CRYOSPHERE PROJECT | in Central Asia

Diagnostic Analysis

OF THE MAIN ISSUES OF THE CRYOSPHERE MONITORING, OBSERVATION AND RESEARCH IN CENTRAL ASIA

BY UNESCO REGIONAL OFFICE IN ALMATY

Acknowledgments

UNESCO Regional Office in Almaty, which implements the GEF-UNDP-UNESCO full-size Project ”Strengthening the Resilience of Central Asian Countries by Enabling Regional Cooperation to Assess Glacio-nival Systems to Develop Integrated Methods for Sustainable Development and Adaptation to Climate Change“ (GEF-UNDP-UNESCO Cryosphere Project), extends sincere gratitude to country delegates and participants of the 1st Subregional Workshop on development of the Diagnostic Analysis (DA) on the Cryosphere’s Main Issues in Central Asia, held on April 2-3, 2024 in Almaty, series of the National Workshops held in all five project countries within May-October 2024, and of the 2nd Subregional Workshop on DA development took place in November 4-5, 2024 in Almaty for their valuable contribution in identification of the main issues of the cryosphere observation, monitoring and research in Central Asia, assessing the impact of the main issues, distinguishing a country context each of identified main issues, exercising causal-chain analysis, identifying leverage points and the way ahead in managing water resources in order to address the impact of the climate change on the cryosphere and water resources.

The current DA is based on four fundamental Thematic Reports: Thematic Report -1 (TR-1) “The Current State of the Cryosphere and Its Impact on Water Availability in Central Asia” (ANNEX 1), Thematic Report -2 (TR-2) “Climate Change Scenarios for Glaciers and Meltwater Contribution on Water Availability in Central Asia (ANNEX 2), Thematic Report – 3 (TR3) Development of high-resolution climate change impact scenarios on Central Asian snow cover (ANNEX 3), and Thematic Report-4 (TR-4) “Needs and gaps assessment of the higher education programmes in the field of cryosphere in Central Asia” (ANNEX 4). Thematic Reports are the result of the collaborative efforts of the National Research Institutions and of the other international project partners led by the team of researchers and specialists from University of Fribourg, which brought a quality international expertise and advanced approaches not only for the development of these Thematic Reports and the current DA, but also contributes to the research of the cryosphere jointly with a number of the research institutions in Central Asia within and beyond of the GEF-UNDP-UNESCO Cryosphere Project.

UNESCO Regional Office in Almaty acknowledges the contribution of the National Project Implementing Partner Institutions: Central-Asian Regional Glaciological Centre category 2 under the auspices of UNESCO, Kazakhstan; Central Asian Institute of Applied Geosciences, Kyrgyzstan; State Scientific Institution “Centre for the Glaciers Study under the National Academy of Sciences” and the Institute of Water Problems, Hydropower and Ecology of the National Academy of Sciences, Tajikistan; Hydrometeorological Research Institute and National University of Uzbekistan for collection of data and drafting chapters on system boundaries, institutional and legal framework relevant to identified main issues of the cryosphere, review of the water governance, analysis of socio-economic and water abstraction and use indicators.

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List of Authors and Contributors

Coordination Group	**Project National Focal Points:** Kazakhstan - Aizhan Mamedalieva, Ministry of Ecology and Natural Resources Kyrgyzstan - Gulnara Zhunushova, Ministry of Natural Resources, Ecology and Technical Supervision Tajikistan - Ramazon Rahmonov, Glaciology Centre of the Agency of Hydrometeorology, Committee for Environmental Protection under the Government Turkmenistan - Makhtumkuli Akmuradov, Ministry of Foreign Affairs, Serdar Eyeberenov Ministry of Environment Protection Uzbekistan - Sayora Abdulaeva, National Centre for Climate Change under the Ministry of Ecology, Environmental Protection and Climate Change
	UNDP IRH: Dr. Vladimir Mamaev, Regional Technical Advisor, Water & Ocean Governance Programme, BPPS, UNDP Istanbul Regional Hub
	UNESCO: Project Manager: Nana Baramidze National Coordinators: Kazakhstan - Larissa Kogutenko, Kyrgyzstan - Zuura Mamadalieva, Tajikistan - Khurshedmo Aknazarova, Turkmenistan - Diana Charyyeva, Uzbekistan - Kudratkhon Bakhadirov
International Project Implementing Partner	**University of Fribourg, Switzerland:** Serikzhan Atanov, Martina Barandun, Tomas Saks, Martin Hoelzle
National Project Implementing Partners	Kazakhstan: Central-Asian Regional Glaciological Centre category 2 under the auspices of UNESCO, Republican State Enterprise “Kazhydromet. Kyrgyzstan: Central Asian Institute of Applied Geosciences; Institute of Water Problems and Hydropower of National Academy of Sciences; State Hydrometeorological Service of the Ministry of Emergency Situations. Tajikistan: Glaciology Centre of the Agency of Hydrometeorology, Committee for Environmental Protection under the Government; State Scientific Institution “Centre for the Glaciers Study under the National Academy of Sciences”; Institute of Water Problems, Hydropower and Ecology of the National Academy of Sciences. Turkmenistan: National Committee for Hydrometeorology (Turkmengidromet), National Institute of Deserts, Flora, and Fauna, Turkmen National Institute of Hydrometeorology (Turkmensuwylymtaslama) Uzbekistan: Hydrometeorological Research Institute; Glacial Geology Centre of Institute of Geology and Geophysics; National University of Uzbekistan.

TDA International Consultant	Talaibek Makeev, Zoi Net, Switzerland
Authors	Khurshedmo Aknazarova, Serikzhan Atanov, Kudratkhon Bakhadirov, Nana Baramidze, Martina Barandun, Diana Charyeva, Meerim Dzholdosheva, Martin Hoelzle, Anvar Homidov, Lidia Karandaeva, Larissa Kogutenko, Talaibek Makeev, Zuura Mamadalieva, Jafar Niyazov, Nina Pimankina, Tomas Saks, Nazrialo Sheralizoda, Gulomjon Umirzakov, Ryskul Usubaliev, Karabek Uzakbayev, Saltanat Zhakenova
Contributors	Kazakhstan: Lyazat Abdirova, Ainur Abenova, Alimzhan Abulkhan, Diana Aripkhanova, Ravza Ashanova, Takir Balykbayev, Saniya Beisenbayeva, Olga Blagoveshchenskay, Viktor Blagoveshchensky, Assem Bodauova, Irina Dikikh, Svetlana Dolgikh, Gulmira Imasheva, Vassiliy Kapitsa, Murat Kassenov, Alexandr Kokarev, Viktoriya Krylova, Svetlana Mogiluyk, Aida Munaitpassova, Zhanar Naurozbayeva, Nikolay Popov, Zhanar Raimbekova, Sandugash Ranova, Igor Severskiy, Almas Shabdanov, Elena Smirnova, Tatyana Sorokina, Boris Stepanov, Amrazhan Tairov, Mariya Tatkova, Turebek Tokmagambetov, Lidiya Toleubaeva, Kalima Tursymbay, S. Userbaeva, Zamira Usmanova, Roza Yafyazova, Alexandr Yegorov, Zulfiya Yesniyazova, Tuganbek Zhaparkulov Kyrgyzstan: Adilkhan Azhikeev, Nazgul Alybayeva, Madina Amanova, Ulan Abdybachaev, Salamat uulu Abdyzhapar, Erlan Azisov, Sultan Belekov, Murataly Duishonakunov, Sergei Erokhin, Olga Kalashnikova, Adilet Makeshov, Bolot Moldobekov, Cholponbek Ormukov, Adilhan Oskonov, Andrey Podrezov, Daurbek Sakyev, Ekaterina Sakhvaeva, Ryspek Satylkanov, Gulmira Satymkulova, Sabira Soltongeldieyva, Azamat Sharshebayev, Sheishenaly Usupaev, Gulnara Zhunusheva, Aleksandr Zubovich Tajikistan: Umarali Abdulloev, Ahmadjon Akramov, B. Akramov, I. Aliev, Bahromjon Ahmadzoda, Orif Amirzoda, Hasan Asoev, Mahmadsharif Haqdod, Suman Huseinova, Tamlikho Jurabekov, Khusrav Kabutov, Abdulhamid Kayumov, Kh.Khudododov, Vladimir Lekarkin, Shavkat Manonov, Sitora Mirzokhonova, Farkhod Nasrulloev, Kamoliddin Nazirzoda, Suhaylo Qurbonmamadova, Takhmina Saburova, A. Safarov, Gul Sharifov, Angubin Shirinova, Shamsiddin Soliev. Turkmenistan: Serdar Eyeberenov, Uzbekistan: Khayitboy Abduvaliev, Fahriddin Akbarov, Irina Dergacheva, Oyjamol Kholtojieva, Halimjon Mamirov, Maxim Petrov, Mohidil Shamsiyeva, Sarkor Suvonkulov, Zukhra Tillakhodjaeva, Daniyar Turgunov, Gabit Zulpikharov

Introduction

The Transboundary Diagnostic Analysis (TDA)[1] is a technical document and within Global Environmental Facility's International Waters (GEF IW), it is commonly referred to as a "living document" meaning that it will grow and change as conditions and information does. The TDA focuses on shared issues and shared concerns for water management through a multi-stakeholder process. This enables the governments of the participating countries to include the interests of key water dependent sectors, like agriculture, hydropower, municipal water, and the environmental sectors. The TDA and the Strategic Action Programmes (TDA/SAP) process includes concerns from these sectors to optimize water management through harmonized transboundary Integrated Water Resource Management (IWRM). In areas where there are possible differences between sectoral priorities, these can be identified and addressed to optimize water use across the basin.

The methodology of the TDA is to identify the priority transboundary issues, working with a multiple stakeholder team from the project countries. The TDA process is country driven, so that even though an international consultant may provide guidance on the methodology each basin uniquely develops their own TDA based on specific conditions and local expertise.

The TDA process enables countries to identify the priority issues, to collect and systematically analyse existing empirical evidence related to them. Based on the evidence, the countries develop recommendations to reduce stresses on the cryosphere and ecosystems. The TDA approach is used in river basins around the world to assist countries to define and examine challenges, and then to recommend prioritized and harmonized water resources management efforts. In this project, this approach has been exercised with the support of project stakeholders.

Considering specificity of the cryosphere's geography in Central Asia, it was agreed with the stakeholders that this document will be named Diagnostic Analysis (DA), which does not compromise the transboundary effects wherever applicable.

The priority issues identified and examined in the DA are:

- Insufficient quality, limited accessibility, or absence of the data on cryosphere;
- Lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change;
- Deficiency of qualified specialists on cryosphere research, monitoring and management.

The DA addresses these issues through the review of baseline institutional, socioeconomic conditions, stakeholders' view analysis on the identified issues in the region. For each issue the DA examines how these issues are contributing to and impacted by the existing condition. A cryosphere specific in-depth analysis was made in three Thematic Reports that serve as a key supplement to thoroughly treat identified issues, including the climate change impact now and in the future.

A causal chain analysis has been conducted for each issue to examine the direct, intermediate and root causes of the priority issues, as well as the impacts and super impacts that these have on physical and socio-economic settings. Stakeholders' interests and concerns, relevant institutional context and socio-economic conditions as well development trends are reviewed. Based on these

[1] https://iwlearn.net/manuals/tda-sap-methodology/tdasap-methodology

combined analyses by the DA drafting team, in coordination with key stakeholders the set of recommendations was formulated.

The DA was improved through expert teamwork at the first subregional workshop, followed by national workshops in project countries. These workshops aimed to:

- Review identified DA issues, their evidence base, impact, and causal chain from a country-specific perspective;
- Identify leverage points and priority tasks to address these issues;
- Determine national priorities for awareness raising, capacity building, and pilot activities.

Project National Coordinators were responsible for the formation of the National Expert Groups on the DA observing UNESCO procedures and the GEF principles for DA development.

Additional expert work was commissioned to project partner organisations and individual consultants at country level to complete the DA with relevant country and subregional level information and analysis, those then also to be used for the elaboration of the concept and actions on the awareness raising, knowledge and data management, capacity building work of the project, namely on:

- Legal and institutional analysis of cryosphere management including through the national legislation and the set of established mandate, multilateral and bilateral treaties: – obligations on 2030 Agenda with relevant Sustainable Development Goals (SDGs), to United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement, Sendai Framework and others;
- Brief Socio-Economic Analysis (statistics-based on macroeconomy, demography, relevant trends);
- Water resources management situation (data-based on abstraction, use, efficiency)
- Stakeholder analysis.

The second Subregional Workshop held in November briefly reviewed findings of the national workshops on the DA through the subregional perspectives; reviewed the cryosphere climate scenarios for the subregion; and exercised developmental scenarios to support recommendations of the DA.

The DA document and process as a “living document” to be reviewed and revisited at regular intervals and to serve as a baseline against which to gauge the progress made through the cooperation in cryosphere observation and research.

The recommendations from this DA based on the guidance from UNDP-GEF IW will serve for the programming activities at both regional and national (country) levels.

System Boundaries

Central Asia (CA) is the largest landlocked subregion in the world, consisting of five project countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. CA is even larger considering Afghanistan as an immediate landlocked neighbour Nation of the above CA countries. However, the project system boundaries consider only five participating project countries.

There are obvious up and downstream transboundary water dependences in CA due to its main geographical features. CA is a vast, landlocked region characterized by diverse physical geography, including expansive deserts, towering mountain ranges, and fertile river valleys. The region is dominated by the rugged Tian Shan, Pamir, and Altai Mountain ranges, which provide a dramatic contrast to the vast arid plains and basins, such as the Kyzylkum and Karakum Deserts.

Inland downstream natural water bodies of the CA: Aral Sea, Balkhash and Issyk-Kul lakes, being greater or lesser snow-glacier or glacier-snow fed are the natural indicators of the water fluctuation in the subregion, those historically reflecting the multiyear, century and millennial climate periodicity or changes.[2]

The Amudaria and Syrdaria Rivers are the main arteries linking the CA cryosphere with catastrophically shrank Aral Sea. The irrigated agriculture of all project countries heavily relays on water of these two rivers, while the hydropower in Kyrgyzstan and Tajikistan almost entirely generated on them. Thus, the cryosphere, which mainly includes glaciers, snow cover and permafrost, plays a crucial role in the formation of water resources, ecosystems, and socio-economic development of the subregion.

The rather more detailed description of the subregion's cryosphere, hydrology, climate change impact and scenarios is given in the Thematic Report -1 (TR-1) "The Current State of the Cryosphere and Its Impact on Water Availability in Central Asia" (ANNEX 1), Thematic Report -2 (TR-2) "Climate Change Scenarios for Glaciers and Meltwater Contribution on Water Availability in Central Asia" (ANNEX 2), Thematic Report – 3 (TR-3) "Development of high-resolution climate change impact scenarios on Central Asian snow cover" (ANNEX 3).

The TRs provide a comprehensive picture to stakeholders on the status and the role of the cryosphere in water resources along with identified main challenges in research and monitoring. It served the basis for key stakeholders to identify main cryosphere related issues to address in near future, including through this project. Thus, the further proceeding with the development of this Diagnostic Analysis (DA) is to serve elaboration of agreed actions to change the situation with:

- Insufficient quality, limited accessibility, or absence of the data on cryosphere;
- Lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change;
- Deficiency of qualified specialists on cryosphere research, monitoring and management.

Due to uneven geography and the role of the cryosphere in CA countries and its uneven share in water resources, ecosystems as well as in adding value to the socio-economic development of each country, this chapter further briefs cryosphere's system boundaries country by country.

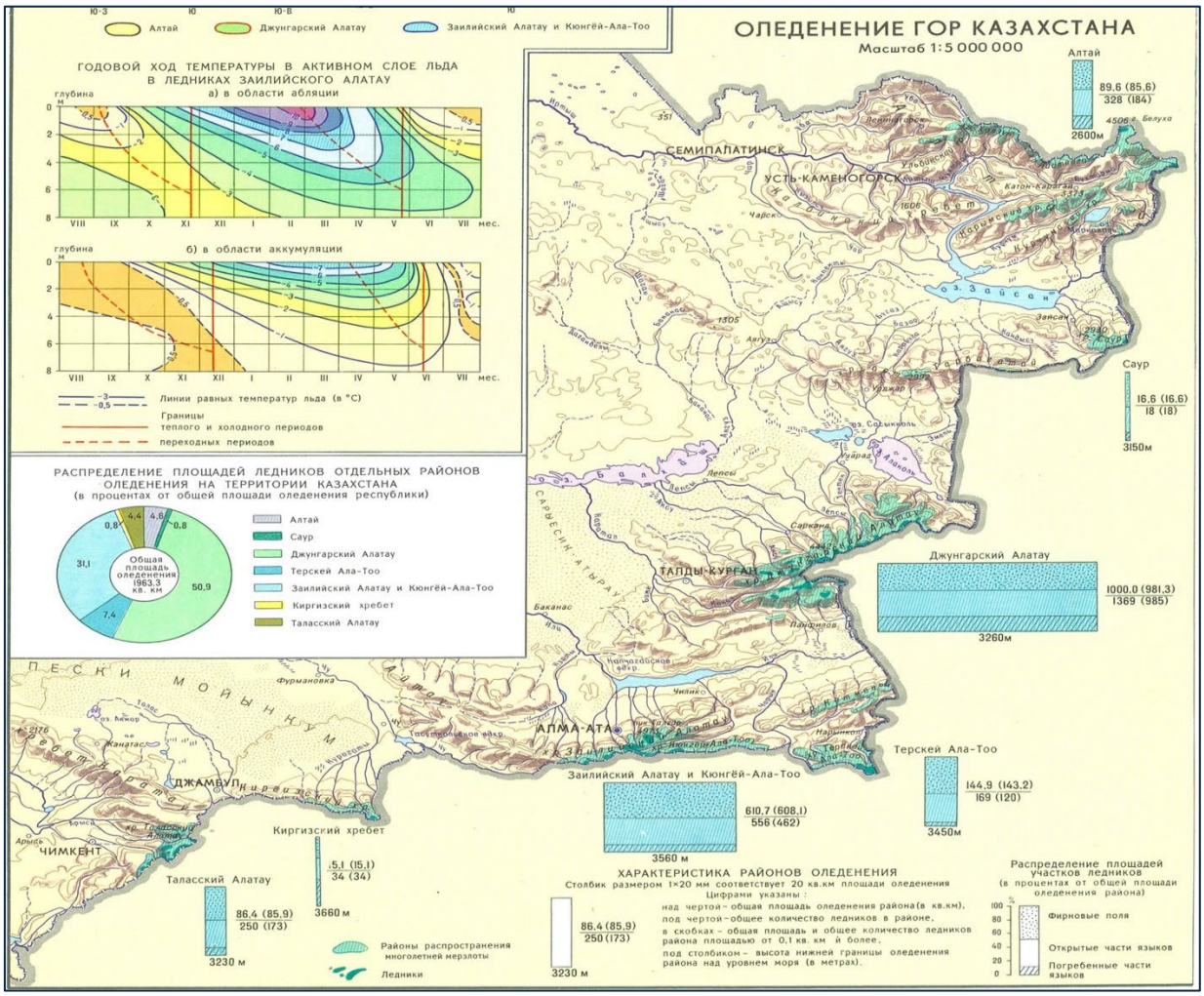
[2] https://izvestia.igras.ru/jour/article/viewFile/342/335; https://earthpapers.net/gornoe-oledenenie-severnoy-evrazii-v-golotsene

Kazakhstan

Kazakhstan's mountains, particularly the northern reaches of the Tien-Shan, Dzungar Alatau, are home to over 2,000 glaciers that cover an area of approximately 1,000 km^2.[3] These glaciers serve as natural water storage and release water during the dry summer months when demand for irrigation is highest. Glacial meltwater contributes significantly during the dry summer months to the flow of major rivers such as the Ili, Syr Darya, and Irtysh, which are lifelines for agriculture, industry, and domestic water supply.[4]

In addition to glaciers, the seasonal snow cover and permafrost are essential components of Kazakhstan's cryosphere. Snow cover acts as a temporary water storage, releasing water mainly during the spring melt season. Permafrost, found in the country's high-altitude regions, influences groundwater flow, soil stability, and carbon storage.

Figure 1: Glaciation of the Mountains of Kazakhstan



Source: Atlas of the Kazakh SSR (Volume 1: Natural Conditions and Resources), edited by G. Ts. Medoyev (1982)

[3] Diagnostic Analysis of the Current State of the Cryosphere and Water Supply in Central Asia, University of Fribourg (2023)

[4] Accelerated Glacier Area Loss in the Zhetysu (Dzhungar) Alatau Range (Tien Shan) for the Period of 1956–2016, Syrlybekkyzy et al. (2023), journal "Remote Sensing", https://www.mdpi.com/2072-4292/15/8/2133

However, climate change poses significant threats to Kazakhstan's cryosphere. Rising temperatures have led to accelerated glacier retreat, with some studies suggesting that the country's glaciers could lose up to 50% of their mass by 2050.[5] Changes in snow cover duration and permafrost degradation are also expected to alter hydrological regimes[6] and increase the risk of natural hazards such as landslides and glacial lake outburst floods (GLOFs).[7]

Given the importance of the cryosphere for Kazakhstan's water security, ecosystem integrity, and sustainable development, it is crucial to have a robust understanding of its status and the future, to strengthen its observation, monitoring, and to thoroughly analyse its impact to all aspects of country's development, specifically under the effect of the climate change.[8]

Above is also important due to the geographical development features of the country. It is given that the mountainous provinces e.g. Almaty, Jetysuu. Zhambyl, Turkistan and East Kazakhstan Oblasts with Almaty and Shymkent cities located in them accommodate 2/3 of the population and nearly half of country's economy, while being a home for all cryosphere components on the territory of the country and also being dependent of the cryosphere fed transboundary water resources, specifically for irrigated agriculture.

Rapid spring snowmelt in transboundary basins (e.g., Ural, Tobol) has intensified flooding risks in northern Kazakhstan. In 2024, ice-jam floods from Russian upstream areas submerged 12 settlements and 15,000+ hectares of farmland in Kostanay Oblast.[9] Projected winter precipitation increases (+20-35% by 2100)[10] may exacerbate snowpack accumulation and meltwater flooding. Glacier retreat has formed 43 new moraine-dammed lakes in Zhetysu Alatau since 2000. The Kishi Almaty basin shows highest GLOF susceptibility due to (i) Proglacial Lake volume increases ($\leq$0.05 km³/Yr); (ii) Ice-contact slope instability ($\geq$35° inclines) and (iii) Seismic activity (M$\geq$5.0 events every 8-10 years).[11] Degrading permafrost (active layer thickness +23% since 1970s) alters groundwater pathways, causing (i) Summer baseflow reduction: $\leq$15% in Ertis Basin[12]; (ii) Winter discharge increases: +44% in Ulken Almaty River (glacierized catchments) due to prolonged melt seasons.[13]

Kazakhstan's population and economy are significantly dependent on the cryosphere for several reasons. Up to 70% of all water resources in Kazakhstan are used for irrigation, with irrigated farming essential for food production. Glacial meltwater is essential for sustaining agricultural activities during dry summer months, where precipitation is often insufficient, with annual averages as low as 100-200 mm in desert regions and 200-500 mm in steppe areas.[14] Furthermore, snow and glacier melt contribute approximately 80% of the total river runoff in Central Asia[15], including major rivers such as the Syr Darya. This highlights that while the cryosphere is vital for

[5] https://climateknowledgeportal.worldbank.org/sites/default/files/2021-08/15834-WB_Kazakhstan%20Country%20Profile-WEB.pdf
[6] https://www.shareweb.ch/site/Climate-Change-and-Environment/Documents/NexusBrief-Cryosphere-ENG-Okt2019.pdf
[7] IPCC ALARM REPORT: Global Climate Trends and Forecasts for Kazakhstan, United Nations Development Programme (UNDP) in Kazakhstan, https://www.undp.org/kazakhstan/stories/ipcc-alarm-report-global-climate-trends-and-forecasts-kazakhstan
[8] Diagnostic Analysis of the Current State of the Cryosphere and Water Supply in Central Asia, University of Fribourg (2023)
[9] National Hydrometeorological Bulletin (2024)
[10] 8th National Communication (2022)
[11] Barandun et al. (2020)
[12] Hoelzle et al. (2019)
[13] https://www.shareweb.ch/site/Climate-Change-and-Environment/Documents/NexusBrief-Cryosphere-ENG-Okt2019.pdf
[14] https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15834-WB_Kazakhstan%20Country%20Profile-WEB.pdf
[15] https://unrcca.unmissions.org/sites/default/files/old_dnn/Glacier%20Melting%20Brochure_ENG.pdf

specific regions, its effects ripple through various ecological and hydrological systems across Kazakhstan.

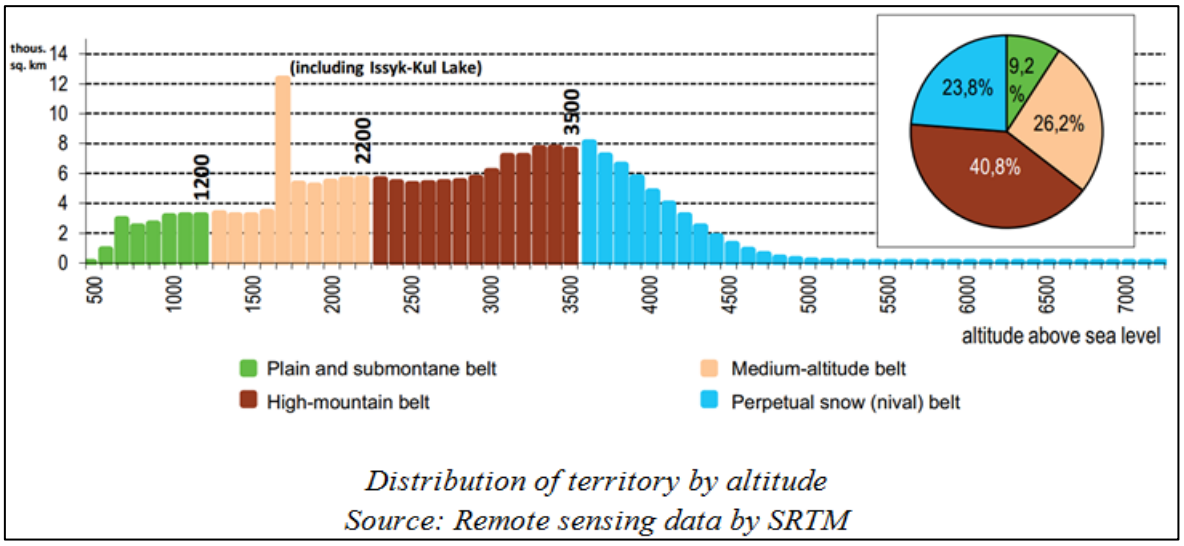
In addition to agriculture, the cryosphere significantly impacts energy production from hydropower. Rivers fed by glaciers account for about 30% of Kazakhstan's total hydropower generation[16], primarily through facilities along the Syr Darya and Irtysh basins. As climate change leads to fluctuations in water availability,[17] both agricultural productivity and energy generation are increasingly at risk. Therefore, understanding these interrelations is crucial for effective management strategies that address current conditions and anticipate future climate scenarios.

Kyrgyzstan

Kyrgyzstan is entirely located within the Tien-Shan and Pamir-Alay Mountain systems. It elevates from the lowest point (488 m above sea level) at the crossing of the Naryn River to Uzbekistan and to the highest one Victory Peak (7439 m A.S.L.) in the East of the country. The average altitude of the territory above sea level is 2630 m A.S.L. The diversity of landscapes and natural and climatic conditions of Kyrgyzstan can be combined into four natural and climatic zones: valley-foothill - up to 1200 m A.S.L., mid-mountain - from 1200 to 2200 m A.S.L., high-mountain - from 2200 to 3500 m A.S.L. and the nival zone - above 3500 m A.S.L.

The climate of Kyrgyzstan is sharply continental, mostly arid, somewhat smoothed out by the increase in cloudiness and precipitation due to the high-mountain relief. The climate features are determined by the location in the Northern Hemisphere in the center of the Eurasian continent, as well as the distance from larger water bodies and the close proximity of deserts. As can be seen from the lower figure, less than 30% of the republic's territory is in areas with comfortable living conditions: valley-foothill and mid-mountain belt.

Figure 2: Distribution of the area in Kyrgyzstan by the altitude and major landscapes



Source: *Third National Communication of the Kyrgyz Republic under the UN Framework Convention on Climate Change*

[16] https://www.osce.org/files/f/documents/8/8/513787_0.pdf
[17] Diagnostic Analysis of the Current State of the Cryosphere and Water Supply in Central Asia, University of Fribourg (2023)

The diverse physic-geographical features determine the uneven formation of snow cover and its uneven distribution by the altitude as well as different duration of the period of occurrence and its melt. From the formation of stable snow cover, its thickness is constantly growing and reaches its greatest layer on average in February. The melt of stable snow cover occurs in March-April, but in some places, it is delayed until May.

As of 2013-2016, there are 9959 glaciers with a total area of 6683.9 km² (3.345% of the total area of Kyrgyzstan).[18] Glacial-snow and snow-glacial fed rivers account for about 80% of the total number of them. Rivers with snow-rain feeding - 15% and purely snow-fed only 5%.[19]

Fragmented permafrost exists above 3,300 m A.S.L. Continuous permafrost begins above 3,600 m A.S.L. The total area of the continuous and discontinuous permafrost in Kyrgyzstan, according to preliminary estimates, reaches almost 67,000 km^2, i.e. occupies 33.4% of the total area of Kyrgyzstan.[20] The water contained in permafrost is an additional source of water and is constantly involved in the formation of the river flow, but it is very difficult to determine and assess them. Only seasonal, upper layers of soil thawing participate in the formation of river flow, and it is possible that their contribution is increasing due to global warming, due to the expansion of their zones and the deepening of the soil thawing layer.

The water resources of the Kyrgyz Republic are entirely formed on its own territory, with most of it being formed at and within the mountain environments. This suggests that the entire territory, population, and agriculture of the country are significantly dependent on the state of the cryosphere.

The share of tourism in GDP growths instantly in Kyrgyzstan, reaching 5% prior of COVID-19 pandemics (2018) and gradually recovering in a post-pandemic (3.6% in 2023)[21] with significant contribution of the mountain tourism e.g. tracking/ hiking and skiing, thus significantly contributed by the cryosphere.

Tajikistan

Tajikistan's area is 143,100 km²; it borders Kyrgyzstan in the North (630 km), China in the East (430 km), Afghanistan in the South (1,030 km), and Uzbekistan in the North and West (910 km). Three mountain systems: Tien-Shan, Gissar-Alai and Pamir make 93% of the country's territory. The altitude varies from 300 to 7,495 m A.S.L., with almost half of the country's territory located above 3,000 m A.S.L.[22] Country's highest mountain peak is a Ismoili Somoni Peak (7,495 m A.S.L.) in Pamir, while Tajikistan has 72 mountain peaks above 6,000 meters.[23]

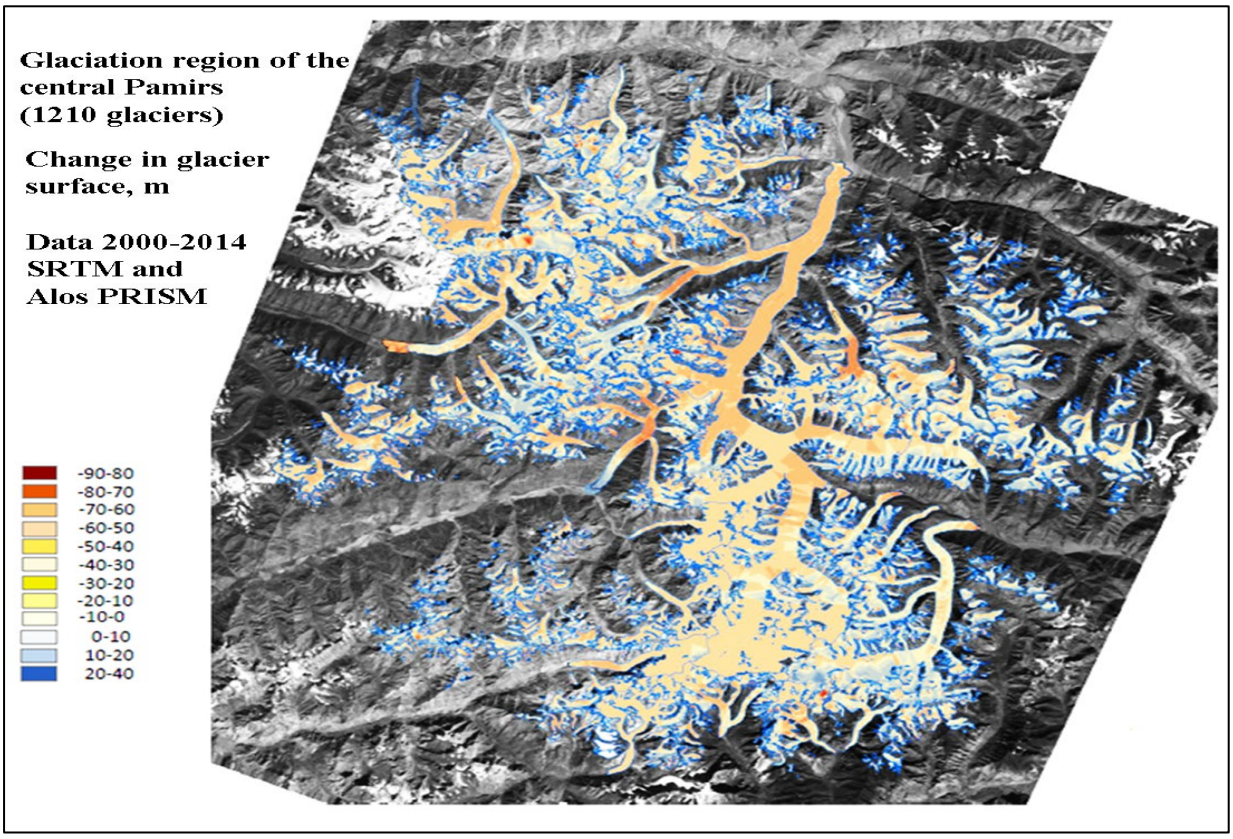
The west of the country is characterized by foothills and steppes (semi-arid grassy plains), while lowlands are found only in the river valleys of the southwest and in the far north, where Tajikistan owns a strip of land that includes part of the fertile Fergana Valley.

[18] http://www.caiag.kg/phocadownload/projects/Catalogue%20%20%20of%20glaciers%20Kyrgyzstan%202018.pdf
[19] Schultz, 1965
[20] Gorbunov, 1966
[21] https://stat.gov.kg/en/opendata/category/130/
[22] http://tajmigration.ru/respublika-tadzhikistan.html
[23] https://www.mewr.tj/?faq=%D0%BB%D0%B5%D0%B4%D0%BD%D0%B8%D0%BA%D0%B8

The climate in the country is continental, however, the large amplitude of altitudes in combination with a very complex relief determines the formation of unique regional and local climatic zones with large temperature differences, characterized by significant daily and seasonal fluctuations in weather conditions. Average annual precipitation changes sharply - from 500-600 mm in the Vakhsh River valley to less than 100 mm in the south of Eastern Pamirs, meanwhile a maximum of more than 2000 mm on the Fedchenko Glacier.[24]

High mountains are permanently covered with snow and ice, and glaciers occupy about 6% of the total area of the country The volume of glaciers is 845 km³, and the area is 11,146 km².[25] Melting snow and glaciers feed the rivers of the Aral Sea basin with fresh water in the amount of 6-13 km³ per year, which is about 10-20% of the total river flow.[26] In addition, Tajikistan is a home of high-mountain lakes with a total area of more than 705 km²,[27] most of which are located in the eastern part of the Pamirs, some of those are result of earthquakes an rockfalls of the past.

Figure 3: The morphology of the glacial surface of the Fedchenko Glacier in Pamir



Source: http://maps.theia-land.fr/couches-cartographiques-theia.html

Cryosphere on the territory of Tajikistan plays a crucial role in supporting vital development pillars such as water supply, agriculture, power generation not only within the country, but also beyond to downstream countries. Glaciers and snow cover provide a constant flow of water that feeds ecosystems.

[24] https://www.mewr.tj/?page_id=390
[25] https://www.mewr.tj/?faq=%D0%BB%D0%B5%D0%B4%D0%BD%D0%B8%D0%BA%D0%B8
[26] https://www.mewr.tj/?page_id=390
[27] https://www.mewr.tj/?page_id=390

However, climate change is causing a shrinkage of glaciers, which threatens these important economic sectors. This can lead to water shortages, reduced crop yields, reduced power generation and weakened tourist attractiveness. As a result, the shrinkage of the cryosphere poses serious risks to economic growth, the sustainability of natural systems and the socio-economic development of the country, requiring measures to adapt to new climatic conditions.

Since the mid-sixties of 20th century, in a number of river basins - Obihingou, Surkhob, Muksu (Vakhsh), Zeravshan, Karatag, Western Pamir, Vanj (Panj), Eastern Pamir and Varzob - after thorough the studies thirty reference glaciers of various morphological types were selected for a regular monitoring and research. Regular expeditionary observations of their condition and behavior began on these glaciers. Today, these glaciers are either active, stationary, or at the degradation stage.[28]

There is no regular monitoring of the permafrost. With global warming, permafrost may begin to melt, which contributes to changes in soil composition and hydrological conditions, which affects the ecosystem of the high mountain regions of Tajikistan.

Turkmenistan

Turkmenistan is a country with an arid climate and most of the country is occupied by the Karakum Desert. There are no high mountains or glaciers on the territory of Turkmenistan. The highest peak of the region is Mount Ayribaba, which reaches a height of 3,137 m A.S.L. The main water resources of Turkmenistan are formed outside and have a transboundary nature and originate in the mountains and glaciers of Afghanistan and Tajikistan.

The mountains of Turkmenistan, which stretch along the South-Western border of the country with Iran (Kopetdag) and in the Eastern territory serve as a natural border with Uzbekistan (Pamir-Alay or Koytendag), is a source of vital resources such as fresh water.

In the context of intensive development of the national economy, Turkmenistan attaches great importance to cooperation with the countries of the world in the field of high technology, the introduction of modern advanced knowledge and management solutions. The country's water resources are mainly used for irrigation of agricultural lands. Water resources are one of the important natural resources and a key factor in the economic development and well-being of the population of Turkmenistan

The cryosphere of Turkmenistan is characterized by a limited presence of snow and seasonal ice which contribute to the climate and water resources. The main water sources are associated with transboundary glaciers. Water resources of Turkmenistan are formed outside the country, fed by mainly cryosphere of Afghanistan and Tajikistan. Mountain systems play an important role in preserving fresh water reserves. The snow cover also plays an important role in maintaining the ecological balance, water resources and economic development of Turkmenistan.

[28] https://meteo.tj/ru/-10

The Amu Darya River begins in Tajikistan, in the Pamir Mountains, and flows through Uzbekistan before reaching Turkmenistan. The Amu Darya is the country's main river, providing fresh water for both domestic use and for irrigating agricultural land. The Amu Darya formed by the merge of the such main tributaries as the Vakhsh and the Panj. These rivers are important sources of water supply for Turkmenistan. Water from these rivers is used for irrigation and water supply to the population.

The foothills of the Kopetdag Mountains contain many sources of groundwater, which are key to providing water supplies, especially in drier areas. In the spring, when the snow melts, underground springs are replenished, the water reservoirs are temporarily filled in some places.[29]

The Murghab River originates in the mountains of eastern Turkmenistan. The river is also used for irrigating agricultural land, especially around the city of Mary. The Tejen River originates in the Kopetdag Mountains and runs through Turkmenistan. This river is used for irrigation and as a source of drinking water for the population.

Mountain water sources in Turkmenistan, including rivers and groundwater, are vital for the agriculture and the provision of water to the population. In the context of climate change and increasing demand for water resources, effective management of these sources is becoming especially important.

Gaining experience and knowledge about the state of the cryosphere and the impact of climate change necessitates international cooperation to exchange hydrometeorological information and forecast floods and mudflows typical for Turkmenistan.

Uzbekistan

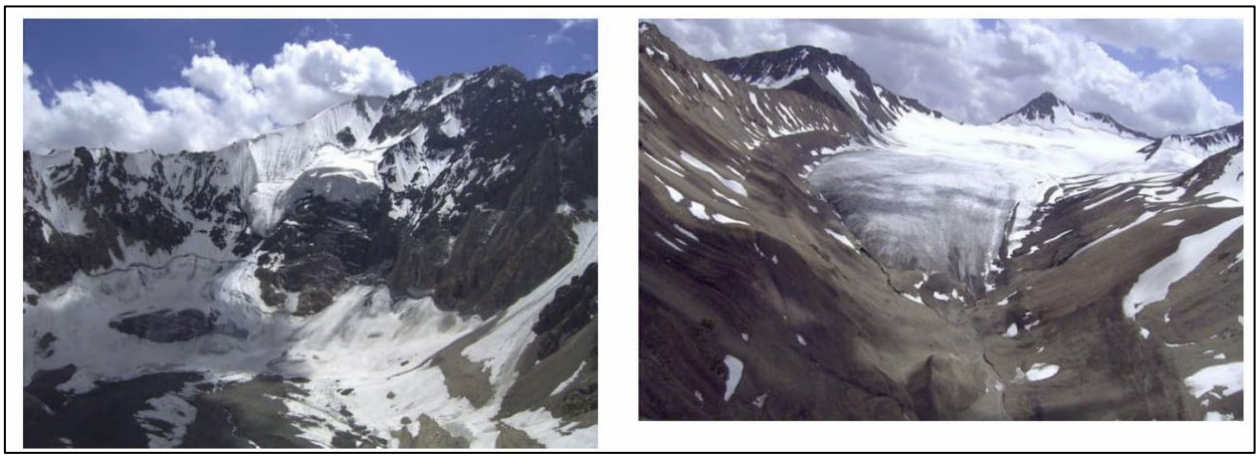
Uzbekistan shares a total of 6,221 km of mainly land state borders, with the following neighbour countries: 2,203 km with Kazakhstan, 1,651 km with Turkmenistan, 1,161 km with Tajikistan, 1,069 km with Kyrgyzstan, and 137 km with Afghanistan. The country's landmass extends 1,430 km from West to East and 930 km from North to South. Its highest point is at 4,643 m A.S.L. on the Hisar Ridge, and the lowest at -12 min the Kyzylkum Desert.

The cryosphere in Uzbekistan is concentrated in the Tien Shan and Gissar-Alai mountains, playing a role in water supply for the Syr Darya and Amu Darya rivers. Glaciers, snow make up a significant portion of river runoff needed for irrigation and hydropower. Climate change is accelerating glacier melting, which may reduce water availability during the growing season and exacerbate competition for water resources.

In Uzbekistan, snow cover forms on the plains by late November and in the south by late December. A stable snow cover lasting at least a month is consistently observed only on the Ustyurt Plateau and in mountainous areas. In northern Uzbekistan, snow cover lasts over 60 days, while in the mountains, it exceeds 100 days. Snow depth varies annually, averaging 1–8 cm on the plains (maximum 30 cm), 10–20 cm in the foothills (maximum 60 cm), and over 60 cm in the mountains, where it can reach 1.5–2.0 meters.[30]

[30] Чуб В. Е. Изменение климата и его влияние на гидрометеорологические процессы, агроклиматические и водные ресурсы Республики Узбекистан //Узгидромет, НИГМИ, «Voris-Nashriyot» Ташкент. – 2007. – Т. 132.

Figure 4. Glaciers in Pskem river basin: Barkrak (lest), Pakhtakor (right)[31]



Source: Karandaeva L.M., Karandaev S.V., Kudyshkin T.V., Petrov M.A., Tarasov Yu.A. Glaciological studies in the Pskem River basin // Hydrometeorology and environmental monitoring. - 2021. - No. 4. - P. 89-102. - Tashkent.

The main glaciers on the territory of Uzbekistan are in the Pskem Valley of the Chirchik River Basin in the Tien-Shan and in the East of Gissar-Alay, covering the basins of the Kashkadarya and Surkhandarya rivers. The total area of glaciers in these areas is about 188 km², around 700 glaciers (including Shakhimardan basin glaciers).[32] Over the past 50 years, glaciers in the Gissar-Alai and Pskem river basins have decreased by 16% and 27%.[33] Rapid shrinkage of glaciers due to climate change reduces the share of glacial runoff, which may lead to water shortages in the future.

The permafrost is extremely rare in Uzbekistan and occupies insignificant areas. Permafrost research is not carried out in the country due to its limited impact.

Glaciers, snow cover and permafrost in the Tien Shan and Pamir provide up to 25% of river runoff in dry years, which is critical for agriculture and hydropower in Uzbekistan. Forecasts indicate the possible disappearance of glacial runoff, which will reduce summer river runoff by 10-25%.[34] With the population and economic growth, access to cryosphere meltwater remains key for irrigation, hydropower and drinking water supply.

[31]Карандаева Л.М., Карандаев С.В., Кудышкин Т.В., Петров М.А., Тарасов Ю.А. Гляциологические исследования в бассейне реки Пскем // Гидрометеорология и мониторинг окружающей среды. – 2021. – № 4. – С. 89–102. – Ташкент.

[32] Кудышкин Т. В., Тарасов Ю. А., Яковлев А. В. Изменение оледенения речных бассейнов с преобладанием малых ледников во второй половине XX-начале XXI века //Вопросы географии. – 2014. – Т. 2014. – С. 45.

[33] Кудышкин Т. В., Тарасов Ю. А., Яковлев А. В. Изменение оледенения речных бассейнов с преобладанием малых ледников во второй половине XX-начале XXI века //Вопросы географии. – 2014. – Т. 2014. – С. 45.

[34] United Nations Development Programme. (2022). Climate Change and Water Resources in Uzbekistan.

Institutional and Legal Landscape Relevant to the Main Issues of the Cryosphere

This Chapter was developed to brief the legal provisions, national policies and institutional settings relevant to the identified three major issues of the cryosphere in Central Asia.

- ❖ Insufficient quality, limited accessibility, or absence of the data on cryosphere
- ❖ Lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change
- ❖ Deficiency of qualified specialists on cryosphere research, monitoring and management

Kazakhstan

National Legislation, Policies and Development Programs

The foundation of Kazakhstan's environmental legislation is the Environmental Code.[35] Key provisions of the 2021 Environmental Code relevant to the cryosphere include provisions, which:

- Establishes the basic principles of environmental legislation, including sustainable development, ecosystem preservation, and climate change mitigation and adaptation;
- Outlines measures for climate change adaptation, including the requirement to develop and implement a National Adaptation Plan;
- Mandates the inclusion of climate change impacts in environmental impact assessments for projects and activities;
- Requires the state to monitor climate change and its impacts on ecosystems, including glaciers and permafrost.

The Code also introduces the concept of ecosystem services and recognizes the importance of preserving natural ecosystems for climate regulation and water provision. This is particularly relevant for mountain and cryosphere ecosystems.

In addition to the Environmental Code, the Law "On Specially Protected Natural Territories" (2006, last amended in 2021)[36] provides a framework for protecting areas of high ecological value, including glaciers and their surrounding ecosystems. This law enables the designation of protected areas such as national parks and nature reserves in mountainous regions, which helps preserve cryosphere resources.

The primary legislation is The Water Code which contains several provisions related to the management of water resources generated by glacier melt. Furthermore, the new version of the Water Code includes a separate article on the specifics of glacier and snowfield protection (Article 84), further confirming the importance of this issue for Kazakhstan. The Code:

[35] https://adilet.zan.kz/eng/docs/K2100000400
[36] https://adilet.zan.kz/eng/docs/Z060000175_

- Establishes the principles of water legislation, including the basin approach to water management and the need for sustainable and rational use of water resources.
- Outlines the requirements for state planning in water use and protection, which should consider the impacts of climate change on water resources.
- Mandates the development of schemes for the integrated use and protection of water resources for each river basin, which should account for all water sources, including glacial meltwater.
- Establishes limits on water use, which are particularly important for managing water resources in regions dependent on glacial melt.

The primary legislation governing disaster risk reduction in Kazakhstan is the Law "On Civil Protection" (2014, last amended in 2021).[37] This law establishes the framework for preventing and responding to natural and man-made disasters, including those related to the cryosphere such as glacial lake outburst floods (GLOFs) and avalanches. The law regulates activities aimed at protecting the population, environment, and infrastructure from natural and man-made emergencies. The law requires individuals and legal entities to comply with civil protection requirements, develop and implement measures to ensure industrial and fire safety, and immediately inform authorities about any emergencies.

It also establishes the power and responsibilities of state bodies in civil protection, including the Ministry for Emergency Situations.[38] Key provisions relevant to cryosphere-related hazards:

- Outline the main tasks of civil protection, including forecasting and prevention of emergency situations.
- Establish the requirements for emergency prevention, including the development of disaster risk reduction plans and early warning systems.
- Mandate the monitoring and forecasting of hazardous natural phenomena, which would include cryosphere-related hazards.

The national legislation on water management and disaster risk reduction (DRR) is supplemented by various regulations and programs.

The State Program for Water Resources Management of Kazakhstan for 2020-2030,[39] approved by Government Decree No. 235 dated May 27, 2020. This program recognizes the impacts of climate change on water resources and includes measures to improve water use efficiency and adapt to changing hydrological conditions.

Specific tasks for disaster risk reduction are reflected at the central level in the National Security Strategy of the Republic of Kazakhstan,[40] which includes general directions for the development of nationwide measures aimed at prevention and elimination of natural and man-made disasters and their aftermaths, emergency medical and psychological aid to populations in disaster zones.

At the oblast level, disaster risk reduction activities, along with economic and social development activities, are stipulated in the Comprehensive Development Plans for territories to 2025.[41] These

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[37] https://adilet.zan.kz/eng/docs/Z1400000188#:~:text=This%20Law%20regulates%20public%20relations,to%20population%20being%20in%20the

[38] https://www.gov.kz/memleket/entities/emer?lang=en

[39] https://adilet.zan.kz/rus/docs/P2400000066.

[40] https://adilet.zan.kz/eng/docs/Z1200000527

[41] https://online.zakon.kz/Document/?doc_id=36771000&pos=2;-52#pos=2;-52

plans include issues of infrastructure development, improvement of the environmental situation, development of the agro-industrial complex, etc.

According to the Plan of Action for Liquidation of Global and Regional Emergencies in Kazakhstan,[42] the Ministry of Ecology and Natural Resources, through the Kazhydromet is responsible for constantly submitting data on environmental pollution levels, rising water levels, hazardous phenomena and natural hydrometeorological events to the governing bodies of the state civil defence system during emergencies.

At the national level, Roadmaps outlines specific preventive measures and activities to reduce the risks of floods, mudflows, landslides, and avalanches in the country, such as:

- Roadmap of flood control measures for 2021-2023[43]. Some measures aimed at minimizing flood risks now included in the regional development plans for 2025-2029.
- Roadmap for ensuring mudflow, landslide and avalanche safety.[44] This Roadmap addresses the risks of landslides, mudflows, and avalanches, which are relevant hazardous phenomena in the mountainous regions of Kazakhstan, such as the Tien Shan.

In conclusion, Kazakhstan has developed a comprehensive legislative framework addressing environmental protection, water resources management, and disaster risk reduction. While specific legislation focused on the cryosphere is lacking, existing laws and regulations provide a foundation for addressing cryosphere-related issues. The country's participation in international agreements and regional cooperation initiatives further strengthens its capacity to address the challenges posed by climate change and cryosphere degradation.

Kazakhstan is a party to several international agreements and frameworks relevant to the cryosphere and climate change adaptation. The country has made significant strides in aligning its national development strategies with the UN 2030 Agenda for Sustainable Development and its seventeen SDGs. The institutional structure to coordinate and implement the UN SDGs includes:

- A Coordination Council on SDGs chaired by the Deputy Prime Minister, overseeing the overall implementation 15. Five inter-sectoral working groups aligned with the 5 Ps of the SDGs (People, Planet, Prosperity, Peace, and Partnership), each chaired by relevant ministers.
- The Ministry of National Economy plays a central role in coordinating SDG efforts across government agencies.
- An interdepartmental working group on SDG monitoring indicators is developing a system of global and national indicators, considering Kazakhstan's priorities. The Bureau of National Statistics is responsible for monitoring and reporting on SDG indicators.
- A Parliamentary Commission was created to oversee and coordinate sustainability efforts within legislative processes, including budget alignment with the SDGs 16.

The country has integrated 87 crucial SDG indicators into its state planning system, including National Projects and Regional Development Programmes, setting target values for these indicators by 2025. However, despite this progress, Kazakhstan faces challenges in fully realizing its commitments to the SDGs, particularly in the areas of clean water and sanitation (SDG 6), sustainable cities and communities (SDG 11), climate action (SDG 13), and life on land (SDG 15).

[42] https://adilet.zan.kz/rus/docs/P1700000486#z2
[43] https://www.gov.kz/uploads/2021/1/18/7379c43bf2b059aa12e73ba47144f13d_original.64164.xlsx
[44] https://online.zakon.kz/Document/?doc_id=38563062&pos=33;-55#pos=33;-55

Government Agencies

Several government agencies play crucial roles in cryosphere observation, monitoring, and research. These agencies are responsible for implementing national policies, coordinating research efforts, and managing data related to the cryosphere.

Table 1: The list of major Government bodies with relevant mandate and functions to major issues of the cryosphere

Government bodies	Mandate and key functions relevant to cryosphere
The Ministry of Ecology and Natural Resources (MENR)	Is the primary government body responsible for environmental protection, natural resource management, and climate change policy in Kazakhstan.[45] *Relevant functions:* • Developing and implementing national policies on climate change adaptation and mitigation: • Coordinating research activities related to glaciers, permafrost, and snow cover: • Overseeing the implementation of international agreements on climate change and environmental protection
The National Hydrometeorological Service (Kazhydromet)	Kazhydromet[46] is a subsidiary entity to the MENR. It is responsible for monitoring and studying the cryosphere as part of its mandate. It maintains a network of over 300 meteorological stations and 300 hydrological posts at rivers and lakes across the country. Kazhydromet's Department of Environmental Monitoring collects, processes, and analyses data on the state of snow cover and glaciers, providing important information for assessing climate change impacts and water resource management. It also produces periodic data publications on snow cover.[47]
The Ministry of Emergency Situations (MES)	Is the central executive body of the Republic of Kazakhstan, exercising leadership in the areas of prevention and elimination of emergency situations of natural and man-made nature, civil defense, fire and industrial safety, the formation and development of the state material reserve, ensuring the functioning and further development of the state civil defense system, organizing the prevention and extinguishing of fires.[48] *Relevant functions:* • Developing and implementing disaster risk reduction strategies, including under the Sendai Framework for Disaster Risk Reduction: • Coordinating emergency response efforts for cryosphere-related hazards: • Collaborating with research institutions to improve early warning systems for GLOFs and avalanches.
Ministry of Education and Science	The ministry has been instrumental in supporting key research institutions, such as the Institute of Geography and Water Security, which conducts extensive research on glaciers and permafrost in Kazakhstan. *Relevant functions:* • Allocating research funding for cryosphere-related projects; • Supporting the development of academic programs in glaciology, hydrology, and related fields; • Facilitating international scientific cooperation in cryosphere research.
National Space Agency (Kazcosmos)	The National Space Agency of Kazakhstan, also known as Kazcosmos, contributes to cryosphere observation through its Earth observation satellites and remote sensing capabilities. Kazcosmos has been involved in projects using

[45] https://www.gov.kz/memleket/entities/ecogeo?lang=en
[46] https://www.kazhydromet.kz/en
[47] https://www.kazhydromet.kz/ru/ecology/ob-ekologicheskom-monitoringe
[48] https://www.gov.kz/memleket/entities/emer/about?lang=ru

	satellite data to monitor glacier changes and assess water resources in the region.[49] *Relevant functions:* • Providing satellite imagery for glacier and snow cover mapping; • Supporting the development of remote sensing technologies for cryosphere monitoring; • Collaborating with international space agencies on Earth observation projects.
Oblast and Local Authorities	Oblast and local authorities in Kazakhstan's mountainous regions play important roles in implementing cryosphere-related policies and managing local water resources. The involvement of local authorities is crucial for effective implementation of national policies and for addressing the specific challenges faced by communities in cryosphere-affected areas[50]. *Relevant functions:* • Implementing local adaptation measures to address cryosphere changes; • Managing water resources at the local level, including those derived from glacier melt; • Collaborating with national agencies and research institutions on cryosphere monitoring and research projects.

Research Institutions

Research institutions play a pivotal role in advancing our understanding of the cryosphere and its response to climate change. Kazakhstan, with its extensive glacial resources and vulnerability to climate change impacts, has several research institutions actively involved in cryosphere studies:

The Central Asian Regional Glaciological Centre (CARGC), established under the auspices of UNESCO is a key research institution focused on cryosphere studies in Central Asia[51]. Based in Almaty, Kazakhstan, CARGC conducts research on glaciers, snow cover, and permafrost in the region. Their staff includes experts in glaciology, hydrology, and climate change, contributing to monitoring and understanding cryosphere dynamics in Central Asian Mountain systems. The Centre aims to promote scientific cooperation, data sharing, and capacity building among Central Asian countries in the field of glaciology and related areas.

Institute of Geography and Water Security[52] under the Ministry of Education and Science, is the primary institution conducting cryosphere research in Kazakhstan. It operates one scientific mountain station - BAO in the Ile Alatau range near Almaty, conducting year-round observations on snow cover. The institute has participated in over 20 international projects and collaborates with scientists from Germany, France, Finland, Sweden, Japan, China, Russia, and Uzbekistan.

In addition to above the Al-Farabi Kazakh National University's involvement in cryosphere studies is limited and fragmented. While Department of Meteorology and Hydrology nominally conducts research on climate change impacts on the cryosphere and water resources in Kazakhstan[53], it's important to note that the university does not conduct regular observations or

[49] Yao, T., Thompson, L. G., Mosbrugger, V., Zhang, F., Ma, Y., Luo, T., ... & Fayziev, R. (2019). Third Pole Environment (TPE). Environmental Development, 32

[50] Shahgedanova, M., Afzal, M., Severskiy, I., Usmanova, Z., Saidaliyeva, Z., Kapitsa, V., ... & Petrakov, D. (2018). Changes in the mountain river discharge in the northern Tien Shan since the mid-20th Century: Results from the analysis of a homogeneous daily streamflow data set from seven catchments. Journal of Hydrology, 564

[51] https://cargc.org/en/staff/

[52] https://ingeo.kz/?lang=en

[53] https://farabi.university/department/52?lang=en

send students for practical training on glaciers or at field stations. Student participation is sporadic, with only select staff and students involved in writing articles.

The Faculty of Geography and Nature Management hosts the UNESCO Chair for Sustainable Development, which focuses on preparing specialists in sustainable innovative energy and ecological development. The university also leads the Eurasian platform "The Green Bridge Through Generations", which aims to involve young people in promoting sustainable development initiatives, including those related to the cryosphere. While some researchers at the university have been involved in projects assessing glacier retreat, snow cover variability, and hydrological changes in the Tien Shan mountains, these efforts appear to be individual initiatives rather than part of a structured, ongoing program.

International research institutions collaborate with Central Asian counterparts on cryosphere studies, contributing expertise in areas like glacier monitoring systems and climate adaptation strategies. Key initiatives include expanding cryosphere observation networks, developing region-specific climate services, and implementing remote sensing technologies such as glacier webcams for real-time monitoring and public awareness.

Academic institution and capacity building

Several universities in Kazakhstan are nominally associated with cryosphere studies, but their involvement is limited. Key institutions include:

- Al-Farabi Kazakh National University[54]
- Satbayev University[55]
- Saken Seifullin Kazakh Agrotechnical Research University (KazATIU)[56]
- Kazakh National Agrarian University[57]
- Eurasian National University.[58]

However, it's important to note that these universities do not have dedicated programs for cryosphere studies. Instead, cryosphere-related topics are typically integrated into general courses such as Climatology, Meteorology, Hydrology, and Hydrogeology. At Satbayev University (formerly Kazakh Polytechnic Institute), there may be a section on "Frozen Soils" within the Soil Science course.

The educational approach to to the cryosphere at these universities is characterized by:

- Core Disciplines: While programs cover some essential subjects related to glaciology, hydrology, meteorology, and environmental science, there is a notable absence of specialized courses like sedimentology and climate modelling, which are crucial for a comprehensive understanding of cryosphere systems.
- Lack of Practical Experience: Students rarely participate in field practices on glaciers or in high mountain environments. Most of the work related to cryosphere studies is limited to individual student projects rather than structured programs.

[54] https://www.kaznu.kz/en/
[55] https://official.satbayev.university/en
[56] https://kazatu.edu.kz/en
[57] https://www.kaznaru.edu.kz/
[58] https://www.enu.kz/en/%5B4

- Teaching Methodologies: The teaching primarily relies on theoretical lectures, with limited practical laboratory work. While Field trips and internships are mentioned as integral parts of the curriculum, their implementation in cryosphere-related studies appears to be minimal.
- Use of Technology: Some institutions incorporate modern software tools for data analysis and modelling (e.g., GIS applications), although there is a significant gap in the use of advanced programming languages and simulation software essential for contemporary cryosphere research.

Challenges identified:

- Curriculum Gaps: There is a mismatch between educational offerings and industry needs. Many graduates report feeling unprepared for the job market due to insufficient practical training and lack of exposure to modern tools used in cryosphere research.
- Limited Research Opportunities: Funding for research projects focused on cryosphere studies is often limited, constraining universities' ability to engage in cutting-edge research or collaborate effectively with international institutions.
- Professional Development Needs: Graduates frequently express a need for additional training in specialized areas such as remote sensing and data analysis techniques relevant to cryosphere studies.

Capacity Building

Despite the presence of dedicated research institutions and universities, the capacity and resources for cryosphere research and monitoring in Kazakhstan are limited. Many research projects rely on international collaborations and funding[59]. There is a need to strengthen the technical and human resources of national institutions to ensure long-term and sustainable cryosphere monitoring and research.

Capacity building initiatives, such as training workshops and exchange programs, have been organized by international organizations like UNESCO and the World Meteorological Organization (WMO) to enhance the skills and knowledge of local researchers and specialists. However, more efforts are needed to build a strong and self-sufficient scientific community in Kazakhstan capable of addressing the challenges posed by climate change to the cryosphere and water resources.

The CARGC aims to develop human and institutional capacity for assessing climate change impacts on snow and glaciers using modern methodologies, including satellite imagery and GIS technologies.

Kazhydromet conducts regular research and offers training programs aimed at understanding changes in the cryosphere and their impact on water resources. However, these training initiatives are primarily funded through international projects, limiting their sustainability and reach.

These institutions collaborate closely with international partners and participate in regional initiatives contributing to a better understanding of the cryosphere in Kazakhstan and informs policy decisions on climate change adaptation and sustainable water management.

[59] Hoelzle, M., Barandun, M., Bolch, T., Fiddes, J., Gafurov, A., Muccione, V., ... & Yakovlev, A. (2017). Re-establishing glacier monitoring in Kyrgyzstan and Uzbekistan, Central Asia. Geosciences

While there are ongoing efforts to build professional capacity related to the cryosphere in Kazakhstan through various initiatives led by organizations like UNESCO and UNDP and others, significant challenges remain that need to be addressed:

- Limited Resources: Funding constraints often limit the scope of training programs. The CARGC and other institutions struggle with inadequate budgets that affect their ability to provide comprehensive training or invest in modern equipment necessary for effective cryosphere monitoring.
- Inconsistent Training Quality: The quality of training programs can vary significantly across different regions and institutions. While some workshops are well-organized and informative, others may lack depth or fail to engage participants effectively.
- Fragmented Data Systems: There is a lack of standardized data collection methods across various organizations involved in cryosphere studies. This fragmentation complicates efforts to share information effectively among stakeholders, limiting education opportunities.

Kyrgyzstan

National Legislation, Policies and Development Programs

The main law in the field of ecology is the Law "On Environmental Protection", adopted in 1999, with the latest amendments in June 2024.[60]

The Law defines the objects of protection: "The land and its subsoil, soil cover, water, forests, flora, fauna and their genetic fund, atmospheric air, other natural objects, complexes and ecological systems, as well as the climate and ozone layer of the Earth and the Earth as a whole as a planet are subject to protection from pollution, damage, depletion, destruction, annihilation and other negative impacts". The components of the cryosphere are not separately identified in the Law.

The Law establishes measures to ensure environmental protection, including standardization of environmental quality (maximum permissible concentrations of harmful substances in the atmospheric air, water, soil, subsoil and other natural objects).

It defines the principles of conducting environmental expertise when planning economic activities. Relations related to environmental assessment are regulated by the Law "On Environmental Assessment".[61] It also defines measures to protect the climate and the ozone layer of the atmosphere.

It also provides that in order to ensure observation, accounting, assessment, forecast, control and management of the state and change in the environment and its resources on the territory of Kyrgyzstan, a system of state environmental monitoring is created.

The Law "On Specially Protected Natural Areas"[62] was adopted in 2011 with the latest amendments in June 2024. In accordance with the Law, specially protected natural areas include protection of a natural and / or artificially created natural complexes and natural objects, including glaciers and snowfields, which are given the status of specially protected natural areas by decision of the Cabinet of Ministers.

[60] https://cbd.minjust.gov.kg/218/edition/11538/ru?anchor=r5
[61] https://cbd.minjust.gov.kg/219/edition/638848/ru
[62] https://cbd.minjust.gov.kg/203262/edition/1205628/ru

The Water Code [63] was adopted in 2005 with the latest amendments in December 2021. The Code regulates water relations in the sphere of use, protection and development of water resources for guaranteed, sufficient and safe water supply to the population, environmental protection and ensuring rational development of the water fund of the republic.

The Code defines the basin approach to water resources management. In each main basin, a corresponding basin water administration and basin council are created, which are responsible for certain aspects of water resources management in accordance with the provisions of this Code.

It also provides the requirements for the protection of glaciers and prohibits activities that affect the acceleration of glacier melting, using coal, ash, oils or other substances or materials, as well as activities that may affect the condition of glaciers or the quality of the waters contained in them. A conclusion on the possibility of implementing such activities is made by the authorized state body, taking into account the results of an independent examination.

Kyrgyzstan, recognizing the problem of climate change, commits to the provisions of the UNFCCC,[64] the Paris Agreement,[65] other environmental Conventions, as well as the SDGs.[66] Thus, Kyrgyzstan aligned its national legislation and policy documents on sustainable development and climate change.

The first patterns of climate change by 2000 were assessed in the First National Communication on Climate Change of Kyrgyzstan[67] was submitted in 2003. In 2008 the Second National Communication[68] was prepared. The Third National Communication of Kyrgyzstan[69] was published in 2015 and now the country is at the stage of preparing the Fourth National Communication on Climate Change of Kyrgyzstan.

Currently, number of important processes to reduce risks and adapt to climate change have been launched. Within the framework of the Paris Agreement, the country has developed NDC[70] and is completing the development of the National Adaptation Plan (NAP) and its corresponding programs.

The above opens a wide range of opportunities to program and address identified issues of the cryosphere, including improvement of monitoring and data production, knowledge on the cryosphere. To take into account human potential issues and a comprehensive approach to building a sustainable system of training and retraining necessary for the transformation of personnel, as well as expanding the coverage of the population and involving various interested organizations and groups in this work.

At the global level, Kyrgyzstan is actively integrating into the political and financial system being built to combat climate change. In 2023, the Ministry of Natural Resources, Ecology and Technical

[63] https://cbd.minjust.gov.kg/1605/edition/1201418/ru
[64] https://cbd.minjust.gov.kg/17016/edition/297110/ru
[65] https://cbd.minjust.gov.kg/111972/edition/979958/ru
[66] https://www.gov.kg/ru/p/sustainable_development
[67] https://unfccc.int/sites/default/files/resource/english_1p.pdf
[68] https://unfccc.int/resource/docs/natc/kyrnc2e.pdf
[69] https://unfccc.int/sites/default/files/resource/NC3_Kyrgyzstan_English_24Jan2017.pdf
[70] https://unfccc.int/sites/default/files/NDC/2022-06/%D0%9E%D0%9D%D0%A3%D0%92%20ENG%20%D0%BE%D1%82%2008102021.pdf

Supervision[71] presented the Action Plan for (NDC in the Water Resources Sector.[72] The Action Plan sets solutions in the following areas:

- Conducting scientific research on the impact of climate change on water resources;
- Forming a water sector development policy;
- Increasing the climate resilience of the irrigation network infrastructure and drinking water supply and sanitation;
- Stimulating increased efficiency in the use of water resources.

Government Agencies

The are several Government Agencies and Services have the mandate and functions relevant to the identified issues of the cryosphere in Kyrgyzstan:

Table 2: The list of major government bodies with relevant mandate and functions to major issues of the cryosphere

Government bodies	**Mandate and key functions relevant to cryosphere**
The Ministry of the Natural Resources Ecology and Technical Supervision	The Ministry[73] is an authorized state executive body that develops and implements state policy and coordinates in the areas of environmental protection, ecology and climate, geology and subsoil use, use and protection of natural resources, including bioresources, subsoil. *Relevant functions:* • Coordinate country efforts toward Paris Agreement e.g. NDCs and the NAP; • Adapt to climate change by coordinating issues of attracting financial resources and investments of climate and other funds, promoting investments, implementing programs and projects; • Manage the protected areas and valuable natural objects, including in the glacio-nival zone.
The Ministry of Emergency Situations (MES)	The Ministry[74] is an authorized state executive body in the country, implementing a unified state policy in the field of civil defense, fire safety, safety of people on water bodies, hydrometeorology and forestry. *Relevant functions:* • Monitoring and risk reduction on GLOFs in Kyrgyzstan; • Snow avalanches monitoring, risk reduction and response; • Senday Framework Programmes development, coordination and implementation.
The State Meteorological Service under the Ministry of Emergency Situations (Kyrgyzhydromet)	Kyrgyzhydromet [75] monitors components of the environment, forecasts hazardous and natural hydrometeorological phenomena, issues weather forecasts, river water content and water inflow into reservoirs, and avalanche hazard forecasts. For these purposes, Kyrgyzhydromet creates an observation network consisting of all hydrometeorological stations and posts located in the territory they serve, processing and summarizing the results of network observations. The main purpose of the network of observation hydrometeorological stations is to conduct regular and high-quality hydrometeorological observations, including observations of snow cover, and study the hydrometeorological regime in the territory of the country.

[71] https://unfccc.int/sites/default/files/NDC/2022-06/%D0%9E%D0%9D%D0%A3%D0%92%20ENG%20%D0%BE%D1%82%2008102021.pdf
[72] https://mnr.gov.kg/ru/posts/our-projects

[73] https://cbd.minjust.gov.kg/158727/edition/5591/ru
[74] https://cbd.minjust.gov.kg/158694/edition/5578/ru
[75] https://www.mchs.gov.kg/ru/structures_

	Relevant functions: • Observation and forecast over the precipitations, including the snow and snow cover; • State of glaciers monitoring (one reference glacier); • Snow Avalanches monitoring, forecast and early warning
The Ministry of Education and Science	The Ministry[76] is responsible for developments in the primary and higher education and coordination of the development of Science in the Country both in the system of higher education (Universities) and in the Academy of Science. *Relevant functions:* • Commission research and analysis of the labor market, including for cryosphere research monitoring and knowledge; • Justification and introduction of the required specializations in higher and vocational education relevant to cryosphere research, monitoring and knowledge; • Commissioning scientific research and programs relevant to enable science-based knowledge on the cryosphere's status and future as of the climate change impact.

Research Institutions

The systematic observation and research of glaciers in Kyrgyzstan is carried out by 3 organizations on 9 glaciers: Kyrgyzhydromet - on 1 glacier,[77] Tien Shan High Mountain Research Center[78] of the Institute of Water Management and Hydropower of the National Academy of Sciences (IWMH)[79] - on 3 glaciers and the Central Asian Institute of Applied Geosciences (CAIAG)[80] - on 5 glaciers.

The CAIAG is a non-profit research organization that conducts scientific research, as well as events to educate and improve the skills of scientists in the field of Earth sciences in the following areas:

- Geodynamics and geocatastrophes;
- Climate, water resources and environmental threats;
- Use and conservation of natural resources;
- Creation of technical infrastructure.

The research results are transferred to interested government agencies and other organizations for decision-making and use in their activities.

The IWMH is a research organization that conducts scientific research in the following areas:

- Study of regional patterns of formation, regime, distribution, interrelation of surface and groundwater, assessment of water and hydropower resources of the Issyk-Kul and Chui regions and their dynamics against the background of global climate change;
- Development of scientific foundations for rational use, protection of water and hydropower resources;
- Scientific assessment of complex use and environmental safety of water resources;
- Glaciology, biogeography, coastal processes, highland ecology;

[76] https://edu.gov.kg/
[77] https://meteo.kg/
[78] https://iwp.kg/?page_id=761
[79] https://iwp.kg/
[80] https://www.caiag.kg/

- Monitoring of the risk of outburst of high-mountain lakes.

The Tien Shan High Mountain Research Center (TSHMC), established in 2006 at the Institute of Water Problems and Hydropower of the National Academy of Sciences of the Kyrgyz Republic, is the successor to the Tien Shan Physical-Geographical Station (TShPGS), founded in 1948 by the Institute of Geography of the USSR Academy of Sciences. The station was created to carry out comprehensive geographical research aimed at studying physical-geographical processes in their dynamics and development. The station participated in the compilation of the USSR Glacier Catalog, Volume 14; the number of glaciers surveyed is 2,720, and the total area of glaciers surveyed is 3,908 km2. Today, the scientific infrastructure of the TSHMC includes the Kara-Bulun AMS - 1,609 m; AMS Balykchy - 1609 m, AMS Chon-Kyzyl-Suu - 2555 m, AMS Kara-Batkak - 3300 m / 3420 m / 3460 m / 3900 m, AMS Sary-Tor - 4080 m, AMS Bordu - 4080 m, AMS Grigoriev - 4300 m, GP Kyzyl-Suu – 1760 m, GP Lesnoy Kordon – 2000 m, GP Kashka-Tor-estuary – 2550 m, GP Kashka-Tor-istok – 3260 m.

During field work, the instrumental measurements of ablation and accumulation, the boundaries of the tongue and glacier runoff are carried out on glaciers every year. The snow line and area of the glacier are determined by remote sensing methods. Based on in-kind measurements, remote sensing and automatic weather stations, the mass balance of the glacier is calculated.

Also, certain types of glaciological work are carried out on the South Enilchek (Central Tien Shan, CAIAG) and Adygene (Ala-Archa River basin, northern slope of the Kyrgyz ridge, IWMH) glaciers.[81] In 2018, CAIAG updated the Catalog of Glaciers of Kyrgyzstan, created in 1977 in the USSR, based on the interpretation of space images from the Landsat 8 and Sentinel 2 satellites.[82] As of 2013-2016, there are 9959 glaciers with a total area of 6683.9 km², which is 3.345% of the total area of Kyrgyzstan.[83] Currently, the Catalog of Glaciers is updated based on monitoring data.[84]

The study of permafrost is carried out by CAIAG based on soil temperature and moisture sensors installed in the ground to a depth of 1 m, which are part of the CAIAG automatic weather station complex. Temperature and humidity sensors are installed at the following weather stations: Taragay (3,530 m), Aksay (3,023 m), Golubin (3,300 m), Baytik (1,543 m), Merzbacher (3,300 m), Abramov (4,102 m), Koke-Meren (1,435 m), Maidantal, Uzbekistan (1,446 m), Maidanak, Uzbekistan (2,578 m) and Kumbel, Uzbekistan (2,261 m). In addition, automatic soil temperature measurements to a depth of 30 m are carried out in borehole 50/1, located in the Akshiyrak massif area (3,585 m), equipped in 2022 as part of the collaboration with CROMO-ADAPT project. [85]

The locations of stations located at an altitude of more than 2,500 m A.S.L. could be found on the web-page of CAIAG. Temperature and humidity are recorded at the automatic weather stations of CAIAG and the CROMO-ADAPT project every 3 hours, with data being transmitted via satellite and cellular communications to CAIAG and stored in the Sensor Data Storage System.[86] The data is freely available to all users.

[81] https://iwp.kg/?page_id=766
[82] https://www.caiag.kg/ru/projects-ru/297-katalog-lednikov-kyrgyzstana
[83] ttps://www.caiag.kg/phocadownload/projects/Catalogue%20%20%20of%20glaciers%20Kyrgyzstan%202018.pdf
[84] ttps://www.caiag.kg/phocadownload/projects/Catalogue%20%20%20of%20glaciers%20Kyrgyzstan%202018.pdf
[85] https://www.unifr.ch/geo/cryosphere/en/projects/smd4gc/cromo-adapt.html
[86] http://sdss.caiag.kg/sdss/.

Academic Institutions and Capacity Building

The leading university specializing in training professionals directly related to the field of cryosphere is Kyrgyz National University named after J. Balasagyn (KNU),[87] which offers education in the field of hydrometeorology. The Faculty of Geography, Ecology, and Tourism at KNU offers a specialized training program in Hydrometeorology since 2024.[88] The curriculum integrates theoretical knowledge with hands-on experience, including practical training at Kyrgyzhydromet and field expeditions. The core subjects with the highest workload (in hours) include: Physics of the Atmosphere and Hydrosphere; Methods and Instruments for Hydrometeorological Measurements; Modeling of Hydrometeorological Processes; Hydrometeorological Forecasting; Glaciology and Permafrost Studies and Agroclimatology.

Hydrogeology and Engineering Geology specialty was established in 1965 and is based at the U. Asanaliev Kyrgyz Mining and Metallurgical Institute of the Kyrgyz State Technical University named after I. Razzakov.[89] In 2021, a departmental branch was founded at the Central Asian Institute for Applied Geosciences (CAIAG) to facilitate the implementation of a master program in Georisks. Faculty members at the branch deliver lectures and laboratory sessions, oversee diploma projects and scientific research aligned with CAIAG's focus areas, supervise master's theses and final qualification projects, and coordinate internships.

As part of the professional training for the water sector at Kyrgyz Agrarian Academy named after K. Skryabin,[90] students receive comprehensive education in key disciplines, including meteorology, climatology, geosystems, and integrated water resources management.

Training Center of the Hydrometeorological Service under the Ministry of Emergency Situations[91] conducts specialized capacity-building training for professionals in the field of hydrometeorology. The training programs cover the following key areas:

- Meteorological Observation Procedures for meteorological technicians;
- Meteorological Observation Procedures for meteorological engineers;
- Hydrological Monitoring and Hydrometeorological Data Management in Kyrgyzstan;
- Hydrological, Agrometeorological, and Environmental Pollution Monitoring in Kyrgyzstan;
- Hydrological Forecasting.

In particular, the Glaciology and Avalanche Safety Department of Kyrgyzhydromet[92] plays a key role in developing and delivering training programs to enhance the qualifications of specialists in modern cryosphere and glacier observation methods. These courses focus on numerical modeling, remote sensing techniques; cryosphere and glacier monitoring. The primary objective of this training is to strengthen specialists' competencies in utilizing advanced tools for glacier and cryosphere monitoring, as well as for analyzing and interpreting collected data.

[87] https://www.knu.kg/ky/faculties
[88] https://www.knu.kg/ky/faculties
[89] https://kstu.kg/bokovoe-menju/instituty/kyrgyzskii-gorno-metallurgicheskii-institut-im-akad-u-asanalieva/vodnye-neftegazovye-resursy-i-georiski/vsklvlkvlkdlk
[90] https://fgeizu.knau.kg/
[91] https://www.mchs.gov.kg/ru/structures_old/kr-okm-karashtuu-gidrometeorologiya-boyuncha-agenttigi/
[92] https://www.meteo.kg/ru/pages/about-us

Tajikistan

National Legislation, Policies and Development Programs

The legislation of Tajikistan in the field of the cryosphere is based on the Constitution of the country and includes relevant codes, laws, regulations, as well as international law and international agreements, to which Tajikistan is a party.

The main cryosphere-related law is the Law on the Protection of Glaciers.[93] The law establishes the legal, economic and organizational foundations for the conservation of glaciers as environmental objects and strategic water resources. It regulates public relations in the field of scientific research, monitoring and protection of glaciers, as well as measures of state and international policy for their conservation. The law consists of four chapters:

- The first chapter covers the basic concepts, legislative framework, state policy and principles of glacier conservation, as well as property rights issues;
- The second chapter defines the objectives of state regulation, the powers of the government and local authorities, as well as the assessment of the impact of economic activity on glaciers;
- The third chapter concerns the organization of scientific research, glacier monitoring and the use of the obtained data, including the creation of a database and an observation network;
- The fourth chapter includes final provisions, international cooperation, liability for violation of the law and the procedure for its entry into force.

The State Programme on the Study and Conservation of Glaciers for 2010-2030.[94] The Programme emphasizes that due to global warming, glaciers are degrading; they are melting more than they are forming.

The Programme states that the area of glaciers on the outskirts of mountain systems is decreasing by 0.8-1.0% per year. The world's largest mountain glacier, Fedchenko, has retreated by 1-1.5 kilometers in a hundred years, and its area has decreased by 11 km^2, losing 2 km^3 of ice in volume. It is currently retreating at a rate of 15-20 meters per year. According to climate forecasts, by 2050 the average air temperature in the region may increase by 1-2 degrees. The total area of glaciation has decreased by 30% over the observation period since 1930. The Programme covers the following tasks:

- Inventory of large, medium and small glaciers of Tajikistan according to the glacier catalog
- Organization of systematic climate observations and scientific research;
- Application of new modern technologies and advanced experience in the field of glaciology
- introduction of modern glaciological monitoring;
- Models in the field of modeling the impact of climate change on glaciers during the research period;
- Development of methods for adaptation measures in the field of hydropower, agriculture, and human activity in the context of climate change;
- Climate observations and scientific research;
- Creation of an information base on glaciological objects of the Republic of Tajikistan and adjacent territories.

[93] https://adlia.tj/show_doc.fwx?rgn=147104
[94] https://www.adlia.tj/show_doc.fwx?rgn=15407

As of the international commitments, Tajikistan became the Party to UNFCCC in 1999[95] and actively participates in global efforts to combat climate change, including the protection of the cryosphere (glaciers, snow cover).

Under the UNFCCC, the country:

- Developed a National Adaptation Strategy (NAS) [96] in 2019, which includes measures to protect glaciers, combat their melting and reduce the impacts of climate change;
- Uses national greenhouse gas emissions reports and has developed monitoring programs to assess the impact of climate change on glaciers.

Being a Party to the Convention on Biological Diversity (CBD) since 1992,[97] the country ensures efforts on:

- Protection of ecosystems, including glacial ecosystems, which play an important role in maintaining biodiversity;
- Monitoring programs for the state of glaciers and their impact on ecosystems.

Tajikistan ratified the UN Paris Agreement in 2016.[98] This agreement has a significant impact on the protection of the cryosphere, as its goals are aimed at:

- Reducing greenhouse gas emissions, which in turn helps slow the rate of glacier melting;
- Developing resilient and adaptive infrastructure to protect against climate change, including preserving glaciers as an important source of water resources.

As part of fulfilling its obligations under the UNFCCC, the country developed and submitted four National Communications in 2002,[99] 2008,[100] 2014[101] and 2022.[102] As of the NDCs, Tajikistan submitted the first one in February 2017[103] and the updated version of the NDCs in October 2021.[104]

After signing the Paris Agreement, the country has developed several strategic documents, programs and concepts aimed at reducing the impact of climate change and implementing adaptation measures.

The main document that defines the risks and adaptation measures is the NAS until 2030.[105] In April 2023, an interdepartmental working group was established under the Committee for Environmental Protection,[106] including representatives of ministries and departments, to

[95] https://www.adlia.tj/show_doc.fwx?Rgn=134928
[96] https://www.adlia.tj/show_doc.fwx?Rgn=134928
[97] https://www.un.org/ru/documents/decl_conv/conventions/biodiv.shtml
[98] https://vkh.tj/ru/main/view/1403/uchastie-ministra-inostrannykh-del-na-tseremonii-podpisaniya-parizhskogo-soglasheniya
[99] https://unfccc.int/documents/81655
[100] https://unfccc.int/documents/144656
[101] https://unfccc.int/documents/144677
[102] https://unfccc.int/documents/614376
[103] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://unfccc.int/sites/default/files/NDC/2022-06/INDC-TJK%20final%20ENG.pdf
[104]chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://unfccc.int/sites/default/files/NDC/2022-06/NDC_TAJIKISTAN_ENG.pdf
[105] https://www.adlia.tj/show_doc.fwx?Rgn=134928
[106] https://www.adaptation-undp.org/projects/naps-gcf-tajikistan

implement the NAS and develop a national adaptation action plan for 2024-2026.[107] The Committee is tasked with monitoring and reporting on the implementation progress annually. In addition, sectoral adaptation plans (SAPs) are being developed for key economic sectors such as agriculture, water, energy, transport, industry and forestry.

These plans were developed within the framework of the project "Ensuring an effective national adaptation plan process for Tajikistan,"[108] implemented by the UNDP[109] and funded by the Green Climate Fund (GCF).[110]

The Sendai Framework for Disaster Risk Reduction (Sendai Framework)[111] was adopted at the 3rd World Conference on Disaster Risk Reduction in 2015 in Sendai, Japan. Under the Framework Tajikistan developed and implementing the National Risk Management Strategy (NRMS).[112] The implementation of the Framework is aligned with achievement of relevant SDGs and the Paris Agreement. This has resulted in integrated approaches to address climate resilience and adaptation issues.

There were awareness-raising and training campaigns conducted at the national and community levels, development of the early warning systems, strengthened infrastructure for emergency response, including the development of governance systems at all levels. Despite the results achieved, there are number of gaps that need to be addressed to effectively achieve the Sendai Framework's goals, such as uneven implementation of the strategy, weak coordination and problems with the integration of climate action. To address these gaps, there is a need for increased financial support, better use of data and local specificities in risk management strategies.

Government Agencies

Based on the analysis of the Regulations of Ministries and Agencies approved by the Government of Tajikistan, the functions of the ministries and agencies in terms of climate change and cryosphere are presented in the below Table 3.

Table 3: The list of major government bodies with relevant mandate and functions to major issues of the cryosphere

Government bodies	Mandate and key functions relevant to cryosphere
Ministry of Economic Development and Trade	Responsible for the development of concepts, short-, medium- and long-term strategies, programs for agricultural development, water and land resources use and environmental protection and climate change. *Relevant functions:* • Analysing proposals of ministries, departments and executive authorities of local districts, cities and regions for a future development including for agricultural development, ecology and water and land resources use; • Harmonization of environmental policy with other sectors of the economy
Ministry of Education and Science	Together with the Committee for Environmental Protection: • Conduct awareness raising activities in the field of environmental protection and climate change; • Develop training modules and programs for secondary schools and higher education institutions on environmental protection and climate change issues.

[107] https://www.adaptation-undp.org/projects/naps-gcf-tajikistan
[108] https://www.undp.org/tajikistan/press-releases/process-designing-and-implementing-national-adaptation-plan-climate-change-discussed-first-session-relevant-inter
[109] https://www.undp.org/tajikistan
[110] https://www.greenclimate.fund/
[111] https://www.undrr.org/implementing-sendai-framework/what-sendai-framework
[112] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://faolex.fao.org/docs/pdf/taj224304E.pdf

Committee on Emergency Situations and Civil Defence under the Government	Responsible for implementation of state policy in the field of civil defence, organization of civil defence surveillance and laboratory control network; carrying out dispersal and evacuation of the population to safe regions from cities classified as vulnerable groups of civil defence, organization of informing the population about the threat and occurrence of emergencies. *Relevant functions:* • Organization of informing the population about the threat and occurrence of emergencies, creation and control of the system of informing the population about emergencies; • Organization and provision of international cooperation and conclusion of international legal acts on disaster risk reduction; • Coordination of the implementation of the priorities of the Sendai Frameworks and relevant SDGs.
Committee on Environmental Protection under the Government	Responsible for promotion of the state environmental policy, management of the sphere of environmental protection and rational use of natural resources; implementation of state control over environmental protection and rational use of natural resources; determining the efficiency, compliance and feasibility of the activity of the objects of expertise with environmental requirements; management of specially protected natural territories; organizing and conducting environmental monitoring, forecasting and systematic study of the state of the environment; organizing and conducting state environmental expertise. *Relevant functions:* • Organisation of the scientific research and study of environmental protection and climate change issues; • Development of draft programs, concepts, strategies and action plans on environmental protection and climate change; • Coordination of the implementation National Strategy on Adaptation to Climate Change for the period up to 2030. Implementation of the and the updated NDCs, the National Designation Authority (NDA) for the Adaptation Fund (AF) and GCF.
Agency for Hydrometeorology under the Committee for Environmental Protection	Carrying out the state system of meteorological, hydrological, agrometeorological, and environmental monitoring; Improving the system of collecting, processing, analysing and communicating information on environmental protection to users; Timely provision of users with hydrometeorological forecasts, warnings on the occurrence of deterioration of weather conditions, climatic processes and ozone layer for taking necessary operational measures. The Agency leads the process of preparation of national communications, biennial reports and update of the Nationally Determined Contribution (NDC) in coordination with relevant ministries and agencies; The Agency has a Glaciology Centre, as well as a Centre for Climate Change and Ozone Layer Research. *Relevant functions:* • Maintaining a policy on glaciology; • Conducting expeditionary observations of glaciers; • Monitoring of cryosphere and related disasters, dynamics of meteorological parameters and their impact on cryosphere.

Research Institutions

State Scientific Institution "Centre for Glacier Studies" of the National Academy of Science of Tajikistan (NAST)[113] was established in 2018. The Centre is responsible for a study of glaciers and permafrost zones and related natural disasters; modelling of glacier degradation and breakthrough of dangerous glacial lakes; development of methodology for glaciological

[113]https://www.cryosphere.tj/en/

observations and snow cover studies; introduction of innovative methods for determining the volume and area of glaciers.

Institute of Water Problems, Energy and Ecology of NAST is modelling the surface waters availability and snow cover assessment on the territory of the Republic. Study of anthropogenic activity impact on ecosystems and development of measures for their protection and restoration.

Academic Institutions and Capacity Building

The major higher education body teaching specialisations relevant to cryosphere research, monitoring and knowledge is the Tajik National University (TNU).[114] Its Faculty of Physics Department of Meteorology and Climatology issues a meteorologist diploma (bachelor and master). The potential of water and hydropower resources, a developed network of water arteries and a huge number of glaciers caused the need to train highly qualified specialists to implement measures for their rational use, and in 1995, the specialty meteorology was included in the curriculum of the Physics Department.

In 2009, the Department of Meteorology was established. In 2014, at the suggestion of the Physics Department and the senior management of the TNU as well as with the support of the Government, the Department of Meteorology was transformed to the Department of Meteorology and Climatology.[115]

The main relevant scientific research areas of the department are:

- Monitoring the state of glaciers and the impact of global climate change;
- Monitoring emergency situations related to water factors and development of adaptation mechanisms;
- Monitoring meteorological conditions of transboundary river basins of Central Asia;
- Study of hydrological characteristics of the main rivers of Tajikistan.

The department provides diplomas on the specialties: 25.00.27 - Land hydrology, water resources, hydrochemistry; 25.00.30 - meteorology, climatology, agrometeorology, as well as 25.00.36. - Geoecology.

The Faculty of Geology of TNU, the Department of Hydrogeology and Engineering Geology[116] teaches the specialty: Hydrology and Glaciology and issues a Bachelor diploma of hydrologist-glaciologist. The specialty was formed on the basis of the department of hydrogeology and engineering geology in 2016. It teaches subjects: Modern problems of hydrology, Structural glaciology, River hydrology, Climate change and water problems of Central Asia, Integrated water resources management, glacial runoff, avalanche formation, shape and structure of glaciers and moraines.[117]

[114] https://tnu.tj/index.php/en/
[115] https://physical.tnu.tj/ru/kafedra-meteorologii-i-klimatologii/
[116] https://tnu.tj/index.php/en/main/
[117] https://geological.tnu.tj/ru/kafedra-gidrogeologii-i-inzhenernoj-geologii/

Khorog State University has a Faculty of Natural Sciences Department of Engineering Disciplines, which trains specialists in the fields of Geology and mineral exploration, Hydrogeology and engineering geology, Hydraulic engineering Geology and mineral exploration.[118]

The State Pedagogical University, Department of natural geography.[119] The main scientific topic is "Water resources and their rational use" and "Methods of protecting glaciers".

The Centre for the Study of Glaciers of NAST runs advanced training courses for young specialists on the glaciology. It also runs information courses and trainings for universities, schoolchildren and the general public.

The Glacier Research Centre of the National Academy of Sciences of Tajikistan conducts advanced training courses for young specialists in glaciology. Information courses and trainings are also held for universities, school students, and the general public.

Uzbekistan

National Legislation, Policies and Development Programs

The following legal acts provide the observation, monitoring and research of the cryosphere in Uzbekistan:

The Law "On Nature Protection"[120] establishes the legal, economic and organizational foundations for preserving the conditions of the natural environment, rational use of natural resources. It aims to ensure a balanced harmonious development of relations between man and nature, protection of ecological systems, natural complexes and individual objects, guarantee the rights of citizens to a favorable environment.

The surface, underground and sea waters on the territory of the country are subject to the preservation of the required amount of water in natural circulation, ensuring its regulatory purity, preserving aquatic flora and fauna, preventing pollution of water bodies, maintaining ecological balance in them and not causing damage to the reservoir as an element of the landscape.

Local authorities, environmental protection and climate change authorities and water management authorities are required to carry out reforestation and afforestation in river flow formation zones, coastal strips of water bodies and ensure their preservation. Protection of water bodies as a strategic resource of fresh water. Support for scientific research on the study of the cryosphere and its impact on water resources.

The Law "On Hydrometeorological Activity"[121] regulates the state system of hydrometeorological observations, which plays a key role in studying the state of the cryosphere. Important aspects are:

- Conducting scientific fundamental and applied research in the field of hydrometeorology, climate change, pollution of the environment;

[118] https://khogu.tj/ru
[119] https://www.tgpu.tj/index.php?option=com_content&view=article&id=5&Itemid=2&lang=en
[120] https://lex.uz/uz/docs/7065
[121] https://lex.uz/docs/5819321

- Provision of specialized hydrometeorological information and other services in the field of hydrometeorological activity is carried out through the preparation of analytical materials, laboratory and research work.

Based on the request of higher education organizations and scientific institutions, access to relevant hydrometeorological information on the research topic is provided to consumers free of charge, subject to independent work with the materials of the State Fund of Hydrometeorological Information of Uzbekistan.

The Law "On Protected Natural Areas"[122] defines the legal mechanisms for the protection and conservation of natural areas, hydrological (swamp, lake, river and others), designed to preserve natural water bodies, including glacial zones. The main measures for the regime of water protection zones and coastal strips also apply to the formation zones of surface and groundwater.

The Concept of Environmental Protection until 2030[123] includes areas for sustainable development, environmental protection and adaptation to climate change. It foresees the scientific support for environmental protection and expansion of international cooperation in the field of environmental protection, strengthening international cooperation - participation in the efforts of the world community to maintain a safe level of the environment and combat climate change, attracting additional external investment in environmental protection and rational use of natural resources.

Uzbekistan is a part of the global movement to mitigate and alleviate modern environmental challenges, such as ozone layer depletion, climate change, prevention of desertification and land degradation.

Uzbekistan is a party to the UNFCCC since 1993, the Kyoto Protocol to this Convention was signed in 1998 and ratified in 1999, and the Paris Agreement was signed in 2017 and ratified in 2018. Continuing global warming trends pose a great risk to human health and the country's economic development. Uzbekistan is among the countries most vulnerable to climate change. In the absence of additional resource-saving measures, the country may face a shortage of water resources, an increase in the number of droughts and hazardous phenomena leading to instability of agricultural production and threatening food and environmental security.

Desertification and land degradation in Uzbekistan, 80% the territory thereof is occupied by deserts and semi-deserts, the issues of combating desertification and drought are a priority in ensuring sustainable development.

Scientific support for environmental protection foresees the creation of favorable conditions for human health, preservation of ecological balance, rational sustainable use of natural resources requires the use of modern ecologically neutral technologies in all spheres of human activity. Scientific research in the field of environmental protection should be carried out by scientific institutions under government orders through budget programs and grants, including international ones. However, at present, scientific activity in the field of environmental protection is practically not carried out.

[122] https://lex.uz/docs/415228
[123] https://lex.uz/docs/4574010

Government Agencies

Several government agencies play important roles in observing, monitoring, and researching the cryosphere. These agencies are responsible for implementing national policies, coordinating research efforts, and managing cryosphere-related data.

Table 4: The list of major government bodies with relevant mandate and functions to major issues of the cryosphere

Government bodies	**Mandate and key functions relevant to cryosphere**
Ministry of Ecology, Environmental Protection and Climate Change	The Ministry[124] is the main government agency responsible for environmental protection, natural resource management and climate change policy in Uzbekistan. *Relevant functions:* • Organization of the hydrometeorological service, monitoring of climate change and environmental pollution; • Development of cooperation with civil society institutions and the public in the field of environmental protection, systematic organization of environmental education, propaganda, education and support for scientific research; • Implementation of the principles of "green" development, reduction of harmful emissions into the environment, reduction of the negative impact of human activities on nature; • Introduction of digital technologies in the field of environmental protection, establishment of a system for reducing and automating the human factor in monitoring; • Further development of ecotourism, hunting and safari tourism, effective use of the potential of forestry and national natural parks (except for areas transformed into reserves) and construction of relevant infrastructure facilities, creation of favorable conditions for foreign and domestic tourists and provision of their services; • Monitoring the state of the environment, identifying factors that may lead to environmental pollution, irrational use of natural resources, and pose a threat to the life and health of citizens.
The Ministry of Emergency Situations (MES)	The MES[125] is responsible for forecasting, preventing and eliminating the consequences of natural disasters, including avalanches, mudflows, freshets and floods caused by melting glaciers. The MES plays a key role in adaptation to climate change, reducing the risks associated with glacier degradation and changes in snow cover. *Relevant functions:* • Monitors the state of glaciers, snow cover and the likelihood of hazardous natural phenomena; • Develops and implements measures to prevent natural disasters associated with changes in the cryosphere; • Coordinates rescue and recovery operations in case of mudflows, avalanches and other disasters; • Interacts with scientific institutes, hydrometeorological services and international organizations to improve efficiency.
Hydrometeorological Service Agency (Uzhydromet)	Uzhydromet[126] units collect, process and analyze data on the state of snow cover and glaciers, providing important information for assessing the impacts of climate change and managing water resources. IT performs the function of

[124] https://www.uznature.uz/en
[125] https://www.fvv.uz/ru/
[126] https://hydromet.uz/ru/node/

	a regional meteorological center in the World Weather Watch system of the World Meteorological Organization. It maintains a network of more than 81 meteorological stations and 124 hydrological posts on rivers and lakes across the country. *Relevant functions:* • Collection of hydrometeorological data, its analysis and generalization; • Creation of a national database of hydrometeorological and climate data; • Provision of hydrometeorological forecasts and warnings for the population; • Special operational hydrometeorological services for agriculture, aviation, national defense and other sectors of the economy; • Monitoring of climate change and provision of its indicative forecasts, as well as contribution to the assessment of its impacts in measures and options for responding to climate change.
Ministry of Higher Education, Science and Innovations	The Ministry[127] supports scientific research in the field of the cryosphere. It develops educational programs for training specialists in glaciology.
Uzbekcosmos Agency	The Agency[128] conducts scientific and innovative research, implements satellite technologies. *Relevant functions:* • Provides remote sensing of the Earth, control of natural resources and environmental conditions; • Organizes training of specialists, including internships at leading foreign universities; • Attracts investments, develops partnerships with financial institutions and commercial structures.

Research Institutions

The Hydrometeorological Research Institute[129] is a key scientific institution in Uzbekistan, specializing in glacier monitoring, snow cover analysis, hydrometeorology, and climate impact studies on natural resources. The institute has a long history of cryospheric research and once housed the Central Asian Glaciological Research Centre, accumulating extensive historical data and scientific materials stored in its research archives.

The institute conducts glacier mass balance monitoring in collaboration with the Centre of Glacial Geology at the Institute of Geology and Geophysics and the National University of Uzbekistan, ensuring comprehensive assessments of glacial changes in Pskem river basin. It applies remote sensing-based snow monitoring using MODSNOW, studies mudflows and other hazardous hydrometeorological processes, and evaluates water quality and isotope hydrology to understand regional hydrological dynamics.

The institute collaborates with over ten international and neighboring organizations working in hydrology, meteorology, climate change, and cryospheric sciences, strengthening Uzbekistan's research capacity and global scientific integration. It also supports doctoral and internship programs in hydrology and meteorology and hosts a Scientific Council on Hydrology, Water Resources, Water Quality and Meteorology&Climatology, playing a pivotal role in shaping Uzbekistan's scientific agenda in these fields.

[127] https://gov.uz/en/edu
[128] https://uzspace.uz/ru
[129] https://nigmi.uz/

The Centre of Glacial Geology[130] at the Institute of Geology and Geophysics named after Kh.M. Abdullaev is a leading research facility in Uzbekistan, specializing in glaciology, hydrology, geochemistry, and geomorphology. Originally established as the Laboratory of Glaciology in the 1960s, the centre conducts field studies in the nival-glacial zone, focusing on glacier mass balance, river runoff structure, and climate change impacts.

A key priority is monitoring hazardous geodynamic processes, including glacial lake outbursts and debris flows. The centre plays a vital role in numerical modelling of glacier hydrology, processing remote sensing data (ALOS, GeoEye, Quikbird), and developing hydrological models for estimating water reserves in the Chatkal-Qurama region.

The centre maintains continuous mass balance measurements of Barkrak Sredniy Glacier, using automatic weather stations and video monitoring installed under CATCOS-2 and CICADA projects. It also employs RAMMS software for simulating glacial hazards and integrates GIS-based remote sensing tools (ArcGIS Pro, Erdas Imagine, Envisat) for analysing glacier dynamics.

The centre is committed to data systematization and open-access publication, continuously updating a spatial database on glaciation in the Chatkal-Qurama region. Through its research, it enhances cryospheric monitoring, climate adaptation strategies, and scientific collaboration in Uzbekistan and Central Asia.

Academic Institutions and Capacity Building

Uzbekistan has a growing academic foundation for cryospheric science, hydrology, and meteorology, with several higher education institutions and research organizations contributing to capacity building in this field. The National University of Uzbekistan[131] (NUU) named after Mirzo Ulugbek plays a leading role in this area through its Department of Hydrology and Meteorology[132], which offers bachelor's and master's degree programs in hydrology and meteorology.

In recent years, NUU has also hosted specialized education in glaciology. A Master's program in Glaciology and Snow Cover was available at the university during 2004–2007 and 2021–2023, providing students with expertise in glacier dynamics, snow cover processes, and climate change impacts. Although the dedicated master's program has been intermittent, related subjects continue to be taught as part of hydrology and meteorology programs. These courses include Glaciology, Climate Change and Its Impact on Natural Resources, Hazardous Hydrometeorological Risks, and other specialized topics covering hydrological, meteorological, and climatological sciences. NUU also offers PhD programs in Hydrology and Meteorology under the broader Geographical Sciences discipline, allowing for advanced research in cryospheric studies, water resource management, and climate adaptation strategies.

Beyond NUU, other institutions in Uzbekistan also contribute to capacity building in cryospheric science and hydrometeorology. Tashkent Institute of Irrigation and Agricultural Mechanization Engineers[133] (TIIAME)-National Research University conducts applied research and collaborates with universities to enhance scientific knowledge and monitoring of glaciers and snow cover monitoring.

[130] https://ingeo.uz/en/service/glyatsial-geologiya-markazi/
[131] https://nuu.uz/en/
[132] https://nuu.uz/en/gidrometereologiyaf/
[133] https://tiiame.uz/

Several regional universities also train specialists in hydrology and meteorology. Karakalpak State University[134], Samarkand State University[135], and other institutions offer bachelor's and, in some cases, partial master's programs in hydrology and hydrometeorology. These universities contribute to preparing specialists who can work in water management, climate monitoring, and environmental protection sectors.

The Central Asian University of Environmental and Climate Change Studies[136] (Green University), established in 2023 under the Ministry of Ecology, Environmental Protection, and Climate Change, aims to become a regional hub for environmental and climate studies. It offers Bachelor's and Master's programs, with a focus on environmental sciences and Sustainable Management, creating potential for advancing cryospheric studies in Central Asia. Green University collaborates closely with research institutes and technical colleges, including the Hydrometeorological Research Institute and the Tashkent Hydrometeorological Technical School, fostering interdisciplinary research, innovation, and workforce development in climate and water resource management.

Despite these academic initiatives, Uzbekistan faces a need for further development of cryospheric science education and research. Strengthening university programs, expanding graduate studies in glaciology, and increasing collaboration with international institutions and regional research centers would significantly enhance national capacity in monitoring and understanding the cryosphere. A key step forward is the integration of cryospheric studies into a regional Master's Program on Cryosphere, ensuring that Uzbekistan develops a skilled workforce capable of addressing the challenges posed by climate change and diminishing glacier resources.

Water Resources Governance Review

[134] https://karsu.uz/en/
[135] https://www.samdu.uz/en
[136] https://greenuniversity.uz/en/

Kazakhstan

Institutional Framework

The Water Council,[137] chaired by the Prime-Minister, is crucial for fostering cooperation on water resources. It develops policies for water protection and facilitates collaboration with neighbouring countries on shared water bodies.

Responsibilities for water quality and quantity are distributed among several government bodies and organizations. State Water Management authority is the Ministry of Water Resources and Irrigation[138] and it is responsible for:

- Developing key strategic documents like the Water Code and concepts for water management system development;
- Establishing water use limits for basins, regions and districts;
- Conducting state water accounting and use;
- Maintaining the state water cadastre and water monitoring;
- Distributing permissions for special water utilization;
- Exercising control over water use and protection.

Water Basin Inspections: These are regional bodies of the authorized water management agency that have key responsibilities for water resource management within specific hydrographic basins. Their functions include:

- Keeping state records and the state water cadastre;
- Conducting state monitoring of water bodies (in cooperation with other authorized bodies);
- Implementing state control over water use and protection;
- Issuing and managing permits for special water use.

Water Supply Organizations: These organizations ensure that water supply systems operate effectively while preventing pollution and depletion of water bodies. They must install metering devices at delivery points in consultation with users. Notably, the Republican State Enterprise Kazvodkhoz, which is operates on regional levels and responsible for:

- Operation and maintenance of hydraulic infrastructure;
- Irrigation management;
- Water resource regulation;
- Monitoring water quality;
- Capacity building.

Other Specially Authorized State Management Bodies: These include bodies responsible for nature protection, mineral resources, fish stocks, flora and fauna, and state sanitary and veterinary control. Notably:

- The Oblast Departments of Natural Resources and Nature Management, operating under the Ministry of Ecology and Natural Resources of Kazakhstan, are responsible for water

[137] https://adilet.zan.kz/rus/docs/R2200000047#:~:text=Водный%20совет%20Казахстана%20(далее%20%2D%20Совет,системы%20управления%20водными%20ресурсами%20Казахстана.
[138] http://www.gov.kz/memleket/entities/water

management, including implementing state policies, regulating water relations, managing communal water facilities, and monitoring water quality and compliance;
- The National Hydrogeological Service "Kazhydrogeology", established in April 2024, will focus on inventorying groundwater deposits and creating an extensive database to improve groundwater resource management;
- The Kazakh Scientific Research Institute of the Caspian Sea will study and monitor the ecological state of the Caspian Sea.

Public Associations and Citizens: They can participate in monitoring water use and protection efforts alongside state bodies.

Strategies and Programmes

The national development policy framework of Kazakhstan encompasses various strategies and plans either targeted or relevant to water sector each with its unique focus and objectives.

The foundational Strategy Kazakhstan 2050[139] is a long-term vision that sets ambitious goals for the country's development. While it acknowledges the importance of sectors like water management, it does not provide explicit and detailed considerations for climate adaptation in these areas.

The Kazakhstan 2030 Strategy[140] emphasizes the importance of effective water management and the introduction of modern irrigation technologies.

In the Address of the President of Kazakhstan Kassym-Zhomart Tokayev,[141] the President emphasizes the need to solve the problem of water scarcity and dependence on transboundary water sources and also points out the importance of the rational use of inland water resources and the introduction of water-saving technologies.

The National Development Plan of the Republic of Kazakhstan until 2029[142] outlines climate change adaptation priorities in water sectors, focusing on improving water use efficiency, implementing water-saving technologies.

The Concept for the Development of the Water Resources Management System of Kazakhstan for 2024-2030[143] reflects various aspects of water resources management, including adaptation to climate change, accounting and monitoring of water resources, modernization of irrigation practices and infrastructure, as well as tariff policies and public participation.

The *Concept* focuses on adaptation to climate change, emphasizing the need to consider climate change when planning the use of water resources. It pays particular attention to the impact of climate change on water resources, including changes in hydrological cycles, increased evaporation, and changes in river flow patterns.

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[139] https://www.akorda.kz/en/addresses/addresses_of_president/address-by-the-president-of-the-republic-of-kazakhstan-leader-of-the-nation-nnazarbayev-strategy-kazakhstan-2050-new-political-course-of-the-established-state.

[140] https://www.akorda.kz/upload/content_files/doc/Gos_programi/Стратегия%202030%20%28англ%29.doc.

[141] https://www.akorda.kz/ru/poslanie-glavy-gosudarstva-kasym-zhomarta-tokaeva-narodu-kazahstana-ekonomicheskiy-kurs-spravedlivogo-kazahstana-18588

[142] https://adilet.zan.kz/rus/docs/U2400000611

[143] https://adilet.zan.kz/rus/docs/U2300000121

The *Concept* proposes creating a unified information system on water resources to systematize and integrate data from state monitoring of water bodies. It also contains plans to modernize and optimize irrigation practices and infrastructure, including the introduction of water-saving technologies and accelerating their implementation to 150 thousand hectares/year.

The *Concept* discusses the need to revise tariff and subsidy policies, although specific measures and approaches are not disclosed in detail. It recognizes the importance of public-private partnerships (PPP) for water conservation, but specific mechanisms and examples of PPP are not presented.

The *Concept* pays attention to the introduction of climate resilience in the aquatic ecosystems of the Caspian Sea, the Northern Aral Sea, and Lake Balkhash, emphasizing the need for adaptation measures to new climatic conditions. It also notes the need to increase transparency and public participation in the management of water resources, including through the creation of a unified information system and public involvement in the decision-making process.

The *Concept* emphasizes the importance of interdepartmental coordination and education, as well as the need to improve the skills of water professionals. The *Concept* acknowledges the challenges posed by climate change and proposes the modernization and reconstruction of irrigation systems and the improvement of water resource use efficiency.

The Ministry of Water Resources and Irrigation has developed a 2024-2026 Roadmap for Water Conservation,[144] featuring strategies for digitalizing the sector, enhancing farmer support, adopting modern water-saving tech, and shifting to cost-effective crops. It entails digitalizing the sector, boosting farmer aid, adopting modern water-saving tech, and transitioning to more viable crops. Moreover, it plans water reuse in enterprises, full metering coverage in communal water systems, treated wastewater reuse in urban areas, water loss reduction, and fostering a culture of resourceful water consumption.

To implement the above, the Hydro.gov.kz[145] is a key component of Kazakhstan's plans to modernize its water resource management system through digitalization and improved data access. This platform will provide electronic access to a wide range of data, including space monitoring, gauging stations, water basin areas, hydraulic structures, and information from the Water Cadastre, while automating the accounting of water management entities.

Kyrgyzstan

Institutional Framework

The water resources are considered a strategic natural resource that determines and supports the socio-economic wellbeing, food and energy security and the preservation of the ecosystem of the country. Water and land resources management and protection are considered in a comprehensive manner. Due to that, thorough vertical governance and decision-making architecture is bult in the country.

[144] Under review by the Government. https://www.gov.kz/memleket/entities/water/press/news/details/731708?lang=ru.
[145] Currently, only a test version of the system is available at test-gidro.gharysh.kz, which requires EDS (electronic digital signature) authorization and is intended for testing purposes only

In 2021, the National Council on Water and Land Resources under the President of Kyrgyzstan was established.[146] The Chairman is the President of Kyrgyzstan. The main tasks and functions of the National Council are the coordination of the activities of ministries, administrative departments and other state bodies in the management of water and land resources, their use and protection.

The Ministry of Water Resources, Agriculture and Processing Industry[147] is an authorized state executive body implementing state policy in the field of water resources, including water resources, drinking water supply and sanitation, land reclamation, irrigation and reclamation infrastructure. The main tasks of the Ministry are:

- Development and implementation of a unified state policy in the field of agriculture, water management, forestry, food and processing industries;
- Efficient and rational use of land resources, water resources in irrigation and reclamation systems, as well as in the field of state supervision and control over compliance with land legislation, water use rules, maintenance of water bodies and water management infrastructure, use of water resources;
- Planning of interstate distribution of water resources formed on the territory of the country, and in accordance with the established procedure, regulation of interstate water relations jointly with the other relevant state bodies.

The Water Resources Service (WRS) of the Ministry of Water Resources, Agriculture and Processing Industry[148] is a state body directly responsible for management, monitoring and regulation of the state and use of water resources, irrigation and reclamation facilities. It carries out executive, administrative and coordinating functions for the implementation of a unified state water policy in the field of rational use and protection of the water fund, management of water resources and water management infrastructure facilities owned by the state, ensuring the water needs of all water users. Among main tasks of the Service are:

- Regulation of relations in the sphere of management of water resources use and their supply for irrigation purposes;
- Development and implementation of programs for the development of irrigation infrastructure facilities;
- Implementation of a unified state policy in the sphere of drinking water supply and sanitation
- Development of international cooperation of Kyrgyzstan in the sphere of water resources in agreement with the Ministry.

The following extension units operate under the WRS across the country:

- Seven Oblast Water Resources Management Departments (OWRMD) in each of the seven oblasts managing the water abstraction and supply via main drains and interdistrict canals;
- Five river basin management organizations: Chu, Talas, Issyk-Kul-Tarim, Naryn-Syrdarya and Kara-Darya-Syrdarya-Amudarya basins;
- Forty district water management departments (DWMD).

[146] https://cbd.minjust.gov.kg/5-9760/edition/1112234/ru
[147] https://cbd.minjust.gov.kg/158106/edition/3674/ru
[148] https://cbd.minjust.gov.kg/158603/edition/1127255/ru

The WRS also includes the State Entity on Development of Drinking Water Supply and Sanitation Facilities,[149] which develops the centralized drinking water supply and sanitation of settlements. The objectives of the State Entity are:

- Development of drinking water supply and sanitation of settlements in accordance with the requirements of regulatory legal acts;
- Strengthening the potential of entities servicing centralized water supply and sanitation systems, including those providing services in the drinking water supply and sanitation sector;
- Development of international cooperation in the field of drinking water supply and sanitation;
- Construction and reconstruction of centralized drinking water supply and sanitation facilities;
- Operation of centralized drinking water supply, sanitation and sewage treatment plants in rural areas and settlements of district significance.

In each city, there are municipal water supply and sanitation enterprises[150] subordinate to mayors' offices - Gorvodokanals.

There are about 500 Water Users Associations (WUAs) in Kyrgyzstan,[151] which are non-profit organizations. WUAs irrigate 749.2 thousand hectares of land or 73.2% of the irrigated land of Kyrgyzstan. The National Union of Water Users Associations (NUWA KR)[152] is one of the largest associations of WUAs, which includes about 400 WUAs and 247,749 communities.[153] The main tasks of WUAs are:

- Operation and maintenance of the irrigation system within the WUA service area and distribution of water between WUA members based on annual agreements;
- Distribution of water on contractual terms to persons who own or use irrigated land within the WUA service area who are not WUA members;
- Rehabilitation and improvement of irrigation systems within the WUA service area and implementation of construction work as needed;
- Receipt of irrigation water from a water supplier based on a water supply contract or implementation of independent water intake from natural water bodies (rivers, lakes and underground sources) in accordance with the established procedure in accordance with the obtained license and regulation of the use and distribution of water within the WUA service area;
- Prevention of water pollution.

The Land and Water Survey Service under the Ministry of Water Resources, Agriculture and Processing Industry[154] carries out state supervision and control over ensuring compliance with the norms and requirements of the legislation in the field of land and water relations. The tasks of the Service are:

- Ensuring compliance with the requirements of regulatory legal acts, technical regulations in the field of land and water relations;
- Protection of the interests of the state and all participants in civil land relations in accordance with land legislation;

[149] http://tunuksuu.kg/
[150] https://bishkeksuukanal.kg/
[151] https://www.water.gov.kg/index.php?option=com_content&view=article&id=252&Itemid=1308&lang=ru
[152] https://www.osoo.kg/inn/00603200610231/
[153] https://water.gov.kg/index.php?option=com_content&view=article&id=399&catid=132&Itemid=435&lang=en
[154] https://www.water.gov.kg/index.php?option=com_content&view=article&id=396&Itemid=1467&lang=en

- Prevention and suppression of land and water offenses in accordance with its competence.

The Ministry of Natural Resources, Ecology and Technical Supervision[155] as well as the Ministry of Health[156] perform functions on water pollution monitoring and water related diseases monitoring and prevention, those of the certain relevance to the water resources governance in the country.

Kyrgyzhydromet[157] is directly responsible for hydrological and water quality monitoring. It also produces a seasonal forecast of the snow cover and its contribution to water flow vegetation period indication e.g. on Chu and Talas River Basins as part of the established practice between Kazakhstan and Kyrgyzstan under the Chu-Talas Water Commission (CTWC).[158]

Strategies and Programmes

There are several strategic and programme documents relevant to water governance in Kyrgyzstan described below:

The National Development Programme (NDP) until 2026,[159] aimed at improving the well-being of citizens, was developed within the framework of the National Development Strategy (NDS) until 2040.[160] The item "Clean Drinking Water" of the NDP notes that the primary issue in terms of ensuring the quality of life of people in rural areas is providing each settlement in the country with clean drinking water. The policy in the field of drinking water supply will be aimed at creating an economically sustainable, affordable service for safe and high-quality water supply. In the next five years, the state will bring water to 95% of the country's settlements. About 100 villages will be connected to clean and safe drinking water facilities annually. Meanwhile, the item "Environmental Sustainability and Climate Change" points that the strategic objective of the state is to create an environment favorable for human life by preserving the unique natural ecosystems of the country and rational use of natural resources.

The National Water Strategy (NWS) by 2040[161] is to create a sustainable water resources management system for the benefit of current and future generations. To achieve it, the following priority areas are foreseen:

- Protection of water resources from depletion and pollution;
- Rational use of water resources;
- Reforming the water resources management system.

The measures of the NWS aimed at people to reduce anthropogenic pressure on the ecosystem and at water as a life-supporting potential and an indicator of anthropogenic impact. The measures will be implemented through demand management for water use as a potential for the development and management of water-related risks, protecting water bodies, improving state water accounting, increasing social motivation for rational use of water and ensuring safe and high-quality water supply, sanitation and wastewater disposal.

[155] https://mnr.gov.kg/ru/
[156] https://mnr.gov.kg/ru/
[157] https://www.mchs.gov.kg/ru/structures_old/kr-okm-karashtuu-gidrometeorologiya-boyuncha-agenttigi/
[158] https://nwrmp.water.gov.kg/page_id=9935&lang=en_US
[159] https://www.effectivecooperation.org/Kyrgyzstan-national-development-vision-and-plans
[160] https://adam.kg/media/uploads/2022/04/15/national-strategy-of-kyrgyz-republic-2018-2040.pdf
[161] https://www.effectivecooperation.org/Kyrgyzstan-national-development-vision-and-plans

It will also be aimed at integrated water resources management (IWRM), digital transformation via establishing the Unified Water Information System[162] and creation of water resources management mechanisms that stimulate rational water use. The reforming the water resources management system foresees managing water resources within the main basins, as one of the principles of integrated water resources management. The NWS will contribute to achieving the goals of the NDS for 2018-2040 by:

- Inclusion of the natural environment to the system of socio-economic relations as the most valuable component of the national heritage;
- Building a new economic model based on harmonious coexistence with nature;
- Ceasing that the natural resources will pass from an expenditure part of the budget to become a revenue part;
- Ensuring environmental sustainability with the country's economic growth.

The State Programme for the development of irrigation for 2017-2026[163] provides construction and reconstruction of irrigation infrastructure in existing and new irrigated lands to ensure the development of regions and will also contribute to solving issues of food security and the fight against poverty. The state program foresees the introduction of 66.5 thousand hectares of new irrigated lands, increase the water supply to 51.08 thousand hectares, transfer 9.5 thousand hectares from machine to gravity irrigation, and improve the melioration state of lands on 50 thousand hectares.

The Programme of development of drinking water supply and sanitation systems in settlements until 2026[164] is aimed at increasing the supply of the population with drinking water of standard quality, improving the health and quality of life of the population, reducing the harmful impact on the environment through the construction, reconstruction and modernization of drinking water supply and sanitation systems. To achieve these goals, it is planned to solve the following priority tasks:

- Providing the population with safe drinking water of standard quality;
- Ensuring the safety and security of water consumers from threats to their health;
- Adaptation of the drinking water supply and sanitation sector to climate change;
- Improvement of the regulatory framework in the sphere of drinking water supply and sanitation;
- Institutional development of the drinking water supply and sanitation sector;
- Improvement of the information basis for sector management, including through the creation of a national database on drinking water supply and sanitation.

For achieving the financial and economic sustainability of drinking water supply and sanitation services the Programme foresees the improvement of tariff policy and ensuring the financial sustainability of drinking water supply and sanitation service providers, creation of conditions for attracting investment and development of public-private partnerships.

[162] https://cbd.minjust.gov.kg/434906/edition/1230660/ru
[163] https://cbd.minjust.gov.kg/100162/edition/860377/ru
[164] http://tunuksuu.kg/wp-content/uploads/2024/11/KG_ESMF_WSSUAP_PIU_SIDDWSWD_ENG.pdf

Tajikistan

Institutional Framework

The state executive bodies implementing regulation and control in the field of use and protection of water resources include the Ministry of Energy and Water Resources, the Ministry of Health and Social Protection, the Committee for Environmental Protection under the Government, the Agency for Land Reclamation and Irrigation under the Government, the Main Department of Geology under the Government, the Service for State Supervision of Industrial Safety and Mining Supervision under the Government, local authorities and self-governance bodies of settlements and villages. In cooperation with the state executive bodies, drinking water supply and sanitation organizations, water user associations and other public organizations carry out their activities in providing services.

Ministry of Energy and Water Resources (MEWR)[165] is a leading governmental body of the country for implementation of state policy and legal acts aimed at the energy sector, water resources management and development of renewable energy sources.

As part of the water sector reform, the National Water Information System[166] has been created under the MEWR in order to collect, store, process and issue information for information support for the development of state policy, forecasts, concepts, strategies and development programs in the field of water resources, basin plans, projects and activities related to the management, use and protection of water resources, strategic and operational decision-making and informing the public in the field of water resources. The River Basin Organizations (RBOs)[167] established and functioning under the MEWR.

The Ministry of Health and Social Protection[168] and the Committee for Environmental Protection under the Government[169] are responsible for the control of quality of drinking water and the control of water pollution respectively.

Land Reclamation and Irrigation Agency under the Government[170]is responsible for development of a unified state policy and normative-legal regulation in the sphere of land reclamation and irrigated lands, use and conservation of water management facilities, water supply and protection; operation and maintenance of water management facilities, design and construction of new hydraulic structures, bank protection works to prevent climate change risks; supervising land reclamation and water use, water resources management for irrigation purposes; support of Water Users Association and water resources management in land reclamation and irrigation systems on the basis of integrated water resources management at the levels of basins and sub-basins of large and small rivers.

The Main Department of Geology under the Government[171] is responsible for the control over the use of the aquafers and ground waters used for a drinking water supply. While the Service for State Supervision of Industrial Safety and Mining Supervision under the Government[172] is responsible

[165] https://www.mewr.tj/
[166] https://www.mewr.tj/?page_id=447
[167] https://www.mewr.tj/?page_id=447
[168] https://moh.tj/en/main/
[169] http://tajnature.tj/en/
[170] https://alri.tj/en
[171] https://mino.tj/en/biz/main-department-of-geology-under-the-government-of-the-republic-of-tajikistan-dushanbe
[172] https://nazorat.tj/?lang=ru

for the control of the water use in the industrial sector and responsible for the reduction of the risks and prevention of the water pollution by industrial operations and accidents.

National Strategies and Programmes

The implemented strategies and state programs in the water sector yield positive results and create a reliable platform for achieving the goal of sustainable development of Tajikistan until 2030. Within the framework of the implementation of the state program for reforming the water sector (2016-2025)[173] it is guaranteed supply of all water consumers with water, achieving cost-effective and environmentally sustainable water resources management and improving it through the full implementation of the IWRM principles are envisaged.

For the further sustainable development of the country's water sector, a draft National Water Strategy for the period up to 2040[174] was developed. In line with that there are several programmes under the development and implementation e.g.:

- Water Sector Reform Program of Tajikistan for the period 2016-2025[175];
- National Strategy of the Republic of Tajikistan for Disaster Risk Reduction for 2019-2030[176];
- Program for Improving the Provision of the Population with Clean Drinking Water for 2008-2020[177];
- Program for Improving the Reclamation Condition of Irrigated Agricultural Lands for 2019-2023[178];
- State Environmental Program of the Republic of Tajikistan for 2023-2028.[179]

The priority direction of the NWS and of subsequent programmes is the implementation of the following mechanisms:

- Development and adoption of the Law "On Land Reclamation and Irrigation";
- Development and adoption of by-laws and regulations based on water legislation;
- Separation of political and regulatory functions from economic ones in the field of water supply and sanitation, as well as the definition of an authorized state body in the field of drinking water supply and sanitation at the level of the central executive body of state power;
- Strengthening the capacity of state executive bodies that regulate and control the use and protection of water resources;
- Development of basin plans for water resources management that consider all aspects of the use and protection of water resources, including climate change and disaster risk reduction
- Development of standards for permissible impact on water bodies that consider regional features and individual characteristics of water bodies;
- Development of new rules for the use of reservoirs;
- Conducting state monitoring of water bodies;
- Improvement of drinking water supply and sanitation norms and standards, including wastewater treatment and reuse, targeted use and conservation of water resources;

[173] https://www.fao.org/faolex/results/details/en/c/LEX-FAOC189751/
[174] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.wis.tj/wp-content/uploads/2024/12/Nati_vodnaya_strat_RT_do_2040.pdf
[175] https://www.adlia.tj/show_doc.fwx?Rgn=126214
[176] https://www.adlia.tj/show_doc.fwx?rgn=132889
[177] https://www.adlia.tj/show_doc.fwx?rgn=10462
[178] https://www.alri.tj/en/about-measures-for-improvement-of-ameliorative-condition
[179] https://www.adlia.tj/show_doc.fwx?rgn=144616

- Development of the improved mechanisms and procedures to strengthen and maintain institutional capacity in the water supply and sanitation sector (including sanitation and hygiene);
- Digitalization in the water sector, including through the introduction of new technologies, such as the use of the ability to control physical facilities using the Internet and artificial intelligence to improve the efficiency of operation and maintenance, maintaining the functionality of infrastructure, water quality management and strengthening the metering of water intake and consumption, improving the effectiveness of water management, implementation taking into account the adoption of security measures to protect against cyber and other threats and vulnerabilities
- Improvement the maintenance of a unified National Water Information System.

Uzbekistan

Institutional Framework

The Ministry of Water Resources[180] is the key Government body in water resources of water facilities management, water accounting and reporting, maintenance of the state water cadaster and the formation of a corresponding database.

It is responsible for:

- Development of interstate relations in the field of management and use of transboundary water resources, active participation in the activities of international organizations in the field of water resources management, attracting foreign investment and grant funds, as well as technical support;
- Systematic organization of training of specialists in the field of water resources management, strengthening of integration between water management organizations and educational and research institutions, systematic organization of implementation of scientific and technical achievements in practice.

The Ministry of Mining and Geology[181] implements long-term, medium-term and annual programs of geological exploration based on deep scientific analysis of geological and other information on the subsoil using advanced forecasting methods, search results and assessment of groundwater deposits, formation of information on non-and their reliability in order to increase the growth of reserves of fresh, slightly brackish and mineral groundwater, their rational use, timely prevention of the development of exogenous geological processes and the development of environmental recommendations.

The responsibility of the Ministry includes:

- Performing hydrogeological, engineering-geological and geoecological work aimed at ensuring an increase in the quality and reliability of the results obtained based on the use of advanced production methods, modern techniques and technologies;
- Analysing and monitoring the reliability of the information provided on groundwater resources and reserves and developing recommendations for the rational use of groundwater;
- Conducting work on monitoring groundwater, systematically processing information and ensuring interdepartmental cooperation in the field of water resources management to expand

[180] https://gov.uz/suvchi
[181] https://gov.uz/mingeo

the market for consumers of hydrogeological information and promptly submitting the necessary materials to the relevant ministries and departments.

The Law on Water and Water Use[182] regulates water resources management, including glacial runoff, which is especially important for Uzbekistan as a country dependent on transboundary water resources. Key provisions:

- The Unified State Water Fund includes streams, sais, rivers, reservoirs, lakes, seas, canal waters, collector and drainage networks, springs, ponds and other surface waters, underground waters, snow reserves and glaciers;
- The right to use waters from transboundary water bodies (the Amu Darya, Syr Darya, Zarafshan rivers, the Aral Sea and other transboundary water bodies) is established by international treaties of Uzbekistan;
- All waters (water bodies) are subject to protection from pollution, contamination and depletion that may cause harm to public health, as well as lead to a decrease in fish stocks, deterioration of water supply conditions and other adverse phenomena due to changes in the physical, chemical, biological properties of waters, a decrease in their ability to naturally purify, disruption of the hydrological and hydrogeological regime of waters;
- Contamination of the surface of catchments, ice cover, reservoirs and the surface of glaciers with industrial, household waste, garbage and emissions, as well as oil and chemical products, the washout of which will lead to a deterioration in the quality of surface and groundwater;
- The Procedure for accounting, reporting and monitoring of water use and water consumption is being implemented through special water users and special water consumers keep records and reports on water use in accordance with the established procedure;
- Monitoring of water resources is carried out by competent authorities to identify changes in water resources, including groundwater, their assessment, prevention and elimination of negative processes and development of forecasts of the state of water resources.

National Strategies and Programmes

The procedure for accounting, reporting and monitoring of water resources for special water use and special water consumption is established by the Cabinet of Ministers of the Republic of Uzbekistan. Decree of the President of Uzbekistan "On approval of the concept of water management development for 2020-2030[183]".

This decree defines the main directions for the development of water management in the context of climate change. Key provisions and definition of priority areas of the Concept:

- Improving forecasting and accounting of water resources, the system of formation and ensuring transparency of the database;
- Ensuring the safety and reliable operation of reservoirs, flood reservoirs and other water management facilities;
- Development of interstate relations on the use of transboundary water resources;
- Development and promotion of mutually acceptable mechanisms for joint water resources management and programs for efficient water use that ensure a balance of interests of the Central Asian countries;
- Training of qualified personnel for the water management sector, improvement of the employee promotion system, development of mutual cooperation in the spheres of education, science and production, as well as the introduction of scientific achievements and know-how into production.

[182] https://lex.uz/uz/docs/93202
[183] https://lex.uz/uz/docs/4892946

Analys of Relevant Socio-Economic and Water Indicators

Demography and Trends

The national demographic statistics of Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan were gathered and analysed by experts representing each of the above country on the given indicators. The time-series of the national demographic statistics for most of the CA countries and of the World Bank[184] and of the Worldmeter[185] the source of data on Turkmenistan were used to make an analysis of the demography and its trends on the CA.

As for the DA, the demography is considered through the prism of the development of the settlements, which need to be supplied with primary utilities and facilities, including the water and hydropower primarily sourced by the cryosphere, as well as the need to provide the water as a living source to the rural population, including the irrigated agriculture to secure food.

The DA also considers the demography via existing and possible future pressure on the cryosphere, which is a crucial builder of landscapes and ecosystems in the CA. The last but not the least, the DA explores the demography through the prism of the labour source and human capacities to empower the cryosphere knowledge, monitoring, research and harmonious "know-how" life within it.

Table 5: The population dynamic in Central Asia for 2024

	Population	Yearly Change %	Yearly Change	Migrants (net)	Median Age	Urban Population %	Urban Population
Kazakhstan	20,592,571	1.29%	262,467	-7,368	29.6	55.20%	11,360,335
Kyrgyzstan	7,186,009	1.59%	112,493	3,645	25.3	35.10%	2,520,990
Tajikistan	10,590,927	1.94%	201,128	-21,236	22.1	27.40%	2,905,902
Turkmenistan	7,222,194	1.10%	77,940	-2,729	30.0	47.00%	3,392,896
Uzbekistan	36,361,859	1.99%	709,552	-7,066	27	48.40%	17,614,842
Central Asia	**82,225,864**	**1.72%**	**1,415,700**	**-17,379**	**26.12**	**42.46%**	**37,867,786**

*Source: Data for Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan - Worldometer[186], * data for Turkmenistan - State Statistics Committee of Turkmenistan as of January 1, 2025.*

The population's geography in the CA is significantly bound to the main rivers, river-rich territories, and oases in arid CA. In the meantime, most of the rivers in the CA begin in the mountains and harvest their waters from the snow and glaciers. Such a geography is inherited from the region's deep and rich population history.

The Ferghana Valley alone was and is the most densely populated region of the CA. The total population of the Valley in three countries is more than 15 million people, or about 30% of the total population of the three countries. The Kyrgyz part is home to 3.5 million people, the Uzbek

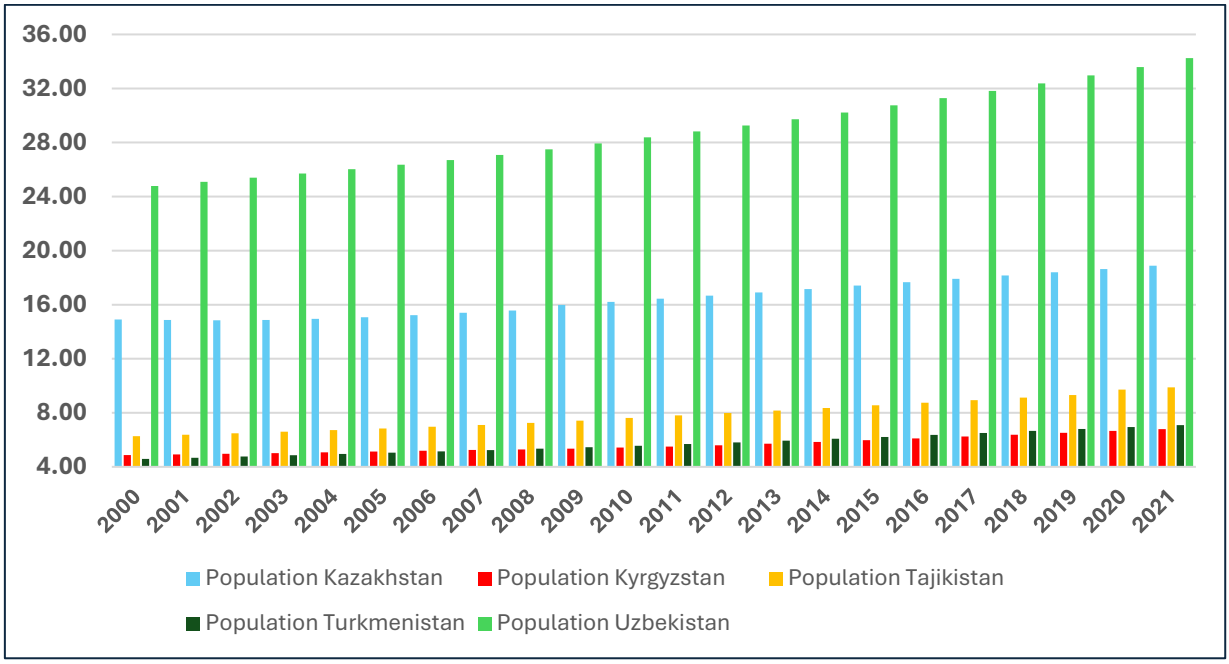
[184]https://data.worldbank.org/indicator/SP.POP.TOTL?view=chart%20,https://www.worldometers.info/world-population/turkmenistan-population/%20for%202023-24
[185] https://www.worldometers.info/world-population/turkmenistan-population/
[186] https://www.worldometers.info/world-population/population-by-country/

part of the valley is home to 9.5 million people, and the Tajik part is home to 2.5 million people as of 2020.[187]

Meanwhile, the population in the middle and upper reaches of the other greater and smaller river basins accommodate large urban conglomerates in the CA, e.g. Tashkent, Almaty, Dushanbe, Bishkek, and Shymkent. The midstreams are not only highly populated but also accommodate the massive water infrastructure and most of the arable croplands, and it prices in higher growth e.g. in Uzbekistan the provinces with population growth rates above the national average: Andijan (33.16%), Jizzakh (34.97%), Kashkadarya (36.10%), Namangan (35.76%), Samarkand (34.93%), and Fergana (32.10%).

The growing population expands to the mountain sub-footings and mountain valleys, which expose people to the higher risks of the natural disasters and the life within the cryosphere with winter snow and turbulent rivers fed by melting glaciers like in Almaty and Almaty Oblast in Kazakhstan, those are home of to 3.8 mln people and the City of Dushanbe and Districts of the State Subordinacy in Tajikistan with 1.2 mln and 2.2 mln population in 2022 respectively.

Graph 1: The population dynamic of the CA countries for 2000-2021



*Source: for Kazakhstan, Kyrgyzstan and Tajikistan the National Statistics, for Turkmenistan*https://data.worldbank.org/indicator/SP.POP.TOTL?view=chart *and* ,https://www.worldometers.info/world-population/turkmenistan-population/ for 2023-24, *for Uzbekistan -* https://www.worldometers.info/gdp/uzbekistan-gdp/ *by 2010 and the national statistics from 2010 to 2024*

Meanwhile far lower reaches and bottom lands of Aral Sea Basin face huge environmental problems and lower population growth trends e.g. Bukhara (26.76%), Navoi (26.27%), Khorezm (27.79%), and the Republic of Karakalpakstan (22.71%) in Uzbekistan for 2010-2024 the lowest growth rate in Uzbekistan within 2010-2024.

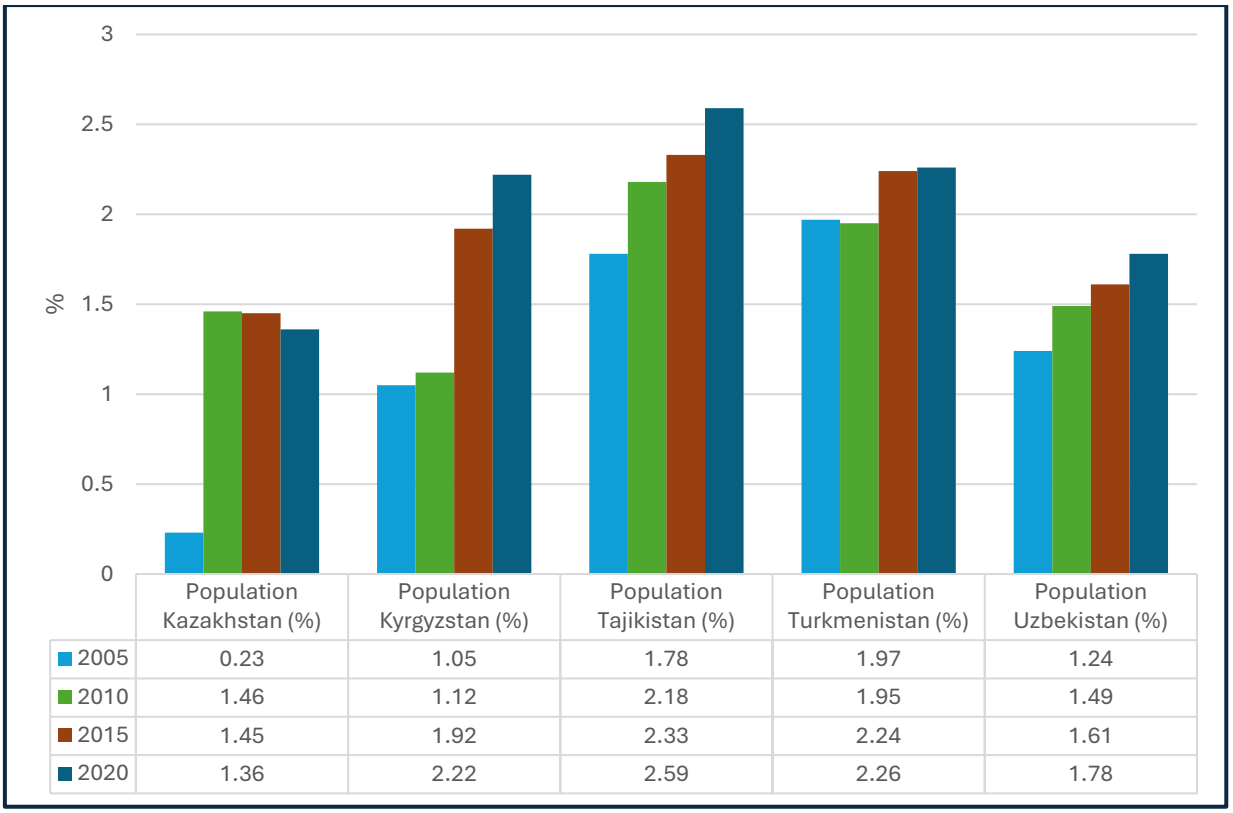
The territorial distribution of the population bound to water-rich and mountain framed South and the East is visibly distinct for Kazakhstan, with the lowest density of the population (8 per km²)

[187] https://www.caa-network.org/archives/19693

and highest rate of the urban population (55%) in the CA.[188] Almaty, Zhambul, Turkistan, Eastern Kazakhstan, Zhetisu Oblasts along with the cities of Almaty and Shymkent accommodate 49% of the country's population, while by the territory these regions make less than 1/4 of the total area of Kazakhstan.

Rapidly growing population of the CA, in one hand, is the great resource for the development and in the other, it rises needs to ensure harmonious development of the people from their infantry through the childhood to the age, when people choose their way ahead, first, being educated and trained and then finding the job and building the decent life. All these require thorough consideration and efforts of the Governments and people themselves.

Graph 2: Mean five-year periodic growth rate of the population by countries in CA in 2000-2020



	Population Kazakhstan (%)	Population Kyrgyzstan (%)	Population Tajikistan (%)	Population Turkmenistan (%)	Population Uzbekistan (%)
2005	0.23	1.05	1.78	1.97	1.24
2010	1.46	1.12	2.18	1.95	1.49
2015	1.45	1.92	2.33	2.24	1.61
2020	1.36	2.22	2.59	2.26	1.78

Source: summed up on the basis of data from the Worldometer[189]

The fast population growth in the past two decades is also featured, with the large share of the youth and working-age population giving an existing and, most probably, near-future excess labour force, which CA economies cannot accommodate. This makes the CA, except Kazakhstan, the large source of the labour migration. While remittances of labour migrants, within the past twenty-year period played visible role in investing the economies of their home countries e.g. Kyrgyzstan, Tajikistan and Uzbekistan.

[188] https://www.worldometers.info/world-population/kazakhstan-population/
[189] https://www.worldometers.info/world-population/population-by-country/

The major and larger cities and their suburbs are the centres for the internal migration. It increases the share of the urban population in the CA countries as well as increases the population close to these cities. From 1999-2019, most cities in Kazakhstan experienced population growth, with ten cities growing by more than 50%.[190] The city of Tashkent's high growth within 2010-2024 was driven by internal migration, reaching a 36.10% increase.[191] Data on interregional migration in Kyrgyzstan indicate that the receiving regions are Bishkek and Chui Oblast, and the donors are all other Oblasts, with some exceptions for Osh Oblast. This indicates a concentration of job opportunities and a better standard of living in Bishkek and Chui Oblast.

With the high mean growth rate (1.72%) and young mean age of the population (26.2), there is a significant growth of the population under working and working ages in the CA within 2000-2024. These two groups form more than 90% of the population of the CA.

Among people younger than working age, the number of men and women is relatively balanced. In working age, there is also a relatively small difference in the number of men and women, with a slight preponderance in favor of women in recent years. In older age, the composition is significantly different, and here there is a noticeable predominance of women, which is associated with the longer life expectancy of women.

In addition, women in mountain regions of Central Asia are directly affected by cryosphere-related climate impacts, including glacial melt, changes in river regimes, and increasing risks of natural hazards. Their daily roles in water collection, subsistence farming, and household care make them both highly vulnerable and essential actors in resilience-building. This underscores that gender-responsive approaches are not only a matter of equality, but also a critical factor in building effective and sustainable responses to cryosphere-related climate challenges.

Macroeconomy and Trends

The subchapter is built to showcase the ability of the economies to afford needs for the steady improvements in funding the research, observation and providing the human capacities to address the main issues of the cryosphere. It is also built to show the abilities of the economies to develop the territories as well as ensure their sustainability, where the cryosphere is spread out.

The size of the economy defines ability of the country to be a funder or recipient of the Official Development Aid (ODA) to fulfil commitments on the sustainable development being a party to relevant international treaties. The economic power is the resource to adapt the climate change and address the severity of its impact to the economy and ecosystems either deploying the own economic power or being also eligible for ODA.

The stronger economies, in a view of the future shrinkage of water resources including through the shrinkage of the cryosphere as an effect of the climate change, are able to address the issues of

[190] https://documents1.worldbank.org/curated/zh/207061511933292030/pdf/121727-BRI-P154478-PUBLIC-Kazakhstan-Snapshot-Print.pdf
[191] stat.uz/en/official-statistics/demography

the inefficient water use, huge water losses, structurally change the economy to make it less water dependent and more resilient.

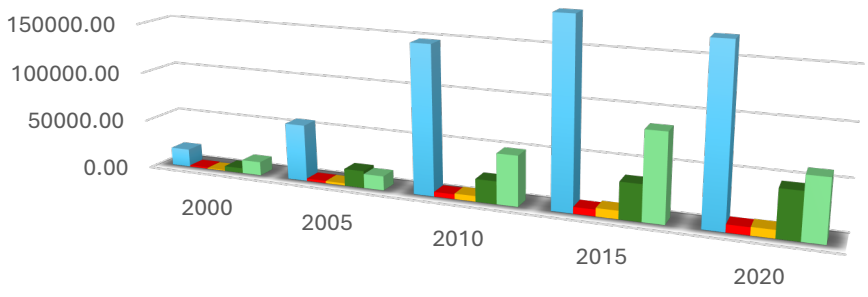
People empowerment via investing the education is also a sign of the stronger economy along with investing the research and science, which would enable the economy to be more resilient with on-time decisions and measures to prevent internal and external shocks.

Graph 3: Gross GDP in current prices ($) for 2000-2020 in the CA

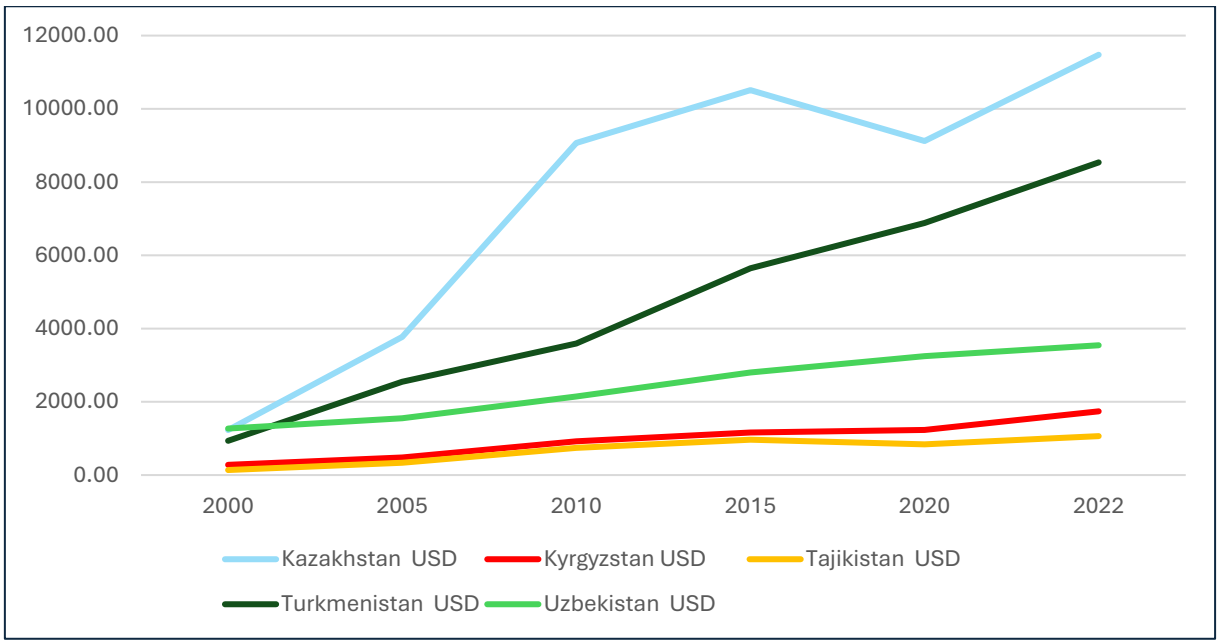
Source: National Statistics for Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan - https://www.worldometers.info/gdp/uzbekistan-gdp/, for Turkmenistan, the State Statistics Committee

Kazakhstan's economy as twice as larger than all other economies in the CA together. Kazakhstan's gross GDP has been on an upward trajectory. In 2023, the country's GDP reached approximately $220 billion, marking a significant increase from previous years. The GDP per capita, a key indicator of economic well-being, stood at around $12,000, placing Kazakhstan in the upper-middle-income category globally.

Graph 4: GDP per capita in current prices (USD) in Central Asia for 2000-2022



	2000	2005	2010	2015	2020
Kazakhstan mln USD	18292.40	57123.70	148052.40	184387.00	171083.70
Kyrgyzstan mln USD	1369.61	2460.36	4794.81	6678.20	7735.55
Tajikistan mln USD	860.54	2312.35	5642.22	8271.43	8133.96
Turkmenistan mln USD	5022.12	17174.04	22583.16	35799.71	45818.06
Uzbekistan mln USD	13760.51	14307.51	49765.68	86196.26	60224.70



Source: National Statistics for Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan - https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=TM, for Turkmenistan, the State Statistics Committee

The GDP per capita shows a significant upward trend from 2000 to 2023. Starting from a low base, it steadily increased until around 2014, followed by some fluctuations. After a dip between 2015 and 2017, the GDP per capita began to rise again, reaching its highest point in 2023. This suggests overall economic growth and an increase in individual prosperity over the period, despite some periods of stagnation.

The analysis of Kazakhstan's total trade turnover from 2020 to 2021 indicates a positive trend characterized by a significant recovery in exports driven by increased global demand, a moderate rise in imports reflecting domestic economic needs, and strengthened trade relationships with both regional partners e.g. Commonwealth of Independent States (CIS) and Euro Asian Economic Union (EAEU) and major global markets (European Union (EU) and Asia), highlighting the country's ongoing efforts to diversify its economy and enhance its position in international trade networks while navigating global economic challenges.

The total trade turnover increased by approximately 17.6% from 2020 to 2021, indicating a recovery and growth in Kazakhstan's foreign trade activities post-pandemic. Exports saw a substantial increase of about 26.9%, reflecting a stronger demand for Kazakh goods internationally. Imports also increased by approximately 6.4%, suggesting a moderate rise in the demand for foreign goods.

From 2015 onwards, there is a marked acceleration in growth rates of Kazakhstan's wholesale and retail trade sector, suggesting significant expansion driven by economic reforms and heightened market demand. The most dramatic increase occurs between 2020 and 2023, coinciding with post-pandemic recovery efforts that have revitalized consumer activity. By 2023, the sector's value exceeds 20,000 million tenge, underscoring its vital contribution to Kazakhstan's economy amidst ongoing challenges such as inflation and competition from open markets. This growth trajectory highlights the importance of continued investment and adaptation within the sector to maintain momentum and address emerging challenges effectively.

Kazakhstan's wholesale and retail trade sector, including vehicle and motorcycle repair, plays a crucial role in the national economy, contributing approximately 18.2% to the country's GDP as of 2023. This sector has demonstrated resilience and growth, particularly in recent years, despite facing challenges such as inflation and supply chain disruptions. According to the Bureau of National Statistics, retail sales increased by 13% year-on-year in October 2024, reflecting robust recovery from the impacts of the COVID-19 pandemic and ongoing economic reforms aimed at enhancing market efficiency. In 2023, retail sales reached 19,234.2 billion tenge, which is a 7.7% increase compared to the previous year.

Investment trends also indicate a positive outlook for the sector. In the first half of 2024, investments in fixed assets related to wholesale and retail trade reached approximately 8.3 trillion tenge (about $17.4 billion), marking a slight increase from previous years.

The growth of e-commerce has further transformed the retail landscape in Kazakhstan, with online sales volume reaching 2.4 trillion tenge ($5.3 billion) in 2023, representing a 79% increase from 2022.Additionally, the share of cashless payments increased from 82.5% to 86.2% throughout the country in 2023, indicating a significant shift towards more convenient transaction methods.

The unemployment rate in Kazakhstan has shown a significant decline from 2001 to 2023. In 2001, the unemployment rate was approximately 8%, and by 2023, it had decreased to around 4.9%. This trend indicates a steady improvement in the labor market over the past two decades.

The decline in the unemployment rate suggests robust economic growth and successful job creation initiatives. This is likely due to various factors, including government policies, foreign investment, and development in key sectors. The stability in the number of unemployed individuals, despite the growing population, indicates a balanced labor market where job creation is keeping pace with population growth. While the overall trend is positive, the slight increase in the unemployment rate in recent years may indicate emerging challenges, such as economic slowdowns or structural changes in the economy.

Expenditure on science and education as a percentage of GDP has been relatively low:

- Science: 0.17% of GDP in 2023, down from 0.28% in 2000;
- Education: 4.6% of GDP in 2023, up from 3.7% in 2000.

The decline in science spending as a share of GDP indicates it has not kept pace with overall economic growth. Education spending has improved but remains below levels seen in many developed countries.

In general, key macroeconomic indicators show that the economy is demonstrating positive macroeconomic trends: GDP growth, a decrease in unemployment and poverty, and an increase in spending on education and foreign trade. However, the problem of poverty remains relevant, and positive economic changes have not yet led to a uniform improvement in the standard of living in all segments of the population. Investments in education and science, increased foreign trade, and an improvement in the labor market give hope for further growth and an increase in the standard of living.

In Kyrgyzstan in 2023, GDP was $13,980.6 million, showing steady growth compared to previous years. While 2020-2021 saw a decline in GDP due to the pandemic, real GDP in 2022-2023 significantly exceeded the pre-pandemic level. The growth rate in 2023 was 106.2% compared to the previous year, indicating a significant increase in productivity and economic activity, possibly due to investment and development of key sectors. GDP per capita is also increased from $556.1 in 2006 to $1,969.2 in 2023, which is an important indicator of the increase in the level of welfare of the population. An increase in the population's income against the background of growing GDP indicates an improvement in the standard of living.

In 2000, industrial production amounted to 41.4 billion soms, and by 2023 it had grown to 482.8 billion soms. This indicates a significant increase in production, especially noticeable in the period 2017-2023. The largest increase is observed in 2021, when production amounted to 370.5 billion soms, and in 2023 - already 482.8 billion soms. The 10-fold increase in industrial production over the period under review reflects the expansion of production capacity, the development of new technologies and a likely increase in foreign investment. This suggests that the country has come a long way in industrialization, which is accompanied by improved infrastructure and logistics.

At the beginning of the period, in 2000, the volume of agricultural production amounted to 41.0 billion soms. By 2023, this figure has grown almost 10 times - to 378.7 billion soms. In recent years, from 2021 to 2023, agricultural production has seen the greatest growth, as has industry. While agricultural growth is significant, it is still at a slower pace than services. This is because as the economy grows, agriculture plays a smaller role in the structure of GDP, although it remains an important sector for food security and exports. Increased production in industry and agriculture may indicate the introduction of new technologies and the modernization of processes. This indicates that old infrastructure is gradually being replaced with more efficient ones.

The growth of industrial production and agricultural products during the period under review was 10-12 times, while the growth of services in the field of trade and hotels and restaurants was almost 40 times. This indicates that the economy has undergone a structural change: a shift towards the service sector.

Services become an important part of the economy as incomes increase and demand for activities such as trade, tourism, hospitality, and entertainment. The acceleration of growth in the service sector, especially the hotel and restaurant business, indicates an increase in the standard of living, as well as the development of tourism. There has probably been a change in the structure of demand, with the population spending more on services, and tourist flows have increased.

In the period from 2006 to 2023, there was an increase in the gross value added (GVA) in the tourism sector. In 2006, it amounted to 4,015.8 million soms, and in 2023 it reached 43,645.1 million soms. The most noticeable increase was observed in 2011, when GVA increased from 8,241.5 to 12,877.2 million soms. In 2020-2021, there was a significant decline in this indicator due to the pandemic. However, in 2022-2023, GVA continues to grow, and it exceeded the pre-pandemic value of the indicator by 50%. In the period from 2006 to 2019, the share of tourism in GDP ranged from 3.5% to 5.0%, with a peak point in 2016 and 2017, when the share was 5.0%. Subsequently, starting in 2020, the share has been decreasing, which may be due to the impact of the COVID-19 pandemic on the tourism industry.

In 2020, the share of tourism in GDP fell to 2.9%, but in the following years, a gradual increase began, reaching 3.6% in 2023. Investments in fixed assets in the tourism sector grew from 2006 to 2019 from 2,216.4 million soms to 27,184.2 million soms. The most significant increase in investment was observed in 2011-2017, where investments increased from 6,951.7 million soms to 22,795.1 million soms. However, in the period from 2020 to 2023, there is instability accompanied by decreases and increases in the indicator. This may indicate the impact of external factors, such as the pandemic and possible economic difficulties. The recovery of tourism industry development indicators after the pandemic in 2022-2023 indicates the resilience of the sector, but additional investment and support measures are required for a full recovery.

The hotel and restaurant services' sector is significantly smaller in volume, but also shows steady growth: from 1.19 billion soms in 2000 to 42 billion soms in 2023. However, in 2020, as in the trade sector, there was a temporary decline to 16 billion soms, probably related to the pandemic, after which there is a rapid recovery to 42 billion soms in 2023.

The trade sector has shown one of the most significant growths: from 35.1 billion soms in 2000 to 1.38 trillion soms in 2023. This sector has significantly outpaced industry and agriculture in terms of growth rates. It should be noted that in 2020, there was a temporary decline to 537.3 billion soms, but after 2021, there was a strong growth, with trade volumes almost doubling within four years, which may be due to increased commercial activity and possibly the impact of trade digitalization.

Foreign trade turnover in 2023 reached $15,660.8 million, which demonstrates positive dynamics with an increase of 29.91% compared to 2022. If in 2019-2020 there was a decrease in indicators, then in 2021-2023 there was a significant increase in foreign trade turnover. The increase in exports and imports indicates the expansion of international economic ties. The country is actively integrating into the global economy, which can contribute to the sustainability of its economy against the backdrop of global challenges, such as changes in commodity prices or exchange rate fluctuations.

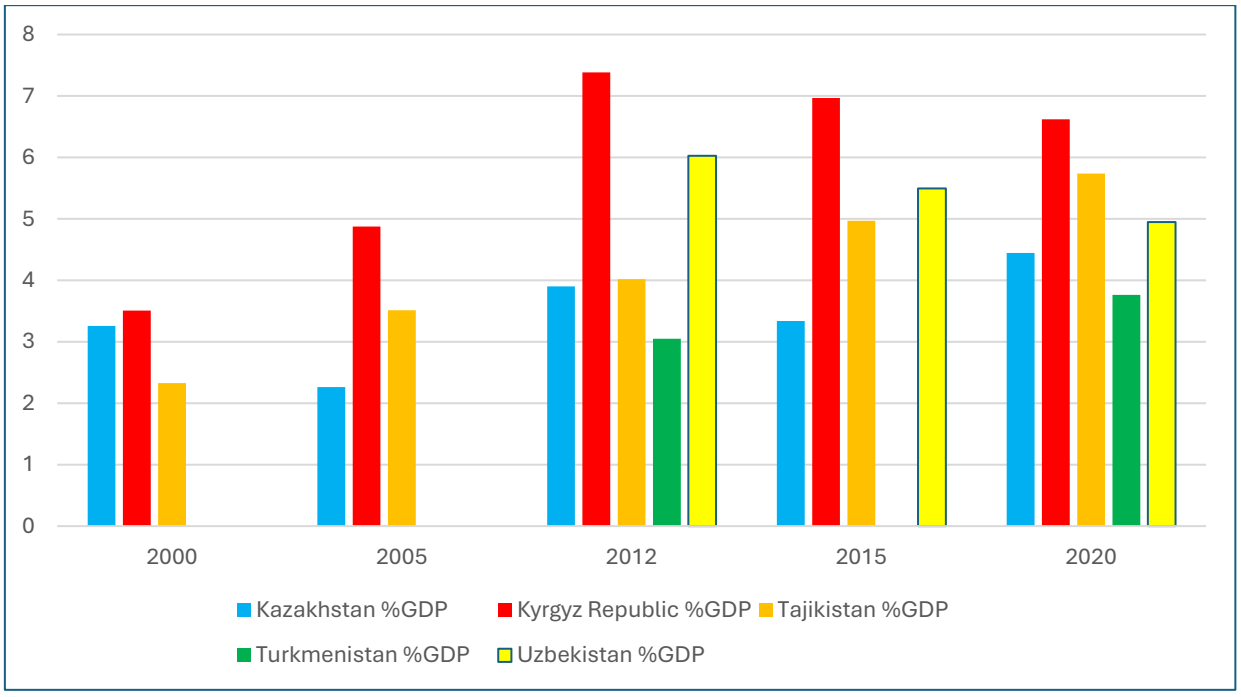
Growth in all key sectors of the economy indicates overall economic development and an increase in the standard of living of the population. Growth in the service sector is particularly important for the economy, as it indicates that more people can afford to spend on services that are not basic. It is possible that significant growth in services, especially hotels and restaurants, may also indicate greater income differentiation, with wealthier groups consuming more services, such as tourism, restaurants and hotels. An important factor in the growth of the service sector is urbanization, as services for the population are concentrated in large cities, and consumption of such services is also increasing. The transition to the service sector, the growth of trade and industrial production show that the economy has become more diversified, modernized and oriented to meeting the new needs of both domestic and foreign demand.

The unemployment rate has fallen by more than half compared to 2006 to 4.1% in 2023, which is a significant improvement. Such low figures may be the result of active private sector growth and effective employment policies, which reduce the social burden on the economy and increase the population's income. However, it is important to note that low unemployment may also indicate a potential problem of labor shortages in certain sectors of the economy, which may limit further economic growth.

Despite positive changes in the economy, the poverty level remains a significant problem. In 2023, 30.34% of the population are below the poverty line, which, despite a decrease of more than 2 times compared to 2000, remains a high indicator. This state of affairs may be due to the uneven distribution of income, as well as the uneven development of individual regions.

A significant increase in spending on education, especially higher and secondary education, indicates the state's priorities in improving the skills of the workforce. In 2022, spending amounted to 73.2 billion soms, which is more than twice the 2016 figure. At the same time, a sharp increase in the indicator was observed in 2022 - more than 1.5 times compared to 2021. Such investments in education can eventually contribute to increased labor productivity and accelerated innovative development of the economy. The increase in spending on education indicates a focus on long-term development strategies. Improving skills, developing innovations and technologies can become important factors for further economic growth. Spending on science in 2021-2022 did not grow so much and reached 791 million soms. The share of technical, scientific and professional activities in GDP in absolute terms increased from 6.8 billion soms in 2020 to 15.8 billion soms in 2023.

Graph 5: Government expenditure on education, total (% of GDP)



Source : https://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS?view=chart

In general, key macroeconomic indicators show that the economy is demonstrating positive macroeconomic trends: GDP growth, a decrease in unemployment and poverty, and an increase in spending on education and foreign trade. However, the problem of poverty remains relevant, and positive economic changes have not yet led to a uniform improvement in the standard of living in all segments of the population. Investments in education and science, increased foreign trade, and an improvement in the labor market give hope for further growth and an increase in the standard of living.

Tajikistan's total GDP in 2022 was $10.7 billion, including $1,063 per capita. Agricultural products account for 25.5% of the GDP, industry for 17.7%, retail trade for 15%, and other services for 17.4%. Tajikistan's public external debt as of July 1, 2022, was $3.3 billion (41.6 percent of GDP). According to the World Bank, real GDP growth for 2022 has increased to 8%.

Tajikistan has an agrarian-industrial economy, based on agriculture: cotton growing, crop production, livestock farming, as well as industry, mechanical engineering, aluminum production, mineral fertilizers, textile and light industry, energy and consumer goods production. Relative remoteness and communication isolation from the existing global transport infrastructure, high mountainous terrain, and lack of access to the sea determine the unfavorable economic and geographical position.

Economic activity is supported by the mining industry, manufacturing and construction. Of the total employed population, 46% are employed in agriculture, 6.8% in industry, 8.6% in construction, 12.2% in trade and services, 4.6% in public administration, 4.1% in healthcare, 8.1% in education and 9.3% in other sectors of the economy (finance, communications, science, etc.).

For the period reviewed, and specifically from 2010 to 2023, **Uzbekistan's** GDP increased significantly. During the period from 2010 to 2022, Uzbekistan's GDP exhibited an average annual growth rate of 24%. The highest growth rate was recorded in 2017, with an impressive increase of 40%, while the lowest growth rate occurred in 2020, which saw a mere 12% increase. This significant decline in growth rates during 2020 can be attributed to the global COVID-19 pandemic, which severely impacted economies worldwide and disrupted various sectors within Uzbekistan.

The unemployment rate in the country averaged 6.8% from 2010 to 2023. Due to the pandemic in 2020, the unemployment rate rose to 10.5%. The highest unemployment rates were recorded in the Republic of Karakalpakstan in 2010 (7.4%), and in 2023, the same rate was observed in the Surkhandarya and Syrdarya Oblasts, which also stood at 7.4%.

The employment rate in the country averaged 67.4% from 2010 to 2023. During the years 2010-2019, the regions of Bukhara, Navoi, and Syrdarya recorded the highest levels of employment compared to other administrative territories. In these years, employment levels in these regions consistently exceeded 70%. The highest employment rate in the country was observed in Tashkent Oblast, which averaged 72.7% from 2010 to 2023. The capital city, Tashkent, demonstrated even higher employment levels, with an average rate of 80.9% during the same period and reaching 82.3% in 2023.

The data indicates a relatively stable and high employment rate across Uzbekistan over the past decade. The significant employment figures in Bukhara, Navoi, and Syrdarya highlight the effectiveness of local economic policies and initiatives aimed at job creation. This trend suggests that these regions may have benefitted from targeted investments or industrial developments that fostered job opportunities.

Tashkent's exceptional employment figures can be attributed to its status as the capital and economic hub of the country, likely benefiting from greater investment in infrastructure, services, and commerce. The capital's higher employment rates may also reflect a concentration of educational institutions and training programs, enhancing the workforce's skills and employability.

However, it is essential to consider the quality of employment as well. While high employment rates are positive, they do not necessarily indicate that jobs are secure or adequately compensated. It would be beneficial to explore the nature of the jobs created in these regions, including whether

they offer sufficient wages and benefits, and to investigate the informal employment sector, which might not be captured in official statistics.

Future policies should aim not only to maintain high employment rates but also to ensure that job quality is prioritized, facilitating sustainable economic growth and enhancing overall living standards for the population.

The education system in Uzbekistan is structured into several stages: preschool education and upbringing, general secondary and specialized secondary education, vocational training, higher education, postgraduate education, retraining, professional development, and extracurricular education.

Between 2010 and 2023, the literacy rate among the population aged 16 and older has remained stable in Uzbekistan. The literacy rate was recorded at 99.8% in 2010 and slightly increased to 99.9% in 2011. Since 2012, this rate has reached an impressive 100%, reflecting the success of the country's compulsory general secondary education system.

In recent years, Uzbekistan has been actively developing private partnerships within the education sector. Privatization has been widely implemented in preschool education, general secondary education, and higher education. As of the first quarter of 2024, there are 213 higher education institutions (HEIs) registered in the country, including 116 state-owned, 67 non-state, and 30 foreign institutions. Currently, approximately 1.3 million students are enrolled across all 213 HEIs. This represents a significant increase in enrolment coverage from 34% in 2022 to 42% in 2024.
Furthermore, state funding for education in Uzbekistan has tripled between 2018 and 2023. In 2018, government expenditure on education amounted to 20,721.1 million soums, which surged to 61,220.3 million soums by 2023.

From 2010 to 2023, investments by enterprises and organizations in the education sector have increased significantly. In 2010, these investments totalled 264.4 million soums, which grew exponentially to 66 times that amount by 2021 and reached 72 times by 2022. In 2023, while there was a slight decline, the total still amounted to 10,616.5 million soums, marking a 40-fold increase compared to 2010.

The volume of scientific research has also risen sharply. Key factors contributing to this growth include increased government support for scientific research, the establishment of a conducive innovative environment, and greater attention to training scientific and pedagogical personnel. Recent governmental initiatives include the introduction of policies such as “Regulations on Additional Payments for Scientific, Scientific-Pedagogical, and Labor Activities of Employees with Scientific Degrees in State Organizations of Science and Education”, “Measures to Establish a Management System for Scientific and Innovative Activities”, and the “Concept for the Development of Science until 2030”. These initiatives demonstrate the government’s commitment to enhancing the education sector.

As a result of these efforts, funding for scientific research has significantly increased. For instance, in 2008, funding amounted to 47,252 million soums, which grew to 336,482.5 million soums by 2018 and further to 1,379,718.3 million soums by 2022. This reflects a remarkable 29-fold increase compared to 2008.

Uzbekistan’s education system is undergoing significant transformation, marked by high literacy rates and substantial investment in both education and research. The ongoing efforts to privatize and diversify educational opportunities are enhancing access and quality, while increased funding is paving the way for a more robust educational infrastructure. Continued focus on these areas will

be crucial for developing a skilled workforce and fostering socio-economic progress in Uzbekistan.

The macroeconomic indicators highlight the resilience and potential of Uzbekistan's economy, demonstrating its ability to recover from external shocks and continue on a path of substantial growth. As the country navigates the challenges posed by global economic fluctuations, strategic measures will be essential to sustain this upward trajectory and enhance overall economic stability.

It also important to highlight that women in Central Asia are actively involved in the economy, particularly in the education and healthcare sectors. However, traditional gender stereotypes persist, limiting their participation in decision-making and access to high-paying sectors. At the same time, women in mountain and rural areas are directly impacted by cryosphere-related climate change, such as glacier retreat, water scarcity, and natural hazards. Such involvement demonstrates that empowering women in cryosphere-affected areas directly contributes to stronger community resilience, more inclusive adaptation strategies, and long-term climate security.

Water Abstraction and Use

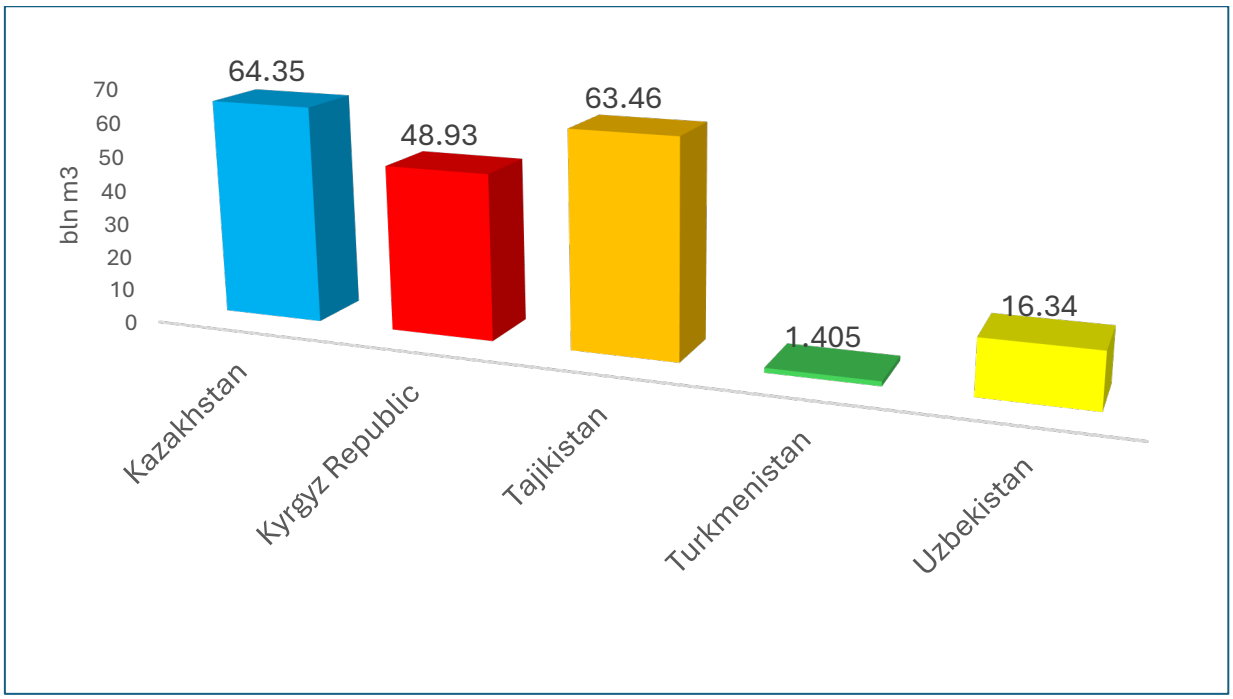
The water use in the CA is a critical issue as it was identified in the GEF-7 Strategy. The CA is one of the Asia's subregions, where the cooperation on water is an imperative to support the need for water, food, energy, and ecosystems security and related dimensions for each nation.[192]

This chapter is built on the data collection on the set of water abstraction and use indicators from the open national statistical sources as well as on the World Bank's Open Data Portal.[193] The rationale in data gathering and then review is to interface with the climate scenarios on cryosphere (glaciers and snow cover) and its impact on water resources.

The story telling goes to review the national water abstraction and use, while graphs made to tell for themselves comparing the water abstraction and use features in comparison among the CA countries.

Graph 6: Annually available internal freshwater resources in CA (in bln m³) in 2021

[192] https://www.thegef.org/sites/default/files/documents/Focal_area_GEF-7_Programming_Directions_International_Waters.pdf
[193] https://data.worldbank.org/



Source: https://data.worldbank.org/indicator/ER.H2O.INTR.K3?view=chart

In Kazakhstan the renewable freshwater resources reveal significant variability influenced by natural and transboundary factors. Total renewable freshwater resources calculated as the sum of internal and external inflows, reflect overall freshwater availability in Kazakhstan. This availability varies considerably, ranging from a low of 78,420 million m³ in 2012 to a high of 180,820 million m³ in 2010. Such variability presents challenges for water management, necessitating flexibility to adapt to changing water availability from year to year. Long-term planning shall consider both wet and dry years. While total abstraction has remained relatively stable in recent years, shifting sectoral demands and variability in renewable supplies highlight the need for prudent water management strategies. Special attention should be given to agricultural usage to improve efficiency and sustainability.

Total freshwater abstraction (surface and groundwater) has fluctuated over the 20-year period, ranging from a low of 20,474 million m³ in 2008 to a high of 23,812 million m³ in 2010. From 2015 to 2022, total abstraction has remained relatively stable in the 22,700-25,600 million m³ range annually. The majority of freshwater abstraction comes from surface water sources, accounting for over 95% of the total each year, while groundwater makes up a small portion, typically 1,000-1,200 million m³ annually.

Freshwater use segmented into several key economic sectors:

- Household consumption: Increased gradually due to population growth from 624 million m³ in 2000 to 1,126 million m³ in 2022;
- Agriculture, forestry, and fishing: The largest consumer sector, accounting for approximately 9,000 to 13,000 million m³ per year (50-60% of total use);
- Manufacturing: Exhibits considerable volatility with peaks around 2014-2015 followed by declines due to changes in industrial practices or economic shifts;
- Electricity and gas supply: Increased substantially from 2015 onwards, reaching 5,069 million m³ in 2021 due to growing energy needs balanced with more efficient water use;
- Other economic activities: Variable year-to-year usage ranging from 38 to 5,647 million m³.

Agriculture consistently accounts for the largest share of freshwater withdrawal, ranging between 10 and 15 billion m^3 throughout the period, emphasizing the critical role of water in primary industries. However, there have been notable shifts in recent years, with household and electricity/gas use increasing markedly.

Water use intensity is measured as total water use per unit of GDP (in cubic meters per constant 2017 international $). This intensity has decreased significantly over the period from 120.5 m^3/$ in 2000 to 39.9 m^3/$ in 2022—a reduction of 67%. This indicates that economic growth has become less water-intensive over time due to efficiency improvements and structural economic shifts. However, the rate of intensity reduction has slowed; from 2015-2022 it decreased by only 14%, compared to a reduction of 53% from 2000-2015. Continued efforts are necessary to decouple water use from economic growth.

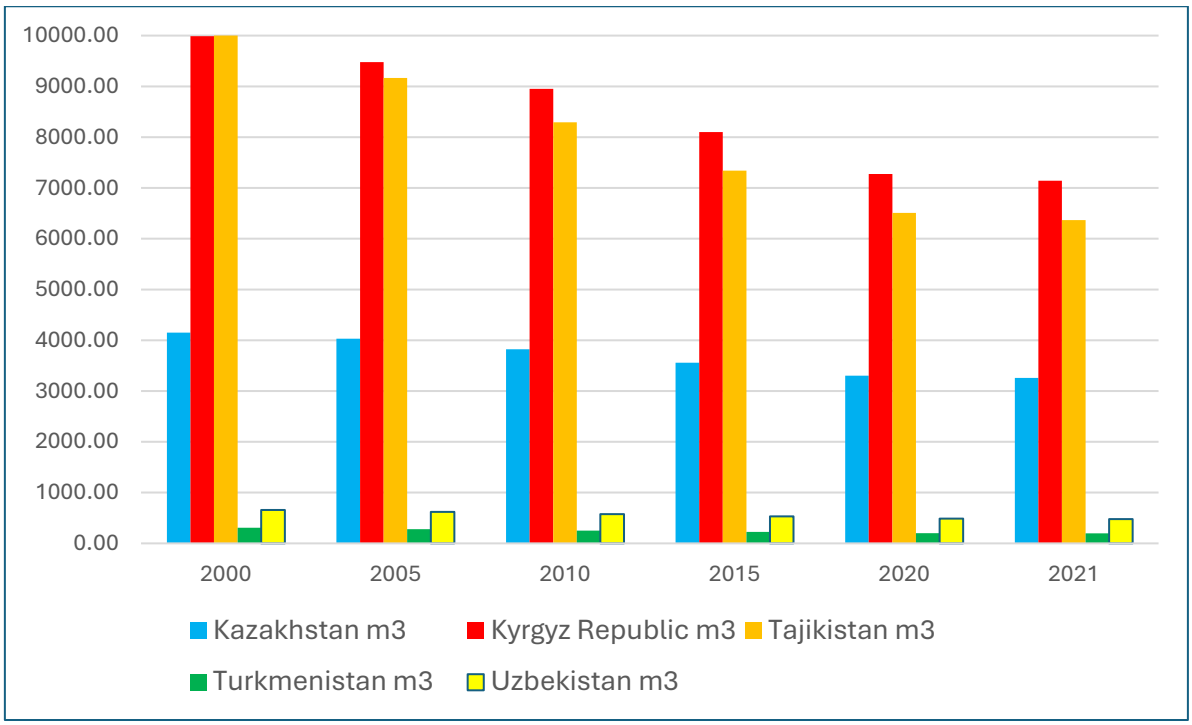
Water losses during transportation showing a gradual increase over time, potentially indicating aging infrastructure or expanded water distribution networks and have fluctuated between 1,500-3,800 million m^3per year, accounting for 7-15% of total water abstracted.

The total population connected to centralized water supply shows a steady increase from about 13.5 million in 2010 to nearly 19 million in 2022. There's a notable dip around 2015-2016, followed by accelerated growth. Urban population demonstrates consistent growth, rising from approximately 7.5 million in 2010 to about 12 million in 2022. This trend indicates significant urbanization over the period. Rural population data only appears from 2015 onwards, starting at around 5.5 million and gradually increasing to about 7 million by 2022.

Overall, there has been an improvement in centralized water supply access across all population segments. Urbanization is evident, with urban population growth outpacing rural growth. The widening gap between total and urban populations suggests improved rural coverage. However, the absence of rural data before 2015 limits historical comparisons. The rate of improvement appears to have accelerated post-2016 for all categories.

Household water consumption per capita has remained relatively stable around 29-31 m^3 per year recently after declining in the early 2000s. The total household consumption has steadily increased, driven by population growth and infrastructure development.

Graph 7: Renewable internal freshwater resources per capita (cubic meters)



Source: https://data.worldbank.org/indicator/ER.H2O.INTR.PC?view=chart

There's a significant lack of data for sewerage services after 2017 and for wastewater treatment before 2018, which limits ability to analyse trends across the entire period. Despite data gaps in other areas, the urban population shows consistent growth throughout the entire period. Until 2017, there was a positive trend in sewerage access, closely following urban population growth. The appearance of wastewater treatment data from 2018 suggests the beginning of data collection in this area. The sudden disappearance of sewerage data and appearance of wastewater treatment data might indicate changes in data collection or reporting methodologies too.

The water supply trends in rural areas in Kazakhstan are available from 2001 to 2023. Data on population with access to sewerage services, which are only available from 2015 to 2018, shows a slight increase from about 0.8 million to 0.9 million people. Limited data on sewerage services and wastewater treatment makes it difficult to assess long-term trends in rural sanitation. The substantial gap between the total rural population and those with access to sewerage services or wastewater treatment suggests significant challenges in rural sanitation infrastructure.

While some Oblasts like East Kazakhstan and Zhetysu maintain high standards of wastewater treatment, others, particularly Almaty and Turkestan, face considerable challenges. The following analysis highlights the need for targeted interventions and possibly a review of wastewater management policies and practices, especially in underperforming regions.

There has been a noticeable increase in total environmental protection costs in Kazakhstan over the period, rising from approximately 257,533,290 thousand KZT in 2015 to nearly 444,514,269 thousand KZT in 2022.

Costs for wastewater treatment have steadily increased, reflecting a growing focus on water management issues. Starting at 61,406,331 thousand KZT in 2015, these costs have gradually climbed to 113,096,310 thousand KZT by 2022. This consistent rise indicates ongoing investments in wastewater infrastructure and technology.

Similarly, costs for the protection and rehabilitation of soil, groundwater, and surface water have shown a gradual upward trend, though at a slower pace compared to wastewater treatment. These costs increased from 21,446,645 thousand KZT in 2015 to 23,695,591 thousand KZT in 2022, suggesting a growing but still developing focus on soil and water rehabilitation efforts.

The overall increase in environmental protection costs indicates Kazakhstan's commitment to addressing environmental issues, likely driven by both internal policy shifts and international obligations. The sharper rise in wastewater treatment costs suggests a prioritization of water-related environmental challenges, such as pollution and scarcity. Investment trends reflect a strategic focus on sustainability, potentially influenced by economic growth, regulatory changes, or international partnerships. Fluctuations in total costs may also indicate adjustments to economic conditions or policy shifts.

From 2003 to 2008, investments increased slowly but steadily from near zero to about 5,000 units (presumably in millions of KZT). Between 2009 and 2013, investments grew more rapidly, peaking at about 27,500 units in 2013. After that year, the investment pattern became more volatile, with sharp increases and decreases. From 2017 to 2020, there was a dramatic rise in investments, reaching around 42,000 units in both 2020 and 2021. However, in 2022, investments significantly dropped to about 27,000 units.

This investment pattern reflects Kazakhstan's efforts to modernize and improve its water and waste management systems, with substantial capital allocated to these sectors, particularly in recent years.

In Kyrgyzstan, over the period under review from 2000 to 2023, there are fluctuations in the volumes of water withdrawal from water bodies, use and losses. The volume of water withdrawal may depend on climatic conditions, the characteristics of economic activity, as well as the state of water resources in specific regions. More informative are the indicators per unit of GDP and per capita.

Water withdrawal per unit of GDP has been decreasing from 2006 to 2023. For example, in 2006, water withdrawal was about 2.81 m^3, while by 2023 it had decreased to 0.63 m^3. This indicates an improvement in the water efficiency of the economy. Water use per unit of GDP has also been decreasing, from 1.59 m^3 in 2006 to 0.48 in 2022, indicating an optimization of water use processes in various industries. This is especially important for economic efficiency and sustainable water use. Water withdrawal per capita also shows a decreasing trend. In 2000, this figure was about 1,646 m,^{3} while by 2023 it had decreased to 1,265 m^3. This is due to both increased water efficiency and potential improvements in water supply infrastructure and the introduction of technologies that reduce water losses.

The main consumer of water resources in the Kyrgyz Republic is agriculture (irrigation), which is confirmed by stable and high volumes of water consumption. More than 94% of water is used for irrigation, 3.4% for domestic and drinking needs and only 1.4% for industrial needs. The total volume of water use for irrigation in the country fluctuated from 4.135 km^3 in 2005 to 5.516 km^3 in 2022. The most significant use of water for irrigation is observed in the Chui Oblast and reaches its maximum in 2022 – 1.437 km.^{3} In the Osh and Jalal-Abad Oblasts, water use for irrigation during the analyzed period also exceeds consumption in other regions.

The lowest use of water for irrigation is in the Issyk-Kul and Naryn Oblasts, due to several factors, including geography, climate, and limited availability of irrigable land. The Issyk-Kul and Naryn Oblasts are located in mountainous areas. Mountainous terrain makes it difficult to create large irrigated areas, as it requires the construction of complex infrastructure for water delivery, such as

canals and reservoirs. Mountainous areas have a colder climate, a short growing season, and high levels of precipitation in the form of snow. This reduces the need for irrigation compared to drier regions such as the Chui and Jalal-Abad Oblasts. These regions have less suitable land for agricultural use, especially for growing crops that require extensive irrigation. For example, the lowlands of the Chui Oblast have much more such land. In Naryn Oblast, much of the agriculture is focused on livestock and pasture use, which require much less water for irrigation than cropping. Variations in water use may be related to climate change, water supply policies, and changes in agricultural needs.

Water losses per capita remain significant, although they vary from year to year. For example, in 2006, water losses were about 342 m^3 per capita, and by 2023 - about 345 m^3. This indicates the presence of problems in the water supply infrastructure, such as leaks and deterioration of water supply systems. Reducing water losses requires the modernization of water supply networks and the use of modern leakage control methods.

Between 2000 and 2010, investments in water conservation and rational use, as well as wastewater treatment, were relatively low. For example, in 2000, investments amounted to 7.4 million soms and remained at a similar level until 2005. A sharp increase began in 2009, when investments amounted to 67.2 million soms, and continued to grow to 420.4 million soms in 2012. In 2013-2014, investment volumes remained moderate (10.8 and 16.9 million soms, respectively), but then in 2017 there was a sharp jump to 2,998.5 million soms. This may indicate the launch of large-scale water conservation projects or the modernization of treatment facilities. The most significant increase was observed in 2018, when investments amounted to 4,417.4 million soms. This may be due to the need to adapt to new environmental standards or the implementation of long-term water protection programs.

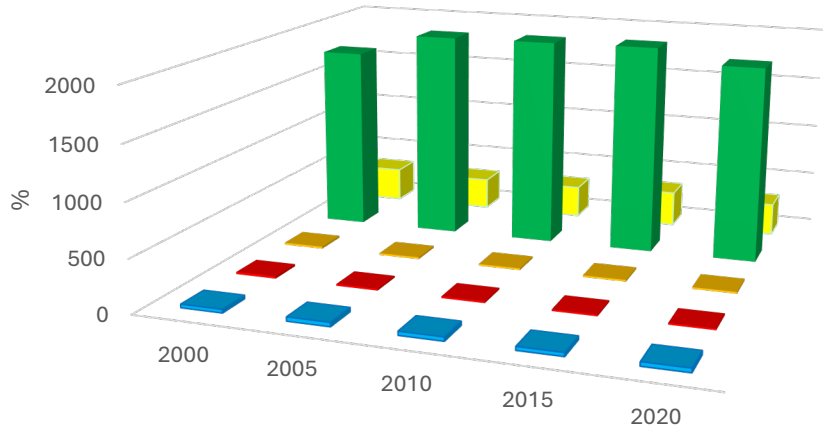
Significant investments are observed in 2021 and 2022 (420.1 million and 535.1 million soms, respectively), which may indicate a continuation of the trend of improving environmental infrastructure. In some years, such as 2015 (17.2 million soms) and 2019 (140 million soms), there is a significant decrease in investments compared to previous periods. This may indicate the completion of certain projects or changes in state environmental policy. Significant fluctuations in investments indicate that the increase in funding is likely due to the implementation of individual large projects aimed at improving water treatment systems and rational use of water resources. The period from 2017 to 2022 stands out in particular, when the volume of investments reached its maximum values. This may be due to the strengthening of environmental safety requirements and the introduction of new technologies. Despite positive trends in individual years, the overall instability of investments may indicate the need for a more sustainable and long-term strategy for financing environmental initiatives.

In Kyrgyzstan, population access to safe drinking water sources has fluctuated. In 2009, 90.4% of the population had access, in 2022 this figure increased to 96.3%. In the ChuiOblast, this figure is 100%. The indicator is also high in the Talas, Issyk-Kul and Naryn Oblasts: 99.6%, 98.2% and 98%, respectively. The lowest indicator values are in the Batken Oblast - 88.3%. In general, the proportion of the population with access to safe drinking water is increasing, which indicates positive changes in water supply.

The total cost of wastewater treatment throughout the country has increased significantly from 225.5 million soms in 2008 to 819.5 million soms in 2022. Overall, there has been an overall increase in the share of the population with sustainable access to sanitation in Kyrgyzstan: from 25.2% in 2009 to 42.6% in 2022. The largest increase in access to sanitation was observed in the Issyk-Kul Oblast, where the share increased from 9.7% in 2009 to 82.0% in 2022. Naryn Oblast also saw a significant increase in the indicator, from 5.9% in 2009 to 29.8% in 2022. In some

Oblasts, such as Osh Oblast, the indicators remain extremely low. Indicators also remain low in Batken, Jalal-Abad and Talas Oblastns, below 10%. High access rates are observed in Chui and Issyk-Kul rOblasts, Bishkek city and Osh city, especially in Bishkek, where the percentage is consistently high (e.g. 97.4% in 2022).

Graph 8: Annual freshwater withdrawals, total (% of internal resources)



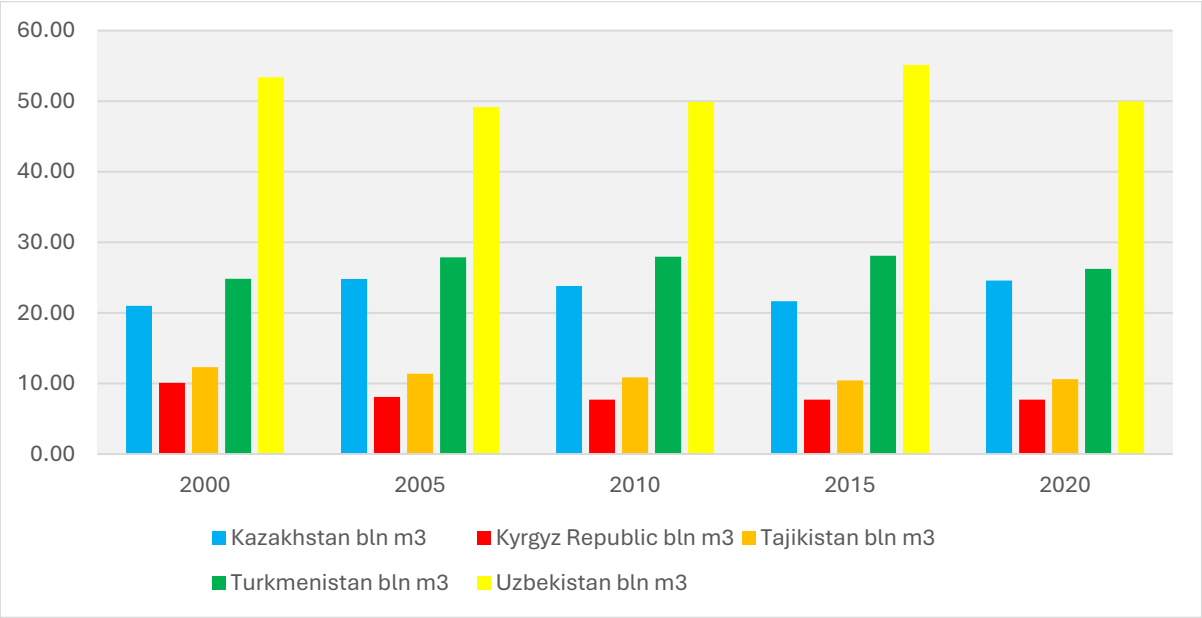
	2000	2005	2010	2015	2020
Kazakhstan %	33	39	37	34	38
Kyrgyz Republic %	21	17	16	16	16
Tajikistan %	19	18	17	16	17
Turkmenistan %	1767	1983	1990	1999	1868
Uzbekistan %	327	301	305	337	306

Source: https://data.worldbank.org/indicator/ER.H2O.FWTL.ZS?locations=KZ-KG-UZ-TJ-TM&view=chart

Overall, there has been an overall increase in the share of the population with sustainable access to sanitation in Kyrgyzstan: from 25.2% in 2009 to 42.6% in 2022. The largest increase in access to sanitation was observed in the Issyk-Kul region, where the share increased from 9.7% in 2009 to 82.0% in 2022. Naryn Oblast also saw a significant increase in the indicator, from 5.9% in 2009 to 29.8% in 2022. In some regions, such as Osh Oblast, the indicators remain extremely low. Indicators also remain low in Batken, Jalal-Abad and Talas Oblasts, below 10%. High access rates are observed in Chui and Issyk-Kul Oblasts, Bishkek city and Osh city, especially in Bishkek, where the percentage is consistently high (e.g. 97.4% in 2022). Increased access to sanitation in some regions indicates improvements in infrastructure and services.

However, low access rates in some regions indicate the need for increased investment and attention to sanitation infrastructure in these regions. Wastewater throughput through sewer systems has fluctuated slightly across the country as a whole. From 2009 to 2015, there was a downward trend in the indicator, from 158.6 million m^3 in 2008 to 111.4 million m^3 in 2015. Since 2016, the indicator has remained relatively stable, fluctuating between 122 million m^3 and 131 million m^3 in regions. There are fluctuations and unstable rates of improvement.

Graph 9: Annual freshwater withdrawals, total (billion cubic meters)



Source *ttps://data.worldbank.org/indicator/ER.H2O.FWTL.K3?view=char*

In Tajikistan, about 64 km³ of surface water is formed annually, including 1.1 km³ in the Syr Darya River basin and 62.9 km³ in the Amu Darya River basin. The total area of glaciation is 11,146 km², which is 8% of the country's territory. The total ice reserve in glaciers is about 845 km³. The volume of water resources in 1,300 natural lakes is 46.3 km³, of which 20 km³ are fresh. In total, the country has 11 reservoirs with a total volume of 15.3 km³ and a useful volume of about 7.63 km³. In 2023, the specific indicators of formed surface waters per capita are about 6,400 m³ / person / year, which is significantly higher than the figure of 1,700 m³ / person / year, which is considered sufficient per capita.

At the same time, it should be borne in mind that the limit allocated to Tajikistan on the basis of regional agreements is only about 1400 m³/person/year, which is naturally a limiting factor for sufficient water use in the country. Potential reserves of underground waters are 18.7 km³/year, while the operational ones are estimated at 2.8 km³/year. More than 200 mineral water sources are registered on the territory of the republic. In the regions of development of Paleozoic deposits and igneous rocks, 86 natural outlets of carbonic and nitrogen waters have been noted, about 70 of them are located in the Gorno-Badakhshan Autonomous Oblast. The highest-flow sources - Obigarm and Khodja-Obigarm are located within the Gissar Range. In total, about 100 sources and deposits of geothermal waters have been identified there.

Water resources in Tajikistan are used for drinking water supply, agriculture, hydropower, industry, fisheries, recreation and the environment. The priority type of water use is drinking water supply. According to the Schemes for the integrated use and protection of water resources of the Amu Darya and Syr Darya river basins, recognized by regional agreements, a limit of 14.3 km³/year has been set for Tajikistan for water withdrawal. Provision of drinking water and sanitation is the most important part of the water sector, and its development is a top priority for the Government of the Republic of Tajikistan.

Currently, about 41% of the country's population has access to drinking water supply systems operated by drinking water supply organizations. Coverage of water supply services in large cities is 95%, in urban-type settlements 48%, but very low in rural areas 22%.

The coverage of sanitation services is currently average in large cities (64%) and very low in urban-type settlements and rural areas (10% and 0.1%, respectively) The drinking water supply and sanitation infrastructure is in a dilapidated state. If prompt comprehensive measures are not taken, there is a risk of disruptions in drinking water supply and sanitation (including non-sewer sanitation services) with negative consequences for public health, in particular during abnormal temperature conditions and natural disasters. In cities and towns, 32% of the existing infrastructure is unusable, while in rural areas this figure is about 60%.

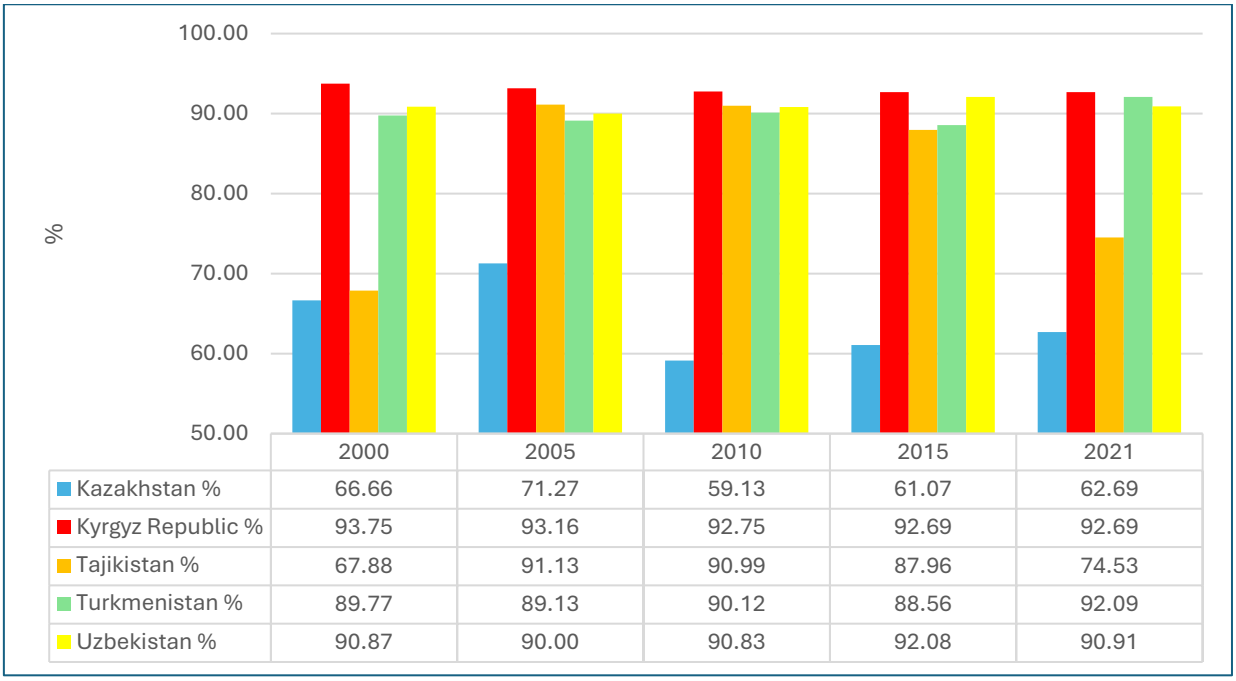
Water losses in urban water supply networks in some cases amount to about 60%, and in medium and small ones - about 20%. The current level of investment in this sector is insufficient and does not correspond to the rate of population growth and economic development. Tariffs for water supply and sanitation services and funds allocated from the budget are insufficient for the modernization and development of the water supply sector, and do not fully cover the costs associated with the operation and maintenance of existing facilities.

The area of land suitable for irrigation in the country is 1.573 million hectares. As of January 1, 2023, the area of irrigated land in the country amounted to more than 763 thousand hectares, or about 49% of the area of land suitable for irrigation. Lands of machine (pump) irrigation make up 38% of the total area of irrigated land in the country. As of 2023, the specific area of irrigated land per capita in the country is about 0.075 hectares / person, which is significantly less than in other Central Asian countries.

The main problems of the land reclamation and irrigation sector are the deterioration of irrigation and drainage systems, insufficient funding, frequent accidents at pumping stations, shortage of machinery and equipment, deterioration of the melioration state and erosion of irrigated lands, and, as a result, the withdrawal of land from agricultural circulation and the ineffectiveness of water user associations.

Along with this, the main factors influencing the deterioration of the situation in this strategically important sector of the country are: lack of proper water accounting, low efficiency of irrigation systems due to large water losses, low productivity of water use, shortage of professional workers, tariffs that do not cover the actual costs of maintaining and operating irrigation and drainage systems, an ineffective system of collecting payments for irrigation and drainage services, insufficient capital investment, lack of modernization of old irrigation and drainage systems. Point and area pollution of surface and groundwater by the agro-industrial complex, untreated industrial and municipal wastewater, discarded plastic, leaks from landfills, the use of chemicals such as fertilizers, pesticides and antibiotics, as well as cattle faeces are problems common to many countries, including Tajikistan. Existing man-made risks, with significant damage to water resources, also require their prevention and reduction of the level of negative impact.

Graph 10: Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)



	2000	2005	2010	2015	2021
Kazakhstan %	66.66	71.27	59.13	61.07	62.69
Kyrgyz Republic %	93.75	93.16	92.75	92.69	92.69
Tajikistan %	67.88	91.13	90.99	87.96	74.53
Turkmenistan %	89.77	89.13	90.12	88.56	92.09
Uzbekistan %	90.87	90.00	90.83	92.08	90.91

Source: Data for Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan - https://data.worldbank.org/indicator/ER.H2O.FWAG.ZS?view=chart, data for Turkmenistan - State Statistics Committee of Turkmenistan

The main water consumer in Tajikistan is agriculture, which consumes 85% of the country's water resources taken from sources. Drinking water supply accounts for 5%, industry - 5%, fisheries - 0.8-1.5% of the total water consumption.

Hydropower, recreation and the environment, in fact, are water users that do not carry out irrevocable consumption of water resources. Tajikistan actually uses only about 20% of the water resources formed on its territory. In fact, the total volume of water consumption in Tajikistan from surface and underground water sources in the late 80s and early 90s amounted to more than 14 km³ / year, and currently about 13 km³ / year. This means that the current actual water consumption per capita reaches 1300 m³/ person / year.

The volume of return water is about 3.5-4.0 km³/year, of which 3.0 km³ is drainage water from irrigated lands, 0.50 k m³ is domestic and industrial wastewater. In Tajikistan, the average volume of water intake per 1 ha of irrigated area is from 8.0 to 13.0 thousand m,³ and losses of irrigation water in irrigation systems reach 40-50%.

The formation of water resources **in Uzbekistan** is intrinsically linked to the Central Asian states, as the majority of the country's rivers hold transboundary significance. The principal rivers, including the Amu Darya, Syr Darya, Naryn, Kora Darya, and Zarafshan, originate from the territories of Tajikistan, Kyrgyzstan, and Afghanistan.

In 2013, the total volume of water in Uzbekistan was recorded at 53,977 km.^{3} This volume remained relatively stable until 2020. During the period from 2013 to 2020, the average total water extraction amounted to 53,822 km.^{3} However, from 2021 to 2023, this figure experienced a significant decline, averaging 44,703 km.^{3}

There have been fluctuations in the amount of water allocated for irrigation from 2013 to 2023. During this period, the average volume of water used for irrigation was 46,037 km,^{3} with the

highest water extraction occurring in 2017. In that year, 53,745 km ^{3} of water were dedicated to irrigation.

However, since 2019, the volume of water used for irrigation has been gradually decreasing. This decline can be attributed to a reduction in the total amount of water received, as well as the adoption of water-saving irrigation methods in agriculture.

From 2013 to 2022, Uzbekistan has averaged a remarkable 51,674 km ^{3} of water allocation annually. The highest volumes of water were consistently recorded during the summer months of June, July, and August, which are critical for agricultural activities in the region. In 2013, these three months accounted for 45% of the total water extracted, while in 2022, this figure slightly increased to 46%.

This seasonal trend underscores the reliance on irrigation during the hot summer months when agricultural demand peaks. The irrigation practices in Uzbekistan are particularly vital, given the country's arid climate and the importance of agriculture to its economy. The significant proportion of water allocated during this period highlights the ongoing challenge of managing water resources effectively to meet both agricultural needs and the growing demands of other sectors, including urban development and industry.

The consistent pattern of high-water extraction in the summer months suggests a need for strategic water management policies that can optimize water usage. This could involve improving irrigation efficiency, promoting water conservation practices, and investing in infrastructure to enhance water storage and distribution systems. Addressing these challenges is crucial for ensuring the sustainability of water resources in Uzbekistan and supporting the country's agricultural productivity in the face of climate change and increasing water scarcity.

However, the area of irrigated land in the country is not that large. In the Navoi Oblast, which has the largest area, there are only 126,000 hectares of irrigated land, accounting for just 2.9% of the total irrigated land of the country.

Meanwhile, the overall production of agricultural products is increasing significantly. For example, in 2010, the total agricultural output amounted to 30,856.7 million soums, while by 2023, this figure had risen to 405,418 million soums. This represents an increase of 13 times from 2010 to 2023.

Agriculture has long been an integral part of Uzbekistan's economy, playing a vital role in its development and sustainability. Historically, the sector has been primarily specialized in cotton production, which has significantly influenced the direction of agricultural practices in the country. This specialization has led to a one-sided development of the agricultural sector, characterized by extensive cultivation practices and high-water consumption.

The Main Issues of the Cryosphere in Central Asia

Identification of the Main Issues

The First Subregional Workshop, held on April 3–4, 2024, brought together over seventy participants from project countries and identified the major cryosphere issues in Central Asia as follows:

- **Insufficient quality, limited accessibility, or absence of cryosphere data**
- **Lack of knowledge about the cryosphere's status and the impact of its degradation due to climate change**
- **Shortage of qualified specialists on cryosphere research, monitoring and management**

The findings were based on interactive discussions including:

- Brainstorming to identify and prioritize key cryosphere management issues in Central Asia and rating them;
- Group work to assess the impact of these key issues;
- Group work to conduct a causal-chain analysis of the main issues.

Given to the large number of participants, the brainstorming session was conducted in three groups, each with at least 20 participants. The groups were formed based on the following criteria:

- Gender balanced;
- Multinational;
- Multisectoral.

The session adhered to key brainstorming principles, ensuring that all participant views were considered without compromise. Participants were asked to frame their suggested issues in a problem-oriented context. As a result, the three groups identified over 80 issues, with approximately 70% (more than 50) being unique across the groups.

After the brainstorming session, participants within each group were asked to individually rate the identified issues using three cards:

- Red card – for issues requiring the most urgent response (3 points)
- Yellow card – for issues of moderate urgency (2 points)
- Green card – for issues to be addressed in the long term (1 point).

The aggregation of scores, followed by a discussion, identified the following key issues:

- Insufficient quality, limited accessibility, or absence of cryosphere data;

- Lack of knowledge about the cryosphere's contribution to water resources, its degradation and the extensive sedimentation of mountain water reservoirs caused by accelerated melting of glaciers, permafrost, and snow;
- Shortage of qualified specialists in cryosphere management;
- Lack of modern methods and technologies for cryosphere observation and monitoring, along with a sparse monitoring network;
- Lack of funding.

After the brainstorming and the ratting exercise, the facilitated discussion concluded that the lack of funding is a fundamental challenge. Addressing this issue long-term development beyond short- and mid-term solutions, ultimately tied to the overall economic growth and prosperity of the countries.

The lack of modern methods and technologies for cryosphere observation and monitoring, along with a sparse monitoring network, was identified as a direct consequence of funding constraints. At the same time, it is also closely linked to three key cryosphere-related issues that can be addressed through actionable and feasible short- and mid-term efforts at both national and subregional levels.

Evidence of the Main Issues

Evidence on:

- **Insufficient quality, limited accessibility, or absence of cryosphere data;**
- **Lack of knowledge about the cryosphere's status and the impact of its degradation due to climate change**

are given in the Annexes 1, 2 and 3.

The **shortage of qualified specialists on cryosphere research, monitoring and management** was selected by participants of the subregional workshop on April 3-4, 2024.

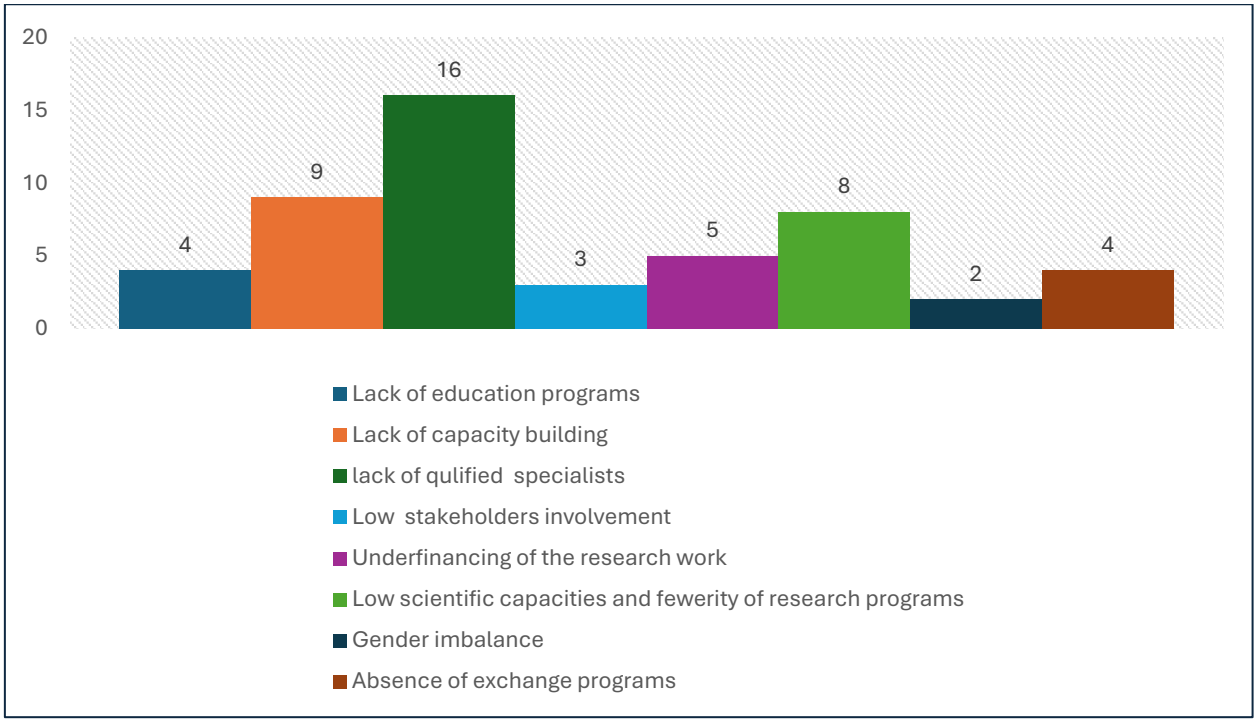
On April 3, 2024, the panel discussion "Science-Policy Dialogue on the Changing Cryosphere in Central Asia" was organized as part of the Workshop.

During the discussion, panellists expressed concerns about the apparent aging of the professional workforce, coupled with a significant lack of young professionals entering the field of glaciology, identifying this issue as a critical challenge for Central Asia.

The panellists called for urgent action to address this issue by fostering an environment conducive to the education and training of the next generation of experts in cryosphere studies. Participants advocated for the establishment of dedicated glaciology programs within at least one university in the region. Such an initiative would not only ensure the continuity of expertise in the field but also serve as a beacon to attract young talent to the study of glaciers and their impact on ecosystems and water resources.

The project started an assessment of needs and gaps of the higher education programmes in the field of cryosphere in Central Asia. The study aims to identify gaps and shortcomings in educational programs relevant to the cryosphere in Central Asia.

Graph 11: Results of the brainstorming on the deficiency of specialists on cryosphere



Source: result of the voting and rating by participants of the 1st Subregional Workshop on development of the DA on the GEF Cryosphere Project in Central Asia, 2-3 April, 2024, Almaty Kazakhstan

Assessment of the Impact of Main Issues

Using the same criteria as the brainstorming exercise, three balanced groups were formed to assess the impact of key issues. Participants selected the issue they preferred to work on and identified both direct and indirect impacts. The outcomes of the group discussions on the impact assessment of key issues are as follows:

Impact assessment on the insufficient quality, limited accessibility, or absence of cryosphere data

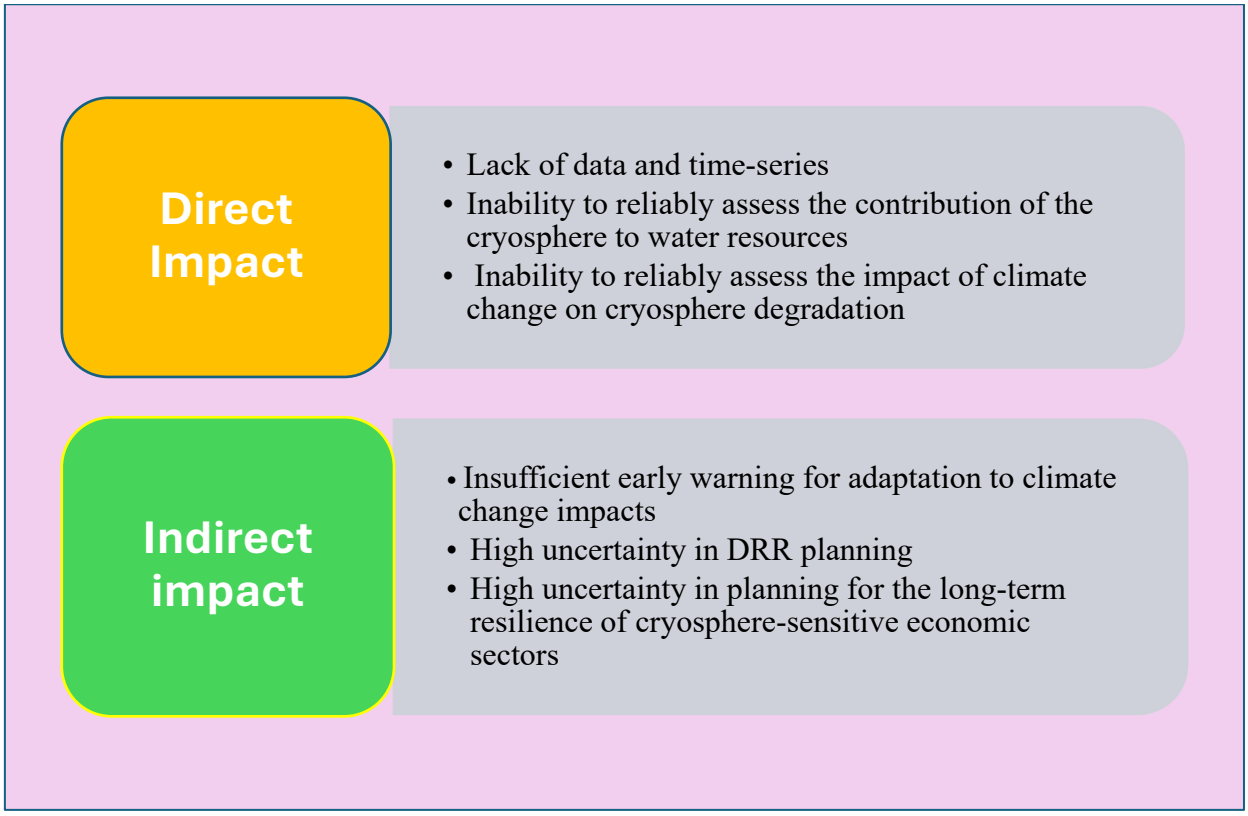
Direct Impact

- Lack of data and time-series
- Inability to reliably assess the contribution of the cryosphere to water resources
- Inability to reliably assess the impact of climate change on cryosphere degradation

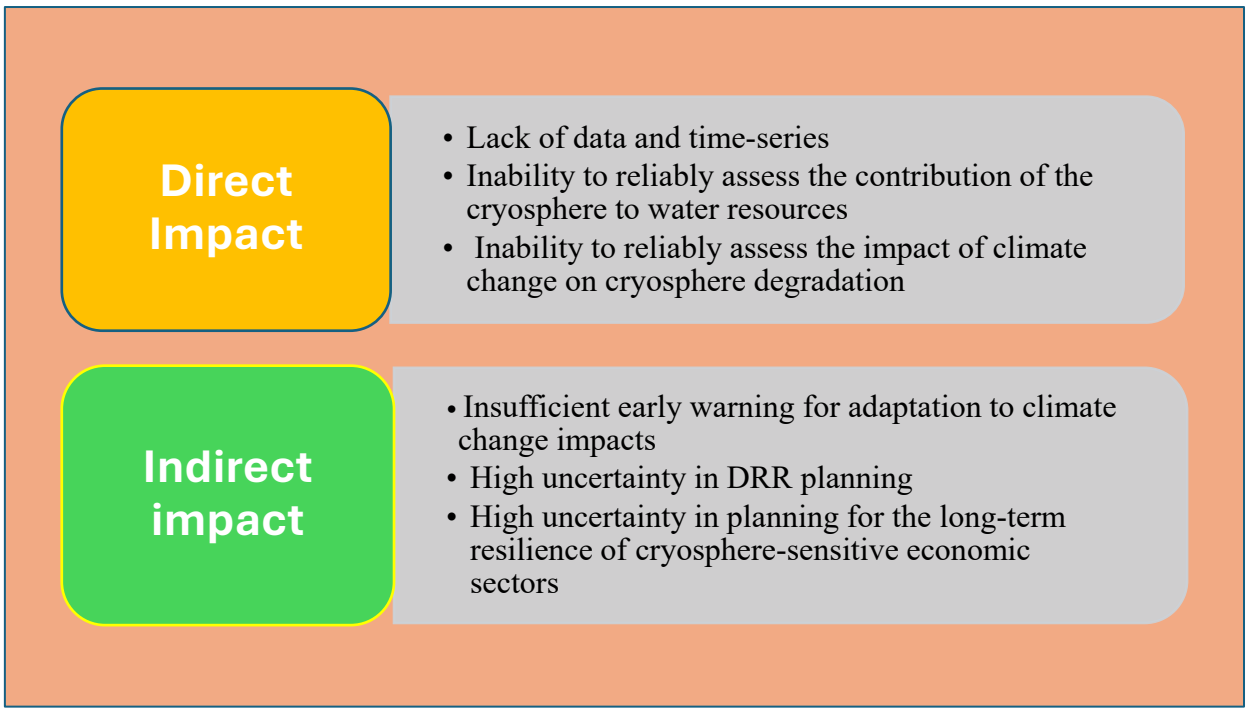
Indirect impact

- Insufficient early warning for adaptation to climate change impacts
- High uncertainty in DRR planning
- High uncertainty in planning for the long-term resilience of cryosphere-sensitive economic sectors

***Impact assessment** on the lack of knowledge on the cryosphere status and the impact of its degradation due to climate change*



***Impact assessment** of the shortage of qualified specialists in cryosphere research, monitoring and management*



Causal-Chain Analysis of the Main Issues

The causal-chain analysis was a participatory exercise started at the first subregional workshop and then continued at the national workshops held in each project country.

Table 6: The matrix of the causal chain of cryosphere's main issues

Main issues	**Insufficient quality, limited accessibility, or absence of the data on cryosphere**	**Lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change**	**Deficiency of qualified specialists on cryosphere research, monitoring and management**
Direct causes	• Lack of data and time-series • Limited ability to assess the contribution of the cryosphere to water resources • Limited ability to assess the impact of climate change on cryosphere degradation	• Underestimated impacts of cryosphere degradation on communities and economies • Limited demand for cryosphere research • Lack of the justifications for cryosphere research, monitoring and management	• Limited capacity to use modern methods of cryosphere research, monitoring and management • Low quality of knowledge products • Limited capacity to assess and justify sector development needs and mobilize resources
Underlying causes	• Uncertain mid and long-term vision for cryosphere science/observations/monitoring • Dependence on donor priorities • Lack of political will to support cryosphere research, monitoring and management • Limited capacity to develop scientific programs, including cryosphere research and observations • Limited scientific capacity to keep up with current requirements and trends in cryosphere research		
Core causes	• Limited share of GDP for cryosphere research, monitoring and management (lack of funding) • Limited set of country commitments/obligations under multilateral or bilateral treaties • Limited requirements of national legislation • Limited and declining institutional capacity of research and education systems • The brain drain		

The country-specific analysis of main issues, their impacts, and causes was conducted during national workshops, yielding the following results:

Kazakhstan:

There is a need in high-quality, timely information on the state of the cryosphere to support scientifically based decision-making. Additionally, improvement and advancements in forecasting and modeling technologies for hazardous processes are essential. Strengthening both domestic and international information exchange is crucial, ensuring equal access to necessary data for organizations, businesses, and the public at all levels. Furthermore, enhancing cross-border knowledge sharing and developing effective warning systems remain key priorities.

Participating experts agree that there is a significant lack of knowledge regarding the condition and projected changes of cryosphere components among planning organizations, local authorities, and communities exposed to snow- and ice-related hazards. Ground and aerial visual surveys of vulnerable areas are insufficient, and the monitoring network remains underdeveloped, including a shortage of automatic weather stations and sensors for tracking water movement and mudflows. Additionally, access to large-scale hazard forecast maps—such as those indicating mudflow and avalanche risks or flood-prone "red line" zones—is not provided to planning organizations, local authorities, or the public, while existing information resources remain inadequate. There is also a pressing need to train specialists, including high-altitude station observers, hydrologists, glaciologists, geophysicists, and cartographers.

The group of civil servants along with Kazhydromet specialists may incorrectly percept that the **insufficient quality, limited accessibility, or absence of the data on cryosphere is a** problem to a minor extent, because the quality of data is affected by the human factor. Solution: To improve the quality of data, it is necessary to automate the process of collecting, processing, checking and analyzing data. However, it is important to note that Kazhydromet's open data alone may not be sufficient for accurate forecasting of hazards, assessment of climate risks, and development of emergency situations related to snow and ice. Specialized observations and measurements are necessary, including solar radiation data, which has been removed from the list of observed variables. The lack of data is not a problem, because all data is publicly available on the official website, and the data is provided upon request free of charge. Nevertheless, this perception may be flawed, as the available data might not meet the specific requirements for comprehensive cryosphere analysis. The data absence is partially a problem, because not all components of the cryosphere are fully covered. Solution: Increasing the number of observation points for cryosphere components, expanding the staff of specialists and providing them with appropriate equipment and supplies, as well as reintroducing crucial measurements such as solar radiation data.

They also percept that the **lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change** is a problem due to the lack of complete data on all components of the cryosphere in its own and transboundary regions. Weak interaction of structures/government bodies in terms of exchanging information on the state of the cryosphere. Low awareness of the state of the cryosphere is a problem for assessing and analyzing the impact of climate change on its degradation. The solution lies in popularizing the coverage of information on the cryosphere.

On **deficiency of qualified specialists on cryosphere research, monitoring and management** they percept there is an acute problem with qualified specialists in the field of glaciology, mudflow studies, and specialists in both remote sensing and those conducting observations of cryosphere components (hydrology technicians). Solution: Opening of the listed specialties in universities. Creation of an IPC for advanced training of engineering staff and technical specialties.

Kyrgyzstan:

There is a lack of systematic glacier research, leading to insufficient up-to-date information. The absence on unified database on the state of the cryosphere further complicates data accessibility and analysis. Additionally, rapid climate change accelerates glacier retreat, rendering existing data quickly outdated.

Existing research often fails to address full scope of cryosphere-related challenges. The lack of systematic data on the state of the cryosphere hinders effective monitoring of changes. Furthermore, most citizens are unaware how cryosphere changes impact water resources, agriculture, and ecosystems, leading to low public engagement with climate change issues. Addressing cryosphere challenges requires interdisciplinary expertise in geography, ecology, and hydrology; however, specialists tend to be highly specialized, limiting knowledge exchange across fields.

Higher education institutions in Kyrgyzstan do not offer courses or programs focused on the cryosphere. Existing scientific and research institutions are often underequipped and lack the necessary resources to attract and retain qualified personnel. Cryosphere research requires the integration of knowledge from various fields: geography, meteorology, ecology and geology. The shortage of specialists in these fields makes it difficult to comprehensively understand the processes occurring in the cryosphere.

Key stakeholders percept that the quality, limited availability or absence of data on the cryosphere impact on:

- Decision makers - lack of accessible information on the impact of the cryosphere on the life and activities of the population, the economy;
- Insufficient material, technical, personnel capacities in government agencies dealing with cryosphere issues;
- Production of customer-oriented products.

Lack of knowledge and awareness of the state of the cryosphere and the impact of climate change on its degradation impact on:

- Insufficient public policy mechanisms;
- Insufficient demand for the state of the cryosphere from government agencies;
- Insufficient understanding of the relationship between climate change, the state of the cryosphere, the economy and the social sphere.

They also percept that it is necessary to develop and implement a program to raise awareness of all target groups.

The shortage of qualified specialists in the field of research, observation and management related to the cryosphere result in imperfect personnel training system, weak labor motivation to build up qualifications, develop science and practice. There is a need to improve the wage system and social package.

Tajikistan:

The inadequate quality, limited availability or absence of cryosphere data poses a significant challenge to conducting high-quality research, directly impacting decision-making and

implementation. Strengthening legislation and regulations is essential to enhancing data accessibility. Improved access to information will, in turn, enhance the quality of existing data, knowledge, and forecasts, supporting more informed decision-making.

Awareness-raising and informational activities, such as courses and training, on climate change and the cryosphere remain insufficient among the general public, government agencies, and universities.

Additionally, there is a lack of specialized education in cryosphere studies within higher education institutions, a shortage of educational materials for training professionals, and low motivation among young people to pursue careers in this field.

Key stakeholders e.g. civil servants and specialists of the Agency of Hydrometeorology percept that the **insufficient quality, limited accessibility, or absence of the data on cryosphere** is one of the main problems for the implementation of short-term and long-term programs of each Mministry and agency. The problem negatively affects all sectors of the economy (priority and cross-sectoral aspects of the country NAS - 2030 and NDC). Regulation of the powers of the relevant bodies, to avoid duplication of results. Improving the quality of monitoring, creating the possibility of digitizing existing archival data.

The lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change is a problem and it requires conducting awareness programs among the population, government agencies and development partners. Improving the culture of nature management. Strengthening coordination between government agencies and stakeholders.

The deficiency of qualified specialists on cryosphere research, monitoring and management is a problem and requires increasing the capacity of the authorized body. Improving qualifications and training personnel. Development of methodological manuals corresponding to international standards.

Turkmenistan:

The lack of knowledge and awareness of the state of the cryosphere and the impact of climate change on its degradation is a key problem. There is a need for bilateral agreements with the Islamic Republics of Afghanistan and Iran on the exchange of hydrometeorological information to compile reliable long-term forecasts of water content and the hydrological regime of rivers, the timing of floods and the locations of mudflows.

Floods and mudflows often form in the mountain basins of small rivers flowing down the southwestern, northwestern and northeastern slopes along the entire length of the Kopetdag and, less frequently, from the slopes of the Greater and Lesser Balkan Mountains. The Murgap, Tedzhen, Firyuzinka, Sumbar, Etrek, Sekizyap rivers are characterized by the greatest flood and mudflow activity.

Often, mudflows are formed on a transboundary basis, originating in the territory of neighboring countries, and their negative consequences manifest themselves in the territory of Turkmenistan. Floods and mudflows are one of the most dangerous (in terms of economic losses) weather phenomena in Turkmenistan. Forecasting mudflow and flood hazards is an important service for warning and alerting all interested enterprises, provided by TurkmenHydromet.

Turkmenistan considers as its priorities to:

- Increase the assessment of the impact of the cryosphere on the hydrological regime of water resources;
- Improve the quality and demand for research; reduce the risks of emergency situations;
- Improve the development of territories and economic sectors, increasing the efficiency of investment;
- Improve knowledge of the impact of cryosphere degradation on the economy and population;
- Introduce modern technologies for studying and assessing;
- Preventing problems in the future;
- Expand cooperation between countries and solve the problem of inability to use new technologies for cryosphere research;
- Deal with lack of education and training of relevant specialists;
- Expand training programs in universities;
- Involve communities in improving the culture of nature management.

Uzbekistan:

Insufficient knowledge and awareness in Uzbekistan and Central Asia result in the neglect of the cryosphere's critical role in regional water security and ecosystems. Limited information and reliance on international donors hinder the development of long-term national strategies for climate change adaptation and cryosphere resource management. The lack of a strong justification for regular research and monitoring of cryosphere degradation further impedes effective water and environmental resource management.

While universities in Uzbekistan train hydrologists and meteorologists, there is a shortage of specialists with expertise in GIS, remote sensing, and modeling for cryosphere research. Insufficient knowledge and experience in applying advanced technologies limit the quality of monitoring and management of cryosphere resources. The lack of professionals skilled in modern research methods slows down effective adaptation and management efforts in cryosphere regions.

Key stakeholders e.g. civil servants and UzHydromet percept that the lack of data on the state of the cryosphere is a key problem. This affects the integration of cryosphere information into strategic water resources and ecosystem planning, making it difficult to develop effective policies to protect the cryosphere and minimize its degradation. The dependence of a stable water supply on the state of the cryosphere is a key problem. This affects their ability to obtain reliable information on glaciers and snow cover, which is necessary to optimize production processes and ensure sustainable resource use.

Science and the education system see the lack/insufficiency of the cryosphere in a separate scientific network as a key problem. This affects the implementation of practical work, such as the creation of a system of continuous staffing and the development of research bases in mountain ranges.

Local communities consider the impact of climate change on the cryosphere to be a key issue. It affects pastures and water availability, which can lead to deterioration of livelihoods and increased vulnerability to natural disasters such as floods and droughts.

The private sector recognizes that the lack of qualified specialists in the fields of hydrometeorology and avalanche control is a key issue. This affects the safety of ski resorts, as the lack of accurate snow cover and avalanche forecast data makes it difficult to plan resorts and can threaten the safety of tourists.

Youth, NGOs and women face limited access to scientific work due to family responsibilities and cultural expectations, which is a key issue. This affects their awareness of the cryosphere and climate change, despite the importance of these topics in their daily lives. Limited data and funding are key challenges for young people, despite their potential to study the cryosphere through access to modern technology and internet resources. This impacts their participation in research and their ability to contribute to solving cryosphere problems.

Conclusions

The cryosphere in the Tien Shan and Pamir is projected to undergo significant changes in the 21st century due to rising temperatures and altered precipitation patterns associated with climate change. Numerous studies indicate a strong decrease in the extent and duration of snow cover in the coming decades, especially at lower elevations, with major implications for regional hydrology and ecosystems. Human-induced climate change will increase the severity of cryosphere changes, threatening downstream communities in Central Asia through shifts in hydrological regimes, unpredictable feedback and increased hazard potential.

The transboundary nature of water resources in Central Asia highlights the need for cohesive and coordinated efforts among the countries of the region. Each country faces unique challenges and relies on diverse water sources, making collaborative cryosphere monitoring and data sharing critical to understanding and addressing dynamic changes in the region's cryosphere.

Given the diverse water demand of Central Asian countries, a collaborative approach to cryosphere monitoring is essential. The establishment of a unified cryosphere monitoring network, building on existing strategies such as the Global Terrestrial Network for Glaciers and the Global Terrestrial Network for Permafrost, can facilitate the exchange of expertise and resources. Jointly managed observing stations across national boundaries would improve the accuracy and reliability of data and provide a comprehensive understanding of cryosphere dynamics across the region.

To ensure the effectiveness of transboundary cooperation, there must be a commitment to open data exchange and standardisation of measurement protocols. A centralised data repository accessible to all participating countries could streamline the exchange of information. Standardised measurement techniques and reporting formats will improve the comparability of data, enabling a more accurate assessment of regional trends and promoting a common understanding of the state of the cryosphere.

Recognising the heterogeneity of water-related challenges in each country, transboundary cooperation should include targeted initiatives to address specific issues. For example, Kazakhstan, characterised by large lakes and rivers, faces uneven water distribution and external dependencies.[194] Kyrgyzstan relies heavily on cryosphere resources for irrigation,[195] while Uzbekistan uses snow and glacier melt from the Pamir and Tien Shan mountains to almost 90% for irrigation.[196] Turkmenistan faces water scarcity problems that are exacerbated by climate change, with a high dependence on the Amu Darya .[197] Tajikistan, a major contributor to the Amu Darya, is predominantly dependent on its extensive cryosphere .[198]

[194] Karatayev et al., 2017
[195] Hill et al., 2017; Saks et al., 2022; FAO, 2016
[196] Zhumaeva, 2021
[197] Zonn, 2012
[198] Dukhovny et al., 2014

Transboundary cooperation is crucial for disaster preparedness, especially in regions prone to avalanches and other cryosphere-related hazards. Establishing and maintaining avalanche monitoring stations and incorporating modern technologies such as UAV surveys and remote sensing will strengthen early warning systems. This shared infrastructure would improve the coordination of disaster response, minimising the impact on communities across borders.

The interconnectedness of Central Asian countries through shared transboundary water resources requires a holistic approach to water security. Joint efforts can contribute to sustainable water management practices that ensure the conservation of ecosystems and biodiversity. This is particularly important for countries such as Tajikistan, which rely heavily on its extensive cryosphere for water resources, and to prevent further water quality degradation in shared river basins.

Effective management of Central Asia''s water resources requires a unified approach that considers the specific challenges faced by each country. Transboundary cooperation is important to mitigate the impact of water-related challenges at the national level on agriculture, energy, industry and the overall well-being of the population, and to ensure water security and environmental sustainability in Central Asia.

Building capacity and disseminating knowledge at different levels, establishing long-term and sustainable cryosphere monitoring networks, improving water management and supporting sustainable regional cooperation in the water sector can make the processes and outcomes of climate risk management in Central Asia more effective. The need to adapt to a changing climate and ultimately mitigate climate change requires more accurate information on the interactions between the atmosphere, cryosphere and hydrosphere to improve our understanding of the major biogeochemical cycles and energy flow. Finally, transdisciplinary and transboundary cooperation is needed to translate knowledge into sustainable climate change strategies and policies.

Recommendations

As the developmental scenario building simulation at the 2nd Subregional DA Workshop in use of the climate change scenarios on glaciers and snow cover showed that the future water availability is to be a problem for entire CA due to the impact of the climate change on cryosphere components and water resources as whole.

The exercise showed that by 2070 the population of the CA may grow for more than 150 million people, while the available water resources may increase from 120 billion m^3 current volume up to 135 billion m^3 by 2050 and then drop to 110 billion m^3 by 2070 as an impact of the climate change on the cryosphere. Then it will make the volume of the available water resources less than 700 m^3 per capita. It will require from CA countries of huge investments to the saving of water, structural changes in water use, specifically in irrigated agriculture.

Existing efforts on the monitoring of the cryosphere is to be strengthened and invested in order to provide a needed data flow for better forecasting available water resources and planning the water abstraction and use by all CA countries. Therefore, the addressing of the issue of **insufficient quality, limited accessibility, or absence of the data on cryosphere** is to be an urgent task.

In combination with that the **lack of knowledge on the status of the cryosphere and of the impact of its degradation under the climate change** is to be addressed too. The proper awareness

raising campaign is needed to inform decision making level on the water availability in CA in the short, mid and long-term perspectives and climate change adaptation needs.

The addressing of third issue identified by stakeholders the **deficiency of qualified specialists on cryosphere research, monitoring and management** is also needed to be addressed urgently.

All countries consider addressing above issues to improve the situation with cryosphere monitoring, observation and research but with country specificity and context. And they consider them as of leverage points. By these, the national and joint subregional efforts could be built around setting solutions at the national and subregional levels.

To foster the cooperation on the issues identified the DA recommends setting the dialogue among project countries and establish the national and the subregional technical teams to explore ways of setting the cooperation both at the national and subregional levels and use the below roadmap to foster need actions.

Roadmap for Transitioning from DA to the National and Subregional Actions

The DA process involves review and prioritization of major challenges to improved cryosphere monitoring, observation and research. This document is highly technical and intended to serve as a baseline against which future progress is measured.

In comparison, the National and Subregional Action Programmes (N/SAP) that is developed subsequently to the DA is a politically negotiated document. This document is intended to link national and regional commitments to shared efforts made by the participating countries. These commitments include accepting that the responsibility for the successful development and implementation of the N/SAP rests squarely with the governments of the countries. By negotiating and endorsing the N/SAP at the highest possible levels, the governments are indicating to each other, and to the wider donor and finance community that the agreed actions are indeed priorities for the countries and that there is sufficient political will to enact these through coordinated efforts.

The N/SAP is developed through a series of inputs from key stakeholder groups, who are responsible for representing the institutions and organizations involved in this process. A multi-sectoral N/SAP will always be stronger and more successful for sustainable management of the cryosphere. The N/SAP development is led by an International Consultant, experienced in the development of N/SAPs, in line with GEF IW Best Practices.

The N/SAP development process includes the development of a long-term vision of the basin, articulated clearly and as simply as possible in the “vision statement”. From this vision statement and based on the realistic review of conditions from the DA, a set of “Ecosystem Quality Objectives” (EQOs) are developed. These EQOs generally reflect the issue specific challenges and reflect the specific quality of the ecosystem condition to be improved upon to realize the shared basin vision.

It is recommended that the countries appoint a Regional Technical Task Team (RTTT) to further develop the N/SAP. Specifically, this RTTT will be charged with developing a set of outcomes to meet the EQOs, based on the prioritized recommendations. The RTTT will develop each priority recommendation:

- sets of measurable outcomes for each priority recommendation;

- a time frame of 3-5 years, 5-10 years, and beyond 10 years for each of the outcomes;
- costed estimates needed to realize these outcomes;
- outputs and actions needed to realize these including:
    - capacity building needed;
    - additional training and professional development support;
    - budgeted support for long term sustainability;
    - institutional and regulatory authorizations; and
    - additional needs.

It is critical that this does not become an idealistic unrealistic wish list but instead is a well thought out strategic plan that can provide prioritized, timely, and costed guidance for governments, the private sector, and the donor and finance communities.

Following the RTTT meetings the International N/SAP Consultant should combine all the inputs from the RTTT and combined these into a single resource. This resource may not be fully articulated in the final N/SAP, but it serves as a critical N/SAP implementation guide and will enable the Commission to reference these materials for future N/SAP implementation efforts. The N/SAP is developed from RTTT resource, in line with GEF IW N/SAP development processes.

This includes drafting the N/SAP, to the outcome level with clear reference to activities to undertaken, rationalization and support for these, and anticipated benefits as a result. The work of the RTTT serves as the foundation for this, as the future oriented effort towards reaching substantial benefits from the TDA/SAP Processes.

Following this draft, members of the RTTT generally provide comments to the Draft N/SAP, summarizing their inputs from the RTTT Meeting. Once cleared through the RTTT, and revised as needed, the International N/SAP Consultant will present the SAP to the stakeholders for their comments and reviews. Following this review and including the negotiated edits and changes, the final N/SAP is developed. The final N/SAP is to be endorsed at the Ministerial Level by at least one Ministry for each country. If possible, endorsement by more than one Ministry signals stronger national support for the N/SAP and enhances opportunities for further collaboration and cooperation between the countries.

The endorsed N/SAP functions as a guidance document that signifies strong commitment to the EQOs and basin vision. This serves a very effective resource for harmonization of national, private sector, donor and international finance efforts in the basin and optimizes the use of limited resources to improve the sustainable development across the basin.

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ANNEX 1

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ANNEX 2

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ANNEX 3

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ANNEX 4