



POLICY BRIEF

GLACIER RETREAT AND WATER SECURITY IN CENTRAL ASIA



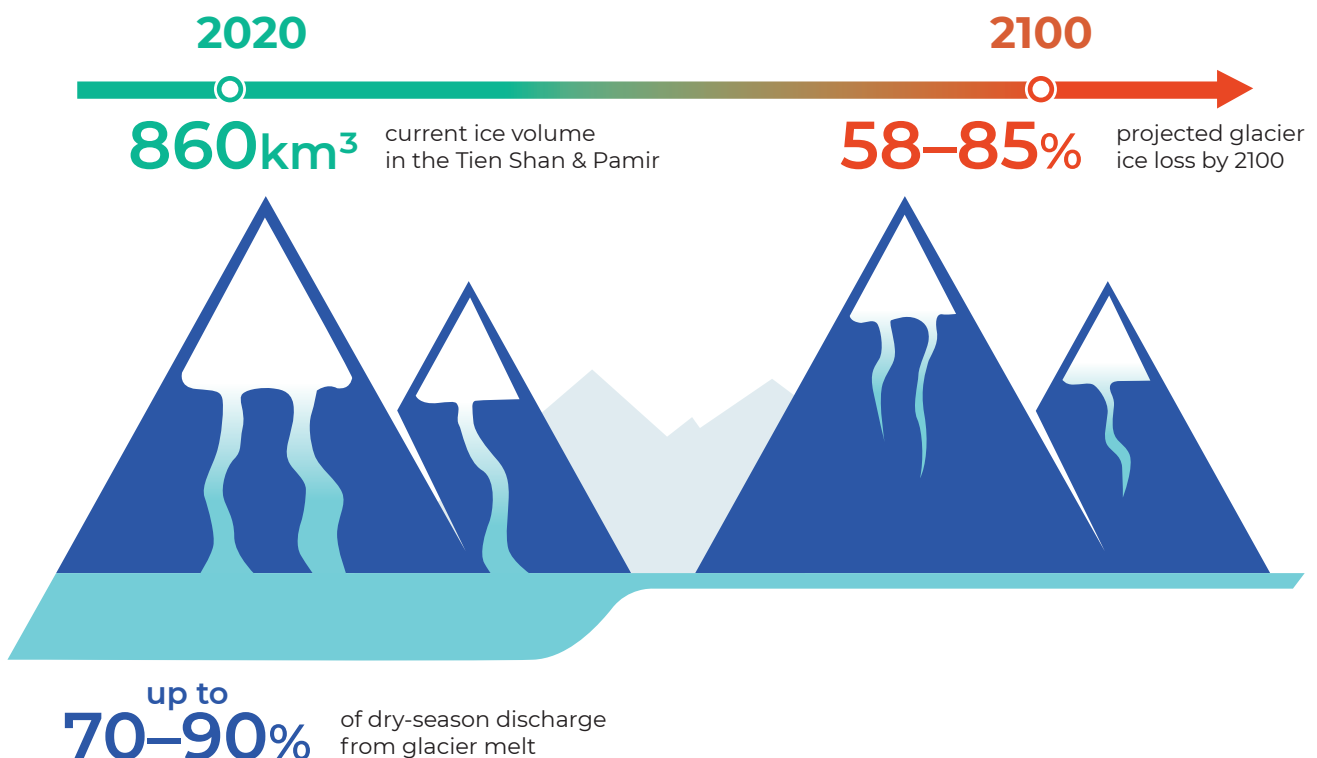
KEY MESSAGES

- **Glaciers in the Tien Shan and Pamir will lose 58-85% of their ice volume by 2100**, with significant implications for water availability for ~80 million people.
- **The Syr Darya basin is approaching a hydrological transition: several catchments are nearing peak meltwater within a decade**, after which glacier contribution will decline. The Amu Darya basin will not peak until after 2100.
- **Late-summer meltwater – when irrigation demand is the highest – will decline by more than 30% in the Tien Shan catchments.** The melt season will shift earlier, starting in late March instead of mid-April.
- **Population growth (to ~155 million by 2100), combined with water stress levels already exceeding 100% in downstream countries,** underscores the need for timely adaptation measures.

THE CRYOSPHERE AS CENTRAL ASIA'S WATER BUFFER

Central Asia's major rivers – the Amu Darya and Syr Darya – originate in the Tien Shan and Pamir mountains, where snowpacks and glaciers serve as natural water reservoirs¹. Snow contributes over 74% of annual runoff in the Syr Darya and 69% in the Amu Darya. Glacier ice adds 2% and 8% respectively on an annual basis².

These annual averages, however, do not reflect the seasonal dependence. During the summer, meltwater can contribute 70–90% of discharge in glacierized basins. This buffering role underpins irrigated agriculture, hydropower generation, and water supply for approximately 80 million people across the region.



¹ Barandun et al., University of Fribourg. Climate Change Scenarios for Glaciers and Meltwater Contribution on Water Availability in Central Asia, 2024. GEF-UNDP-UNESCO Cryosphere Project.

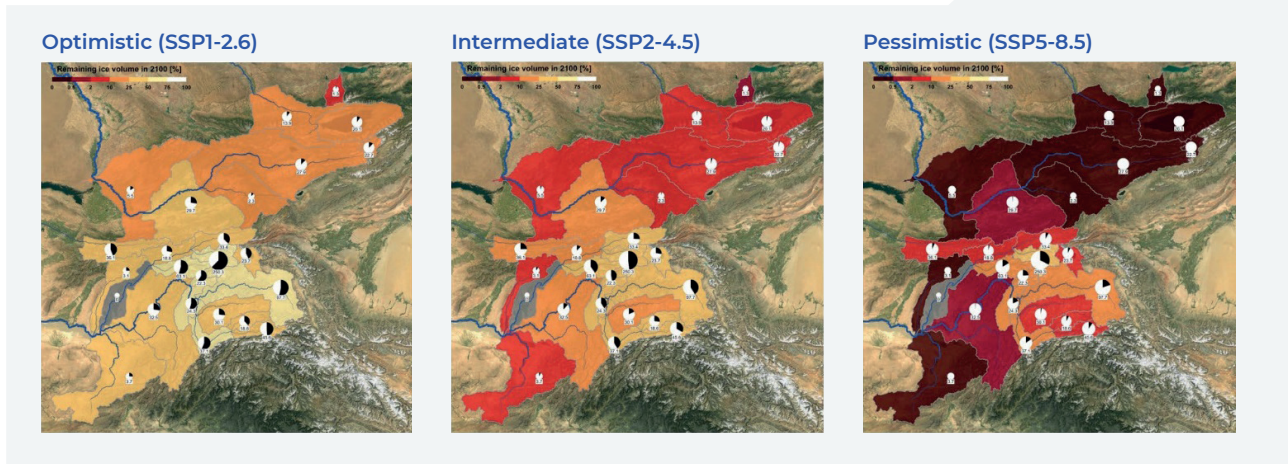
² Armstrong et al., 2019; Saks et al., 2022.

PROJECTED GLACIER LOSS

Modelling results from the Global Glacier Evolution Model (GloGEM)³ project substantial ice volume losses across all Central Asian ranges by 2100: **58% under a low-emission scenario (SSP1-2.6) and 85% under a high-emission scenario (SSP5-8.5)**. Under the latter, only about 140 km³ of the

present 860 km³ will remain. The Tien Shan glaciers are projected to be most affected: under strong warming, they may largely disappear, whereas higher and thicker glaciers in the central Pamir – notably the Vanj-Yakh (former Fedchenko) Glacier – are expected to persist through the century.

Figure 1. Catchment-wide glacier volume loss by 2100. Pie charts show ice remaining (black) vs lost (white). Numbers indicate 2020 volume (km³). Source: Barandun et al., 2024.

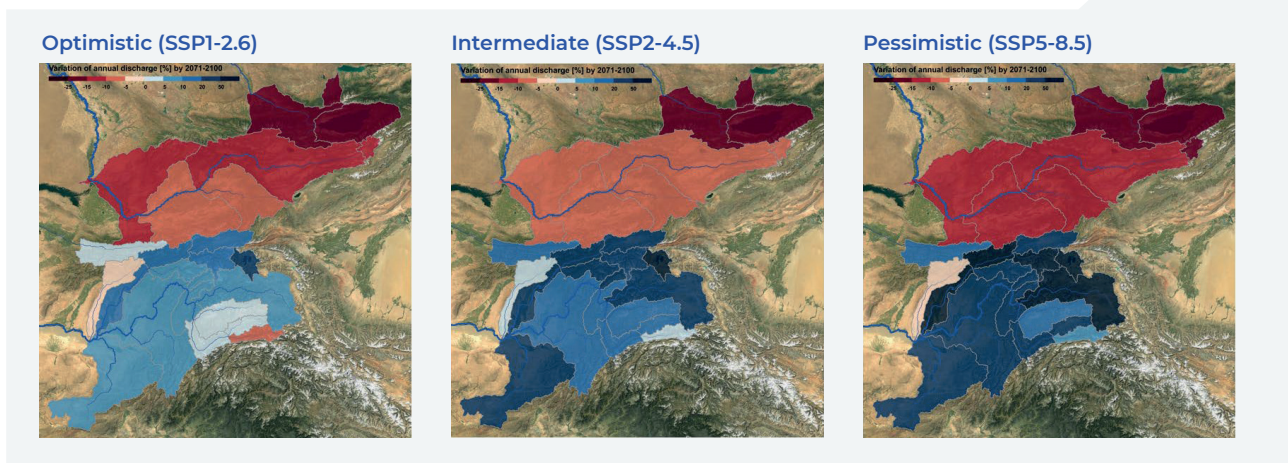


TWO BASINS, TWO TRAJECTORIES

The most policy-relevant finding is the stark **asymmetry between the Syr Darya and Amu Darya basins**. Several Syr Darya are approaching peak meltwater contribution now and will begin declining within the next decade. Other sub-basins will peak by mid-century. After peak water, meltwater input is expected to decrease significantly, with reductions of up to 25% in the most affected catchments.

In the Amu Darya basin, the trajectory is the **opposite**. Peak water will not arrive until the end of the 21st century for most sub-basins, and the Muksu catchment (home to the Vanj-Yakh (Fedchenko) Glacier) may not peak until well into the 22nd century. Under high-emission scenarios, meltwater contributions in the Amu Darya could increase by 35–70%, with Muksu seeing up to 80% more meltwater. Such increases may lead to elevated flood risk, inundation, and additional stress on hydropower infrastructure.

Figure 2. Relative change in glacier meltwater contribution to total annual runoff by catchment and scenario (present–2100). Red = decline (the Tien Shan); blue = increase (the Pamir). Source: Barandun et al., 2024.



³ Huss & Hock, 2018; Rounce et al., 2023. Global Glacier Evolution Model (GloGEM).

DIVERGENT TRAJECTORIES FOR THE TWO MAJOR BASINS:

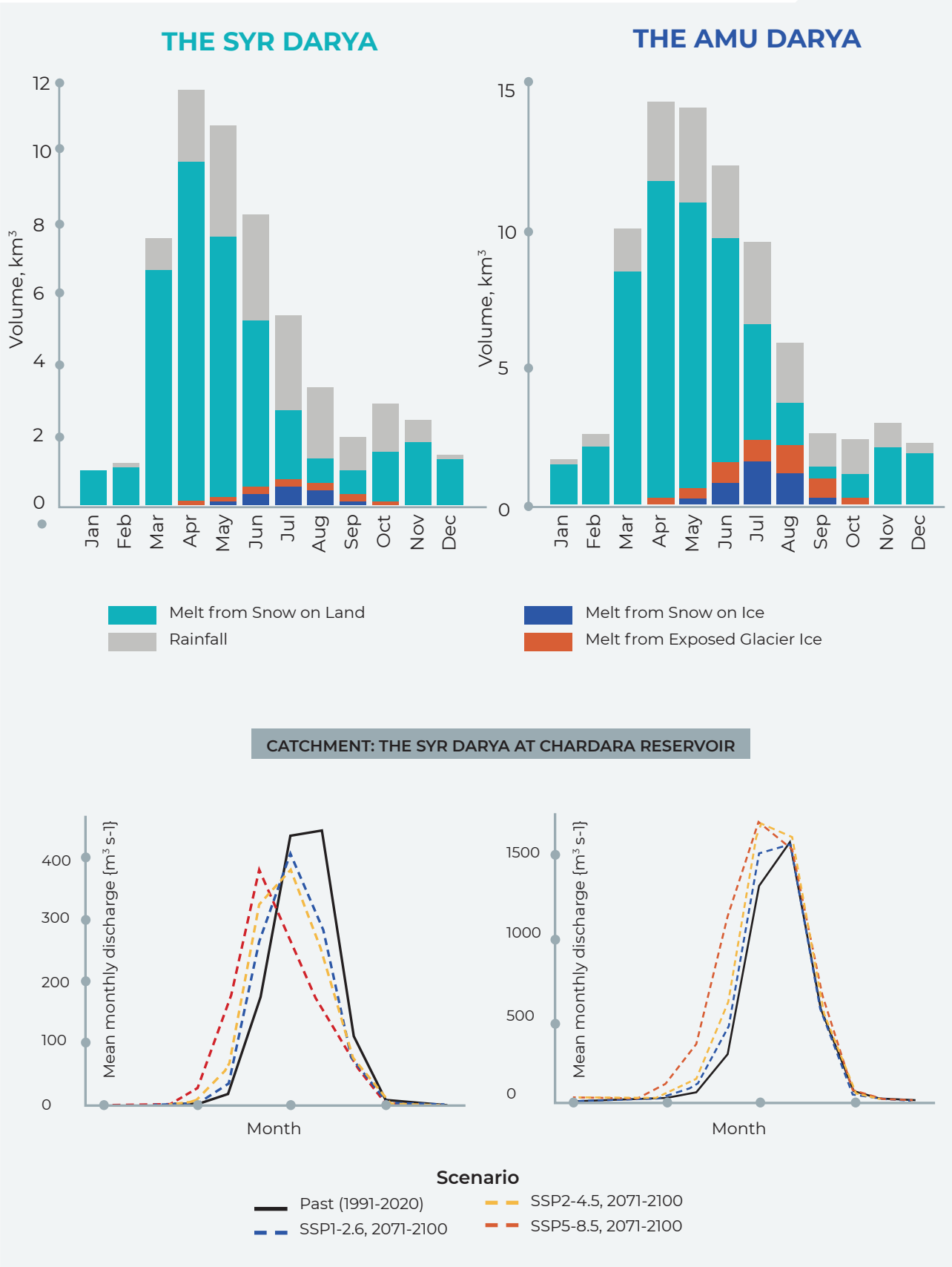


SEASONAL SHIFTS COMPOUND THE CHALLENGE

Beyond annual totals, the seasonal redistribution of meltwater is equally important for water management. Climate warming will push the onset of the melt season from mid-April to late March across most basins. Peak glacier

meltwater will shift from August towards July or even June in some catchments. In the Tien Shan, late-season glacier runoff (August–October) is projected to decrease by more than 30% of total basin runoff by 2100.

Figure 3. Monthly runoff distribution for different water resource components provided in Armstrong et al., (2019) For the Syr Darya and Amu Darya (left). Seasonal glacier meltwater contribution changes for the Syr Darya and Amu Darya catchment in 2100 (right).



EMERGING RISKS

Seasonal water scarcity

Declining late-summer meltwater is expected to affect irrigation reliability and crop yields, particularly in downstream countries of Uzbekistan and Turkmenistan, where water stress levels already exceed 100% (SDG 6.4.2: Turkmenistan 135%, Uzbekistan 122%)⁴. Water use efficiency in Central Asia averages just 3.49 USD/m³, compared to the global average of 20.77 USD/m³.

Hydrological variability

Earlier snowmelt onset increases spring flood risk while reducing dry-season supply. Combined with glacier retreat and permafrost degradation, the frequency of glacial lake outburst floods and slope instability events may increase.

Transboundary tensions

Changing runoff timing complicates water-sharing arrangements in both basins. In 2022, Afghanistan initiated the Qosh Tepa Canal project on the Amu Darya, which has implications for water availability in downstream countries, particularly Uzbekistan.

Demographic pressure

The region's population grew from 71.3 million in 2017 to 75.9 million in 2021 and could reach approximately 155 million by 2100⁵. Central Asian countries are among the highest per-capita water users globally (1,359 m³/year vs world average of 504 m³/year). Growing demand, combined with declining glacier contributions, is expected to increase water scarcity across the region.

RECOMMENDATIONS

SIX PRIORITY ACTIONS ACROSS TWO TRACKS

TRACK 1.

Strengthen Monitoring and Knowledge

- 1. Maintain and expand glacier and snow observation networks.** Integrate in-situ measurements with remote sensing and numerical modelling to reduce uncertainty in sub-regional and catchment-scale projections.
- 2. Integrate glacier-runoff scenarios into national planning.** Use differentiated projections for the Syr Darya and the Amu Darya basins in National Adaptation Plans, water strategies, and infrastructure design standards.
- 3. Invest in seasonal forecasting and early warning.** Link cryosphere monitoring to hydrological forecasting and climate services to enable proactive reservoir management and hazard preparedness.

TRACK 2.

Adapt Water Governance and Infrastructure

- 4. Reform seasonal water management.** Revise reservoir operation rules and irrigation scheduling to capture earlier meltwater peaks and buffer summer shortages. Prioritize improvements in water use efficiency.
- 5. Enhance transboundary cooperation.** Expand regional data sharing and joint planning within the Amu Darya and Syr Darya basin frameworks. Leverage SPECA and the Cryosphere Joint Statement of Action (Goal 5).
- 6. Support mountain communities and downstream resilience.** Invest in climate-resilient livelihoods, water storage infrastructure, and flood preparedness in headwater areas. Downstream, promote the adoption of efficient irrigation methods to reduce per-capita water withdrawal.

⁴ SDG 6.4.2 Water Stress Indicator, FAO AQUASTAT, 2021.

⁵ FAO AQUASTAT, 2021. Population projections based on average annual growth of ~1 million.

UPCOMING OPPORTUNITY FOR REGIONAL COORDINATION

The Regional Ecological Summit in Astana, Kazakhstan (April 2026) offers an opportunity for Central Asian countries to advance a Joint Statement on integrated cryosphere monitoring, differentiated basin adaptation strategies, and improved water-use efficiency. This could support progress toward SDG 6 targets and the Cryosphere Vision 2050.

ABOUT THIS POLICY BRIEF

This policy brief is based on the study Barandun, M., Mattea, E., Huss, M., Atanov, S., Saks, T., Kenzhebayev, R., Fiddes, J., Hoelzle, M. (2024). Climate Change Scenarios for Glaciers and Meltwater Contribution on Water Availability in Central Asia, conducted by the University of Fribourg within the framework of the GEF–UNDP–UNESCO Cryosphere 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.”

The GEF-UNDP-UNESCO Cryosphere project is implemented by the UNESCO Regional Office in Almaty.

Full report: cryosphereca.org



GEF-UNDP-UNESCO 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”

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