpose of the research was to analyze practices and decisions in the distribution of water resources and the use of irrigation equipment at the regional level. For the study, descriptive and theoretical methods were used, including search, selection of facts and their analysis, on the basis of which it is possible to organize work on water accounting and water conservation at the regional level.

2. Results and Discussion
One successful example of water accounting and distribution is the Imperial Irrigation District (IID) of the United States, located in the state of California, with an area of 11,610 km² and a population of 174,528. The average annual precipitation is 76 mm (3 inches), the average annual temperature is 23°C (72.8°F), the average annual minimum is 8.8°C (47.8°F), and the average annual maximum is 36.8°C (98.2°F). Under a 2003 agreement, the district’s water use is limited to 3,824 km³ (3.1 million acre-feet). 98% of the water supplied by IID is used for irrigation of 192 thousand hectares (474 thousand acres) of agricultural land in the Imperial valley. IID operates more than 370 km (230 miles)
of main channels, 2,314 km (1,438 miles) of distribution channels, of which 1,819 km (1,130 miles) have concrete lining or piping, and 2,263 km (1,406 miles) of drainage channels [14]. IID serves 5316 agricultural water users, who use an average of 17,067 m³/ha (5.6 acre-foot of water per acre) per year. The total volume of agricultural production is estimated at $ 2 billion per year. The main crops are forage grasses. Water measuring devices are installed throughout the district. Consumers of irrigation water pay $ 20 per acre-foot, which is approximately equal to 1 ruble per 1 m³, where the installation of water measuring equipment is impractical the price for the supply of one acre-foot is $ 105 per acre per year, with a minimum area of 2 acres. The water access fee is $ 4 per acre per year. The water source for IID water users is the Colorado river, whose waters from the Imperial dam through the All-American Canal flow to three main channels: the East Highline, Central Main and Westside Main. Water for irrigation is supplied to the water outlets of farms through distribution channels with a lower flow rate from them. The IID includes seven regulating reservoirs and four intercepting reservoirs with a capacity of 5.3 million m³ (4,300 acre-feet) of water. The water distribution system in the IID was produced manually until the 1950s, and since the end of the 1950s equipment was installed remotely controlled by telephone, which provided control of land plots along the main channels. In the 1980s IID began replacing outdated remote-controlled systems with new computer hardware. Telephone communication with the land plots was replaced with a radio / microwave communication network, which allowed to automate operational management in the field areas and to control directly from the control room located in the Main Department of the IID. The center for water accounting (water dispatcher) began to electronically control all water in the main channels. The system includes computer screens that show information in online mode, acoustic devices for measuring the flow rate. Water users can order water before noon of the day preceding the delivery date. Department employees enter water orders into a computerized distribution planning system - TruePoint. TrueBill software developed at TruePoint provides a browser-based solution based on the Microsoft platform. Planning for the main channels uses a specially created program based on the SCADA system (Supervisory Control And Data Acquisition), current expenses of distribution channels and schedule for TruePoint distribution channels. Digital solutions based on SCADA and Truepoint technologies are becoming important in the water distribution and accounting system. SCADA systems allow to control the hydro land reclaiming systems, providing flexibility in the supply of water to consumers and significant savings in irrigation water. Thus, according to H. A. Abu Tir, M. A. K. Alsafrya, the introduction of such a system on irrigation systems in the Gaza Strip (Palestine) has saved up to 80% of the water used. The algorithm of the SCADA system functioning is shown in figure 1.

![Figure 1. Principal scheme of the SCADA system.](image-url)

**Figure 1. Principal scheme of the SCADA system.** RTU (remote terminal unit) – operates in a real-time system; it usually consists of sensors that capture and transmit information from the control object to specialized information processing points in real time. MTU (Master Terminal Unit) – receives information from the remote terminal via communication channels and outputs this information using the HMI (human machine interface) for the operator.

This experience can be used in Russia at the level of the water supply organization. It is reasonable to have a digital platform through which all water users can make orders for the supply (diversion) of water, provided that the minimum required response time is met for the correct
operation of main channels. In General, the limit of water for irrigation to an individual water user can be expressed by (1):

\[ V_{jl} = \sum_{i=1}^{m} \sum_{l=1}^{n} M_{Cl} S_{Cli} / \eta_{li} \]  

(1)

where \( M_{Cl} \) – average irrigation norm i-th crop rotation area in the l-th crop rotation of the farm, m3 / ha; \( S_{Cli} \) – the area of the i-th crop rotation plot in the l-th crop rotation, ha; \( \eta_{li} \) – the efficiency of designing an on-farm irrigation system that provides water supply to the I-th section of the crop rotation in the first crop rotation of the farm is considered.

At the farmer level, the amount of water supplied for irrigation can be determined not only by the crop and the area it occupies, but also by the type of sprinkling machines used (SM). Modern high-tech SM of the company "Bauer GmbH" (Austria) can automatically change the mode of water consumption from zero to several hundred liters per second, and this affect the operating modes of the water distribution system as a whole (figure 2) [11].

**Figure 2.** Water intake from the canal at the Linestar installation, sprinkling of fields with the Centerliner installation (with a circular type of movement) of the company "Bauer GmbH" (Austria).

In modern SM with the Zone Control function (programmable opening (closing) of sprinklers), the water consumption on the irrigator is not determined by the maximum performance of its water intake unit \( Q_{iM, max} \), but the sum of the amount of expenses of open sprinklers, which is determined by (2):

\[ Q_{iM,i} = \sum_{j=1}^{n} q_{j} \]  

(2)

where \( Q_{iM,i} \) – actual consumption taken by the SM from the sprinkler in the 1st position, l/s; \( i \) – position number of the sprinkler machine on the irrigator; \( n \) – number of simultaneously operating sprinklers, pieces; \( q \) – consumption of the working of the device, l/s.

Automation of the water distribution control system allows to observe the calculated flow rate in the sprinkler \( Q_{op, pacq} \), which provides maximum performance SM \( Q_{iM, max} \), lower water consumption \( Q_{iM,i} \) (figure 3) [14].
Figure 3. Scheme of interaction of the open water distribution network with the Centerliner front-type sprinkling machine of the company "Bauer GmbH" (1 – distribution channel; 2 – the connection point of the irrigation network to the main canal; 3 – irrigator; 4 – sprinkling machine; 5 – non-working sprinklers; 6 – working sprinklers; 7 – zones with controlled water supply).

3. Conclusion

Thus, the research allowed to know that due to climate change, the value of water resources and competition for access to this resource will increase. Therefore, the role of fair and accurate water distribution between consumers, both between different sectors of the economy and within, for example, the agricultural sector, will increase. Modern examples of automation, such as SCADA (USA), will allow to provide the distribution of water taking into account its cost-effectiveness. The use of world experience, taking into account the capabilities of modern irrigation equipment at the level of water supply organizations will improve the efficiency of reclamation systems, the introduction of new irrigated land into circulation.

References

[1] Melikhov V V, Medvedeva L N, Novikov A A and Komarova O P 2017 Green Technologies: The Basis for Integration and Clustering of Subjects at the Regional Level of Economy Integration and Clustering for Sustainable Economic Growth 365-382
[2] Solomon S et al 2007 Climate Change 2007: The Physical Science Basis. (Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press) p 996
[3] Dway Lee et al. 2020 Escalation of the global impact of complex extreme temperature and humidity conditions with warming, letters on environmental studies
[4] Collins M R et al 2013 Climate Change 2013: the Physical Science Basis (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA) p 996
[5] Vogel E, Donat M, Alexander L, Meinshausen M, Ray D, Karoly D, Meinshausen N and Frieler K 2019 The effects of climate extremes on global agricultural yields Environmental Research Letters 14 (5) 054010
[6] Paptsov A G, Shilovskaya S A, Kolesnikov A V, Amelin A V, Adadimova L Y and Surovtsev V A 2015 Russian agriculture adaptation to global climate change p 44
[7] Fischer G, Tubiello F N, Velthuizen H V and Wiberg D A 2007 Technol Forecast Soc 74 1083–1107
[8] AQUASTAT 2020 FAO Global Water and Agriculture Information System The profiles of countries URL: http://www.fao.org/aquastat/ru/countries-and-basins/country-profiles/

[9] Save R, de Herralde F, Aranda X, Pla E, Pascual D, Funes I and Biel C 2012 Agric Water Manage 114 78-87

[11] Shchedrin V N, Vasilyev S M, Kolganov A V, Medvedeva L N and Kupriyanov A A 2018 Meliorative institutional environment: The area of state interests Espacios 39(12) 28-36

[12] Kulkarni S 2011 International Journal of Water Resources and Arid Environments 1 226–31

[13] Medvedeva L N, Belykh D V, Vagner A S, Medvedev A V, Vaneeva P D and Bondarik I G 2019 Foresights-technologies in the development of land Improvement parks in the countries- participants of Eurasec 3rd World Irrigation Forum (WIF3) 173-182

[14] Korzhov V I, Sorokina O V, Korzhova T V and Matvienko G O 2018 Analysis of the influence of new means and methods of irrigation on water distribution management processes / Scientific journal of the Russian research Institute of reclamation problems 4(32) 105-125