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Integrated Rural Development Project/
Towards Rural Inclusive Growth and
Economic Resilience (TRIGGER)

MELTING MOUNTAINS, SECURING WATER:
A POLICY NOTE FOR ADVANCING MOUNTAIN WATER MANAGEMENT TO STRENGTHEN LIVELIHOODS IN TAJIKISTAN AND CENTRAL ASIA.

Implemented by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FutureWater

Utrecht University

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Project, funding, and partners' contributions

The Integrated Rural Development Project / TRIGGER, co-funded by the European Union and the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, supports the Ministry of Energy and Water Resources of Tajikistan to strengthen the enabling environment for Integrated Water Resources Management, by improving its capacities for water allocation and formulation of a climate-sensitive river basin management plan for Zarafshon River Basin, jointly with Zarafshon's River Basin Organization and Council.

To this purpose, the Integrated Rural Development Project / TRIGGER (IRDP/TRIGGER) mobilized international expertise from the private sector and academia by engaging a Consortium of development partners led by Dutch company Future Water and including the University of Utrecht and the University of Fribourg. The GFA Consulting Group and Helvetas Tajikistan provided fundamental operational and logistical arrangements for the realization of the field interventions that were necessary to achieve the results, lessons learned, and recommendations described in this Policy Note.

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SUMMARY

This Policy Note addresses the **critical challenges to water resources in Tajikistan and Central Asia** stemming from accelerated cryosphere melt and shifting hydrological patterns. Its purpose is to equip water and climate decision-makers, managers, and international development partners with guidance for designing **effective, science-based, and inclusive cryosphere-related interventions** that foster a climate-resilient hydrological cycle in mountainous areas, thereby securing regional livelihoods.

The Note commences with an **Introduction** setting the urgent scene: the region's profound reliance on its melting cryosphere for freshwater. It advocates for a re-evaluation of Integrated Water Resources Management (IWRM) to effectively navigate dynamic hydrological complexities at high altitudes. Building on insights from the EU- and German Government-funded, GIZ-implemented **IRDP/TRIGGER Project**, it then proposes a set of **Actionable Policy Recommendations for a Resilient Cryosphere** aimed at optimizing mountain water management and adaptation strategies. Additionally, the Policy Note highlights the **IRDP/TRIGGER Project's ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade»**, a pioneering initiative that integrated cryosphere work within a rural development framework to assist the Ministry of Energy and Water Resources (MEWR) in improving water allocation. Concluding the document, the **Annex** summarizes the glacio-hydrological and water allocation modeling results from the Zarafshon River Basin, offering the scientific basis for action by all stakeholders. A more detailed analysis of such exercise can be found in the report **«Mountain Water Management Under Climate Change in Zarafshon River Basin»**.

INTRODUCTION:
A CRITICAL JUNCTURE FOR TAJIKISTAN AND CENTRAL ASIA'S HYDROLOGICAL CYCLE AND ADAPTATION TO CLIMATE CHANGE

The Lifeblood Under Threat: Cryosphere Melt and Shifting Hydrology

Tajikistan's and, by extension, Central Asia's freshwater supply is critically dependent on its cryosphere—glaciers and seasonal snow. This vital link makes the region's hydrological regime exceptionally vulnerable to accelerating climate change impacts, particularly rising temperatures that cause mountains to warm at an unprecedented rate. Consequently, these hydrological regimes are undergoing significant shifts in both timing and magnitude, posing an imminent threat to water services, access to drinking water, sanitation, and crucial food and energy production for millions.

The implementation of Integrated Water Resources Management (IWRM) in Tajikistan, a foundational principle of its Water Sector Reform (2016-2025) and National Water Strategy (2024-2030), now faces a profound challenge: a melting cryosphere that diminishes natural water storage. This leads to reduced overall water availability and altered seasonal patterns, complicating daily irrigation supply and impacting agricultural productivity. Simultaneously, environmental factors like lack of vegetation and soil erosion reduce the built storage capacity of reservoirs, as sediment increasingly fills them, contributing to a growing water storage deficit.

The Urgent Imperative: Adapting Mountain Water Management to a New Reality

In this rapidly changing context, it is imperative to re-evaluate how IWRM can effectively address the complexities of a dynamic hydrological cycle in high-altitude regions. Crucially, this requires determining how existing policy, institutions, and management instruments can collectively enhance mountain water management and adaptation strategies.

At the international level, UN initiatives like the International Year of Glaciers' Preservation (2025) and the Decade of Action for Cryospheric Sciences (2025–2034) underscore the global recognition of the urgent challenges posed by rapid glacier melt. These processes are pivotal for mobilizing global action, emphasizing scientific research, international cooperation, and public awareness to address the cascading impacts on climate, water security, and human livelihoods. Recent high-level dialogues, such as those at the International Conference on Glacier's Preservation in May 2025—where the GIZ-implemented IRDP/TRIGGER Project and Green Central Asia Initiative played key roles—highlighted the critical need for enhanced glacier monitoring to ensure long-term water availability in Central Asia. The comprehensive glacio-hydrological and water allocation modeling results for the Zarafshon River Basin, presented at this conference, further exemplify scientific evidence underpinning these concerns.

Overcoming Obstacles: Gaps in Information, Capacity, and Collaborative Action

Despite the clear need, effective mountain water management and climate adaptation face significant hurdles:

- Fragmented Water and Climate-related Policy and Planning Process, Cooperation, and the Digital Divide: The fields of cryosphere monitoring and water resources planning have traditionally been disjointed in development cooperation. International interventions often follow a one-on-one partner model, resulting in cryosphere-specific efforts that are disconnected from ultimate water users. This leads to isolated data storage systems and diverse data collection methods among partners. High-skill data management frequently falls to international partners, while local partners, often financially supported, manage data collection. The absence of a common digital framework for local partners to input diverse datasets creates a significant digital gap across institutions, characterized by varying computational capacities and unequal access to high-speed internet.

- Bridging the Information Gap: Glaciers and snowpack, as natural freshwater storage, demand robust protection and monitoring. However, a critical information gap persists regarding the precise timing and quantity of water released for user access. Tajikistan currently possesses limited capacities, knowledge, and tools to adequately assess and monitor cryosphere melt impacts on water resources. Bridging this gap through advanced management instruments, like hydrology and water allocation models, is crucial for fostering a climate-resilient economy.

Paving the Way Forward: A Call for Science-Based, Collaborative Solutions

Tajikistan and Central Asia are at a critical juncture, facing fundamental and urgent decisions about how to improve mountain water management in a changing climate. The choices made today will define their future water security and resilience.

Against this backdrop, science-based and participatory cryosphere monitoring, coupled with robust water resources planning and allocation, emerge as the most effective policy options for investment. These approaches are essential to improve Tajikistan's mountain water management and adaptation capacities as its cryosphere continues to deplete. This necessitates unprecedented cooperation from a diverse range of stakeholders, spanning decision-makers, technical experts, academics, and international partners. Furthermore, enhancing Tajikistan's existing water resources management framework, including River Basin Organizations and Management Plans, and fostering enhanced cooperation across water- and climate-relevant authorities, are vital to jointly plan interventions and manage infrastructure in response to a rapidly changing hydrological cycle.

ACTIONABLE POLICY RECOMMENDATIONS FOR A RESILIENT CRYOSPHERE

Leveraging insights from the IRDP/TRIGGER Project in Tajikistan and its glacier monitoring and glacio-hydrological and water allocation modeling, this section presents actionable policy recommendations for water and climate decision-makers, managers, and international development partners for the future design of cryosphere-related interventions. These recommendations aim to optimize mountain water management and adaptation strategies across Tajikistan and Central Asia, offering practical, non-regret options to foster a science-based and participatory approach for improved cryosphere monitoring and effective water resources allocation. The recommendations are articulated into 4 pillars: Water and Climate Policy and Planning, Technology, Cooperation and Stakeholder Participation, and Capacity Building and Research (see Figure 1).

Figure 1. Non-regret policy recommendations to optimize mountain water management and adaptation articulated into 4 different pillars or themes.

1. Water and Climate Policy and Planning

1.1 Integrate Mountain Water Management into Policy

Climate change is causing mountains to warm significantly faster than the global average, with temperatures in the Zarafshon River Basin projected to rise by up to 9°C under high-emission scenarios. Given that most of Central Asia's water originates from mountain glaciers and snow, mountain water management must be fully integrated and mainstreamed into all current and future water and climate policies, strategies at local, national, and regional levels. This is essential for effective water and climate policymaking.

1.2 Embed Cryosphere Interventions in Broader Initiatives

Cryosphere-related interventions are most effective when integrated into broader water, climate, and rural development initiatives. This approach bridges the gap between scientific research and policy by actively involving all relevant stakeholders, from scientists to water users. The IRDP/TRIGGER Project, for example, successfully linked cryosphere research (assessing water supply data from rainfall, glaciers, and snowmelt) directly with end-user demand within a rural development framework, demonstrating direct impacts on communities and sectors exposed to climate change. Implementing IWRM and river basin management principles helps connect cryosphere-specific institutions with water-related decision-makers and end-users, particularly small-scale farmers in Tajikistan's mountainous regions.

1.3 Leverage Climate Information Services for River Basin Planning and the WEFE Nexus

Increased investment in climate information services and the Water-Energy-Food-Environment (WEFE) Nexus is critical for achieving higher levels of mountain adaptation. Climate services provide vital information on how climate change affects natural freshwater storage, water source contributions, and availability for consumption and ecosystems. Prospective water resources planning must be supported by climate change assessments that quantify the alterations to various flow components (glacier melt, snowmelt, rainfall, and groundwater). Understanding these changes is essential because of the significant shifts in meltwater seasonality and magnitude that directly impact downstream water availability for irrigation and other water uses. Hence, climate information services must be sustainably institutionalized and fully integrated into water resources planning to ensure climate-resilient river basin development. This includes informing infrastructure development and identifying water-related disaster hotspots. The WEFE Nexus serves as a foundational framework for articulating development assistance, connecting sectors, identifying synergies, and managing trade-offs in resource-scarce regions. During the formulation of the Zarafshon River Basin Management Plan, the IRDP/TRIGGER Project successfully integrated both climate services and the WEFE Nexus approach. This intervention demonstrated two key points: first, how and when diverse water sources become available across the basin for various uses, and second, how climate-change induced shifts in the hydrological cycle could affect downstream water availability for all users under various future scenarios, given altered meltwater seasonality and magnitude.

2. Technology

2.1 Prioritize Proven and Scalable Technologies

To maximize investment impact, future interventions must prioritize proven models and technologies with a demonstrated track record of success. Focusing resources on reliable, scalable, and cost-effective solutions like the SPHY (Spatial Processes in Hydrology) and WEAP (Water Evaluation and Planning) models, which are free, open source tools, enable local stakeholders to develop deep expertise and achieve meaningful, long-term results.

This approach supports continuous improvements in monitoring and modeling and facilitates upscaling to other river basins across Central Asia. Mastering a single, effective model requires significant time and resources, necessitating sustained support beyond individual project lifespans. International development partners are advised to strategically invest in deepening existing local proficiency with proven models and technologies. The introduction of redundant or similar new solutions should be avoided, considering the considerable resources and dedicated time required to guarantee a minimum level of adoption by local partners.

2.2 Design Sustainable and Accessible Technology

When investing in technology, the focus must be on solutions that are cost-effective, intuitive to operate, and straightforward to maintain. A crucial strategy involves adapting and customizing existing open-source technologies to the specific local context, thereby ensuring their capacity to deliver reliable simulations and offer scalable applications. To mitigate the burden on national stakeholders, the ongoing updates and maintenance of these tools should be provided by external expert teams, enabling local professionals to dedicate their efforts to mastering the technology's application and responding effectively to emerging future scenarios.

2.3 Enhance Funding and Collaborative Data Systems

Increased funding is necessary to fully utilize available technologies and define clear roles for stakeholders. Innovative technology can incentivize cooperation among cryosphere-relevant institutions, ultimately benefiting water users. Common shared technology tools and open data are strategic components for sustainable and collaborative information systems among relevant stakeholders. Implementing effective data management systems and promoting open data sharing will enhance the accessibility and utility of climate and water-related information, streamline practices, and strengthen research and evidence-based decision-making. The SPHY and WEAP models, integrated within the National Water Information System of Tajikistan, can serve as a common tool for all local partners to input their collected data, bridging the current digital gap where individual development partners often collaborate with isolated local partners and data systems.

2.4 Reinforce Foundational Hydro-Meteorological Networks

Future cryosphere-related interventions must prioritize establishing reliable hydrometeorological networks. These networks are foundational for effectively monitoring climate conditions and water resources, enabling the accurate calibration and robust results of advanced models like glacio-hydrological and water allocation models. Strengthening the technical and institutional capacities of organizations responsible for data collection is essential for integrating cryosphere data into hydrological models that support water allocation decisions. This requires cooperation between local and international development partners to address existing data and digital gaps.

3. Cooperation and Stakeholder Participation

3.1 Foster Cross-Sectoral and Transboundary Collaboration

Effective climate information services rely on collaboration among various stakeholders including governments, communities, and water managers, to ensure relevance and inclusivity. The ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade» effectively fostered cooperation by integrating partners across water, energy, and agriculture sectors, aligning with IWRM principles. It is highly recommended to expand and mainstream cryosphere work into rural development and transboundary cooperation programs across Central Asia, replicating this cross-sectoral and interdisciplinary approach in future natural resources management and climate adaptation projects. The IRDP/TRIGGER Project and the Green Central Asia Initiative, both implemented by GIZ, serve as a benchmark for designing highly inclusive cryosphere-related project interventions.

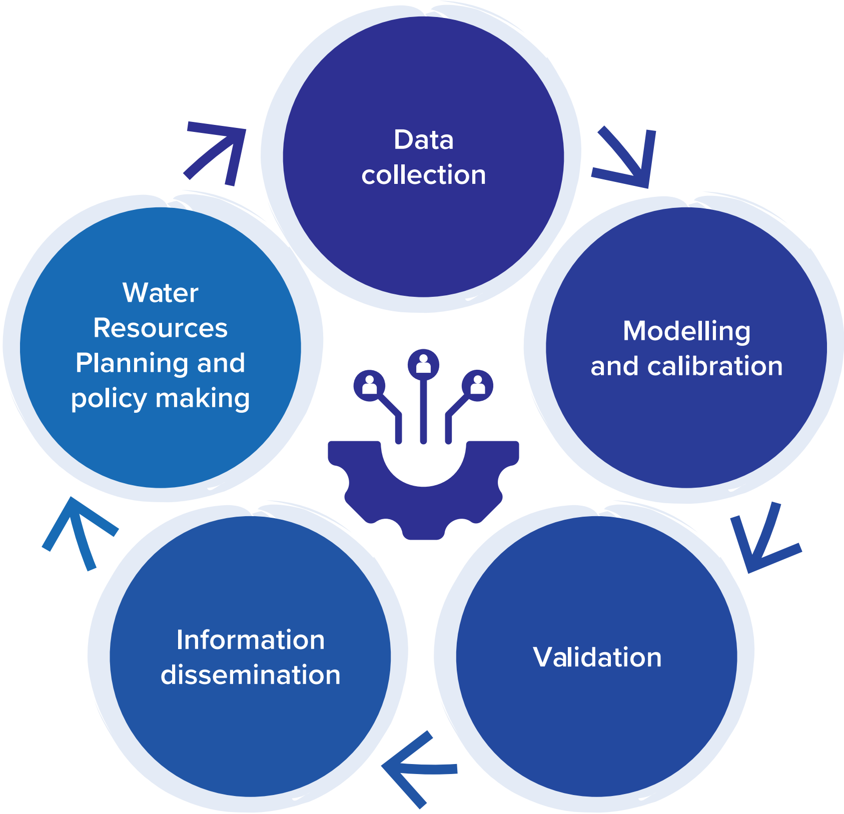

Figure 2. Identification of different roles to articulate cooperation towards improved mountain water management.

3.2 Support Multi-Level Cooperation for Water Allocation

Cooperation at national and local levels among scientists, water resource managers, and policymakers is crucial for informed water allocation. The IRDP/TRIGGER Project exemplifies this by bringing together researchers with decision-makers to support science-based water allocation and river basin planning. Disseminating these results to district-level decision-makers and water users is vital for communities to understand and adapt to local environmental challenges. Beyond national borders, cooperation with national, regional, and international experts should leverage Central Asia's tradition of data sharing and enhance technical networks, ensuring global expertise informs local challenges.

3.3 Leverage Technology as a Driver for Cooperation

Innovative climate information services technology, particularly glacio-hydrological modeling and drone technology proved highly effective in driving cooperation and building trust among relevant stakeholders. These new technologies generated significant enthusiasm, especially among younger staff, fostering initial informal institutional cooperation linkages. The technological tools themselves provided the framework for collaboration, with clear roles for data collection, modeling, and forecasting among partners. Shared mastery of the same technology was a key factor for driving cooperation, creating a common operational ground.

3.4 Formalize Cooperation for Resilience

To ensure the sustainability of successful cooperation, formalizing roles through a Memorandum of Understanding (MoU) is recommended. An MoU, as drafted during the IRDP/TRIGGER Project, can formalize roles, and allow for future partners to join a collaborative workflow around glacio-hydrological and water allocation models (see Figure 2). Establishing robust collaborative national frameworks is essential for facilitating resilience-building efforts and efficient allocation of climate finance. National stakeholders should proactively cultivate a collaborative environment that encourages knowledge exchange and efficient tool and technology transfer from international partners.

3.5 The Role of International Expertise in Fostering Collaboration

The role of international experts and trainers is crucial for correctly articulating the cooperation structure among relevant stakeholders. International experts, beyond technical expertise, must possess advanced moderation and facilitation skills to serve as trust-builders and trigger necessary cooperation on shared technology.

3.6 Tailor Information to Diverse Stakeholder Needs

Effective stakeholder participation necessitates addressing a wide spectrum of data and information needs, spanning various time scales. While some stakeholders, like farmers, need short-term water availability data for immediate planning, policymakers require long-term projections (e.g., 10-50 years) for infrastructure and policy development. Intermediate bodies, such as River Basin Organizations, need medium-term data (3-5 years) for local development plans. Designing initiatives to strategically collect, process, and manage varied data is crucial to ensure tailored information is effectively conveyed to each stakeholder at their required timescales.

3.7 Empower Multi-Tiered Decision-Making with Integrated Models

Effective water resources management hinges on considering all levels of decision-making, which necessitates active participation of diverse stakeholders. The SPHY-WEAP glacio-hydrological and water allocation model offers valuable insights across multiple strategic tiers: providing data for long-term strategic planning (Strategic Level), supporting medium-term river basin and development plans (Tactical Level), and assisting day-to-day water management (Operational Level). This comprehensive water balance approach empowers various stakeholders to make informed water-related decisions at different levels, essential for effective and participatory IWRM.

4. Capacity Building and Research

4.1 Invest in Local Water Professionals' Skill Development

Investing in capacity building is crucial for improving the skillsets of local water professionals. Enhancing national technical capacity to assess and monitor changes in cryospheric and hydrological systems through innovative modeling tools will empower stakeholders to effectively manage sustainable water allocation and use. It is vital that national technical staff are equipped with the necessary knowledge and skills in innovative technology for data collection, modeling, and analysis. For feasibility and sustainability, the recommended approach is to enhance existing institutional strengths and foster collaboration rather than attempting to train all staff in all skills. Capacity building in this field demands significant time and financial resources, as demonstrated by over 150 hours of intensive training provided by the IRDP/TRIGGER Project.

4.2 Bridge the Intergenerational Capacity Gap through Youth Engagement

Focusing on youth is essential to bridge the existing intergenerational capacity gap in water resources management in Tajikistan and Central Asia. Innovative and cutting-edge technologies like drones and computer-based hydrological models are exceptionally well-received by younger staff, who demonstrate rapid understanding and effective adoption. Peer-to-peer working sessions are highly effective for fostering learning and collaboration among young professionals. This smooth collaboration among young technical staff is vital for supporting institutional decision-making. Future projects must specifically target young professionals in the water sector and staff in water- and cryosphere-relevant institutions.

4.3 Ensure Sustainability through Training-of-Trainers and Toolkits

Adopting a Training-of-Trainers (ToT) approach and developing comprehensive toolkits are crucial for the sustainability of capacity-building efforts. The IRDP/TRIGGER Project trained over 20 young staff in Tajikistan and the Netherlands, with a core group achieving high proficiency to function as trainers for their peers, and exposure to international water management technologies and frameworks. A climate services toolkit, including training manuals and the fully developed hydrological model, was deployed on institutional IT servers to ensure constant access for practice and simulations. Sustained commitment from local partners and institutional heads is essential for the continued use of these resources, necessitating a robust exit strategy. The physical deployment of technology, significant ToT investment, and clear allocation of roles are vital for long-term impact.

4.4 Foster Long-Term Support and Research Alignment

Capacity building in cryosphere monitoring and water allocation is a long-term endeavor, requiring sustained investment in human resources and tools beyond single project lifespans. Development partners must incorporate and follow up with training components in their future project designs to ensure cumulative and targeted support for young staff using the same technology. Complementing infrastructure projects with «soft interventions» like capacity building and knowledge sharing, including with research institutes, is essential for a comprehensive approach to climate resilience.

THE IRDP/TRIGGER PROJECT: «FROM PEAKS TO PEOPLE TO GLOBAL TRADE» ECOSYSTEM-WIDE APPROACH TO MOUNTAIN WATER MANAGEMENT AND RURAL DEVELOPMENT IN TAJIKISTAN

In direct response to the climate change challenges facing Tajikistan's cryosphere, the IRDP/ TRIGGER Project successfully supported Tajikistan's Ministry of Energy and Water Resources in the Zarafshon River Basin. This intervention focused on monitoring the melting cryosphere to improve water allocation within the basin and supporting the formulation of its first River Basin Management Plan. The project achieved this through a comprehensive ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade», pioneering the integration of cryosphere work within a rural development framework. Its primary objective was to enhance MEWR's water resource allocation capacities, thereby improving farmers' water access for food production in the Zarafshon River Basin. Led by the MEWR, the intervention involved other key cryosphere-related institutions (Figure 3), focusing on building stakeholder capacity to utilize climate information services for water allocation and river basin planning.

The ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade» comprised several key elements:

Data Collection and Monitoring

This component involved collecting seasonal snow and glacier ice depth data to feed and validate glacio-hydrological and water allocation models. This included **jointly led glacier expeditions** (October 2023, September 2024, May 2025 at GGP Glacier in Zarafshon River Basin) by the Center of Glacier Research and MEWR, incorporating **drone technology training and snow monitoring campaigns**. Participants from the Agency of Meteorology and the Institute of Water Problems also joined these efforts.

Modeling and Climate Change Assessment

This involved the **participatory development of a glacio-hydrological and water allocation model chain using SPHY and WEAP software**. SPHY assessed current and future water availability, while WEAP investigated water allocation and use. The calibrated SPHY and WEAP model chain has been **physically deployed on the IT servers of involved stakeholders** to facilitate cooperation, data exchange, and comparison of model calculations. Comprehensive results are presented in the report «**Mountain Water Management Under Climate Change in Zarafshon River Basin**».

Capacity Building

This component delivered **over 100 hours of technical modeling training** (in Tajikistan, the Netherlands, and online) for specialists from key institutions (MEWR, Center for Glacier Research, Agency of Meteorology, Institute of Water Problems, Hydropower, and Ecology). Training specialists in hydrological models or drone technologies requires significant time and effort (e.g., over 200 hours per trainee for those with prior IT/GIS skills). Training manuals are accessible via Tajikistan's National Water Information System (wis.tj) and the MEWR's Educational Platform (donish.mewr.tj).

Weather Station Installation

An initial set of **13 weather sensors was installed** across the Zarafshon River Basin. These stations collect data on specific parameters (rainfall, humidity, wind speed) to assist in future calibration of SPHY and WEAP models and support continuous improvement of water allocation for sustainable river basin economic development. The weather stations are owned by the Agency of Meteorology and supervised by CARITAS.

Cooperation and Stakeholder participation

This approach integrated **robust stakeholder participation**, encompassing public, private, and civil society entities involved in cryosphere assessment; national and local water- and climate-related institutions; and all relevant water users and economic sectors. Key partners included the **MEWR** (water allocation), the **Center of Glacier Research** (cryosphere assessment, drone expertise), the **Agency of Meteorology** (climate information services), and the **Institute of Water Problems, Hydropower and Ecology** (modeling capacities).

Inclusive, Climate-Resilient and Cross-Sectoral River Basin Planning

The Zarafshon River Basin Organization (RBO) played an **active and crucial leadership role** throughout all components, ensuring that the development of the Zarafshon River Basin Management Plan was firmly based on glacio-hydrological and water allocation modeling results. This enabled the RBO to inform cross-sectoral water allocation to various sectoral users represented in the Zarafshon River Basin Council (RBC). Figure 4 illustrates the **participatory approach** used to develop the Zarafshon River Basin Management Plan, combining scientific data with legislation, applying the WEFE Nexus approach, and fostering public participation to integrate interventions into local district development plans.

Empowering farmers through Improved Water Access, Value Chain development and Access to Domestic and Global Trade

In the Zarafshon River Basin (and beyond), the IRDP/TRIGGER Project's holistic **ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade»** was designed to address multiple barriers that hindered farmers' ability to compete in both domestic and foreign markets.

Farmers in the region faced several key challenges to access domestic and global trade. They often **lacked access to essential agricultural equipment**, which made it difficult to cultivate land and complete tasks in a timely manner. They also had **limited market information**

and business connections, preventing them from finding buyers and selling their products at fair prices. Additionally, **poor post-harvest handling and storage facilities** led to significant food losses, reducing the overall quality and quantity of their produce. Individually, farmers also **lacked the organization and collective bargaining power to attract large buyers**. Other constraints included **the high cost of logistics for international exports, limited access to high-quality inputs** like certified seeds, and social barriers such as gender stereotypes that limited women's participation in entrepreneurial activities.

To overcome these obstacles, the IRDP/TRIGGER Project implemented a number of strategic interventions. It directly supported farmers by providing **access to small agricultural equipment** and installing **drip irrigation systems** and rehabilitating local irrigation channels. This specific intervention was highly effective, leading to a 30% reduction in water consumption, a 40% increase in crop yields, and a doubling of farmer incomes. The project also introduced new innovations, such as the region's first vermicompost production point and new milk collection centers.

To improve market access, the project focused on strengthening **Producer Groups (PGs)** across several value chains, by allowing farmers to aggregate their products, increase their volume, and gain greater bargaining power. The project also actively facilitated Business-to-**Business (B2B) meetings** and matchmaking events, helping farmers build new business relationships and find new export markets. For example, through participation in fairs like «Sughd Expo» a producer group was able to sell 20 tonnes of raisins to buyers in Belarus. Furthermore, the project supported participation in international events, such as **BioFach 2025**, to explore potential access opportunities to the European organic market.

Furthermore, the project provided extensive support for **post-harvest handling** by training 1,483 PG members on topics like storage, processing, and packaging. It also helped construct storage facilities to reduce losses and stabilize prices. The project used a **Lead Firm (LF) approach** to connect farmers with suppliers of high-quality input, ensuring that they had the necessary materials to improve productivity and meet quality standards. Finally, recognizing the importance of inclusivity, the project ran awareness campaigns and provided support to women-led groups in beekeeping and apricot production, which helped boost their financial independence and self-reliance.


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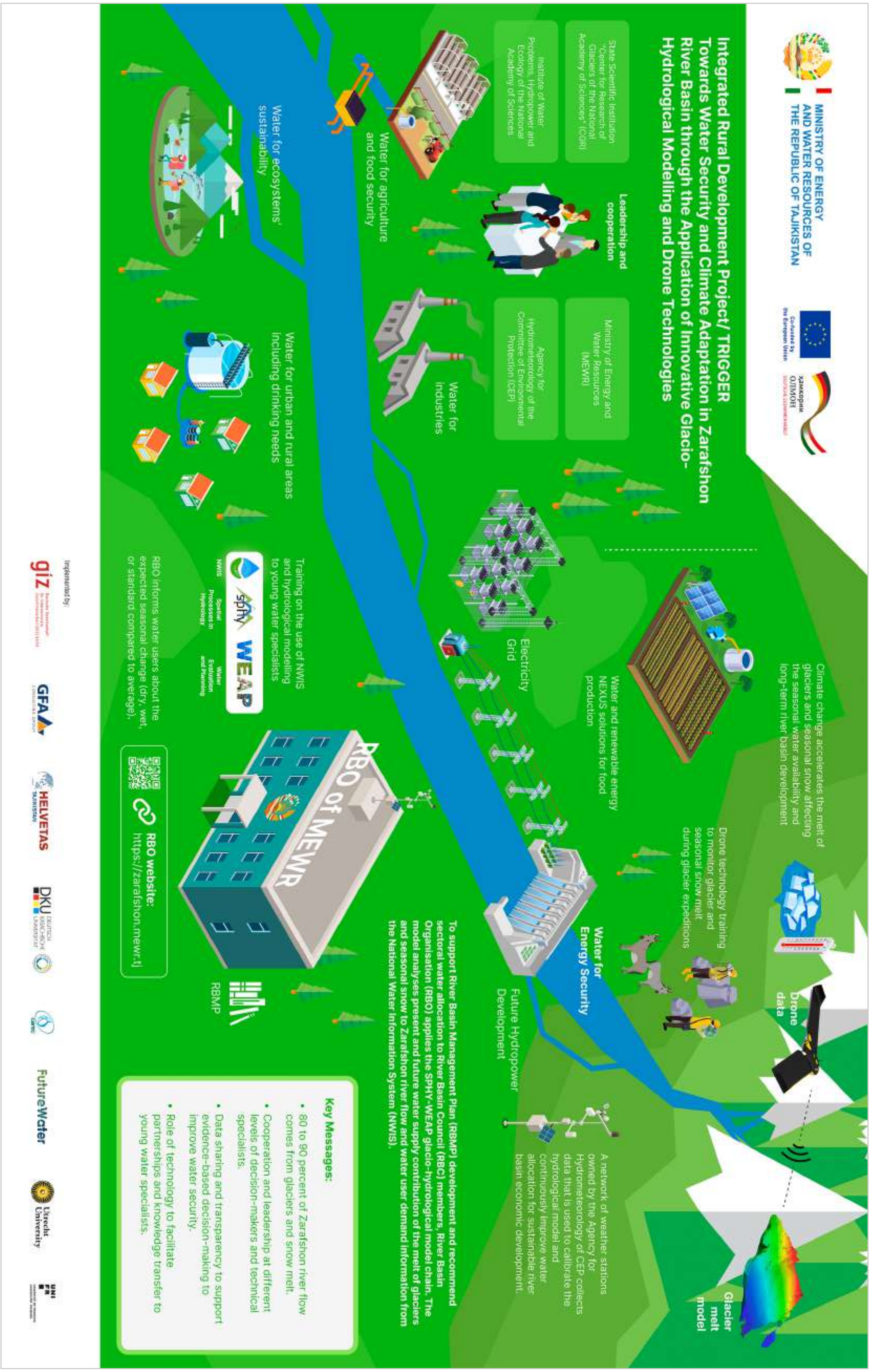

Figure 3. Application of Innovative Glacio-Hydrological Modelling and Drone Technologies in Zarafshon River Basin, within a rural development framework.

3 Tajikistan Country Climate and Development Report, World Bank.

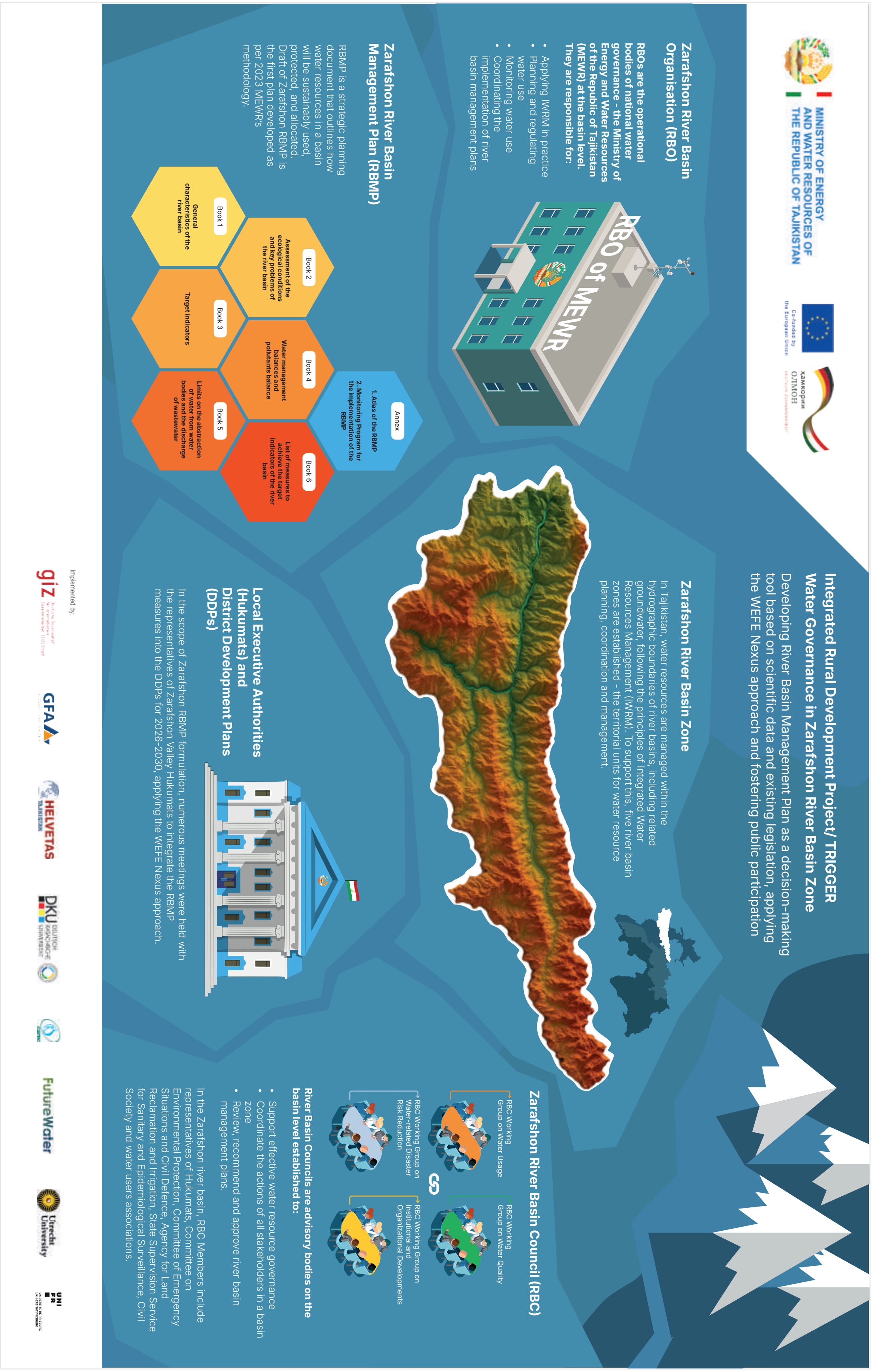

Figure 4. Inclusive, Climate-Resilient and Cross-Sectoral River Basin Planning in Zarafshon River Basin

CONCLUSION: A PATHWAY TO A CLIMATE-RESILIENT HYDROLOGICAL CYCLE IN HIGH-ALTITUDE REGIONS

Tajikistan and Central Asia stand at a pivotal moment. The undeniable evidence of a rapidly melting cryosphere and profoundly shifting hydrological patterns presents an existential challenge to the region's water security and foundational sectors like agriculture and energy. The increasing temperatures and their cascading impacts demand not just awareness, but decisive and integrated action. As current analysis from the Zarafshon River Basin demonstrates, while water resources remain substantial, unmet demand is predominantly driven by inadequate infrastructure and accessibility, rather than a genuine shortage of water itself.

The success of the IRDP/TRIGGER Project provides a compelling case study and a blueprint for navigating this complex future. By integrating cryosphere science with rural development, strengthening institutional capacities, deploying innovative yet accessible technologies, and fostering multi-level cooperation, the project has shown that tangible improvements in water management and farmer livelihoods are achievable. Its ecosystem-wide approach to mountain water management and rural development in Tajikistan «from peaks to people to global trade» underscores that holistic interventions, grounded in scientific evidence and robust stakeholder engagement, are not only possible but highly effective.

Therefore, the path forward is clear. Tajikistan and its international partners must seize this critical juncture to strategically invest in the recommendations outlined in this policy note. This means: (1) Mainstreaming mountain water management into all relevant policies and strategies; (2) Prioritizing sustainable, proven technologies and ensuring their accessibility and continuous support; (3) Fostering formalized, cross-sectoral, and transboundary cooperation that leverages technology as a driver for collaboration; and (4) Investing in long-term capacity building for local water professionals, with a particular focus on empowering youth and ensuring sustainability through ToT approaches and toolkits.

By embracing these actionable recommendations, Tajikistan and Central Asia can move beyond reactive measures towards proactive, science-based, and participatory water management strategies. This collaborative endeavor will not only mitigate the profound impacts of cryosphere melt but also build lasting water security and climate resilience for generations to come, fostering sustainable development across the region. The time for decisive action is now.

ANNEX

Climate Change Impacts on the Zarafshon River Basin's Cryosphere and Hydrological Cycle

Research results from glacio-hydrological and water allocation modeling undertaken in the Zarafshon River Basin, in the framework of the IRDP/TRIGGER Project, explore the temporal and spatial patterns of different streamflow contributors. This analysis aims to show relevant basin stakeholders how glacier melt, snowmelt, rainfall, and groundwater will become available to various water users and economic sectors across time and space in the future.

In this section a summary of the results glacio-hydrological and water allocation modeling is presented. For further details on the glacio-hydrological modeling exercise conducted in the Zarafshon River Basin within the framework of the IRDP/TRIGGER Project, please refer to the report: «Mountain Water Management under Climate Change in Zarafshon River Basin»

Historical climate

The Zarafshon River Basin exhibits significant variations in both precipitation and temperature due to its complex topography (Figure 5b and 5d). Precipitation is higher in the eastern and southern regions (up to 1750 mm/year) and lower in the northwestern and western areas (as low as 500 mm/year). This pattern is mainly influenced by mountainous barriers like the Alay, Tian Shan, and Pamirs. Spring (March–May) accounts for 34% of the annual rainfall.

Temperature varies widely across the basin, ranging from -7.5°C to 15.4°C, with a clear seasonal pattern: warmest in July (11.9°C) and coldest in January (-5.7°C). Winter months show the greatest temperature variability. Unlike precipitation, temperature displays a significant increasing trend, rising at an average rate of 0.035°C per year.

Future climate projections

All climate models agree that the Zarafshon River Basin will experience warming in the future, with summer months projected to show the most significant increases (Figure 5e). For example, the UKESM1-0-LL model projects that, under the SSP585 scenario, temperatures will rise by approximately 7.2°C.

However, projections for precipitation are mixed (Figure 5f). Some models, such as MPI-ESM1-2-HR (under SSP370) and GFDL-ESM4, predict slight decreases in precipitation (3–5%). Conversely, others, like UKESM1-0-LL under SSP585, project substantial increases—up to 23%. While monthly temperatures are expected to rise throughout the year, precipitation changes are projected to vary by season, with potential increases in winter and decreases in summer.

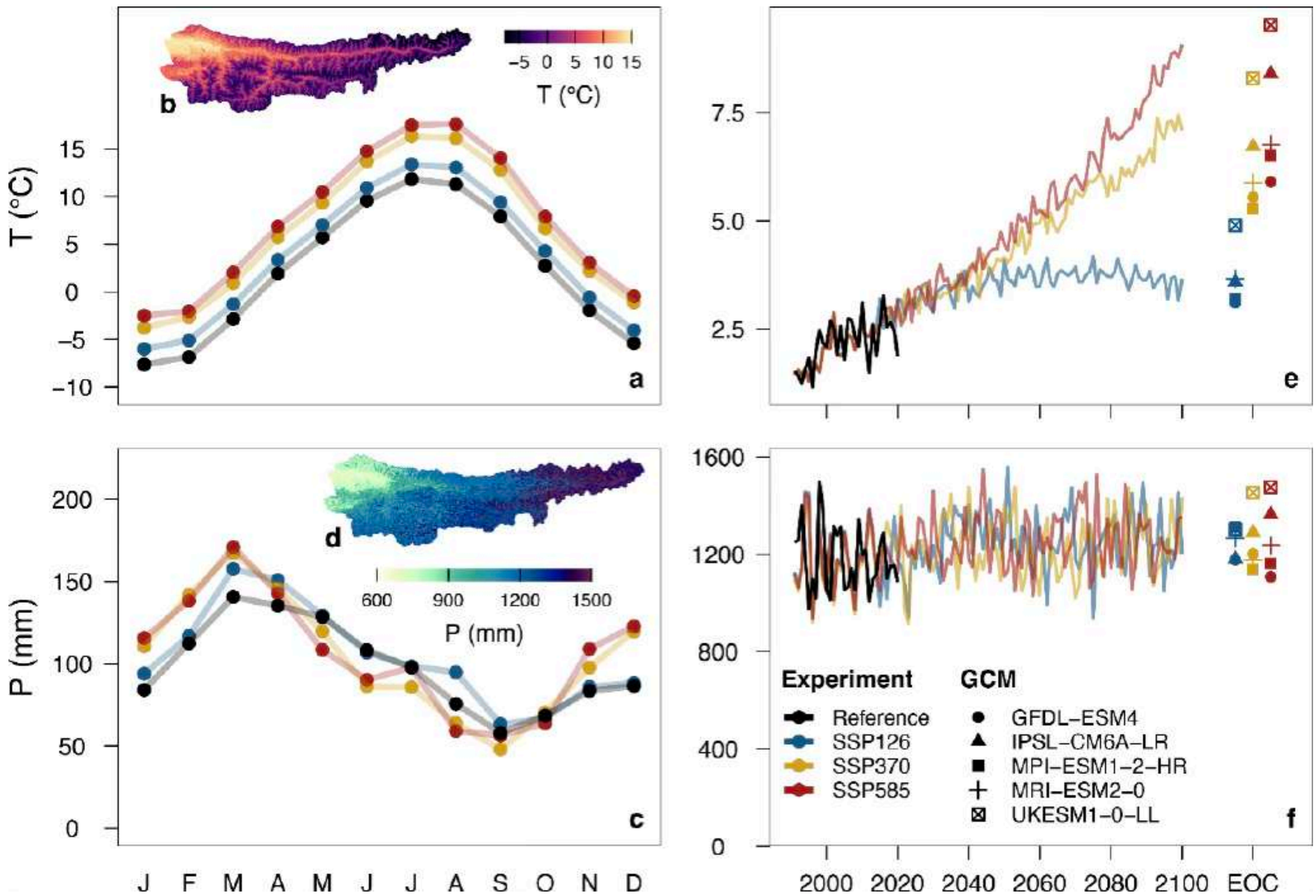

Figure 5. Historical (1991–2020) and projected (2021–2100) temperature and precipitation of the Zarafshon River Basin. Basin-average monthly mean climatological temperature (A) and precipitation (C) for the base period (1991-2020) based on ERA5 TopoSCALE and end of century (EOC, 2071–2100) based on ISIMIP3b SSP ensemble means. Spatial distribution (B, D) of mean annual temperature and precipitation of the ERA5 TopoSCALE reference (1991-2020). Basin-average annual mean temperature (E) and precipitation (F) of the ERA5 TopoSCALE reference and ISIMIP3b SSP ensemble mean future projections. The points denote the EOC (2071–2100) mean temperature (E) and precipitation (F) of each individual GCM within the SSP ensembles.

Present-day hydrology and trends

The Zarafshon River Basin's outlet is predominantly fed by snowmelt, which contributes 53% of the annual runoff (Figure 6). This contribution typically begins to increase in April, reaching its peak in June–July as temperatures rise, even though the majority of snowfall occurs earlier in the spring. Baseflow is the next significant contributor, providing 23.1% of the annual runoff. It is a consistent source throughout the year, notably increasing during the dry, colder months (September–February) as infiltrated snowmelt makes its way into the groundwater system. Rainfall-runoff accounts for 21.3% of the total, with its highest contributions observed in June before gradually declining after August. While glacier melt contributes the least annually (2.6%), its monthly share becomes most significant in September, reaching around 11% when other sources of river flow are typically lower.

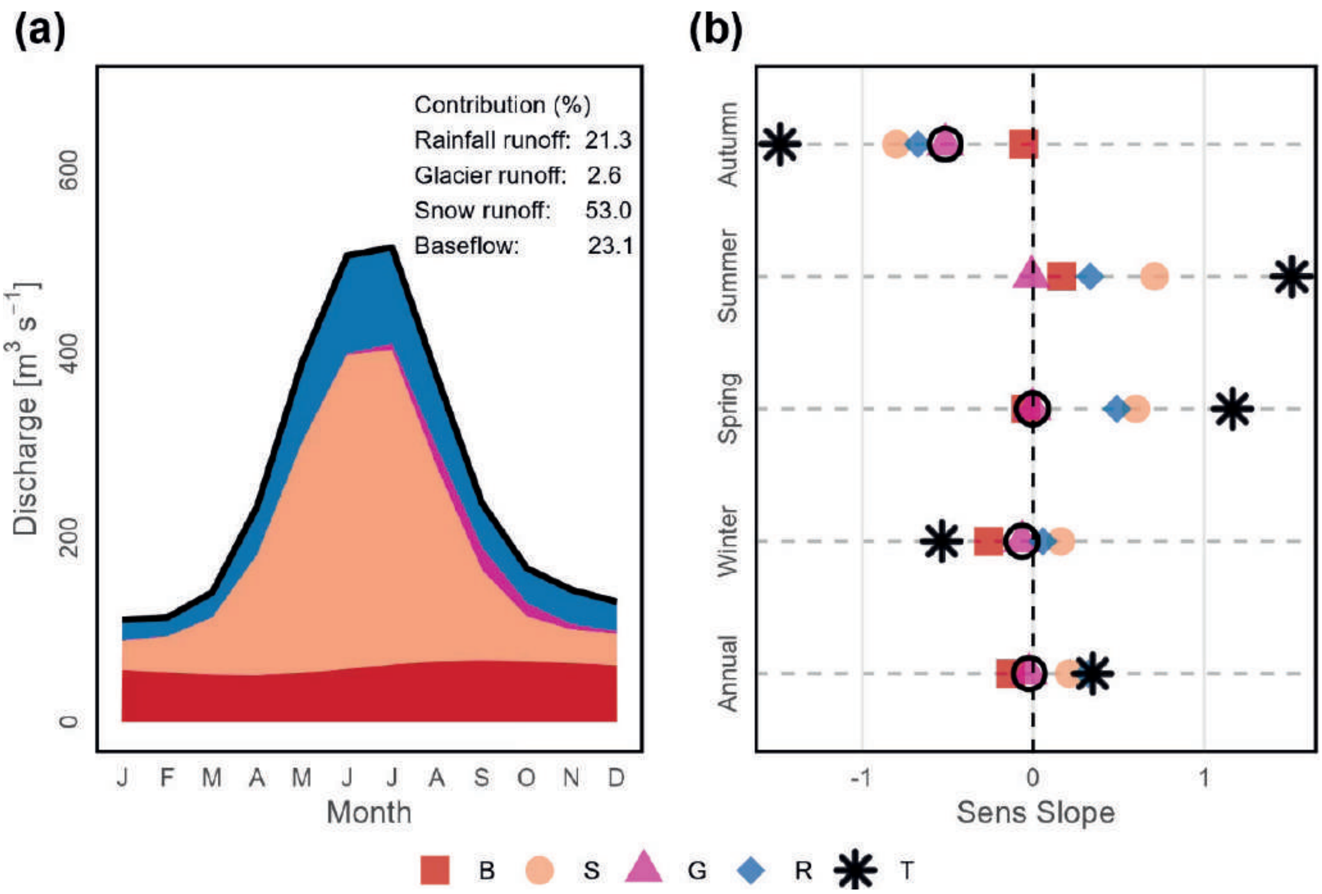

Figure 6. (a) Baseline averaged monthly runoff with the distinction of flow components (B: Baseflow, S: Snow flow, G: Glacier flow, R: Rainfall runoff and T: Total runoff) at the outlet of ZRB basin (just before the Zarafshon River enters Uzbekistan) for 1991–2020. The top right part of the figure shows the contribution of stream flow contributors to the total flow (expressed in %). (b) Linear trends of average seasonal (Winter: DJF, Spring: MAM, Summer: JJA, Autumn: SON) and annual runoff components (base, snow, glacier, and rain-runoff flow). The shapes and colors represent different flow components. The black circle represents whether the trends are significant (Mann-Kendall $p < 0.05$) for a particular flow component.

The Zarafshon River Basin exhibits distinct spatial runoff patterns. Snow and glacier melt runoff contribute significantly to the upstream river reaches (Figure 7). Specifically, the Zarafshon glacier accounts for approximately 70% of the total runoff in the upstream 'Matcha' river. Conversely, snowmelt is the dominant contributor to the upstream Fondarya River tributaries, providing around 90% of their runoff. Overall, the upstream catchment is primarily influenced by snowmelt and glacier runoff. In contrast, the lower basin flow is mainly driven by snowmelt and baseflow. While most annual and seasonal flow components show no significant trends (Mann-Kendall, $p<0.05$), glacier melt runoff is an exception (Figure 4). It exhibits a declining trend, with the most pronounced decrease observed in Autumn (SON) across all timescales except summer.

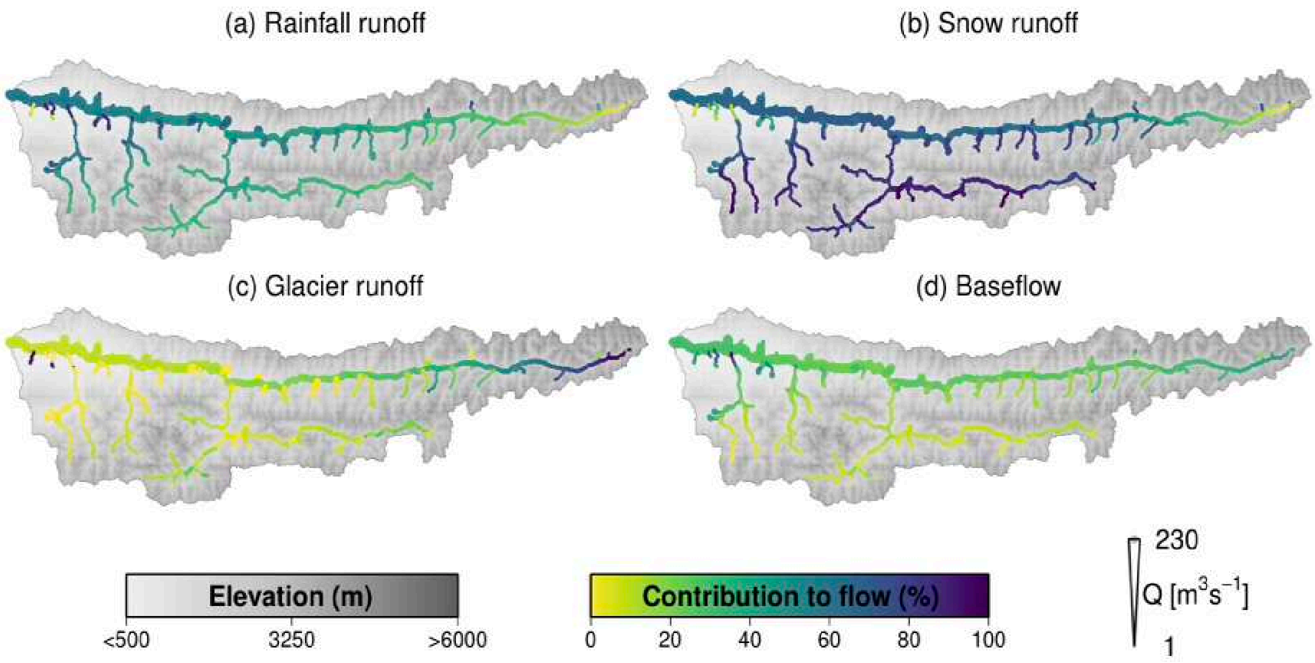

Figure 7. Spatial contribution patterns of the flow components for the ZRB (just before the Zarafshon River enters Uzbekistan) for 1991–2020. (a) Rainfall-runoff (b) Snow melt runoff (c) Glacier melt runoff and (d) Baseflow The background is elevation; color represents the contribution, and size represents the discharge values.

Changes in Cryosphere

Future projections for the Zarafshon River Basin indicate a significant decline in both snow persistence and glacier extent by both mid-century (MC, 2036-2065) and the end of the century (EoC, 2071-2100).

Snow persistence is expected to decrease across all climate scenarios, with more pronounced declines by EoC and under higher-emission scenarios such as SSP585 (Figure 8a, b, and c). For instance, average snow persistence is projected to drop from a reference value of 0.59 to 0.45 under SSP370 and to 0.39 under SSP585 by EoC. This reduction is primarily attributed to decreased snowfall resulting from warming temperatures.

Glaciers in the Zarafshon River Basin are also projected to shrink significantly. While the rate of glacier volume and area loss remains similar across scenarios until 2040, sharper declines are anticipated thereafter, particularly under high-emission pathways. By 2070, SSP245 and SSP585 scenarios project an approximate 50% loss in glacier volume from 2020 levels. By 2100, glacier volume loss is expected to reach 79.6% under SSP585, compared to 38.6% under SSP126. Glacier area is projected to shrink even more rapidly than volume, primarily due to the quicker disappearance of smaller glaciers.

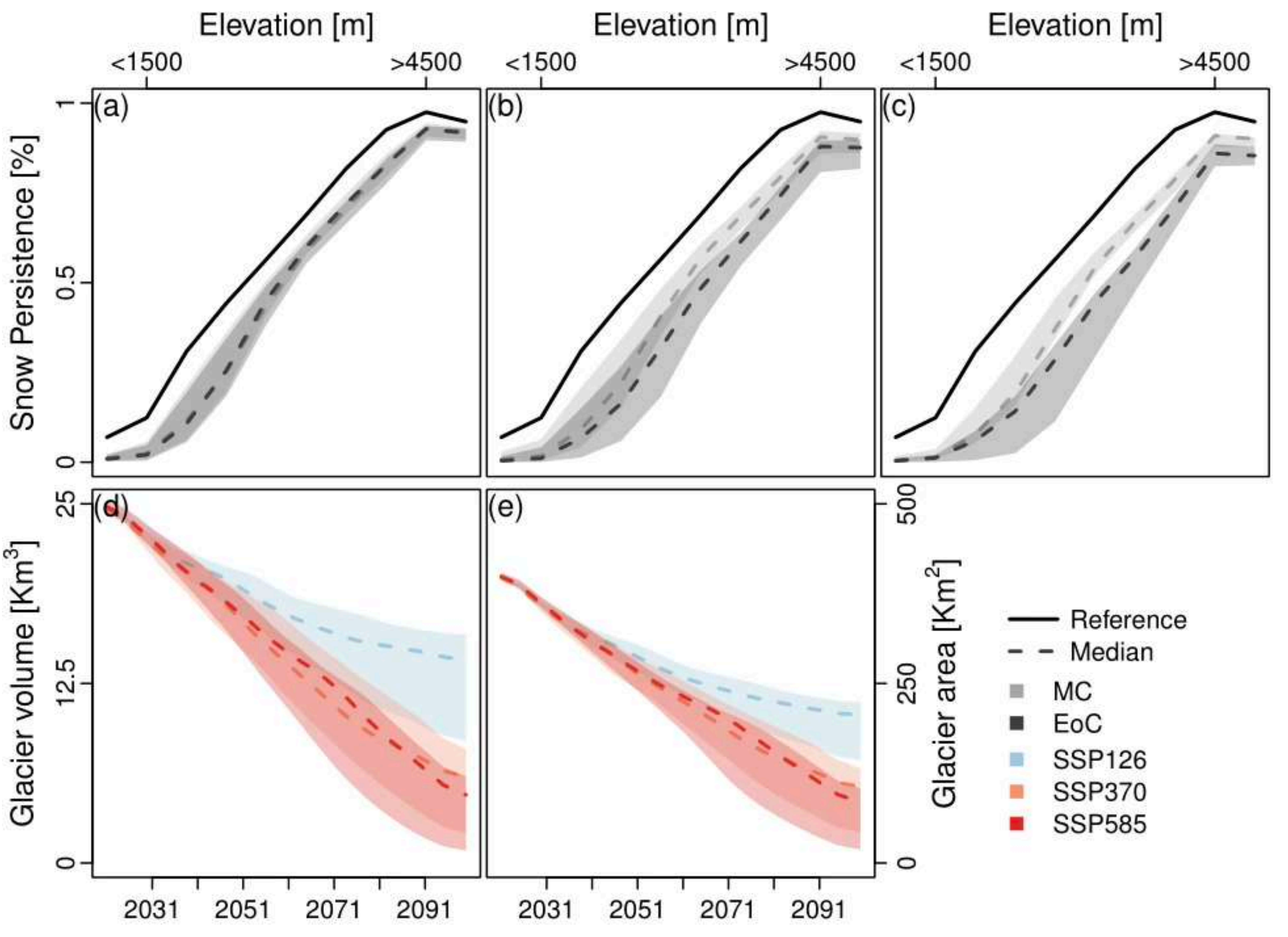

Figure 8. Snow persistence per 500m elevation band bins for the entire ZRB for reference, mid-century (MC, 2036–2065) and end of century (EOC, 2070–2100) horizons for (a) SSP126 (b) SSP370 (c) SSP585 scenarios. Long-term changes in the (d) total volume and (e) area of all the glaciers in the ZRB (just before the Zarafshon River enters Uzbekistan) from 2021 till 2100. The bandwidth represents the variability (minimum and maximum) of the five climate models with each SSP. The dashed line represents the median of the five climate models.

Seasonal changes in hydrology

Future projections indicate that the Zarafshon River Basin's hydrological regime will undergo substantial changes in both magnitude and timing during the mid-century (MC) and end of the century (EoC) horizons across all Shared Socioeconomic Pathways (SSPs). These shifts are primarily driven by temperature-induced alterations in solid precipitation (snowfall) and runoff generation mechanisms (Figure 9).

For both MC and EoC horizons, glacier-melt runoff is projected to decrease across all SSP scenarios compared to the baseline. Similarly, snowmelt runoff will decline across all SSPs for both periods, with more significant reductions observed by EoC, and a more pronounced decrease under SSP585 compared to SSP126 and SSP370.

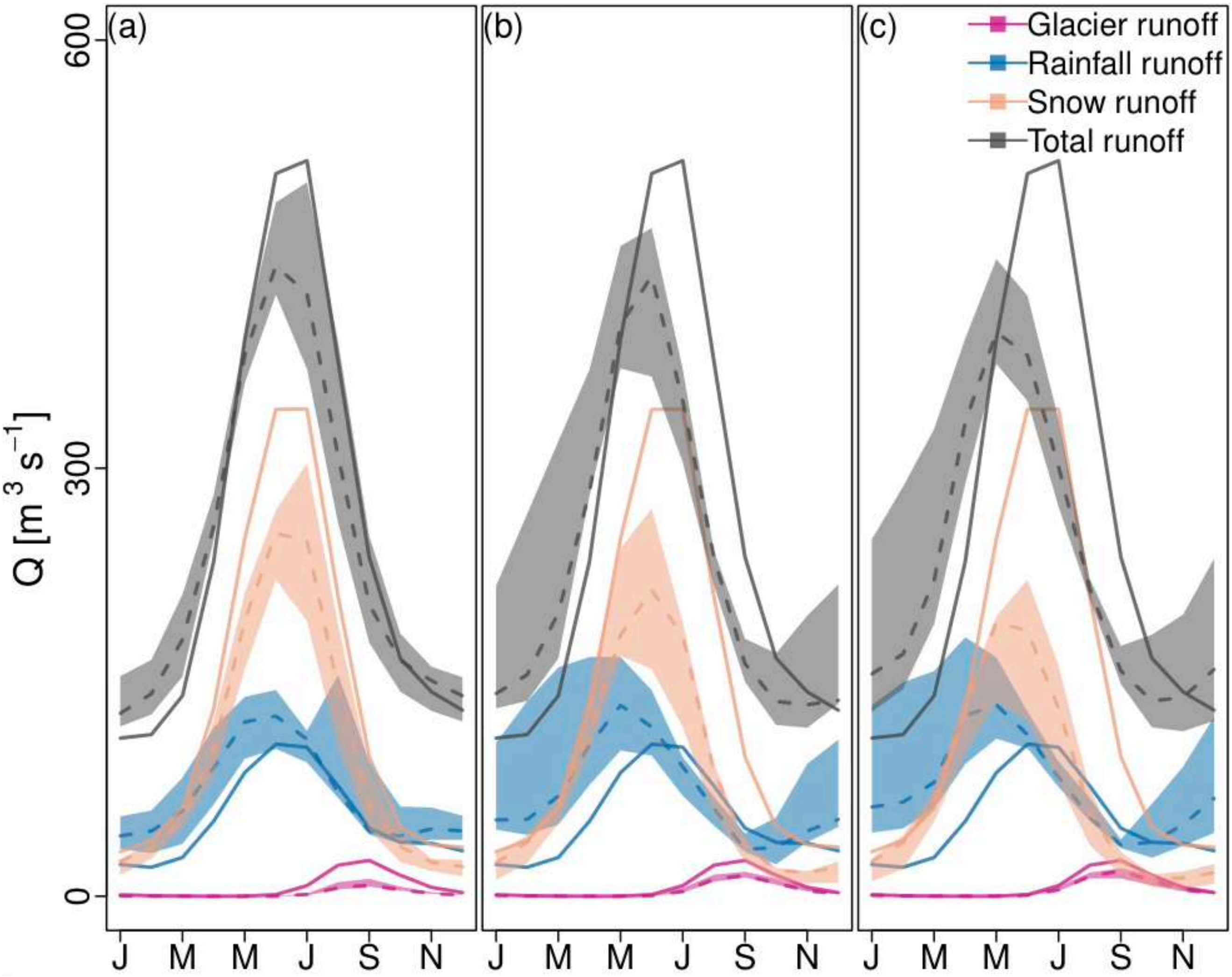

Figure 9. Seasonal changes in the hydrological regime for the end of century (EOC, 2071–2100) at the outlet of the ZRB (just before the Zarafshon River enters Uzbekistan). The panels represent three Shared Socioeconomic Pathways, i.e. SSP126, SSP370 and SSP585. The shaded color represents the variability (minimum and maximum) of the flow contributors. The dashed and solid coloured line represents the median of the five climate models and baseline flow (1991-2020).

A notable reduction in snowmelt runoff is anticipated during the winter months (September to December). For instance, October snowmelt runoff is projected to decrease by -24.3% (SSP126), -41.8% (SSP370), and -44.6% (SSP585). The most substantial absolute reductions, however, are expected during summer (May–August), with August snowmelt runoff dropping by -40.4% under SSP585.

Concurrently, rainfall-runoff is projected to increase due to enhanced liquid precipitation. This leads to a shift in the peak total runoff from July to June for SSP370 and SSP585. Total summer flows are expected to decrease significantly, with August reductions reaching -21.9% (SSP370) and -20.0% (SSP585).

By the EoC, both the magnitude of flow reduction and the shift in peak flow become more severe. Snowmelt runoff exhibits greater declines, with September reductions reaching -33.9% (SSP126), -62.3% (SSP370), and -74.9% (SSP585). Total runoff reductions are also more pronounced in peak summer months, with July flows decreasing by -18.1% (SSP126), -32.7% (SSP370), and -41.6% (SSP585). The seasonal runoff peak shifts further, moving from July to June under SSP370 and to May under SSP585. This is accompanied by a decrease in the magnitude of the peak flow of -15.6% (SSP370) and -23.3% (SSP585). By the EoC, September snowmelt runoff is projected to be reduced by approximately 63% for SSP370 and 75% for SSP585 compared to the baseline.

These significant seasonal changes, encompassing both a reduction in the magnitude of total flow and a shift in the timing of the peak flow, will profoundly impact downstream water users, making water allocation increasingly challenging.

Water allocation across sector users

Adequately allocated water is critical for the survival and well-being of the Zarafshon River Basin's population and for its climate-resilient development. To address this, an extensive scenario analysis was conducted using the WEAP water allocation model. This analysis revealed that, despite abundant water resources (Figure 10), all unmet water demand in the basin stems solely from limitations in the water supply infrastructure, including canals, pumps, and pipelines.

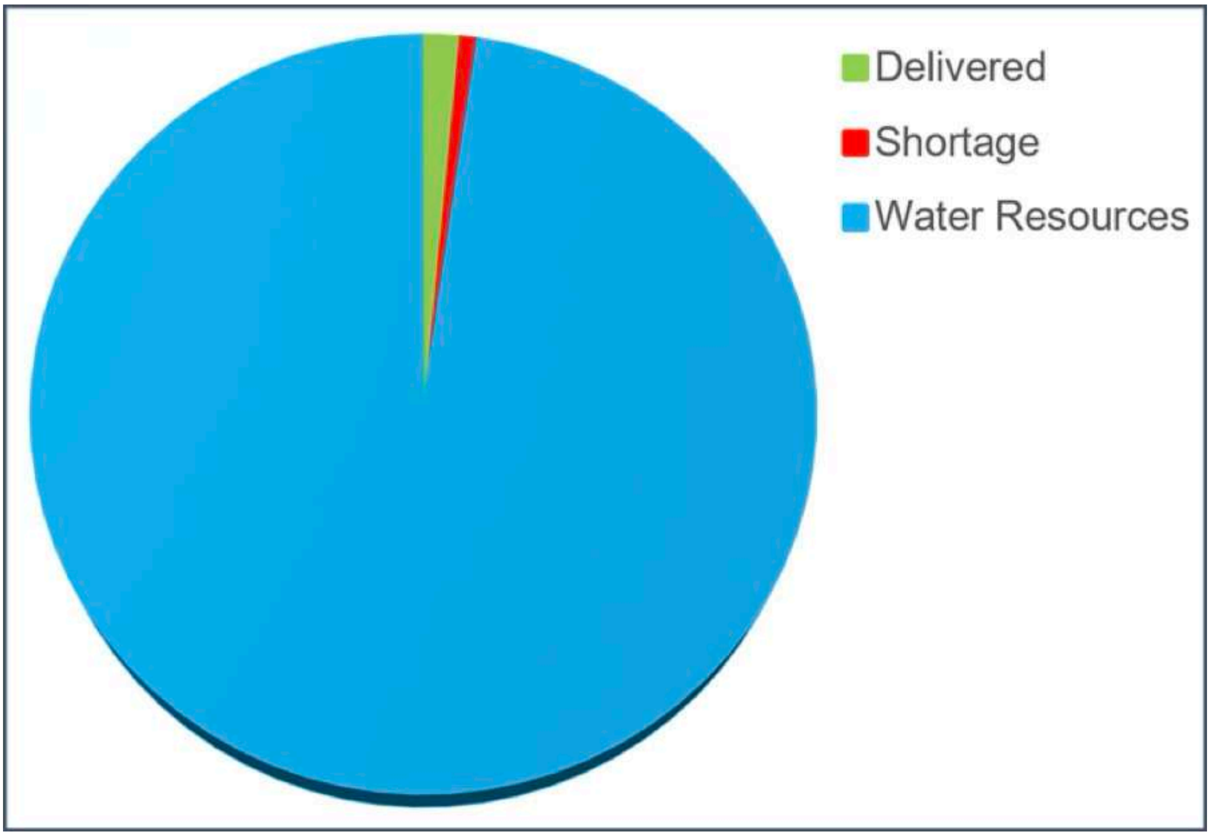

Figure 10. The graph illustrates that the combined water demand (delivered plus shortages) is considerably lower than the available water resources. Yet there is a significant shortage in water access, the supply infrastructure cannot meet the demand.

The scenarios combined projections (factors beyond the influence of water managers, such as climate change and socio-economic development) with interventions (actionable measures that can be implemented by water managers and policymakers).

Regarding the projections, both climate change and socio-economic development were considered. Initially, a series of exploratory sensitivity analyses assessed the impact of key assumptions on projected water allocation. These results indicate that, given the substantial availability of water resources, neither climate change nor socio-economic development is expected to exacerbate water shortages.

The main conclusions from this exploratory sensitivity analysis are:

I. Water demand constitutes approximately 2% of water resources.

II. Water shortage, or more precisely unmet demand, primarily stems from a lack of water accessibility due to insufficient infrastructure.

III. Approximately 79% of delivered water is consumed, with the remainder flowing back to streams.

IV. During a dry year, water resources can decrease by around 25%.

Secondly, a comprehensive climate change analysis was conducted using the WEAP model to evaluate the full range of projected climate scenarios previously described. A total of 15 distinct GCM-SSP model combinations were assessed, utilizing outputs from the SPHY model. The complete SPHY outputs were then evaluated within WEAP to determine their impact on key water allocation metrics, including total demand, supply, and unmet demand.

The most significant findings from this climate change analysis are:

I. Water demand is projected to increase by 18% to 60% in the near future and by 56% to 102% in the distant future.

II. Water shortages (unmet demand) will further escalate, with average increases of 113% for the near future and 222% in the distant future.

III. A detailed analysis confirms that these water shortages are predominantly caused by a lack of water accessibility (due to inadequate water infrastructure), rather than a genuine shortage of water resources (Figure 11).

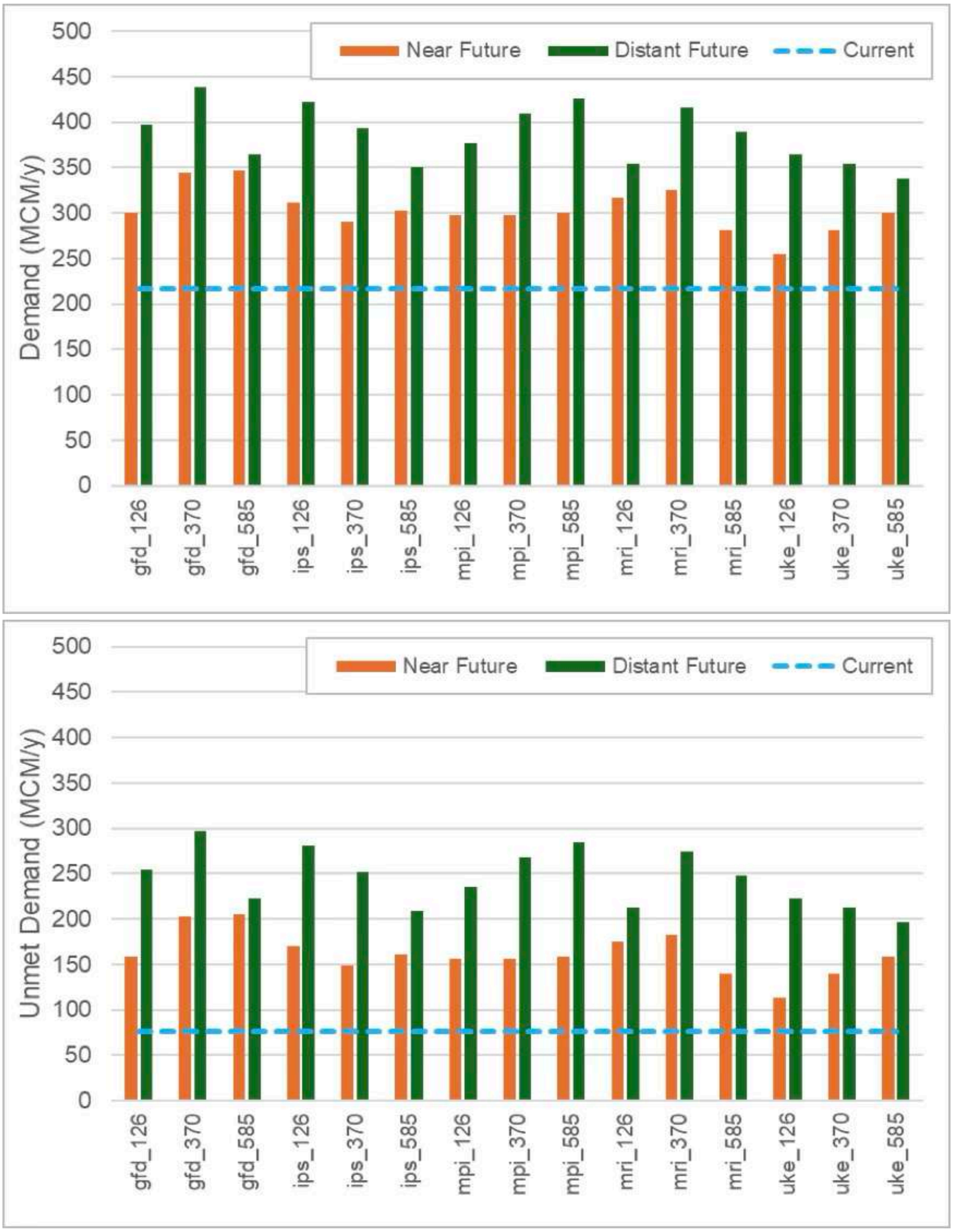

Figure 11. Average annual water demand (top) and unmet demand (bottom) for the 15 GCM-SSP combinations. Near Future is 2031-2050; Distant Future is 2061-2080; Current reflects 2001-2020.

Regarding interventions, the scenarios focused on two key strategies: expanding supply capacity and improving infrastructure maintenance. The results demonstrate that both strategies, especially when combined, significantly reduce unmet demand by addressing critical bottlenecks in water delivery systems.

These findings underscore the importance of targeted investments in supply infrastructure and maintenance to optimize water resource allocation and meet the growing demands of the basin's population. Specifically, the interventions can effectively reduce water shortages. In the near future, average water shortages (across all GCM-SSP scenarios) can be reduced by 64%, from 162 to 60 MCM/year. For the distant future, shortages can be reduced by 46%, from 224 to 134 MCM/year (Figure 12).

Additionally, the impact of these interventions on overall water resources is minimal. The total streamflow at the Zarafshon River outlet in Tajikistan, before crossing into Uzbekistan, is projected to decline by only approximately 1%. The key message is clear: water resources are not a critical limiting factor under any climate scenario. Instead, supply capacity and infrastructure maintenance remain the primary constraints on water availability.

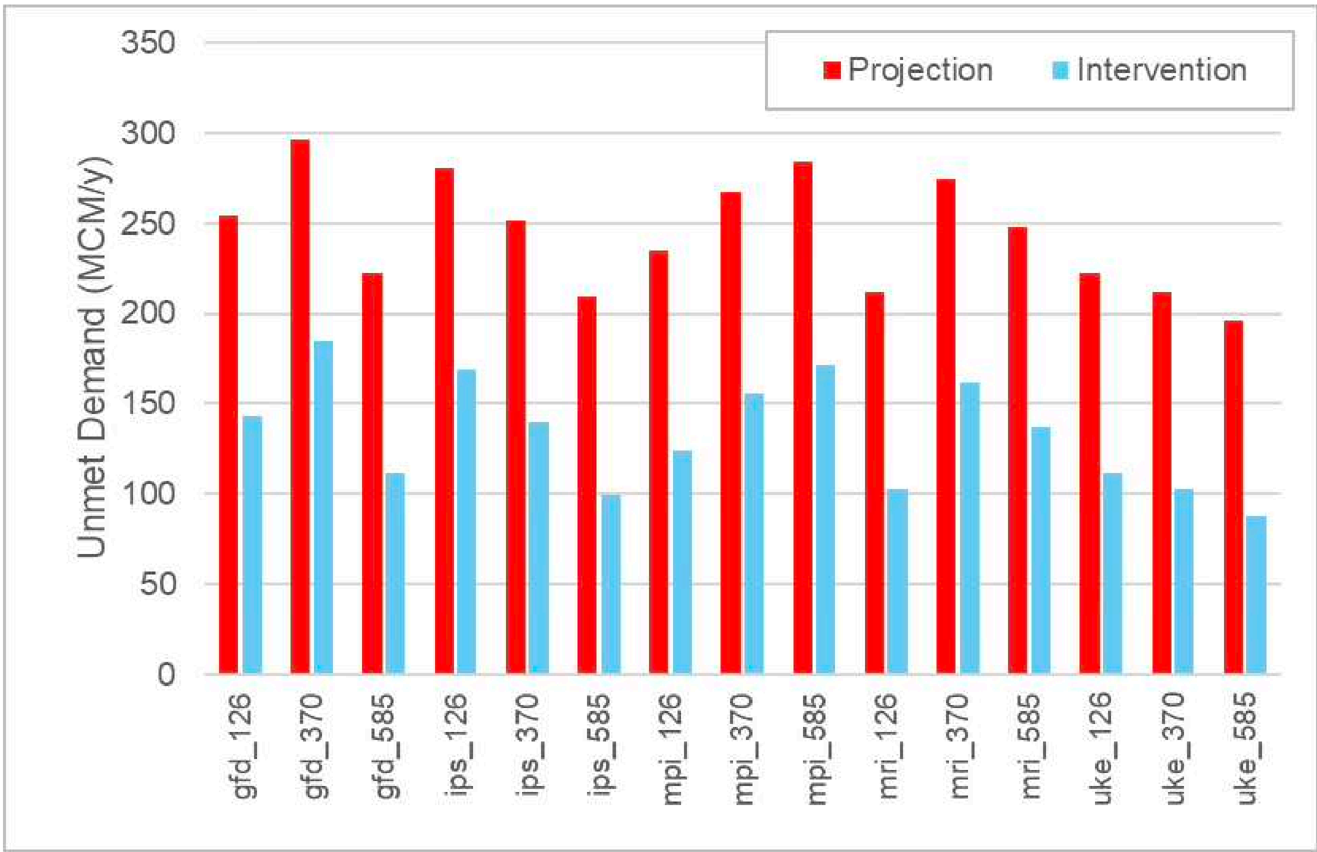

Figure 12. Impact of interventions (enhanced infrastructure) on reducing unmet demand. Results represent the distant future (2061-2080).

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Project

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