Water shortage and water management balance in the Republic of Crimea: current values and forecast for 2030

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Abstract. The paper analyzes the modern water management balance of the Republic of Crimea in the context of administrative and territorial units. The possibility of using the ArcGIS 10.4 software package for visualization of spatial statistical data that characterize the water balance is shown. The forecast values of the water balance of the Republic of Crimea for 2030 are given. Maps of the current water management balance for the administrative-territorial units of the Republic of Crimea for the current period and for 2030 based on statistical observations have been constructed. It has been established that the territory of the Republic of Crimea is extremely water-deficient and only in certain administrative-territorial units a positive water balance is observed (Bakhchisarai and Belogorsk regions of the Republic of Crimea, Sudak urban district, Alushta urban district and Yalta urban district). At the same time, according to forecasts, by 2030 it will be possible to significantly reduce the water deficit, but a number of regions of the Republic of Crimea will still have a negative water balance.

1. Introduction

2020 was marked by a huge shortage of water resources for the territory of the Crimean Peninsula (the Republic of Crimea and the city of Sevastopol), due to the fact that an extremely small amount of atmospheric precipitation fell during the period from autumn-winter 2019 to winter-spring 2020. In addition, the water problem is unresolved for the territory of the Crimean Peninsula in 2020, due to both natural and socio-economic and political reasons. The natural conditions for the water problem emergence on the territory of the Crimean Peninsula are associated with the geographical position of the Crimean Peninsula and the consequences of this situation, which directly affects the water balance of the Crimean Peninsula. This is primarily revealed in the distribution of the amount of incoming solar radiation and the amount of precipitation. In addition, the relief of the Crimean Peninsula is of great importance in the spatial distribution of these indicators. According to [1], the Crimean Peninsula is subdivided into three unequal parts according to the history of the geological development of the territory: The Plain Crimea, the Kerch peninsula with a peculiar ridge-undulating-flat surface and the Crimean Mountains. The fallout and spatial distribution of solar radiation and atmospheric precipitation is greatly influenced by the barrier effect of the Crimean Mountains. As a consequence, a barrier
inversion of landscape zones is observed on the territory of the Crimean Peninsula and, in contrast to the Black Sea lowland, landscape zones are directed from south to north, and not from north to south. According to [2], more than 1000 mm of precipitation per year can fall within the Crimean Mountains, while in the Plain Crimea the annual precipitation is less than 350 mm per year in the north of the Crimean Peninsula and 450-500 mm per year in the central part of the Crimean Peninsula. At the same time, evaporation in the central parts of the Crimean Peninsula is maximal. As it is indicated in [3], the Vysotsky-Ivanov moisture coefficient for most of the Crimean Peninsula is less than 1, which indicates a clear predominance of evaporation over the amount of precipitation. Moreover, in the Plain Crimea and on the Kerch Peninsula, the moisture coefficient is less than 0.55, which indicates insufficient and scarce moisture.

As a result, as it is shown in [4], the river system density on the Kerch Peninsula and in the Plain Crimea is 0-0.2 km per sq. km, while in the Mountainous Crimea it significantly exceeds 0.5 km per sq. km. Also, according to [4], the average long-term annual flow on the territory of the Plain Crimea and the Kerch Peninsula is less than 1 liter / sec * sq. km, while in the Mountainous Crimea - 1-10 liter / sec * sq. km and can reach 15 liters / sec * sq. km. It means that most of the territory of the Crimean Peninsula experiences a shortage of water resources, and there is a sufficient amount of them only on the territory of the Mountainous Crimea.

For this reason, natural runoff reservoirs were built for the accumulation of fresh water reserves in the Mountainous and Foothill Crimea, and the North-Crimean Canal and bulk reservoirs were built in the Plain Crimea and on the Kerch Peninsula. Before the installation of the North Crimean Canal, fresh water in the steppe part of the Crimea was obtained mainly from artesian wells and was the only source of water supply. At the same time, it would seem that in the Mountainous part of Crimea there are many reserves of water resources, however, there is also a large consumption of them (urban agglomerations of Simferopol, Sebastopol, Belogorsk, Bakhchisarai and the cities of the Crimean southern coast – Alushta, Yalta, etc.). In 2013, the total volume of water withdrawn from the North Crimean canal was 1346.3 million cubic meters (or 86.65% of the total water withdrawal from natural sources).

The political problems of the shortage of water resources on the territory of the Crimean Peninsula are associated with the shutdown of the water supply through the North Crimean Canal in 2014. Since Ukraine has stopped supplying Dnieper water through the North Crimean Canal in 2014, 148 km out of a total length of 293 km of the canal, were used year-round to transfer water from the mountain reservoirs of the Belogorsk District to the eastern part of Crimea (especially to the Kerch Peninsula).

As it is shown in [5], after the cessation of the water supply through the North Crimean canal, the water discharge in the rivers flowing through the Sivash lowland in the North-Eastern Crimea decreased by more than 2 times. Socio-economic problems of water scarcity on the territory of the Crimean Peninsula are associated with the need to use water resources for agricultural production, in the municipal economy and in industry.

2. Materials and methods
The research methodology is represented by the use of geographic information technologies and geographic information systems (GIS). Geographic information technologies allow to accumulate knowledge about the world around us in modern digital form, visually display them in the form of dynamic electronic maps, quickly integrate the information from any place or region and disseminate it in real time [6].

Except the methods of geoinformatics, the work uses literary-analytical, historical, comparative-geographical, statistical and cartographic research methods. The following definition is given in work [6]: «Geographic Information Technologies are technologies for input, integration, storage, processing, analysis, modeling and visualization of geographic (spatial) information». Special software systems representing geographic information systems are used for the practical implementation of geographic information technologies. ArcGIS 10.4 software is used in this article.

Statistical data can be used as materials used in geographic information systems. Statistical data on the water balance of a dry year (95% of availability) for municipalities of the Republic of Crimea were
used for the study and spatial analysis of the problems of water resources deficit on the territory of the Republic of Crimea.

The territory of the Crimean Peninsula has belonged to the regions experiencing a lack of water resources for long time. However, taking into account more than two thousand years of economic use of the territory of the Crimean Peninsula, initially this problem could be solved through the careful use of water by a small population. Nowadays, when about 2.3 million people live on the territory of the Republic of Crimea, and there is an annual influx of recreants and tourists (about 6 million people per year), it creates an increasing pressure on the water management complex of the Republic of Crimea.

In work [7] it is noted that for the Crimea, fresh water is the most important resource, since there is a shortage of it, which became especially sharp in the XX-XXI century.

Even in the work [8] it was mentioned that the need for water on the territory of the Crimean Peninsula is constantly growing due to the development of construction, industry and agriculture.

It is also noted here [8] that the water consumption of the Crimean national economy from year to year is increasing in significant amounts and the water balance deficit is increasing, and it is emphasized that solving this problem through the use of the Dnieper waters does not remove from the agenda the need to use all its own resources, primarily the excess runoff in high-water years from the territories of the mountainous Crimea, which should be accumulated in reservoirs. In general, an insufficient number of works are devoted to the study of the problems of providing the Republic of Crimea with water resources. It is possible to single out a number of works of regional significance and a small number of international publications [5, 9-21].

According to [22], the structure of the water balance of the Republic of Crimea includes input and expenditure parts. The input part of the water balance of the Republic of Crimea takes into account: water yield of existing reservoirs and ponds; the volume of natural surface runoff of rivers from which water is currently being taken (excluding the guaranteed yield of existing reservoirs); the volume of return water discharged into rivers with possible further use and permissible volume of water intake from groundwater objects.

3. Results and discussion
In the expenditure part of the water management balance of the Republic of Crimea, the total volume of water use is taken into account, including the volume of water consumption in such industries as community facilities, industry, energy, recreation, agriculture and others and the volume of water transferred to the federal city of Sebastopol.

Visualization of statistical data on the problems of water shortage on the territory of the Crimean Peninsula, performed using the ArcGIS 10.4 software package, shows that there are a number of regions on the territory of the Republic of Crimea that have a significant shortage of water resources. Most of the administrative-territorial units of the Republic of Crimea are experiencing a shortage of water resources, with the exception of the Bakhchisarai and Belogorsk regions of the Republic of Crimea, as well as the urban district of Sudak, the urban district of Alushta and the urban district of Yalta.

A detailed visualization of data on the deficit of the water balance of a dry year (95% of supply) for the municipalities of the Republic of Crimea is shown in figure 1.

In the long term, by 2030, shown in figure 2, it is planned to reduce the deficit of the water balance in a number of regions of the Republic of Crimea - in the urban district of Kerch, Leninsky and Kirovsky districts of the Republic of Crimea.

If the current period of the water balance deficit in the Republic of Crimea is -152.18 million cubic meters, then by 2030 it will be possible to reduce it to -148.45 million cubic meters. At the same time, even by 2030, most regions of the Republic of Crimea will be characterized by a deficit in water balance and lack of water resources for anthropogenic activities.
Figure 1. Water balance of a dry year by municipalities of the Republic of Crimea.

Figure 2. Forecast water balance in 2030 for municipalities of the Republic of Crimea.

4. Conclusion
As a result of visualization and comparison of modern data and forecast data on the water balance of the Republic of Crimea, it has been established that by 2030 an acute problem of water scarcity will remain on the territory of the republic, which will have a significant impact on the socio-economic, cultural and environmental living conditions of the population. In general, various measures are proposed to solve the problems of water resources shortage on the territory of the Republic of Crimea and the Crimean
peninsula, including the restoration of the network of hydrological observations on most sources and rivers of the Crimean peninsula, the restoration of sources and the competent use of their waters, the construction of new reservoirs and the reconstruction of existing ones, desalination of sea water, causing precipitation by artificial means, as well as the rational use of water in everyday life and the formation of a water usage culture among citizens.

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