# Study of climate change patterns of the Kashkadarya River basin based on GIS technologies

*Abdulkhakim* Salokhiddinov[1], *Jakhongirmirzo* Mirzaqobulov[1*], *Mariya* Radkevich[1], *Bakhodirkhodja* Ismailkhodjaev[1], *Zulkhmor* Alibayeva[2] and *Erali* Abdumajidov[1]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, 39 Str.K.Niyazov, 100000 Tashkent, Uzbekistan
[2]The state committee of the Republic of Uzbekistan for ecology and environment protection, The Tashkent city department, Bunyodkor ave., 7-A, Chilanzar district, Tashkent city, Uzbekistan.

**Abstract.** The article deals with the problem of studying changes in some climatic indicators (temperature, precipitation) in the Kashkadarya River basin. For this purpose, the analysis of land surface temperature and area of snow and ice cover on Landsat 8 images was used. Comparison of the obtained results with the results of analysis of archival data of Uzhydromet and water level data of gauging stations showed that the growth rate of average annual temperatures in Kashkadarya province is 0.21oC, and the rate of reduction of snow-ice cover area is 1% per year. in general, which has decreased over the past 15 years, by 75%. Such trends may lead to a significant reduction in the river flow of the Kashkadarya River in the coming years.

## 1 Introduction

Global climate change is one of the biggest contemporary problems all over the world. Increasing climate variability leads to negative consequences for the economy, especially for developing countries [1]. Weather- and climate-related natural disasters cause a reduction in food production, water pollution, and other economic losses.

Climate change is especially dangerous for countries with a lack of water resources. The Republic of Uzbekistan belongs to such countries. If before 2015, the total water deficit in Uzbekistan was more than 3 billion cubic meters, by 2030 it may reach 7 billion cubic meters, and by 2050 - 15 billion cubic meters. Analyses show that climate change will further exacerbate water shortages in Uzbekistan, may lead to an increase in the duration and frequency of droughts, as in 2000, 2008, 2011, 2014, and 2018, and to serious problems in meeting the needs of the economy in water resources. Over the past 15 years, water availability per capita has decreased from 3,048 cubic meters to 1,589 cubic meters [2].

* Corresponding author: sdgnn.jakhangir@tiiame.uz

Under these conditions, the assessment of water resources formed on the territory of the Central Asian region and, in particular, on the territory of Uzbekistan, and their change under the influence of climatic and anthropogenic factors becomes especially urgent.

Notable researchers such as G.I. Marchuk, D. McKinney, J. Bellarney, et al. [3-5] have studied the problems of climate change impact on water resources potential as well as the creation of appropriate models.

On some territories of Uzbekistan, studies of climate change were conducted by A. Salokhiddinov [6, 7], A. Savitsky [8, 9], V.E. Chub [10], S. Ibatullin and N. Bobrovitskaya [11], and Sh. Bobokulov [12]. The impact of climate change on water resources in Uzbekistan as a whole was studied by V. Dukhovny [13], V. Chub [10], A. Salohiddinov, S. Myagkov, while for individual regions of Uzbekistan, studies were conducted mainly for the Amudarya river basin [10, 13-15], Karshi steppe [7], Samarkand region [12].

However, differences in climatic and hydrological conditions of Uzbek river basins require a detailed study of these problems basin-wise. In addition, in order to make reliable forecasts of temperature changes and accompanying changes in precipitation values, it is beneficial to apply GIS technology, based on the experience of other researchers [16].

Thus, our research aimed to study the patterns and assess the impact of climate change on the potential of water resources (in the example of the Kashkadarya River Basin) using GIS technologies.

## 2 Materials and methods

### 2.1 Study area

The Kashkadarya River basin, located in the Kashkadarya province of Uzbekistan, was chosen as a study area. The valley of the Kashkadarya River is located between the western ends of the Zeravshan and Gissar Ranges, and has is wide area but low-water resources. The length of the river is 310 km, and the catchment area is 8780 km2 (Figure 1).

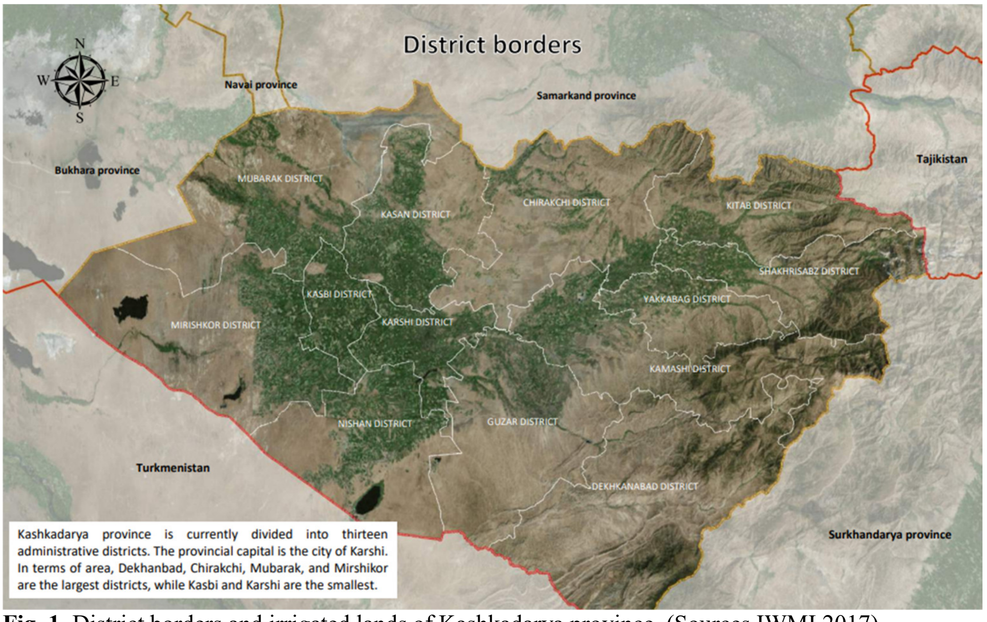



**Fig. 1.** District borders and irrigated lands of Kashkadarya province. (Sources IWMI 2017).

Soil and vegetation covers are characterized by a significant spread of desert and semi-desert types, with the presence of high-altitude belts in the mountain belts and slightly developed zones of humid high-mountain meadow-steppes.

According to natural conditions, the Kashkadarya region is divided into two parts: western - plains and eastern - mountains. Most of the flat area is occupied by the Karshi steppe (absolute height of 200 - 400 m). Its surface is an alternation of extensive ancient terraces of the Kashkadarya River with small residual mountains and channel-shaped depressions occupied by saline.

The territory is open from the northwest and west. The presence of a powerful mountain barrier in the east and southeast of the region affects the spatial and temporal distribution of meteorological elements, especially atmospheric precipitation, as well as the development of wind regimes [8].

The combination of plain spaces with mountain massifs leads to noticeable climatic differences within the region itself. Aridity and sharp continentality are characteristic features of the climate, most clearly manifested in the flat and lowland parts of the territory. Mountainous areas of the region are less continental and more humid.

Intensive irrigated farming is developed in the basin [17], and therefore, both the Kashkadarya River itself and its tributaries are almost completely disassembled for irrigation. The entire western part of the basin is fed by the Amudarya river water, supplied by the Karshi main canal and, partially, by the Kashkadarya River runoff.

## 2.2 Study of long-term climate dynamics

In order to establish the long-term dynamics of climate change and its impact on water resources, also on agricultural production in the Kashkadarya River basin, archival data of Uzhydromet (yearbook, for 1960 - 2019) and the State Special Inspection for Analytical Control under the State Committee for Ecology and Environmental Protection of the Republic of Uzbekistan were collected, and the results of numerous earlier studies [6-17] were summarized.

Representative stations (water availability, temperature, precipitation) for separate regions of Uzbekistan were selected: the area around the Kashkadarya region. The criterion for the selection of such stations was continuous series of observations for not less than 70 last years.

## 2.3 Study of temperature and precipitation changes

In the Kashkadarya River basin, GIS technology and the traditional method (a generalization of data from meteorological stations) were used to determine temperature and precipitation amounts [18, 19]. The locations of the meteorological observation stations are shown in Figure 2.

The land surface temperature was estimated using the thermal ranges of satellite images. For regional scale studies, mid-scale land surface temperature data are the most valuable. The best of such data is provided by Landsat-8. In general, ground surface temperature data can be obtained since 1982 (the year of the Landsat-4 launch). A set of standard equations from the ArcGIS raster image calculator is used to calculate temperature indices [20].

To study precipitation in ArcGIS, the mapping of wetting regimes and snow maps can be used. Snow maps allow us to estimate the water resources of the region, so we applied the analysis using the Normalized Difference Snow Index (NDSI) according to the method described in [21]. Glaciers and snow cover were extracted from Landsat 8 images [22].

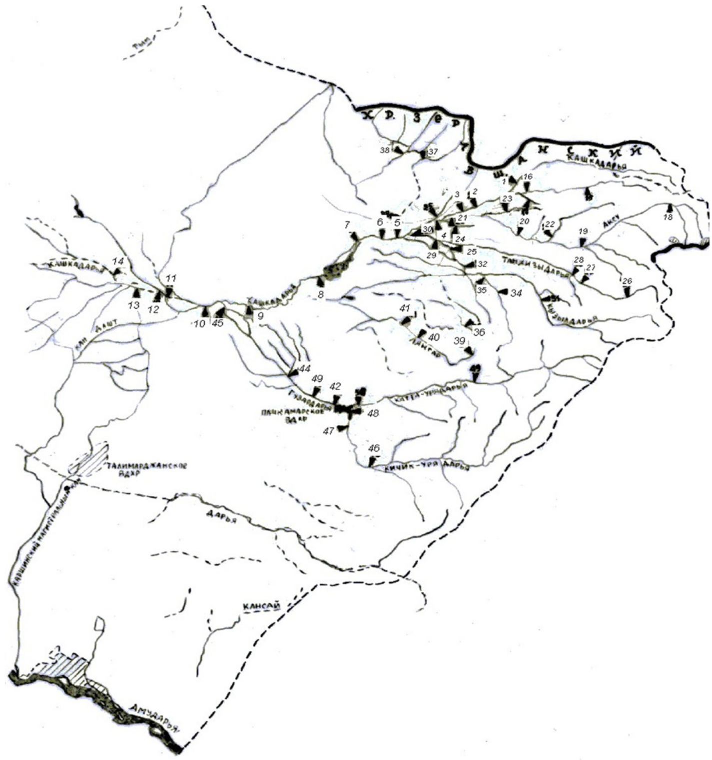


**Fig. 2.** Location of gauges in the Kashkadarya River basin.

### 2.4 Data sets

Various datasets, information on climatic parameters and water resources, and hydrological measurements were used for the study.

The datasets presented in Table 1 were considered to study and investigate changes in temperature, precipitation, and surface water in the regions of Uzbekistan, which were updated as the research progressed further.

**Table 1.** Datasets used in the research.

| | Purpose/datasets | Date (from-to) | Resolution | Type of sources | Date sources |
|---|---|---|---|---|---|
| Meteorological, climatological analysis. | Study data on the average monthly, decade, and yearly air temperature, wind, radiation, absolute humidity, solar radiation, and precipitation from a nearby weather station. | 2 periods: 1.2000-2010 2.2010-2020 | Monthly, Decade, Dyly | copy from annual reports | UzHydromed Centre. **http://www.meteo.infospace.ru** |
| GIS | For NDSI and LST(land surface temperature) | 2 periods: Open dates in usgs.gov from 2000 to 2020 | | | **https://earthexplorer.usgs.gov/** |
| Precipitatio | CRU Analysis | 2 periods: | 0.25° — | | **https://cruda** |

 https://doi.org/10.1051/e3sconf/202338606006

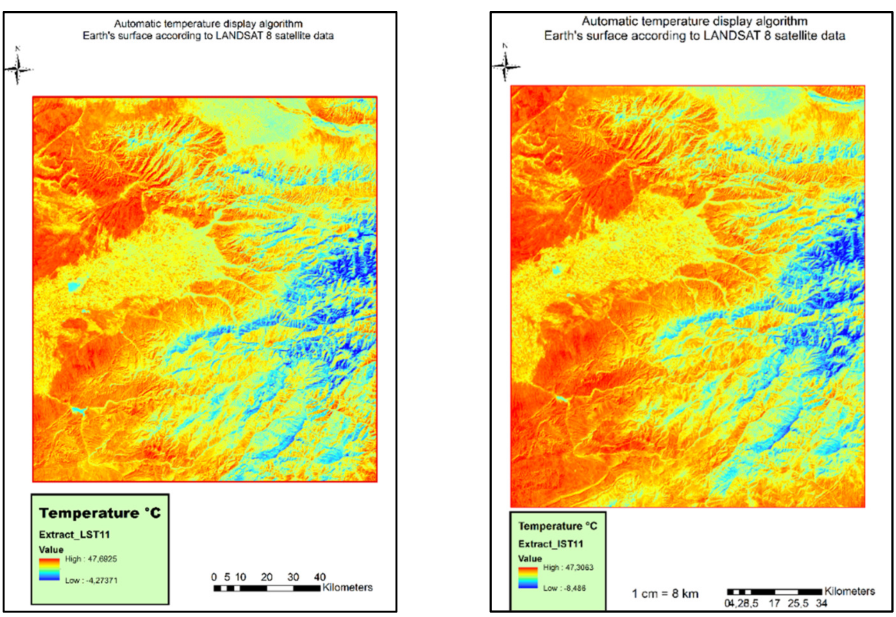
| | | | | | |
|---|---|---|---|---|---|
| n | | 1.2000-2010<br>2.2010-2020 | Monthly | | **ta.uea.ac.uk/cru/data/precip/** |
| Temperature | CRU Analysis | 2 periods:<br>1.2000-2010<br>2.2010-2020 | 0.5° —<br>Monthly | | **https://crudata.uea.ac.uk/cru/data/temperature/** |
| Köppen-Geiger Climate Zone | Climate Zones/ Modelled | 1992-2015 | 300 meters - Yearly | Satellite & modelled | **https://www.esa-landcover-cci.org/?q=node/175** |

# 3 Results and discussion

## 3.1 Assessment of temperature change

The results of the temperature change estimation are shown in Figure 3. In Figures 3a and 3b, you can see the temperature in the study area on the same day with a difference of 7 years. Thus, we can conclude that from August 20, 2013, to August 20, 2020, the maximum air temperature rose by + 0.5° C, and the minimum increased by - 4° C from 2013 to 2020. At the same time, we can see that the area of regions of increasing air temperature has increased.

Calculation shows that the average annual temperature has increased by 0.21 degrees.




a b

**Fig. 3.** Automatic land surface temperature mapping data using LANDSAT 8 satellite data.
a – August 20, 2013; b – August 20, 2020.

Figure 4 shows data of temperature changes obtained in the traditional method for the period 2001-2020 from the Mingchukur hydro post.

 https://doi.org/10.1051/e3sconf/202338606006

The data was split into two periods, that is 2000-2010 and 2011-2021, where we can see that the maximum air temperature has decreased by 0.3°C and the minimum air temperature by 3°C.

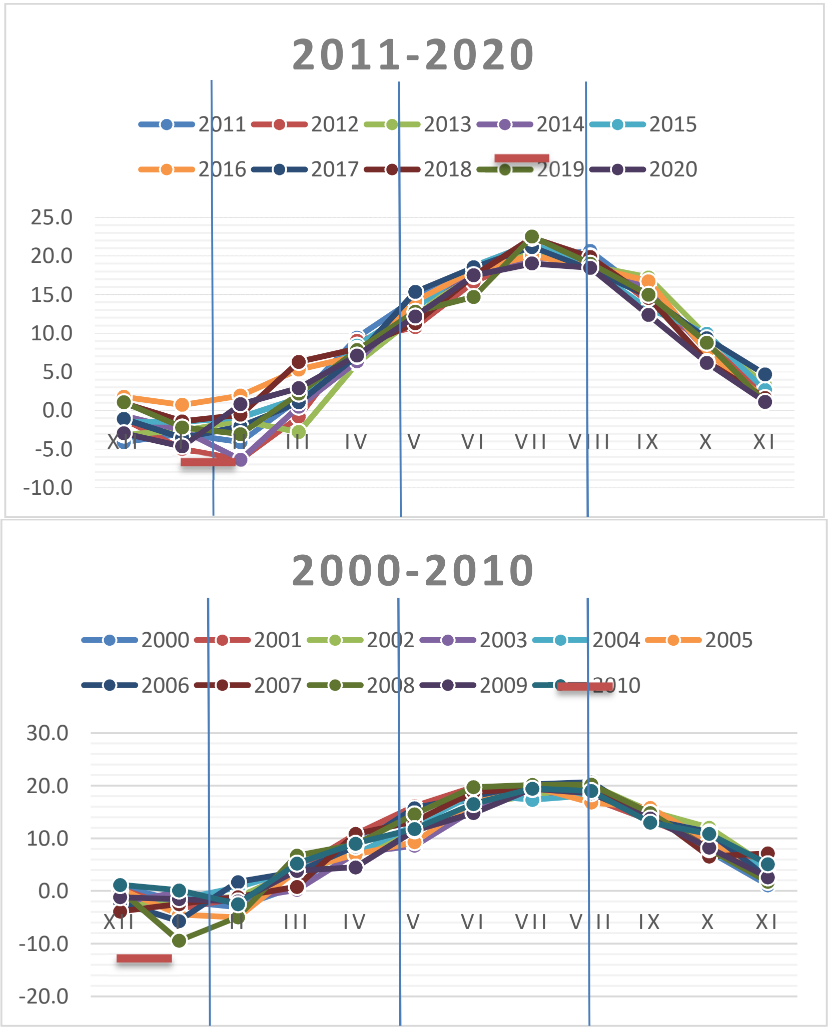



**Fig. 4**. Temperature changes in the Kashkadarya River basin measured by the traditional method.

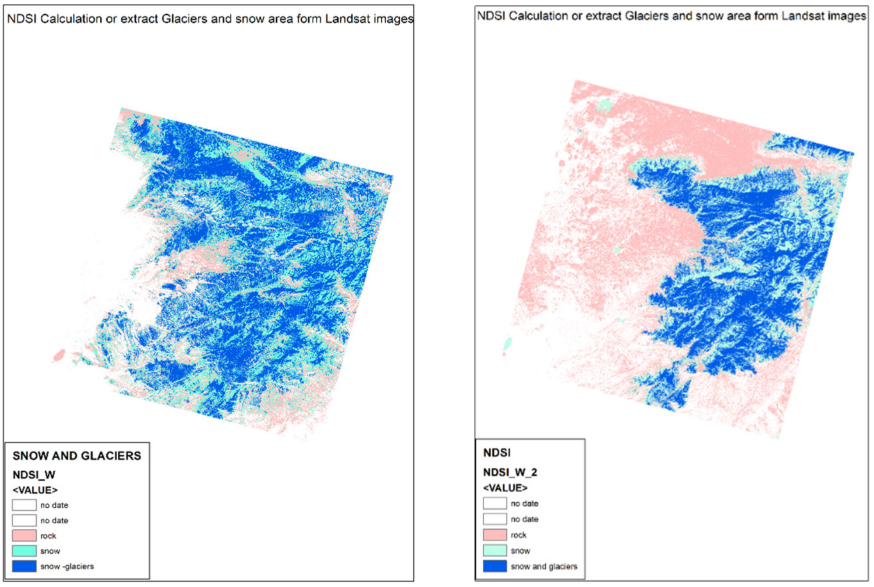
The results of average annual temperature changes and warming rates are generally consistent with data from other researchers on Uzbekistan. According to [10, 23] the average warming rate in Uzbekistan is 0.27 °C for the last decade.

Thus, the rate of warming in Kashkadarya province is slightly lower than in the whole country. Examples of the results of the analysis of glaciers and snow cover from Landsat 8 images are shown in Figure 5.

If we analyze Figure 5, we can see how much climate change has affected the decrease in precipitation: on January 1, 2014, the areas covered by snow were significantly larger than on January 1, 2021. Its area has decreased by more than 74.5%. But this does not mean a decrease in precipitation, like a lack of NDSI. However, the type of precipitation is changing.

A parallel analysis of precipitation data collected at meteorological stations throughout the region was conducted. The data represent a series of observations over the past 100 years on a monthly basis. Figure 6 shows a fragment of the list of gauging stations in the Kashkadarya River basin.

Based on the above data, the vegetation of the study area as of 2021 was studied in the period from March to October. Studies show that vegetation is almost non-existent in March, April, and May. Vegetation peaks from late May to June, and high vegetation is maintained in June, July, and August. From the end of August, the vegetation rate begins to decline, and this condition continues in September and October (Figure 2).




a b

**Fig. 5.** Extracting glaciers and snow cover from Landsat 8 images.a – 07,01,2014; b – 08,01,2021

The variability of climatic characteristics (water content, temperature, and precipitation) has increased during the year. If we analyze precipitation by seasons, an anomalous change in the seasons occurred in the following months: during the winter seasons, the amount of precipitation in December decreased by 50%, that is, by 2.5% year on year. In the spring seasons, the amount of precipitation in April increased by 40%, i.e., increased by 2% year on year. In the summer months, in June, it increased by 28%, i.e., increased by 1.4% year on year. In the autumn seasons, in November, it decreased by 45%, i.e., decreased by 2.25% year on year. We can see that, in general, the amount of precipitation has decreased compared to the last decade.

However, this decrease is insignificant, while the area of snow cover and glaciers during the period from 2014 to 2021 significantly decreased, as already established above. According to Agaltseva [15], the rate of reduction of the area of glaciers in Uzbekistan is 0.2% - 1% per year. This is a confirmation of our results and shows that in Kashkadarya province the rate of reduction of snow and ice cover exceeds the average for the country. Precipitation alone cannot in any way accurately determine the local water situation. However, the 10 percent increase in precipitation can be considered as some indication, which will determine what part of the increase or decrease in river flow is provided by the change in precipitation, and what part of river flow can be provided by the melting of eternal ice, which occurs due to an increase in air temperatures.

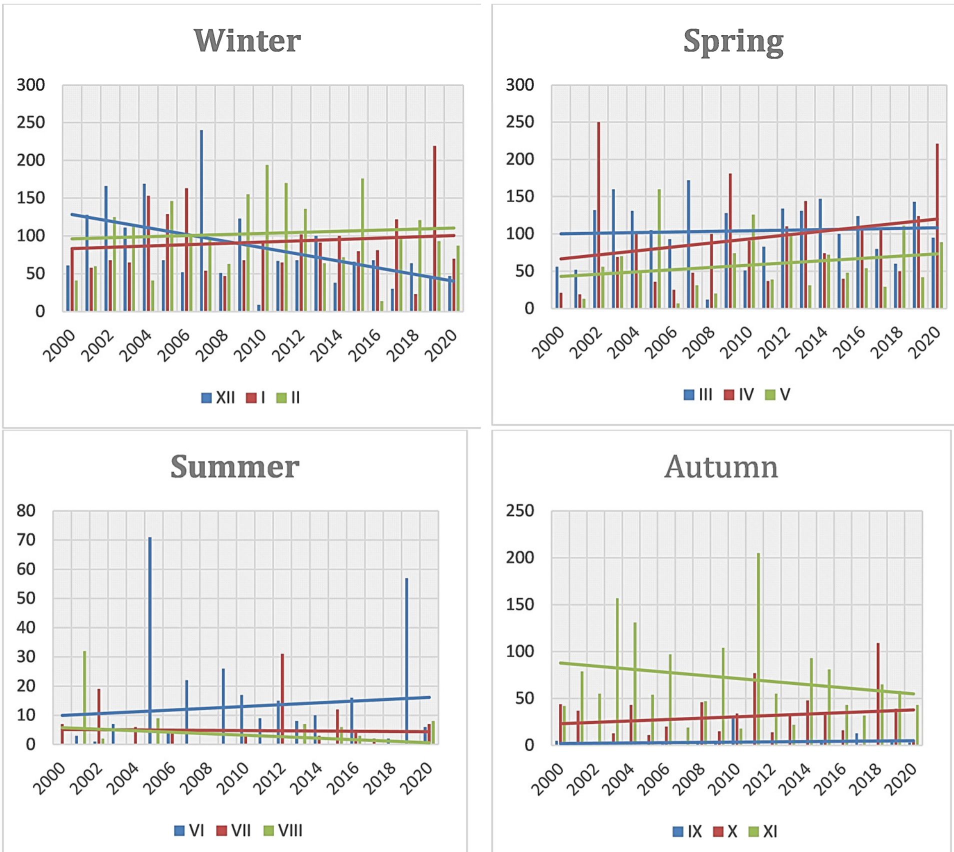



**Fig. 6.** Changes in precipitation for the period of 2000 to 2020 in Kashkadarya River basin.

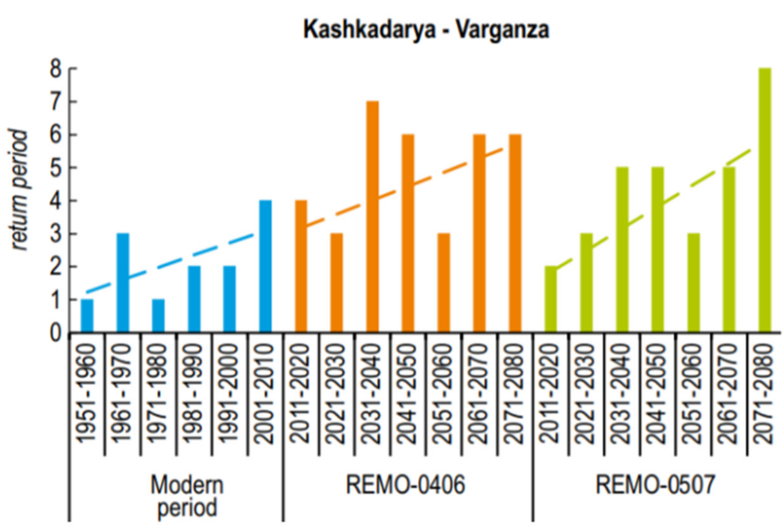



**Fig. 7.** Frequency of low water on the Kashkadarya and Karakulja rivers in the modern period and according to climatic scenarios [24].

Nevertheless, given the rate of reduction in the area of snow and ice cover, it can be assumed that the volume of flow of the Kashkadarya River will decrease in the coming years, which is consistent with the results of other research see Figure 7.

## 4 Conclusions

The studied patterns of climate change in the Kashkadarya River basin confirm the general trends in the Republic of Uzbekistan and cause concern about a growing water shortage. The ultimate goal of research on climate change assessment is to create conditions necessary to meet the ever-growing needs of the population, economic sectors, and the environment for water, to ensure reliable and safe operation of water management facilities, as well as effective management and rational use of water resources, improvement of ameliorative condition of irrigated lands, achieving water security under increasing water shortage and global climate change.

The results of this study can serve as a tool for forecasting the probable consequences of climate change. and developing recommendations on adaptation measures for water resources for the changing climate conditions.

Based on the analyzed maps of temperature changes, geothermal zoning of regions can be done, which enables forecasting the surface temperature under different scenarios of climate warming and of the development of agriculture and urban economy.

## Acknowledgments

We are thankful to the SDG nexus Network Project of the DEAD's "Higher Education Excellence in Development Cooperation—exceed" program for providing the opportunity to work on this study.

## References

1. N. Emodi, N. Ekene Journal of Scientific Research & Reports, **10,** 1-33 (2016)
2. Concept of water sector development in the Republic of Uzbekistan for 2020 - 2030 2020 Decree of the President of the Republic of Uzbekistan No. UP-6024 of 10.07.2020
3. G. I. Marchuk, *Numerical solutions of atmospheric and oceanic dynamics problems* Leningrad: Gidrometeoizdat (1974)
4. D. McKinney,. J. Contemporary Water Research, **8,** 35 **(**1997)
5. J. Bellarby, B. Foereid and A. Hastings, *Cool Farming: Climate Impacts of Agriculture and Mitigation Potential* (Greenpeace International, Amsterdam, 2008)
6. A. Salokhiddinov, A. Savitskiy, P. Khakimova, R. Toryannikova, O. Ashirova, A. Gofurov, J. Irrigation and Melioration, **2,** 7-12 (2021)
7. A. Salokhiddiov, IOP Conference Series: Materials Science and Engineering, **883**, 1207 (2020)
8. A. Savitsky, O. Ashirova, R. Razzakov, J. Ecological Bulletin, **11**, 36, (2019)
9. A. G. Savitsky, O. A. Ashirova, P. A. Khakimova, *Impact of climate change on precipitation in Uzbekistan,* J. Ecological Bulletin, **10 (**2019)
10. V. Y. Chub, *Climate Change and Its Impact on Hydrometeorological and Agroclimatic Processes and on Water Recourses in the Republic of Uzbekistan* (Voris, Tashkent, 2007)
11. S. Ibatullin, N. Bobrovitskaya, *Impact of climate change to water resources in Central*

*Asia Consolidated report* (Regional Center of Hydrogeology, Almaty, 2009)

12. Sh. Babakholov, *Empirical assessment of climate change impacts on agriculture in Samarkand region*, J. Irrigation and Melioration **4,** 28-33 (2020)
13. V. A. Dukhovny, D. R. Ziganshina et al, *The future of the Amu Darya basin in conditions of climate change*, ed by V A Dukhovny (SIC ICWC of Central Asia, Tashkent, 2018)
14. N. A. Agaltseva, A. V. Pak, *Adaptation of flow formation model in conditions of information deficit for future assessment of climate impacts on water resources,* Climatic scenarios, climate change impact assessment. Bulletin**, 6,** 38 -43 (2007)
15. N. A. Agaltseva, M. V. Bolgov et al., *Assessment of hydrological characteristics in the Amudarya basin under climate change*, Meteorology and hydrology**, 10, (**2011)
16. B. T. Gurusamy, A. D. Vasudeo, S. P. Godbole, *GIS based Assessment of Water Resources and Climate Change Impacts across Bundelkhand Region of India, Proc. Roorkee Water Conclave* (Indian Institute of Technology Roorkee and National Institute of Hydrology, Roorkee, 2020)
17. E. I. Chembarisov, D. Kuchkarova, R. T. Khozhamuratova, J. B. Mirzakobulov, *Features of hydrological and hydrochemical monitoring of surface waters in Kashkadarya province* (Navruz, Tashkent, 2018)
18. Zhu Xuan, *GIS for environmental applications: a practical approach* (Routledge, Singapore, 2016)
19. X. Peng et al, *Correlation Analysis of Land Surface Temperature and Topographic Elements in Hangzhou, China,* Scientific Reports, **10(1),** 10451 (2020)
20. G. Kaplan, U. Avdan, Z. Y. Avdan, *Urban heat island analysis using the Landsat 8 satellite data: A case study in Skopje, Macedonia,* Multidisciplinary Digital Publishing Institute Proceedings, **2 7,** 358 (2018)
21. P. Sibandze, P. Mhangara, J. Odindi, M. Kganyago, *A comparison of Normalised Difference Snow Index (NDSI) and Normalised Difference Principal Component Snow Index (NDPCSI) techniques in distinguishing snow from related land cover types,* South African J. of Geomatics, **3(2)**, 197-209 (2014)
22. W. J. Wiscombe, S. G. Warren, *A model for the spectral albedo of snow,* J. Atmos. Sci., **37,** 2712-2733 (1980)
23. N. V. Myagkova, *Ecological aspects of climate change in Uzbekistan,* J. Universum: Technical sciences: electron. scientific **2(59)** (2019)
24. B. Nishonov, R. Taryannikova et al., *Climate Risk Management in Uzbekistan Climate risk profile.* UNDP/Uzhydromet project (Uzhydromet, Tashkent, 2015)