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COMPREHENSIVE ASSESSMENT OF WATER SUPPLY OF THE TURKESTAN REGION FOR THE DEVELOPMENT OF ECONOMIC SECTORS AND RECREATIONAL TOURISM

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Abstract: The purpose of this study was a comprehensive assessment of water supply of the population, territory and economic sectors in the context of water-resource regions of Turkestan region of the Republic of Kazakhstan based on integrated specific water supply index, taking into account the environmental flows of river basins, providing data on the current state of water resources, level of water supply and their changes under influence of natural and anthropogenic factors. The research methodology is based on statistical analysis, long-term information-analytical materials on the hydrological condition of rivers, territorial organization of water consumption and the population of Turkestan region. For a comprehensive assessment of water supply of the population, territory and economy, a methodology was developed that allowed to assess the current state of water supply in the territory of river basins in the region and their changes under the influence of natural and anthropogenic factors. A comparative assessment of water supply in the Turkestan region in terms of water-resource areas based on the proposed methodological approach and the created research base covering the period of 2002-2020 showed that, in general, there is a high level of water shortage, which is associated with water shortage problems in the region. The obtained results of study are of fundamental environmental and economic importance when assessing water supply and can be used as an effective tool for the assessment of the influence of water factors during socio-economic forecasting of the region's development, especially recreational activities.

Key words: water resources, assessment, methodology, water stress, sustainability index, water supply, water consumption

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INTRODUCTION

For sustainable socio-economic development of any region of Kazakhstan, a strategic assessment of the water supply of river basins is necessary, which is the spatial basis of nature management and population, which condition human economic activity and performs important environment-forming and ecological functions. These functions of river basins determine the scientific and practical feasibility of dividing their territory into water resource regions, within which it is possible to conduct a comprehensive assessment of water supply, develop a unified program for their improvement, taking into account the interests of not only individual water users, but also the interests of the entire living population and, in general, for restoration and conservation of the environment. At the same time, a strategic assessment of water supply of the territory of river basins, which for thousands of years served as a great boost for the economic and spiritual development of the living population, should precede the adoption of fundamental decisions regarding the use of their water resource potential for the sustainable and safe development of economic activity. At the end of the XX century, territory of the Turkestan region of the Republic of Kazakhstan became a significant tourist route for popularizing the historical and cultural heritage of the XIII-XIV centuries, which included: reserve museums of Arystan-bab and Khoja Ahmed-Yasawi (UNESCO World

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Heritage List); Museum of Nature "Weeping Cave", located at the foot of Karatau Mountain; Aksu-Zhabagaly Nature Reserve, located at the western tip of the Tien Shan Ridge (https://whc.unesco.org/en/list/1103).

Turkestan region has a huge natural potential for the development of the economy and food security of the Republic of Kazakhstan (Mukayev et al., 2022), since it has an adequate supply of mineral resources, fertile soil, abundance of sunlight and extensive natural fodder resources (pastures), which makes it possible to develop various branches of agriculture in the region, primarily, irrigated cropping and range sheep production using available water resources (Mustafayev et al., 2023). Water resources are essential elements for any touristic destination (Aliyev and Suleymanov, 2023). As part of the development of tourism and water recreation, the level of water utilization has significantly increased in the last decade, which gives priority to study of assessments of the current and forecasted water supply in the region.

Assessment of the water supply of the territory and the population within the boundaries of the catchment area of river basins in the methodological aspect is quite complicated and is associated with the formation of a research base based on long-term information and analytical materials on the hydrological regime of rivers and the organization of water utilization due to various conditions for the formation and use of water resources. To assess the current and forecasted water supply within the catchment areas of river basins, the following criteria are traditionally used: M. Falkenmark (CMF) (Falkenmark, 1986), sustainability index (SI) (Raskin et al., 1997), water resource utilization factor ($WRUF$) (Boulay et al., 2014), specific water supply of the population ($SWSP$) (Shiklomanov, 2008), specific water supply of the territory ($SWST$) (Danilov-Danilyan and Losev, 2006), water stress index (IWS) (Raskin et al., 1997) and complex indicator of specific water supply of the catchment area of river basins ($CISWS$) (Mustafaev, 2022), etc.

One of the common approaches to assessing the water supply of the population in European practice is the M. Falkenmark criteria ($CMF_i = RWR_i / QP_i$, with a quantitative value of less than 1700 m^3/year, indicates the existence of water stress) (Falkenmark et al., 1989). Water shortage in the catchment areas of river basins (Jiang et al., 2023) is defined as the amount of renewable fresh water (AR_i) available to each person (PS_i) every year and is used to assess the state of the world's water resources and the ability of countries to meet the basic needs of their population according to the UN Food and Agriculture Organization (FAO) (https://www.fao.org/home/en; Chenoweth, 2008; Moyle et al., 2022). To assess the water resource potential of river basins of the countries of Africa (Falkenmark, 1989), Russian-Kazakhstan transboundary region (Rybkina and Sivokhip, 2019) and the North Caucasus (Rybak and Rybak, 2021), the trend of water scarcity over the past 2000 years on a scale of units of global food production was taken as a basis (Kummu et al., 2010).

In world practice, to assess the water supply of economic sectors, the sustainability index ($SI_i = WIV_i / RWR_i$) is used, which is equal to the ration of water volume (WIV_i), taken out of natural resources to the total replenished water volume (RWR_i). This indicator was used to assess the integrated water resources management (IWRM) in the Rio-Grande Basin (Morelia, Mexico) (Hernández-Bedolla et al., 2017); sustainable supply and demand levels in Akhachay river basin in northwestern Iran (Karamouz et al., 2017); sustainability of water resources in the Amudarya Basin in Central Asia (Salehie et al., 2022); determine the ecological and hydrological value of the river resource in the Prescott Active Management Zone in north-central Arizona, USA (Oxley and Mays, 2017); water resource potential of a number of developed and developing countries of the world (Friedman, 2015); water shortage on a national scale across Africa (Damkjaer and Taylor, 2017). In accordance with the World Water Assessment Program ($WWAP$) the term "water stress" is widely used to determine the level of water supply in the catchment area of river basins (water stress) ($WS_i = (WIV_i / RWR_i) \cdot 100$), which is defined as the ratio of water intake from water resources (WIV_i) to available renewable water resources (RWR_i). This indicator was used to assess water shortage in the Lower Vu-Gia-Thu-Bon river basin in Vietnam (Mai et al., 2023); geospatial water stress in Africa (Vörösmarty et al., 2005) and river basin using hydrologic unit (HUC) in the USA (Sun et al., 2008); availability of water in Jucar river basin located in the eastern part of the Iberian Peninsula in Spain (Pedro-Monzonís et al., 2014); study the water stress and drought in the Niger River Basin (Bani River, Mali) (Roudier and Mahe, 2010), water-resource potential of the catchment area of Ile and Esil river basins (Ryskulbekova, 2020; Kozykeeva and Kalmashova, 2018); anthropogenic loads on water elements of the environment in the Central Federal District of Russia (Georgiadi et al., 2021), groundwater impact assessments (GF) as a tool for sustainable water management in Mediterranean islands (Kourgialas et al., 2018), impact of tourism development on the water resources and environment of tourist destinations (Cao et al., 2023) and for a preliminary assessment of water use sustainability in industries for Italian sub-basins (Sabia et al., 2023), etc.

An important feature used in the analysis of the distribution of water resources in river basins is the water resource utilization factor ($WRUF_i = FWC_i / RWR_i$), defined as the percentage factor of the total water consumption (FWC_i) (Boulay et al. (2014) and renewable water resources (RWR_i) (Falkenmark et al., 1989). Based on these indicators, assessment were performed - spatial variability in the use of water resources of Indian river basins (Amarasinghe et al., 2005); water scarcity in the Yellow River, Indus, Ganges and Amu Darya river basins, as well as in river basins in the Midwest United States (Oki et al., 2003); overall availability of water resources in the Amu Darya River Basin within Afghanistan (Ibrahimzada and Sharma, 2012); the concept of a global water security index was developed, which was adapted to the state level in Mexico (Arreguin-Cortes et al., 2020) and guaranteed water supply under the conditions of space-time flow variability in the Tobyl River basin (Shevtsov, 2015). In assessing the water supply of the population and the catchment area of river basins, indicator of the specific water supply of the population ($SWSP_i = RWR_i / PS_i$) (Shiklomanov, 2008) is traditionally used, which is defined as the ratio of long-term average annual renewable water resources (RWR_i) (Falkenmark et al., 1989) to the number of population in this territory (PS_i). Specific water supply of the territory ($SWST_i = RWR_i / CARB_i$) is defined as the ratio of available water resources (RWR_i) to its catchment area of the river basin ($CARB_i$) (Danilov-Danilyan and Losev, 2006). These indicators were considered when assessing and justifying the environmental aspects of addressing water and environmental problems and utilization of water resources in the Russian Federation and the Republic of Kazakhstan (Shevtsov, 2015; Tursunova et al., 2022); water resource potential in all constituent entities of the Russian Federation, taking into account river and lake waters (Izmailova, 2019); availability of water resources for the population in the San Francisco Verdadeiro River basin in southern Brazil (Chaves and Alipaz, 2007); future global water availability per capita based on climate change and world population (Parish et al., 2012), etc.

A new approach to the joint assessment of the water supply of the population and the catchment area of river basins is a complex index of specific water supply ($CISWS = \sqrt{SWP_i \cdot SWST_i}$) (Mustafaev, 2022), defined as the geometric mean of the specific water supply of the population ($SWP_i = RWR_i / PS_i$) (Shiklomanov, 2008) and the territory ($SWST_i = RWR_i / CARB_i$) (m^3/person per year) (Danilov-Danilyan and Losev, 2006), which was implemented for the first time in assessing the water resource potential of the catchment area of the Tobol River Basin of the Republic of Kazakhstan (Mustafayev et al., 2021). The above methodology logically presents and considers all the parameters of the water management of river basins. This methodology is relevant in the light of the improvement of natural-science ideas about the ecological mechanisms of water resources use in the aspect of the triad of ecology (ensuring the quality of the human environment), economy (increasing the purchasing power of society) and society (improving the well-being of the population).

The purpose of this study was a comprehensive assessment of water supply of the population, territory and economic sectors in the context of water-resource regions of Turkestan region of the Republic of Kazakhstan based on integrated specific water supply index, taking into account the environmental flows of river basins, providing data on the current state of water resources, level of water supply and their changes under influence of natural and anthropogenic factors.

The object of study is the Turkestan region, located in the south of Kazakhstan, within the eastern part of the Turan lowland, western offshoot the Tien Shan Mountain and the southern part of the Betpak-Dala desert with a variety of landscape systems, which is part of the Great Silk Road in the XIII-XIV centuries (Mukayev et al., 2022). Six water resource regions of river basins have been identified within the region (Figure 1).

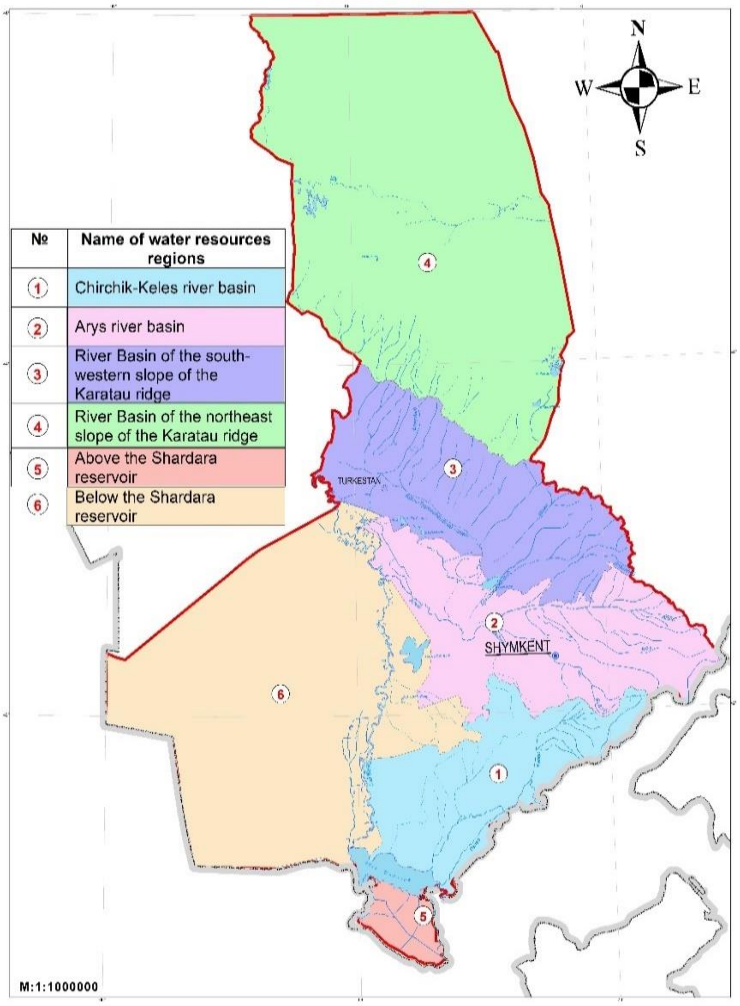


Figure 1. Distribution of six water-resource regions in the territory of Turkestan region of the Republic of Kazakhstan (Source: results of field survey of the territory, 2023)

MATERIALS AND METHODS

The information and analytic database of the study for comprehensive assessment of the water supply in the territory of Turkestan region in the context of a changing climate and anthropogenic activities was created on the basis of long-term data from the Department of the Bureau of National Statistics, Agency for Strategic Planning and Reforms of the Republic of Kazakhstan for Turkestan region and the Aral-Syrdarya basin Inspectorate for regulation of the utilization and protection of water resources of the Republic of Kazakhstan, covering the period from 2002 to 2021. Methodology of the study is presented in Figure 2.

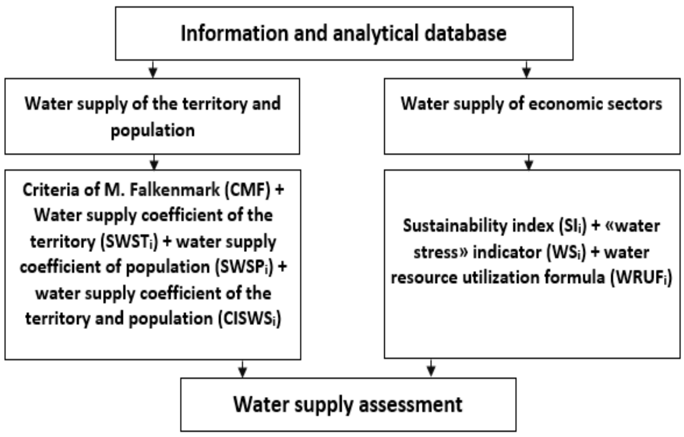


Figure 2. Flowchart of the study methodology in terms of water supply of Turkestan region within the water-resource regions (Source: personal original data)

Turkestan region of the Republic of Kazakhstan includes 13 administrative districts, four cities of regional and republican status, 826 rural settlements, where 3135.47 thousand people live. For a comprehensive assessment of the water supply in the territory of Turkestan region, number of populations living in the territory of six selected water-resource regions of river basins from 2002 to 2021 (Figure 3) were used (About changes in population of the Republic of Kazakhstan, 2021). For this assessment, indicators of available and used water resources in the territory of Turkestan region were also used across water-resource regions (Figure 4 and 5) (Regions of Kazakhstan, 2021). In the future, assessment of the water supply of the territory, the population and economic sectors of the catchment area of river basins, which perform an important environment-forming or ecological function, should not be some isolated form of human perception of reality, but a system of worldview, where, along with philosophical, scientific,political, moral and other values, there are also environmental values, which condition the need for a careful attitude of a man to nature in the interests of not only living, but also future generations. It is time to revise the existing structure of indicators in assessing the water supply of the territory, with the inclusion of the ecological flow of river basins into their composition ($EFRB_i$) (Mustafayev, 2022). In general, the estimated indicators for the assessment of water supply of the territory should include:

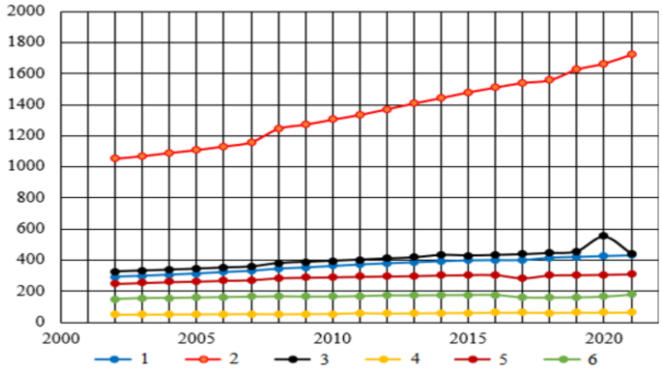


Figure 3. Population of Turkestan region living in the territory of six water-resource regions (1 – Chirchik-Keles river basin; 2 – Arys river basin; 3 – River Basin of the south-western slope of the Karatau mountains; 4 – River Basin of the north-east slope of the Karatau mountains and the Shu river, 5 – above the Shardara reservoir, – below the Shardara reservoir), thousand people

– criteria of M. Falkenmark: $CMF_i = (RWR_i - EFRB_i)/QP_i$, >1700 m^3/person per year – no stress; 1500-1700 m^3/person per year – low stress; 1500-1300 m^3/person per year – average stress; 1300-1100 m^3/person per year – high stress; 800-1100 m^3/person per year – water scarcity; 500-800 m^3/person per year – chronic scarcity; <500 m^3/person per year – absolute water scarcity (Falkenmark, 1986);

– sustainability index: $SI_i = WIV_i/(RWR_i - EFRB_i) \cdot 100$, >10 % – very low level of water scarcity; 10-20 % – low level of water scarcity; 20-30 % – slight water scarcity; 30-40 % – moderate water scarcity; 40-50 % – high level of water scarcity (water stress); 50-60 % – very high level of water scarcity (strong water stress); >60 % – chronic water scarcity (very high-water stress) (Raskin et al., 1997);

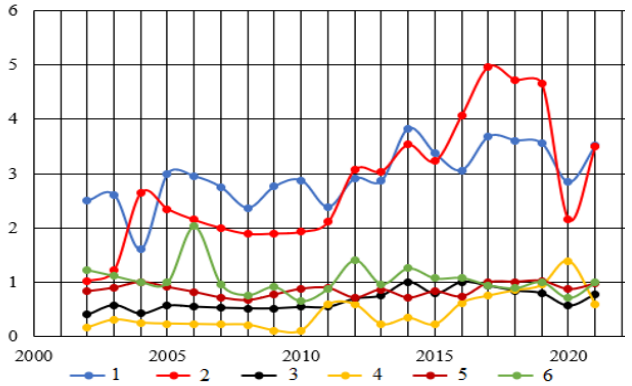


Figure 4. Available water resources of Turkestan region across water-resource regions (1 – Keles-Chirchik river basin; 2 – Arys river basin; 3 – River Basin of the south-western slope of the Karatau mountains; 4 – River Basin of the north-east slope of the Karatau mountains and the Shu river, 5 – above the Shardara reservoir, 6 – below the Shardara reservoir), km^3

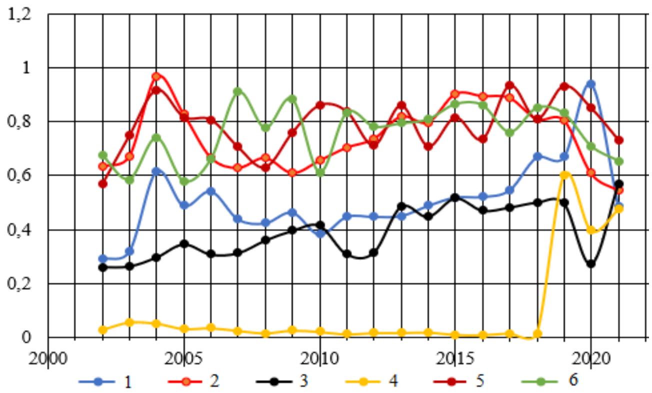


Figure 5. Utilization of water resources by economic sectors of Turkestan region across water-resource regions (1 – Keles-Chirchik river basin; 2 – Arys River basin; 3 – River Basin of the south-western slope of the Karatau mountains; 4 – River Basin of the north-east slope of the Karatau mountains and the Shu River, 5 – above the Shardara reservoir, 6 – below the Shardara reservoir), km^3

– water stress: $WS_i = (WIV_i/(RWR_i - EFRB_i)$, <0.1 – very low; 0.1-0.2 – low; 0.2-0.3 – moderate; 0.3-0.4 – average; 0.4-0.5 – high; 0.5-0.6 – very high; >0.6 – catastrophic (coefficient) (Raskin et al., 1997);

– water resource utilization factor: $WRUF_i = FWC_i/(RWR_i - EFRB_i) \cdot 100$ (in %), <10 % – minimum risk; 10-20 % – moderate risk; 20-30 % – average risk; 30-40 % – increased risk; 40-50 % – high risk; 50-60 % – very high risk; >60 % – catastrophic risk (Boulay et al., 2014);

– specific water supply of the population: $SWSP_i = (RWR_i - EFRB_i)/PS_i$ (thousand m^3/person per year), <1.00 thousand m^3/person per year – catastrophically low; 1.01-2.00 thousand m^3/person per year – very low; 2.01-5.00 thousand m^3/person per year – low; 5.01-10.00 thousand m^3/person per year – moderate; 10.01-15.00 thousand m^3/person per year – average; 15.01-20.00 thousand m^3/person per year – high; >20.00 thousand m^3/person per year – very high (Shiklomanov, 2008);

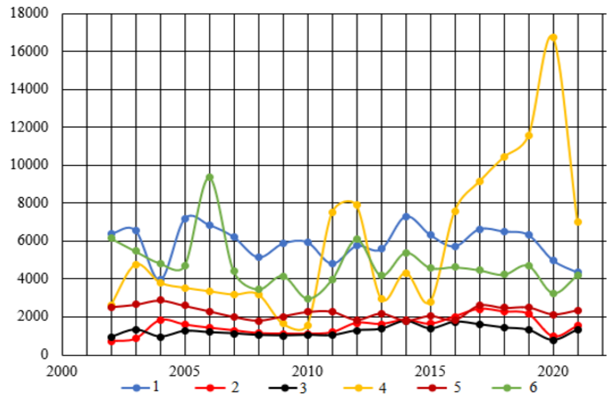
– specific water supply of the territory: $SWST_i = (RWR_i - EFRB_i)/CARB_i$ (thousand m^3/km^2), <5.00 thousand m^3/km^2 – catastrophically low; 5.01-10.00 thousand m^3/km^2 – very low; 10.01-20.00 thousand m^3/km^2 – low; 20.01- 30.00 thousand m^3/km^2 – moderate; 30.01-40.00 thousand m^3/km^2 – average; 40.01-80.00 thousand m^3/km^2 – high; >80.00 thousand m^3/km^2 – very high (Danilov-Danilyan and Losev, 2006);

– complex index of specific water supply of the territory and population: $CISWS = \sqrt{SWP_i \cdot SWST_i}$, where $SWP_i = \sqrt{[(RWR_i - EFRB_i)/PS_i]}$ and $SWST_i = \sqrt{[(RWR_i - EFRB_i)/CARB_i]}$, >5.00 – catastrophically low; <2.25 – very low; 2.25-3.35 – low; 3.35-7.25 – moderate; 7.50-13.70 – average; 13.70-32.40 – high; >32.40 – very high (thousand m^3/km^2) (Mustafaev, 2022). Based on the methodological approaches developed by K.Zh. Mustafaev and Zh.S. Mustafaev [25, 37], comprehensive assessment of water supply of the territory, population and economy of Turkestan region across water-resource regions has been conducted.

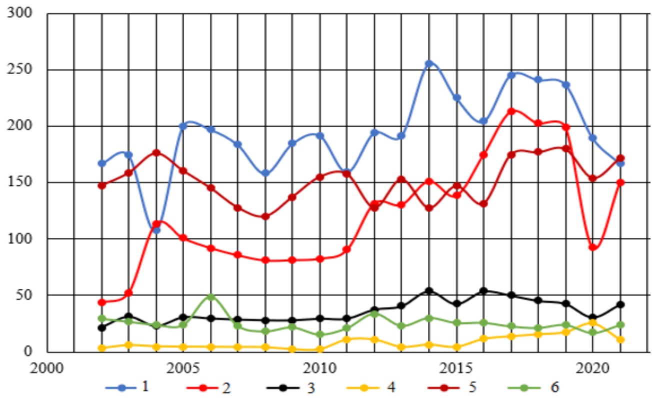
RESULTS AND DISCUSSION

Water supply of the territory and population

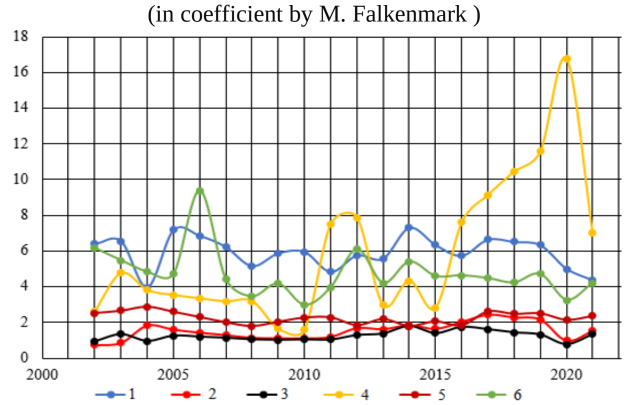
Based on the above methodology and the developed database of the study, water supply of the territory and population of Turkestan region was assessed across water-resource regions using the criteria of M. Falkenmark (CMF), specific water supply of the territory ($SWST_i$) and specific water supply of the population ($SWSP_i$), integrated (complex) index of specific water supply of the territory and population ($CISWS_i$), which enables to assess water security and prospects for the development of the economy and tourism sectors of the region (Figure 6; a) (Falkenmark, 1986); b) (Danilov-Danilyan and Losev, 2006); c) (Shiklomanov, 2008); d) (Mustafaev, 2022):



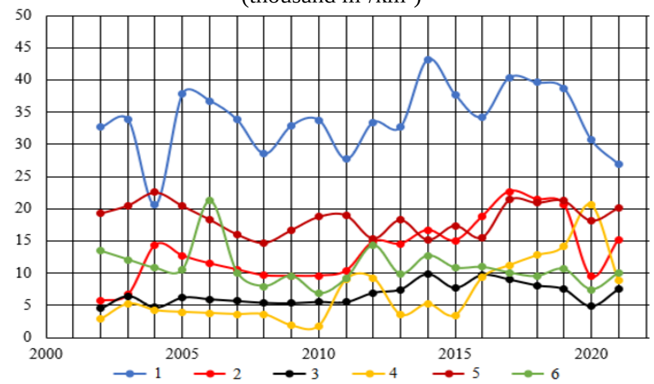
a) according to criteria of M. Falkenmark (CMF)
(in coefficient by M. Falkenmark)



b) according to specific water supply of the territory ($SWST_i$)
(thousand m^3/km^2)



c) according to specific water supply of the population ($SWSP_i$)
(thousand m^3/person per year)



d) according to specific water supply of the population and territory
($CISWS_i$) (thousand m^3/km^2)

Figure 6. Water supply of the territory and population across water-resource regions of Turkestan region
1 – Keles-Chirchik river basin; 2 – Arys River basin; 3 – River Basin of the south-western slope of the Karatau mountains;
4 – River Basin of the north-east slope of the Karatau mountains and the Shu River, 5 – above the Shardara reservoir,
6 – below the Shardara reservoir (Units are represented in each graph)

The assessment of water supply of the territory and population across six water-resource regions of Turkestan region for 2002-2021 showed:

– in the water-resource region of Keles-Chirchik river basin, criteria of M. Falkenmark (CMF) ranges within 3945.0-7305.0 m3/person, no water stress is observed here; specific water supply of the territory (SWSTi) – 107.3-255.4 thousand m3/km2 (from high to very high) and specific water supply of the population (SWSPi) – 3.95-7.31 thousand m3/person (from low to moderate); complex index of specific water supply of the population and territory (CISWSi) – 20.57-43.19 (very high), which indicates a fairly high level of water supply in this water-resource region;

– in the water-resource region of Arys river basin, criteria of M. Falkenmark (CMF) ranges within 727.5-2415 m3/person (from the absence of water stress to chronic scarcity); specific water supply of the territory (SWSTi) – 44.0-212.9 thousand m3/km2 (very high) and specific water supply of the population (SWSPi) – 0.73-2.42 thousand m3/person (catastrophically low); complex index of specific water supply of the population and territory (CISWSi) – 5.56-22.68 (from moderate to high), which reflect fluctuations of the level of water supply of the water-resource region from low to average;

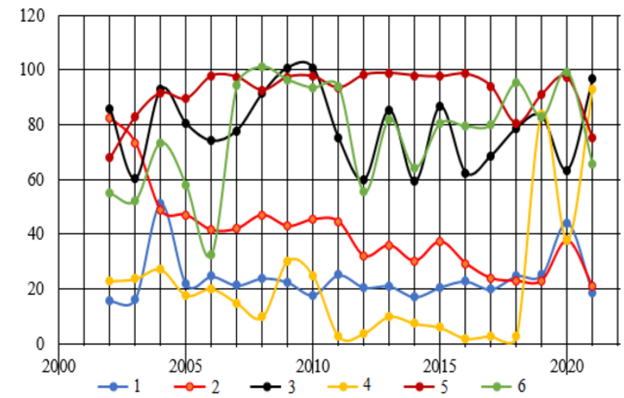
– in the water-resource region of the River Basin of the south-western slope of the Karatau mountains, criteria of M. Falkenmark (CMF) ranges within 930.0-1785.0 m^3/person (from water scarcity to low stress); specific water supply of the territory (SWSTi) – 21.60-53.90 thousand m^3/km^2 (from moderate to high) and specific water supply of the population (SWSPi) – 0.93-1.79 thousand m3/person (from catastrophically low to low); complex index of specific water supply of the population and territory (CISWSi) – 4.49-9.82 (from moderate to average), which show the change in the level of water supply of this water-resource region from low to medium;

– in the water-resource region of the River Basin of the north-east slope of the Karatau mountains, criteria of M. Falkenmark (CMF) ranges within 2625.0-16762.5 m3/person (from low stress to no stress); specific water supply of the territory (SWSTi) – 3.10-17.50 thousand m3/km2 (from low to high) and specific water supply of the population (SWSPi) – 2.63-16.76 thousand m3/person (from low to moderate); complex index of specific water supply of the population and territory (CISWSi) – 1.81-20.69 (from catastrophically low to high), which reflect changes in the level of water supply of this water-resource region from very low to low;

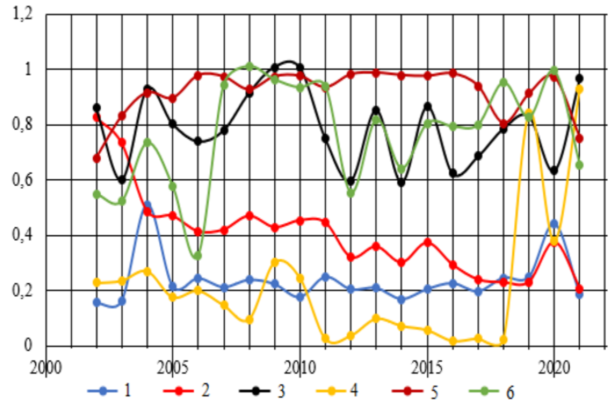
– in the water-resource region of the above the Shardara reservoir, criteria of M. Falkenmark (CMF) ranges within 1792.5-2887.5 m3/person (no stress); specific water supply of the territory (SWSTi) – 127.5-180.0 - thousand m^3/km^2 (very high) and specific water supply of the population (SWSPi) – 1.79-2.89 thousand m^3/person (from very low to low); complex index of specific water supply of the population and territory (CISWSi) – 14.65-22.57 (high), which show the change in the level of water supply of the water-resource region from very low to high;

– in the water-resource region of the below the Shardara reservoir, criteria of M. Falkenmark (CMF) ranges within 2962.5-9375.0 m^3/person (no stress); specific water supply of the territory (SWSTi) – 15.60-48.50 - thousand m^3/km^2 (from high to very high) and specific water supply of the population (SWSPi) – 2.96-9.38 thousand m^3/person (from low to moderate); complex index of specific water supply of the population and territory (CISWSi) – 6.80-21.32 (from moderate to high), which reflect the change in the level of water supply of this water-resource region from very low to high.

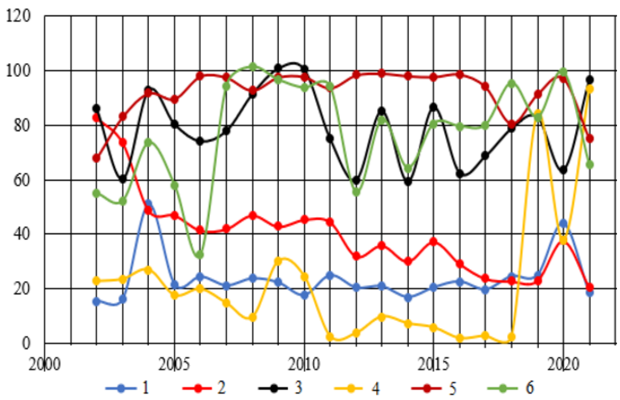
Assessment of the current water supply of the territory and population of Turkestan region across six water-resource regions for 2002-2021, using the criteria of M. Falkenmark (CMF), specific water supply of the territory (SWSTi) and specific water supply of the population (SWSPi), integrated (complex) index of specific water supply of the territory and population (CISWSi), showed that the highest water supply is observed in the water-resource region of Keles-Chirchik river basin; average water supply in two water-resource regions – Arys river basin and southwest slope of the Karatau mountains; low water supply is observed in the water-resource region of the River Basin of the north-east slope of the Karatau mountains, and relatively moderate water supply is observed in two water-resource regions located above and below the Shardara reservoir. Results of the assessment of water supply of the territory and population of Turkestan region should be considered when organizing territorial water utilization and long-term planning of the development of economic and tourism sectors.



a) according to sustainability index, % (SI_i)



b) according to "water stress" indicator, points (WS_i)



c) according to water resource utilization factor, % ($WRUF_i$)

Figure 7 – Water supply of economic sectors of Turkestan region across six water-resource regions

1 – Keles-Chirchik river basin; 2 – Arys river basin; 3 – River basin of the south-western slope of the Karatau mountains; 4 – River basin of the north-east slope of the Karatau mountains and the Shu river, 5 – above the Shardara reservoir, 6 – below the Shardara reservoir

Water supply of economic sectors

Assessment of the water supply of economic sectors of Turkestan region was performed across six water-resource regions for 2002-2021, for applied purposes and taking into account the sustainability index (SIi), "water stress" indicator (WSi) and water resource utilization factor (WRUFi) (Figures 7).

The assessment of water supply of economic sectors of Turkestan region across water-resource regions showed:

– in the water-resource region of Keles-Chirchik river basin, sustainability index (SIi) ranges within 15.57-51.16 % (from low to moderate level of water scarcity); «water stress» indicator (WSi) – 0.158-0.512 (from low to high) and water resource utilization factor (WRUFi) – 15.57-51.16 % (from moderate to high risk), which together reflect a rather low level of water supply in this region;

– in the water-resource region of Arys River basin, sustainability index (SIi) ranges within 20.80-82.57 % (from low to chronic water scarcity); «water stress» indicator (WSi) – 0.208-0.826 (from moderate to catastrophic) and water resource utilization factor (WRUFi) – 20.80-82.57 % (from average to catastrophic risk), which indicate the catastrophic level of water supply of the water-resource region;

– in the water-resource region of the River Basin of the south-western slope of the Karatau mountains, sustainability index (SIi) ranges within 59.18-100.76 % (from very high to chronic water scarcity); «water stress» indicator (WSi) – 0.592-1.008 (from very high to catastrophic) and water resource utilization factor (WRUFi) – 59.18-100.76 % (from very high to catastrophic risk), which show the catastrophic level of water supply of this water-resource region;

– in the water-resource region of the River Basin of the north-east slope of the Karatau mountains, sustainability index (SIi) ranges within 1.92-93.14 % (from low to chronic water scarcity), «water stress» indicator (WSi) – 0.019-0.931 (from very low to catastrophic) and water resource utilization factor (WRUFi) – 1.92-93.14 % (from minimum to catastrophic risk), which show the catastrophic level of water supply of the water-resource region;

– in the water-resource region of the above the Shardara reservoir, sustainability index (SIi) ranges within 67.86-98.85 % (chronic water scarcity); «water stress» indicator (WSi) – 0.679-0.988 (catastrophic) and water resource utilization factor (WRUFi) – 67.86-98.85 % (catastrophic risk), which reflect the catastrophic level of water supply of the region in question;

– in the water-resource region of the below the Shardara reservoir, sustainability index (SIi) ranges within 32.54-101.17 % (from moderate to chronic water scarcity); «water stress» indicator (WSi) – 0.325-1.002 (from average to catastrophic) and water resource utilization factor (WRUFi) – 32.54-101.17 % (from increased to catastrophic risk), which in general, reflect the catastrophic level of water supply of the water-resource region in question.

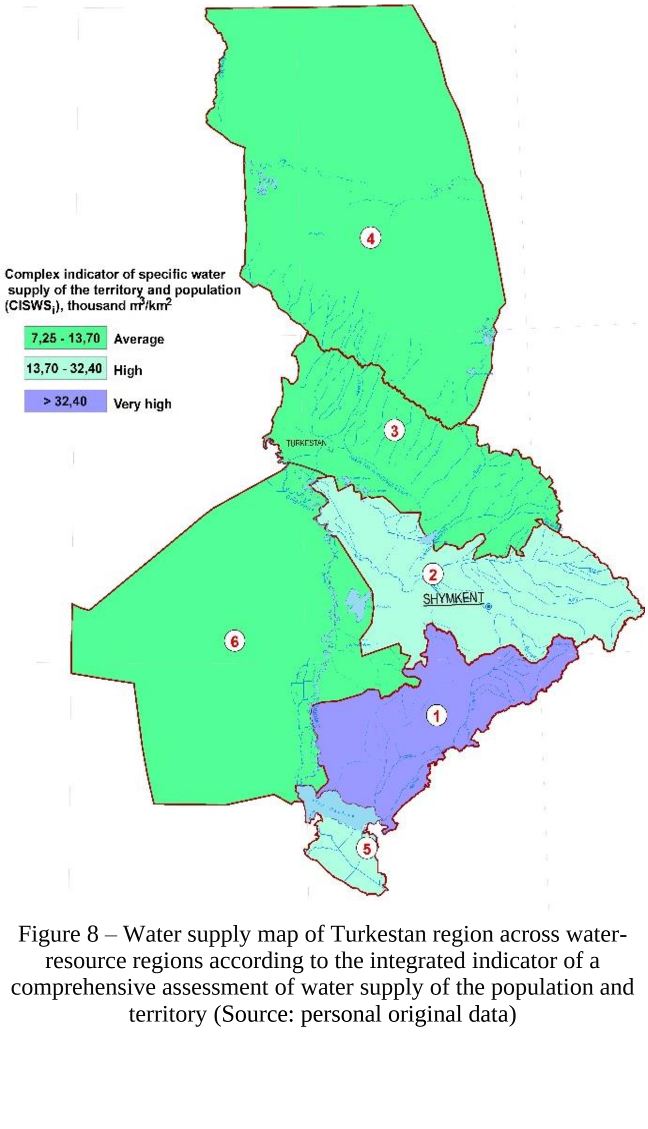


Figure 8 – Water supply map of Turkestan region across water-resource regions according to the integrated indicator of a comprehensive assessment of water supply of the population and territory (Source: personal original data)

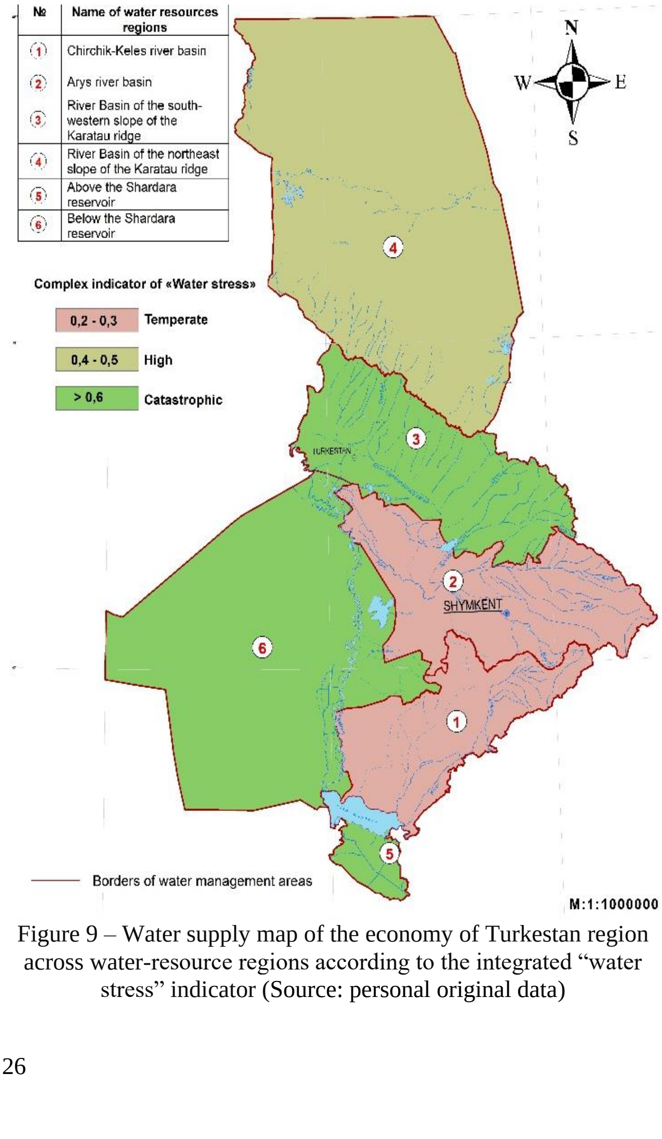


Figure 9 – Water supply map of the economy of Turkestan region across water-resource regions according to the integrated "water stress" indicator (Source: personal original data)

Comparative analysis of the estimated indicators of water supply of economic sectors of Turkestan region indicates that in all water-resource regions, except for the water-resource region of the Keles-Chirchik river basin, a high-stress catastrophic situation has developed, which is associated with water-deficit problems requiring urgent solutions to ensure water security of the economy and sustainable development of the region (economic and tourism sectors).

On the basis of the estimated indicators obtained, water supply maps were developed for the Turkestan region across water-resource regions. One of which was developed on the basis of a comprehensive assessment of water supply of the population and territory, and the other one - integrated “water stress” indicator, characterizing the water supply of the region’s economy (Figures 8 and 9). Maps of water supply of the population, territory and economy of the Turkestan region across water-resource regions are an objective, operational and effective tool during analysis of environmental and socio-economic situations that can be used in long-term territorial planning and organization of economic activities, providing the sustainable development of the region.

CONCLUSION

The developed methodological approaches to the assessment and the created study database can be used as the basic tool to determine the water supply of the territory, population and economic sectors in the catchment areas of river basins, which are the spatial basis of the population and human production activities and is the basis for decision-making when developing measures for economic, environmental and water security of the Turkestan region. Assessment of the water-resource organization (surface water resources) of the Turkestan region using integrated indicators (criteria) of water supply of the territory, population and economic sectors showed that in all six water-resource regions, except for the Keles-Chirchik river basin, there is a high level of water scarcity (water stress), which is associated with the water-deficit problems of the region, has fundamental environmental and economic importance and can be used as an effective tool for consideration of the influence of water factors during socio-economic forecasting of the development of the region.

The proposed and used system of environmental and socio-economic indicators when developing water supply maps of the Turkestan region across water-resource regions objectively characterizes the essence of the existing processes and can be used in the territorial organization of economic activity in the region. The study of water supply of the territory, population and economic sectors of Turkestan region across water-resource regions is a tool for space-time analysis of water management, environmental and related demographic and production problems, determines the scientific and practical feasibility of developing a unified program of environmental and water security of the region, taking into account the interests of not only water users of the region, but also the interests of the environment.

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