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Threat to Central Asia's
Water Resources**

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Glacier Retreat in Tajikistan: A Looming Threat to Central Asia's Water Resources

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Executive summary

With the largest glacier volume in Central Asia, Tajikistan now stands at the epicentre of climate change impacts, facing accelerated glacier retreat, increased water scarcity, and heightened vulnerability to natural disasters. This policy brief examines the impact of climate change on glacier retreat in Tajikistan and Central Asia more broadly, emphasizing the threats to hydrology, ecosystems, and regional stability. It highlights regional vulnerabilities, weak monitoring systems, insufficient data, and the urgent need for adaptation and mitigation strategies to tackle these challenges. The policy brief also explores alarming future climate scenarios, highlighting the severe and dangerous risks associated with continued glacier retreat. It calls for immediate international collaboration on emissions reduction efforts and climate change mitigation to address the underlying drivers of glacier retreat. Additionally, it stresses the importance of sustainable solutions focused on protecting glaciers to ensure long-term environmental and socio-economic resilience.

Keywords: Central Asia, Tajikistan, Glacier retreat, Climate change

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Introduction

Glacier loss has profound and far-reaching consequences for Tajikistan and Central Asia, jeopardizing vital water resources that are crucial for food security, agriculture, ecosystems, public health, and overall regional stability.

Tajikistan's proposal for glacier preservation at the United Nations General Assembly in 2022 reflects the country's deep concern over the rapid retreat of its glaciers, which are crucial for regional water resources and the livelihoods of millions in Central Asia. To combat glacier retreat, Tajikistan has established the Center for Glacier Research, created a glacier monitoring network, published a Catalogue of Glaciers of Tajikistan, and drafted a Law on Glaciers. The country has also conducted 52 scientific expeditions.

In addition, Tajikistan adopted the National Strategy for Adaptation to Climate Change for the period up to 2030 in 2019. The strategy aims to identify the most vulnerable sectors to climate change and develop

a coordinated approach to adapting to challenges, including glacier melt. There are also efforts at the regional level, such as the Climate Adaptation and Mitigation Program for the Aral Sea Basin (CAMP4ASB), which targets climate change vulnerabilities in agriculture, water resources, and ecosystems.

This policy brief examines the impact of climate change on glacier retreat in Tajikistan, focusing on the implications for water security, regional ecosystems, and socio-economic development across Central Asia. It highlights the role of glacier retreat in influencing hydrology, ecology, and regional stability. By enhancing understanding of the risks of glacier retreat, this brief aims to emphasize the urgent need for global cooperation to achieve zero-carbon emissions and combat climate change. It emphasizes improved monitoring systems and collaborative research efforts to address climate change challenges effectively. The brief advocates for sustainable adaptation and mitigation strategies to strengthen resilience against climate change impacts. The policy brief underscores the importance of shared expertise and integrated approaches to promote glacier preservation and ensure long-term environmental sustainability both regionally and globally.

Overview of Glacier Retreat in Tajikistan

Tajikistan is home to 14,509 glaciers covering a total area of 11,146 km², which constitutes approximately eight percent of the country's territory (Gafforzoda et al. 2023). These glaciers are vital components of the hydrological cycle, providing essential water for rivers, ecosystems, and the livelihoods of millions of people throughout Central Asia.

Due to climate change and rising temperatures over recent decades, however, Tajikistan has lost approximately 1,000 glaciers, representing around 30 percent of its total glacier volume (Center for Glacier Research 2022). Since around 1950, 14 percent to 30 percent of the glaciers in the Tien Shan and Pamir mountains of Tajikistan have disappeared. Many smaller glaciers, spanning less than 0.5 km², have already been lost. Currently, the rate of glacier loss in Central Asia is between 0.2 percent and 1 percent annually (UNRCCA 2014).

The last decade was the warmest on record, with intensified temperatures leading to a dramatic acceleration in glacier retreat and ice melt worldwide, and significantly impacting climate patterns and global ecosystems (World Meteorological Organization 2020).

The world's longest glacier outside the Polar Regions, the Fedchenko Glacier, is located in Tajikistan. It is approximately 77 km in length and covers an area of approximately 156 km². However, as seen in Figure 1, it has retreated by approximately 1,400 meters since 1933, highlighting the significant impact of climate change on this critical freshwater resource (NASA Earth Observatory 2012).



Figure 1 Fedchenko Glacier and its retreat process (Source: NASA Observatory 2023; Zoi Environment Network 2011)

Other major glaciers in Tajikistan include Grumm-Grzhimaylo (length 36.7 km, area 142.9 km²), Garamo (length 27.5 km, area 114.6 km²), Jamiyat Geograficheskiy (length 21.5 km, area 82.0 km²), Fortambek (length 20.0 km, area 75.0 km²), Saukdara Kalon (length 25.2 km, area 69.0 km²), Northern Tanimas (length 18.0 km, area 55.0 km²), Gando (length 22.5 km, area 55.0 km²), Sagon (length 7.0 km, area 48.0 km²), Darvaz (length 16.5 km, area 44.0 km²), Maly Tanimasi (length 17.6 km, area 43.5 km²), Rakzovi (length 24.5 km, area 41.2 km²), Bivachi (length 27.8 km, area 37.1 km²), Mazor (length 17.3 km, area 23.0 km²), Yazgulom (length 19.5 km, area 17.0 km²), and Oktyabrskiy (length 16.5 km, area 12.0 km²) among others (RTSU 2024).

This glacial cover is poised to shrink as, based on World Bank data from the multi-model ensemble for the reference period of 1995–2014 (Figure 2), the projected average mean surface air temperature in Tajikistan is expected to rise steadily throughout the 21st century across different scenarios. This increase poses a higher and more dangerous threat to glaciers.

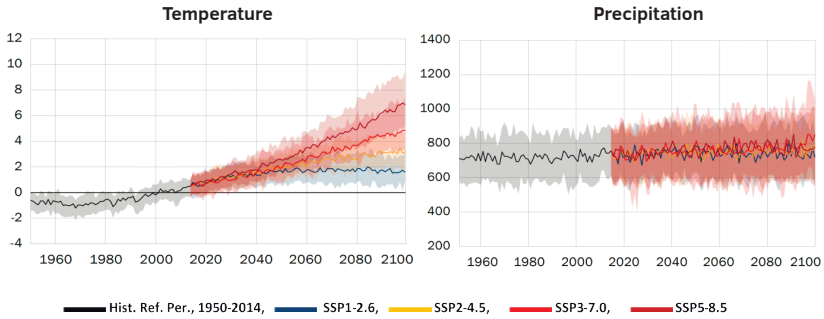


Figure 2 Projected average mean surface air temperature and precipitation Tajikistan; Ref. Period: 1995–2014, Multi Model Ensemble (Source: World Bank 2021)

Multifaceted Implications Arising from Glacier Melt

The melting of glaciers in Central Asia has profound and multifaceted implications for the entire region. In the first stage, glacier melt may temporarily increase river flows and increase natural hazards including the formation of unstable glacial lakes (White et al. 2014; Sharma and Sharma 2008). This raises the risk of glacial lake outburst floods (GLOFs), landslides, rock falls, and flooding as illustrated in Figure 3, which can pose immediate threats to nearby communities and infrastructure. The accelerating retreat of glaciers will likely amplify the frequency and severity of GLOFs in the coming decades (Bajracharya et al. 2008).



Figure 3 *Glaciers of Central Asia (Source: Zoi Environment Network 2011)*

In the mid-term and long-term, glacier melt will have an overall detrimental impact. As glaciers retreat, the supply of water diminishes, leading to water scarcity (Gascoine 2024; Sorg et al. 2014). Disrupted water flows threaten food security, agriculture, ecosystems, public health, and regional stability. Diminished also water resources increase the risk of droughts, negatively affect hydropower generation, and may lead to

significant economic losses. Water scarcity is a significant concern for energy generation, particularly for upstream countries like Tajikistan and Kyrgyzstan, where more than 90 percent of the total energy comes from hydropower (International Energy Agency 2024; Statistical Agency of Tajikistan 2024). Increased water scarcity in the future will fuel social unrest and may lead to conflict over depleting water resources in the region (Sultonov and Pant 2023; Izquierdo et al. 2010).

While localized benefits may arise due to changing conditions, the overall impact of climate change on Central Asia will be largely detrimental. Although it is evident that shrinking glaciers will lead to reduced water availability in both the mid- and long-term, the consequences for regional ecosystems and socio-economic systems remain underexplored.

Tajikistan is a vital source of Central Asia's freshwater supply, contributing more than 50 percent of the region's total water resources through the Amu Darya and Syr Darya river basins (See Figure 4). The water resources in Tajikistan are crucial for the sustenance of neighbouring countries. The country boasts around 1,000 rivers (Rakhimov and Nurmatov 2024), 1,300 lakes, and 8 reservoirs (Krutov et al. 2014). However, with the ongoing retreat of glaciers in Tajikistan, this vital water supply is at risk. Given that Tajikistan holds such a significant share of the region's freshwater, the melting of its glaciers could destabilize the entire Central Asian region.

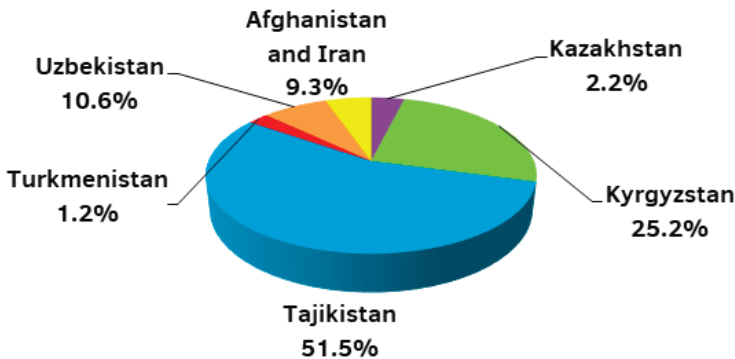


Figure 4 Surface water resources in the Aral Sea basin (mean annual runoff, km³/year) (Source: data from Cawater-info 2019)

Another pressing issue for Central Asia is its heavy dependence on agriculture, which contributes significantly to GDPs across the region. The agricultural sector consumes the majority of the region's water resources, with freshwater withdrawals reaching 91 percent in Uzbekistan, 93 percent in Kyrgyzstan and Turkmenistan, and 75 percent in Tajikistan (See Table 1). Disruptions in water availability in the region could thus result in reduced crop yields, economic losses, and increased food insecurity. Agricultural land also covers a substantial portion of the region. This situation further exacerbates the strain on diminishing water supplies.

Table 1 *Agricultural land, contribution to GDP, and freshwater withdrawals in Central Asia as of 2021 (Source: data from the World Bank)*

Country	Agricultural land (% of land area)	Agriculture contribution to GDP (%)	Annual freshwater withdrawals (billion m ³)	Freshwater Withdrawals for Agriculture (% of Total)
Kazakhstan	79.2	5.0	24.6	63%
Uzbekistan	58.3	24.6	42.5	91%
Tajikistan	35.4	22.4	10.6	75%
Kyrgyzstan	54.0	13.8	7.7	93%
Turkmenistan	72.0	11.0	26.2	93%

Climate Vulnerability and Adaptation Strategies

The Central Asian countries, due to a lack of socio-economic development, challenging terrain, limited resources, and the absence of strong disaster preparedness and management systems, are highly vulnerable to the effects of climate change (Blondin 2019; Lioubimtseva and Henebry 2009). These nations face significant challenges in adapting to environmental shifts, including the accelerated loss of glaciers.

The mountainous regions of Central Asia, particularly in the Pamir Mountains, are highly vulnerable to climate change, including rapid loss of glaciers due to their remote locations, poor infrastructure, and harsh continental climate (Xenarios et al. 2019; Manandhar et al. 2018).

Figure 5 illustrates the increased risk of climate-related hazards in mountainous areas near glaciers, highlighting the vulnerability of these regions to the impacts of glacier retreat.

This is particularly concerning for Tajikistan and Kyrgyzstan, where over 90 percent of their terrain is mountainous and more than 60 percent of their populations reside in rural areas (PROFOR 2024; World Bank 2019) that depend heavily on glacier-fed water resources and are highly exposed to such hazards.



Figure 5 Climate Change Impacts on Central Asia (Source: Zoi Environment Network 2011)

In 2019, Tajikistan adopted the National Strategy for Adaptation to Climate Change for the period up to 2030. This strategy serves as a framework for identifying the country's most vulnerable sectors to climate change and developing a coordinated approach to adapt to these challenges. The strategy prioritizes two key adaptation measures: Integrated Water Resources Management (IWRM) and ecosystem-based adaptations. These measures are classified as “low-cost” or “medium-cost” interventions, combining high adaptive potential and technical feasibility. This makes them practical and impactful in addressing climate change challenges while providing socio-economic and environmental benefits for Tajikistan. The strategy also incorporates a multilevel approach, encompassing national, regional, and local levels (FAO 2019).

Uzbekistan's National Strategy for Adaptation to Climate Change focuses on water management, climate-smart agriculture, renewable energy, and addressing the Aral Sea crisis and its impact (UNDP n.d.). Turkmenistan's National Strategy on Climate Change outlines the country's vision and framework for addressing climate change and its impacts, guiding state policies and actions (UNDP 2021). Kazakhstan started developing its National Adaptation Plan (NAP) in 2019, focusing on agriculture, water resources, and forestry, with support from UNDP and funding from the Green Climate Fund (GCF) (UNDP Kazakhstan 2024). Kyrgyzstan, with support from UNDP and GCF, is developing a National Adaptation Plan (NAP) focusing on key sectors like agriculture, health, and biodiversity. The plan includes creating a climate statistics system for better monitoring of changes (UNDP 2024).

Ongoing programmes by organizations like the Youth Ecological Center (YEC) are making strides in addressing climate change impacts on Tajikistan's rural communities, focusing on women's empowerment and sustainable water and agriculture management. Initiatives such as community water groups and drip irrigation have seen success, particularly in the Kafirnigan River Valley (Global Center on Adaptation 2024). However, these efforts need to be expanded both in scale and scope to reach a wider range of vulnerable communities across the country.

One notable example of climate collaboration among Central Asian countries is the Climate Adaptation and Mitigation Program for the Aral Sea Basin (CAMP4ASB). It focuses on improving climate resilience through shared knowledge, innovative pilot projects, and sustainable development strategies. Funded by the Green Climate Fund and coordinated by the World Bank, the program demonstrates a regional effort to address climate impacts on agriculture, water resources, and vulnerable ecosystems (Green Climate Fund, 2023). Tajikistan and Uzbekistan were initially chosen for the program, likely due to their high vulnerability to climate change impacts and water shortages.

Mitigating Glacier Loss: A Sustainable Development Approach

While Central Asian countries, particularly Tajikistan and Kyrgyzstan, are among the lowest contributors to global carbon emissions, they are disproportionately affected by the impacts of climate change (see Figure 6). Nevertheless, these countries remain committed to and are making considerable efforts toward meeting international obligations aimed at achieving net-zero carbon emissions, despite their relatively minor contribution to global greenhouse gas emissions.

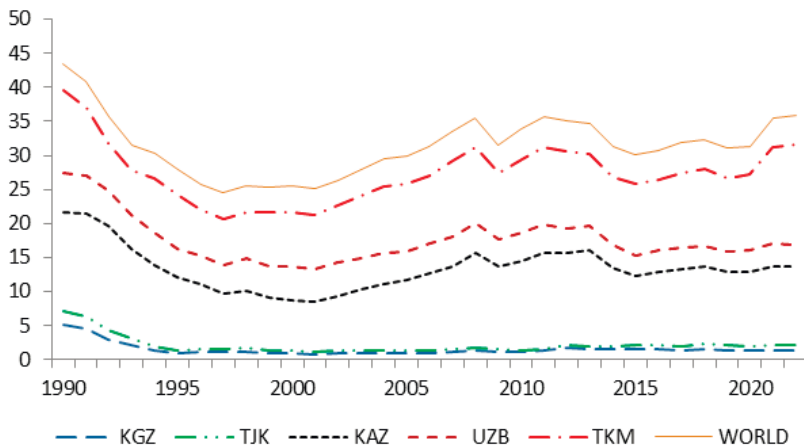


Figure 6 Total CO₂ Emissions in Central Asia and World average (from fuel combustion only) (Source: data from International Energy Agency (IEA) 2023)

Tajikistan's National Development Strategy (2030) and Green Economy Development Strategy (2023–2037) focus on addressing climate change and promoting sustainability in line with the UN Sustainable Development Goals. Key priorities include doubling clean hydro energy, improving energy efficiency, advancing green technologies, expanding renewable energy sources such as solar, wind, and geothermal sources to account for 10 percent of total production by 2030, and facilitating the transition to a green economy (see Figure 7). Tajikistan aims to achieve near net-zero emissions in the power generation and building sectors by 2040, meaning that electricity production and energy use in buildings will result in minimal or no net carbon emissions. The country

further aims to achieve zero emissions by 2050 (World Bank 2022; Government of Tajikistan 2016).

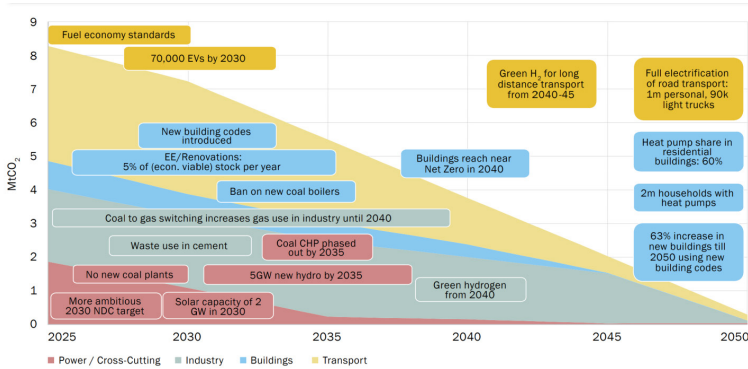


Figure 7 Emission trajectories per sector with corresponding key milestones toward a net zero 2050 energy system, 2025–50 (MtCO₂) (Source: World Bank 2024)

Kazakhstan aims for carbon neutrality by 2060, with 50 percent of electricity generated from renewables or alternatives by 2050. The country also targets a 15 percent reduction in CO₂ emissions from electricity production by 2030 and a 40 percent reduction by 2050 (IEA 2022). The Republic of Uzbekistan has committed to reducing specific greenhouse gas emissions per unit of GDP by 35 percent below 2010 levels by 2030 and achieve carbon neutrality by 2060 (UNDP 2023; World Bank 2022). The Kyrgyz Republic aims to reduce greenhouse gas emissions by 44 percent by 2030 and achieve carbon neutrality by 2050 (IRENA 2022). Turkmenistan's revised Nationally Determined Contribution (NDC) commits to an unconditional 20 percent reduction in emissions by 2030 compared to 2010 levels under a business-as-usual scenario (UNDP 2022). Turkmenistan has recently committed to achieving net-zero greenhouse gas emissions by 2050 (Global Green Growth Institute 2023).

Concern over glacier melt and its severe impacts prompted Tajikistan to initiate global efforts for preservation. This led to the United Nations General Assembly adopting Resolution 77/158 on December 14, 2022, declaring 2025 as the International Year of Glacier Preservation and March 21 as the World Day for Glaciers. The initiative highlighted

the urgency of glacier protection and raised awareness about the consequences of their retreat (United Nations 2020).

The resolution emphasizes that climate change has caused glacier retreat, permafrost thaw, and cryosphere shrinkage, leading to slope instability, floods, landslides, and water scarcity in high mountain areas. Rising temperatures threaten fragile ecosystems, accelerate ice melt, and increase the risks of glacier lake outburst floods (GLOFs), rain-on-snow floods, snow avalanches, and landslides in new locations and seasons. The widespread shrinkage of the cryosphere, including ice sheet and glacier mass loss and snow cover reductions, has destabilized high mountain areas, disrupted the seasonality of runoff, and contributed to water scarcity and declines in agricultural yields (United Nations 2020).

The United Nations resolution outlines key actions, including:

- **Global Participation:** UN member states, organizations, civil society, and stakeholders are urged to engage in activities highlighting glacier preservation, sharing best practices, and promoting sustainable management solutions.
- **UNESCO and WMO Coordination:** UNESCO and the World Meteorological Organization (WMO) will lead efforts to implement the International Year and World Day for Glaciers, providing support and organizing activities.
- **Trust Fund Establishment:** A trust fund will be created to finance glacier preservation, with voluntary contributions welcomed from governments, organizations, and the private sector.
- **International Conference in Tajikistan (2025):** Tajikistan hosted a global conference in Dushanbe to advance discussions on addressing glacier melt and strengthening preservation efforts, demonstrating its commitment to climate action and sustainability.

Tajikistan has implemented several significant domestic measures to address glacier retreat and protect its water resources. These efforts include:

- Establishing the Center for Glacier Research under the National Academy of Sciences;

- Establishing a glacier monitoring network at altitudes of 3,500–4,800 meters;
- Publishing the Catalogue of Glaciological Terms and Glaciers, Terms, and Explanations, along with the Catalogue of Glaciers of Tajikistan;
- Preparing the draft Law of Tajikistan “On Glaciers”;
- Conducting 52 scientific research expeditions and creating a “Hall of Glaciers” at the National Museum;
- Developing a comprehensive framework for the 2025 International Year of Glacier Preservation, including a concept, action plan, and scientific programme (Center for Glacier Research n.d.).

While Tajikistan has made some efforts in addressing glacier retreat and preserving its water resources, it is clear that underdeveloped countries cannot effectively tackle these challenges alone. Robust regional collaboration and strengthened international support are vital for sustaining water resources and mitigating the impacts of glacier retreat due to climate change in the region.

Concluding Remarks and Recommendations

The retreat of glaciers in Tajikistan poses a significant threat to Central Asia's water security, impacting millions who depend on glacier-fed rivers for agriculture, drinking water, and energy. As climate change accelerates glacier loss, the region faces an urgent challenge to protect its critical water systems, with far-reaching implications for both regional and global stability.

Recommendations:

- Zero Carbon Emissions – All Central Asian countries should enhance efforts towards achieving zero-carbon targets by 2050, reducing carbon emissions and promoting sustainable practices.
- Monitoring and Research – Enhance regional cooperation in Central Asia using advanced monitoring technologies and joint research to assess glacier retreat and water resources, enabling informed decision-making.
- Adaptation and Mitigation – Implement strategies including water management, sustainable agriculture, renewable energy diversification, and disaster risk reduction to address climate impacts and mitigate environmental risks.
- International Cooperation – Central Asian countries should strengthen partnerships with global organizations to access resources, technology, and expertise for climate action.

Ultimately, our research highlights the severe consequences of glacier retreat in Tajikistan and Central Asia generally, emphasizing the urgent need for global cooperation in glacier preservation, emissions reduction, and sustainable water management. The policy brief reinforces the importance of regional and international efforts, urging collective action to protect glaciers, which are vital for ensuring water resources for both current and future generations.

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