Use of Water Resources for Irrigation in the Southern Regions of Russia

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Abstract. To substantiate potential sources of water resources, an integrated approach has been developed, including agroclimatic, hydrological and hydrogeological studies, analysis of the dynamics of the population of the regions and the prospects for the development of agriculture, the use of geoinformation technologies. The conditions for the formation of surface and ground waters were studied, taking into account climate change, as well as anthropogenic impact on water resources. The forecast of the dynamics of water consumption in agriculture on the basis of the development of irrigation of agricultural lands for crop yields increase has been developed. On the basis of the studies performed, sources of additional water resources for the development of irrigation in the south of the European Russia have been identified. A digital and geoinformation database has been developed for visualization of the results of zoning and providing of analytical reports on the use of surface and groundwater for irrigation and agricultural water supply to the public.

1. Introduction
Ensuring food security in the southern regions of the Russian Federation is largely determined by the availability of water resources. A number of regions face the problem of water shortage. This circumstance negatively affects the possibility of developing irrigation, which in certain conditions increases the productivity of agricultural crops by 3-5 times. The current processes of climate warming, the unsatisfactory technical condition of water management systems exacerbate issues related to providing the population and the economy with the necessary volumes of water resources [1-4].

The situation with water supply is especially tense in the south of the European Russia. Currently, the irrigated areas are much smaller than during the period of intensive development of land reclamation (in the 1970s-1980s). So, for example, in the Stavropol Territory in 2018, almost two times less land was irrigated than in 1992 and, as a result, 148.1 million m³ of water was used for irrigation in 2018 and 300 million m³ in 1992 year [2,5]. At the same time, the actual physical depreciation tear of irrigation systems varies from 60% to 100%, with the average wear rate in 2018 being 79.12%.

2. Formulation of the problem
The availability of the required volumes of water resources is the main condition for the development
of irrigation. To normalize the situation in water-scarce areas, it is necessary to search for additional sources of water supply. The starting point should be a comprehensive integrated scientific substantiation of the needs for water resources in the water-deficient regions of Russia, taking into account their socio-economic development, global climate changes in the future until 2030 and beyond, with the preference for domestic and drinking water supply, as well as taking into account the needs for water for irrigation.

The purpose of the research is to scientifically and practically substantiate obtaining the required volumes of water resources for the development of irrigation in the zone of insufficient moisture in the European Russia.

3. Theoretical part
To substantiate potential sources of water resources, an integrated approach has been developed, including agroclimatic, hydrological and hydrogeological studies, analysis of the dynamics of the population of the regions and the prospects for the development of agriculture, the use of geoinformation technologies. The research also studies the conditions for the formation of surface and ground waters, taking into account climate change, as well as anthropogenic pressure on water resources, a forecast of the dynamics of water consumption in agriculture with the development of irrigation of agricultural lands to increase crop yields. Based on the studies performed, sources of additional water resources for the development of irrigation are determined.

The theoretical basis for zoning is the idea of a water exchange basin [6]. In artesian basins, water that can be used for irrigation is formed in the zone of active (free) water exchange. This is a zone of drainage of the earth's crust by rivers, where the hydrological cycle of the water cycle is formed. An underground water exchange basin forms the basis of a river basin. In this case, there is a possibility of a discrepancy between the surface and underground boundaries of the catchment areas. Thus, a key hydrogeological structure of the free water exchange zone is formed - a water exchange basin as a drainage basin for ground and surface waters. [6].

In this water exchange system, surface and fresh groundwater resources are formed. Landscape-climatic, geological, hydrological and hydrogeological conditions form such water exchange systems of surface and ground waters that determine the natural provision of the territory with water resources. Taking into account the factors of formation of water resources, the following taxonomic units of zoning were selected:

- water availability of the territory;
- artesian basins of the second order;
- the amount of groundwater reserves within artesian basins of the second order;
- the level of recharge of groundwater reserves;
- average annual level of natural surface water resources;
- the level of renewable surface water resources;
- the level of anthropogenic pressure on water resources;
- groundwater resources potentially available for temporary withdrawal.

4. Practical relevance and research results
Studies on the water supply of regions for irrigation of crops were carried out using geoinformation technologies in the Samara, Saratov, Volgograd, Astrakhan regions, the Republic of Kalmykia, Stavropol and Krasnodar territories. The main part of the selected regions is occupied by the basins of the Lower Volga, the Kuban and Don rivers.

In accordance with the theoretical justification, a GIS project was drawn up, including 8 thematic maps. The data of the official information resources of the Ministry of Natural Resources of Russia and the Ministry of Agriculture of Russia [5,7], as well as the Federal State Budgetary Scientific Institution All-Russian Scientific Research Institute of Hydraulic Engineering and land reclamation database on the objects of reclamation systems were used. The structure of a GIS project includes information about amelioration systems, hydraulic structures, the ecological state of agricultural lands
and the use of water resources.

Attribute tables show the main characteristics of objects. For reclamation systems - the type of system, the nearest settlement, geographic coordinates, year of commissioning, area, annual water intake, land owner and operating organization. For hydraulic structures - purpose, hazard class, length, code of the water management area, assessment of the technical condition and characteristic parameters; to assess the reclamation condition - the year of commissioning, water source, annual water intake, irrigated area; area used in agricultural production (thousand hectares), dry land area; indicators for the use of water resources - the volume of water intake, water use, use of fresh water for irrigation, agricultural water supply, estuary irrigation, watering of pastures, as well as discharge of waste, transit and other waters. GIS-project contains information about more than 1800 hydraulic structures (Figure 1).

![Figure 1. Hydraulic structures located within the territory Astrakhan region.](image)

The publicly available geographic information system Quantum GIS 3.8.1 was chosen as a toolkit for creating, editing, visualizing and analysing geospatial information.

As a result of the research, a comprehensive idea was obtained about the conditions for the formation of surface and groundwater, about the influence of the dynamics of climatic conditions on the conditions of humidification of the territory of the European Russia, as well as on the amount of replenishment of groundwater reserves, the regime and volumes of formation of surface runoff on the formation of surface and groundwater runoff. The studies have shown that the main sources of
additional water resources can be groundwater, drain and discharge water, avoided unproductive water losses during transportation.

The performed analysis of the intensity of anthropogenic pressure on water resources in the regions made it possible to quantify it. According to the proposals of the Organization for Economic Cooperation and Development, the load on water resources is considered as the ratio of water withdrawal to the volume of water resources. All other things being equal, the load is taken as low if it is less than 10% of the renewable fresh water resources; moderate or acceptable - from 10 to 20%; medium-high 20-40%; high 40-60% and very high - over 60%.

In the latter case, the volumes of use determine the depletion of water resources. As shown by the calculations performed according to this classification, in the European part of the country, water bodies are subject to intense technogenic unloading in gradations from “moderate” to “medium-high” (Table 1).

Table 1. Technogenic pressure assessment on water resources [2,5,7].

| Region              | Renewable resources, km³/year | Water extraction, km³/year | Water resources load |
|---------------------|--------------------------------|---------------------------|----------------------|
|                     | groundwaters                  | surface waters            | Total                | utilization, %       | Load level         |
| Republic of Kalmykia| 0.04                           | 1.1                       | 0.02                 | 0.33                 | 0.35               | 30.1               | medium-high        |
| Krasnodar Territory | 2.6                            | 23.0                      | 1.2                  | 5.71                 | 6.9                | 26.9               | medium-high        |
| Astrakhan Region    | 0.48                           | 237.7                     | 0.0                  | 0.70                 | 0.7                | 0.2                | reasonable or acceptable |
| Volgograd Region    | 1.34                           | 2545.2                    | 0.06                 | 0.91                 | 0.97               | 3.8                | reasonable         |
| Rostov Region       | 1.4                            | 26.1                      | 0.1                  | 3.32                 | 3.42               | 13.1               | reasonable         |
| Stavropol Territory | 0.3                            | 6.0                       | 0.07                 | 2.38                 | 2.4                | 38.2               | medium-high        |
| Samara Region       | 1.95                           | 236.8                     | 0.2                  | 0.57                 | 0.77               | 0.3                | reasonable         |
| Saratov Region      | 2.0                            | 241.5                     | 0.07                 | 0.84                 | 0.91               | 0.3                | reasonable         |

Mainly in the economy, surface waters are used for the needs of the agro-industrial complex, therefore there are reserves for increasing the use of groundwater. In general, groundwater reserves in the country amount to 82446.7 thousand m³/days [2]. From 2000 to 2018, water use in agriculture increased by 40%, but in agriculture, groundwater is used insignificantly. So in 2018, 0.7 million m³/day of groundwater was used for irrigation of lands and watering of pastures, which amounted to 4% of the total use of groundwater in the country's economy [2]. As the experience of foreign countries shows, irrigation is provided by groundwater: in Libya by 100%, in Argentina - 70%, in Algeria - 56%, Australia - 46%, the USA and Mexico - by 38%, in Spain, France, Greece, Italy - more than 26% [7-9].

The percentage of groundwater development in the current period in many regions of Russia is less than the proven and approved reserves. With proper quality, they can serve as a supplement to surface water resources for irrigation and water supply. Of the significant volumes of explored groundwater reserves in the Krasnodar Territory only 24% is used, in the Stavropol Territory - 11.4%, in the Volgograd Region - 5.6%, in the Saratov Region - 1.9%, in the Samara Region - 1.0%, etc. etc. [2,5].
The results of scenario studies showed that due to the tense water balance in the long term, the development of irrigation will require the attraction of groundwater as an additional source of water resources in the Saratov and Volgograd regions, in the Krasnodar Territory, etc.

Analysis of theoretical studies and practical experience show that for irrigation of crops with groundwater in small areas of autonomous irrigation (1-2 thousand hectares), a total flow rate of 0.5-1.0 m$^3$/s is sufficient. And for large systems of regular irrigation of about 100 thousand hectares in the arid zone, operational resources of n * 10 m$^3$/s will be required.

During the research it was found that in the regions under consideration increased groundwater recharge in the low-water period increases groundwater resources. In this case, the growth of underground water withdrawal is possible without environmental damage to the natural environment. The acceptable volume of groundwater withdrawal is determined by the average low-water runoff per year. First of all, it is groundwater available for use by farms. In large volumes the withdrawal of groundwater as a forced temporary measure is also possible. At the same time, theoretically, this value can approach the value of the difference between the operational reserves of groundwater and the recoverable volume [6]. But in this case, the selection is supposed only for 1-2 dry years with the subsequent termination of pumping, and, if possible, replenishment of groundwater reserves.

The performed assessment, according to [2], showed that the additional volume of groundwater resources may be roughly: in the Krasnodar Territory 3.1 million m$^3$/day, in the Rostov Region - 0.6 million m$^3$/day, in the Volgograd region - 0.5, in the Saratov region 0.8 million m$^3$/day, in the Stavropol Territory 0.4 million m$^3$/day.

Replenishment of reserves is a necessary measure from the point of view of water resources protection. To replenish groundwater, a combination of certain conditions is necessary, including the presence of a source of replenishment, the required water quality, certain hydrogeological conditions, etc. Such conditions exist in the Krasnodar Territory, in the south and southeast of the Rostov region, in the west and south of the Volgograd region, within the foothill area of Stavropol Territory [8].

For the practical implementation of the research results the scheme of a multipurpose small-contour irrigation and drainage system of the oasis type using pressure water has been developed in the Republic of Kalmykia [10]. Depending on the flow rate and pressure of artesian wells, water is supplied to one or several peasant farms (livestock camps).

To ensure a continuous operation of lenses of fresh groundwater with a possible pumping rate of up to 10-100 m$^3$/day on the territory of the Republic of Kalmykia, an artificial replenishment system is used [10]. In this case, the operation of multipurpose irrigation and drainage systems of the oasis type with small (up to 1-2 ha) areas of regular irrigation is ensured.

Prevented losses due to filtration, evaporation, discharges during water transportation are another source of additional water supply. According to [4], very high level of unproductive losses of water can be traced both in the economy as a whole and in agriculture. So, in 2016, 16.3 km$^3$ of water resources were taken for agricultural purposes, and only 8.4 km$^3$ were used, of which 6.45 km$^3$ was used for irrigation. In the river basin Volga, according to data for 2018, there were high water losses during transportation among all river basins of the Russian Federation, the share of which was 10.6% of the total in the country [2]. Water losses in the Azov Sea basin, where the main economic facilities are located in the Don and Kuban basins, reached 40% of the total in Russia. At the same time, water losses in the Krasnodar Territory are about 966.18 million m$^3$ (16.26% of the withdrawn water), in the Rostov region - 614.76 million m$^3$ (21.34%) [11]. The role of agriculture in these losses is significant due to the technical condition of water management systems. The physical wear and tear of amelioration systems, for example, in the Krasnodar Territory, reaches 79% on average.

With the saving of water resources due to the repair and restoration of hydraulic structures on reclamation systems, the transition to innovative methods and technologies of irrigation with automated control systems, there is no doubt additional volumes of water for irrigation will be obtained.

Treated waste water can become a significant source of water resources. For example, the discharge of wastewater in the Krasnodar Territory into water objects is about 2900 million m$^3$, of
which 72% is conditionally clean and normatively treated wastewater, in the Rostov Region 1234.13 million m$^3$ is discharged, of which 80.71% is conditionally clean and normatively cleaned [11, 12]. It is necessary to consider the possibility of using them for irrigation of lands and to reduce the selection of clean waters for this purpose.

5. Conclusion

The country's food security is largely determined by the efficiency of agriculture in the south of the European Russia. Irrigated agriculture is the main factor in obtaining high and sustainable yields in the regions. However, the scarcity of water resources limits the development of irrigation. To substantiate the potential sources of water resources in the south of the European Russia, an integrated approach is proposed, including agroclimatic, hydrological and hydrogeological analytical studies, analysis of the dynamics of the population of the regions and the prospects for agricultural development, regionalization of the territory by factors of formation of water resources, the use of geoinformation technologies. The theoretical basis for zoning is the idea of a water exchange basin, within which surface and ground waters are formed, and the natural provision of the territory with water resources is determined. Taxonomic divisions of regionalization are substantiated by the factors of formation of surface and underground water resources within the water exchange basin. A quantitative analysis of the intensity of anthropogenic pressure on water resources in the southern regions of Russia was carried out to assess the volume of water resources for irrigation. Scenario studies were carried out, which showed that in 2035-2050 the main sources of additional water resources in the considered regions can be groundwater, waste water, and prevented non-productive losses during transportation.

6. References

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