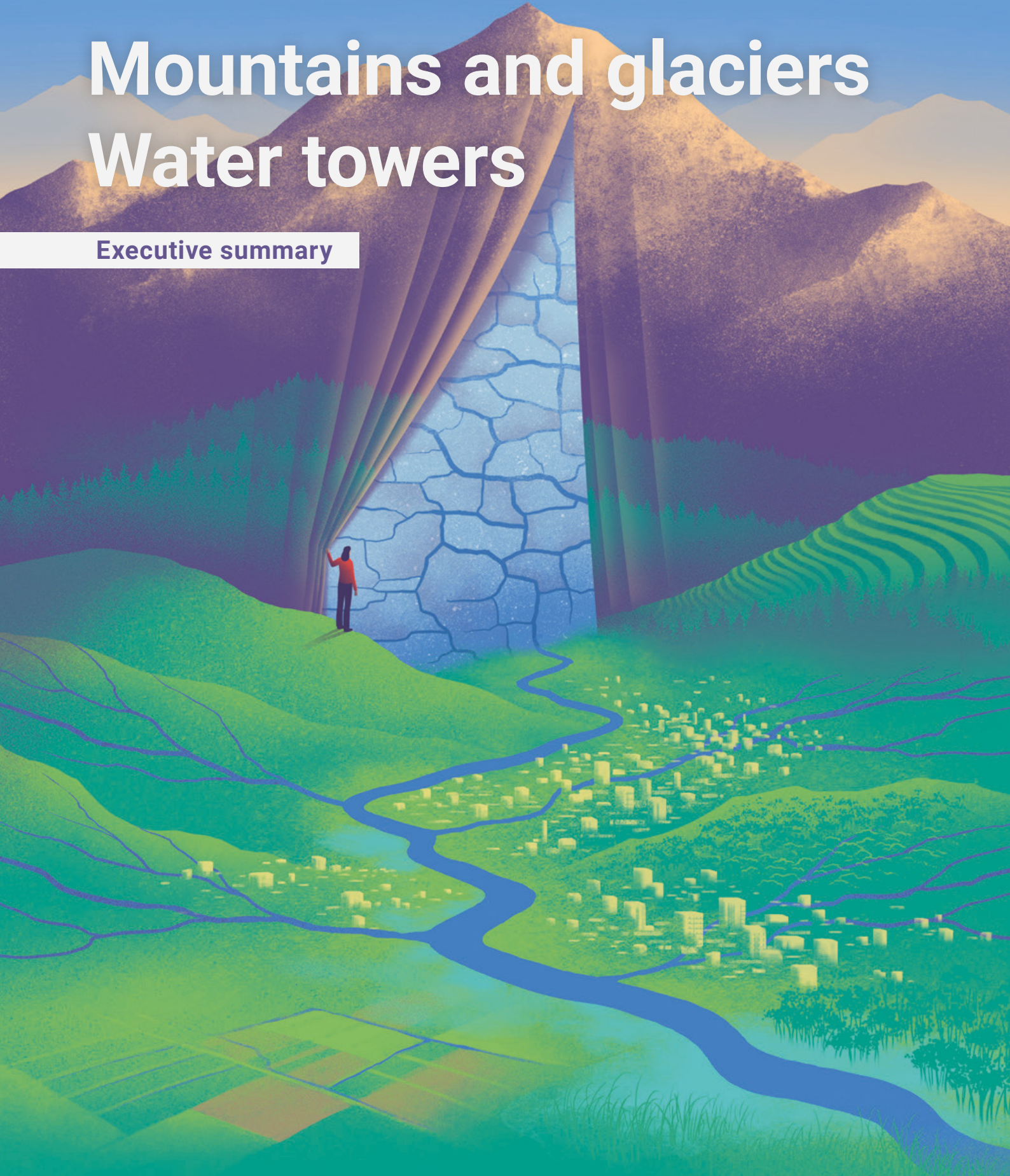


The United Nations World Water Development Report 2025

Mountains and glaciers Water towers

Executive summary



In alignment with the designation of 2025 as the International Year of Glaciers' Preservation and the 2022 resolution of the General Assembly of the United Nations on sustainable mountain development, this report draws worldwide attention to the importance of mountain waters, including alpine glaciers, in the sustainable development of mountain regions and the downstream societies that depend upon them, in the context of the rapidly changing mountain cryosphere.

Status of the world's water resources

According to the most recent global estimates (from 2021), the agriculture sector dominates freshwater withdrawals (72%), followed by industry (15%) and domestic (or municipal) use (13%). Sector-specific freshwater withdrawals vary considerably as a function of a country's level of economic development. Higher-income countries use more water for industry, whereas lower-income countries use 90% (or more) of their water for agricultural irrigation.

Over the period 2000–2021, global freshwater withdrawals increased by 14%, corresponding to an average growth rate of 0.7% per year. Most of this increase occurred in cities, countries and regions undergoing rapid economic development. Population growth does not appear to play a highly significant role in increasing demand for water. In fact, countries where per capita water use is the lowest, including several countries in Sub-Saharan Africa, are often those with the fastest growing populations.

Twenty-five countries – home to one-quarter of the world's population – face 'extremely high' water stress every year. Approximately 4 billion people, or half the world's population, experience severe water scarcity for at least part of the year.

Climate change is increasing seasonal variability in, and uncertainty about, water availability in most regions. Pollution, land and ecosystem degradation, and natural hazards can further compromise the availability of water resources.

Progress towards Sustainable Development Goal 6

Sustainable Development Goal (SDG) 6 seeks to ensure the availability and sustainable management of water and sanitation for all.

Progress towards all SDG 6 targets is off track – some severely.

For example, an estimated 2.2 billion people (27% of the global population) were without access to safely managed drinking water in 2022, with four out of five people living in rural areas lacking even basic drinking water services.

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The situation concerning sanitation is worse, with 3.5 billion people worldwide lacking access to safely managed sanitation in 2022. Only half of the population had access to these services in Latin America and the Caribbean, and Central and Southern Asia. Coverage in Sub-Saharan Africa was a mere 24%.

Data gaps and deficiencies in monitoring continue to impede accurate assessment of the other SDG 6 targets, including on the management of water resources, water quality, water-related ecosystems and the enabling environment.

Mountain regions

As the ‘water towers’ of the world, mountains are an essential source of fresh water. They are vital for meeting basic human needs such as water supply and sanitation. These waters are also vital in ensuring food and energy security to billions of people living in and around mountain regions and in areas downstream.

The main economic activities in mountain regions are agriculture, pastoralism, forestry, tourism, mining, cross-border trade and energy production. Mountain regions provide high-value products such as medicinal plants, timber and other forest products, unique mountain livestock and speciality agriculture products. They are global hotspots of agrobiodiversity, with a large fraction of the world’s gene pools for agriculture and medicinal plants preserved in mountains.

Mountains feature a diverse range of ecological zones, each resulting from a specific combination of factors such as elevation, geomorphology, isolation and microclimatic conditions (e.g. insolation). Consequently, they often have higher endemic biodiversity than lowlands, including important genetic varieties of agricultural crops and animals. They also have an equally diverse range of human cultures.

Glaciers and the mountain cryosphere

The mountain cryosphere is one of the most-sensitive components of the Earth system to global climate change. Mountains generally supply more surface runoff per unit area than lowlands, due to higher precipitation and lower evaporation. Alpine glaciers also store and release water, albeit over much longer time-frames. In many high mountain regions, the formation of seasonal snow cover provides most of the freshwater storage.

Most of the world’s glaciers, including those in mountains, are melting at an increasing rate. However, snow-melt accounts for a greater volume of streamflow in most river basins with a cryosphere component, and is often substantially higher than glacier melt.

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Global warming is accelerating glacier melt, decreasing snow cover, increasing permafrost thaw, and prompting more extreme rainfall events and natural hazards. Water flows from mountains will become more erratic, uncertain and variable. Changes in the timing and volume of peak and low flow periods, increased erosion and sediment loads will affect water resources downstream, in terms of quantity, timing and quality.

Dust, combustion-related soot deposits including black carbon, and microbial and algal growth on snow and glacier surfaces are becoming more common due to increased frequency and/or intensity of dust storms, air pollution and wildfires. They can accelerate melt rates by decreasing surface albedo until the next snowfall.

The consequences of climate change, including higher temperatures, glacial recession, permafrost thaw and changing precipitation patterns, can affect flood and landslide risks. The processes associated with these risks, such as debris flows and floods, avalanches, rock- and icefalls, landslide dam outburst floods and glacial lake outburst floods (GLOFs), can pose significant threats to communities, wildlife and infrastructure.

Food and agriculture

Agriculture and pastoralism are essential sources of livelihoods for people in rural mountain areas. One in two rural mountain dwellers in developing countries are vulnerable to food insecurity. Remoteness and inaccessibility, as well as land degradation (which leads to poor quality soils) and large variations in seasonal water supply, combine to create significant challenges for mountain agriculture.

Mountain communities preserve many of the rarest crop varieties and medicinal plants. They have developed valuable traditional knowledge and techniques in crop cultivation, livestock production and water harvesting that help to sustain entire ecosystems.

Indigenous Peoples in mountains have unique and valuable local knowledge, traditions and cultural practices that contribute to sustainable food systems, land management and biodiversity preservation. Terrace farming can be adapted to local slope conditions. Its numerous benefits include reducing surface water runoff, promoting water conservation, reducing soil erosion, stabilizing slopes, enhancing habitat and biodiversity production, and sustaining cultural heritage.

Responses to climate-driven impacts in mountains vary significantly in terms of goals and priorities, speed of implementation, governance and modes of decision-making, and the extent of financial and other resources to implement them. Adaptation responses commonly include changing farming practices, infrastructure development including for water storage, application of Indigenous knowledge, community-based capacity-building and ecosystem-based adaptation (EbA).

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The remoteness of mountain communities, difficult terrain and heightened exposure to natural hazards often lead to higher costs for transport, infrastructure, goods and services

Human settlements and disaster risk reduction

Roughly 1.1 billion people live in mountain regions, two-thirds of whom live in towns and cities. The remoteness of mountain communities, difficult terrain and heightened exposure to natural hazards often lead to higher costs for transport, infrastructure, goods and services. These also pose particular challenges for the financing, development and maintenance of water supply and sanitation systems, drainage networks and other essential water infrastructure.

Rapid and unplanned urbanization in mountain regions is also placing pressure on fragile mountain ecosystems, affecting water availability, quality and security. Decentralized water and sanitation systems can be particularly effective in mountain regions, reducing the risk of infrastructure damage in rugged terrain subject to frequent landslides.

Natural hazards such as landslides, earthquakes, floods, GLOFs and avalanches can damage the water supply and sanitation infrastructure, and disrupt access to water, sanitation and hygiene services. Such hazards increase the vulnerability of already vulnerable and often marginalized mountain communities, and destabilize some of their wealth-generating sectors, including agriculture, tourism and biodiversity.

Examples of adaptation actions in mountain regions include: feasibility studies for building emergency storage and bypasses and controlled releases from glacial lakes; river basin management and planning for basin optimization; monitoring temporal changes in glaciers; and establishing GLOF risk reduction and early warning systems in glaciated river basins.

Industry and energy

Water-dependent industries have developed in mountain areas where water and other resources are found in relative abundance. In addition to industrial and energy production, water is also required to process minerals, produce timber and develop tourism in mountain areas.

Hydropower generation is one of the main industries in mountain areas. The presence of a slope and the shape of mountain valleys make it possible to generate hydropower without building large dams and reservoirs. However, the construction and presence of dams and reservoirs, transmission lines and substations can have a significant negative impact on fragile mountain ecosystems.

Beyond water availability, a significant challenge for industry and energy is the elevation at which it is possible to operate. As such conditions can generate huge investment and running costs, industrial activities are typically limited to those with high returns on investment.

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Industrial and energy development can affect water quality. Remote mountain areas can be difficult to regulate, resulting in uncontrolled water withdrawals and discharges, including pollutants.

Responses are available and are being developed to make industry and energy production in mountain areas more sustainable. The circular economy promotes water-use reduction, recycling of used water and reuse of water resources. Environmentally sound technologies encompass practices such as the use of less-polluting technologies, better resource management and efficient waste recycling. The greening of grey infrastructure or its replacement with green infrastructure can be particularly effective in mountain areas.

Environment

Mountain and highland ecosystems provide essential ecosystem services to people living in mountains, and to billions in connected lowland areas. Water regulation (including water storage and flood regulation) is one of the most important services.

Other key ecosystem services include reducing the risk of erosion and landslides, cooling local temperatures, carbon sequestration, providing food and fibres, and maintaining pools of genetic resources for locally adapted crops and livestock.

Forests cover an estimated 40% of mountain areas, performing a protective function against natural hazards by stabilizing steep slopes, regulating flows to groundwater, reducing surface runoff and soil erosion, and mitigating the potential for landslides and floods. Unsustainable tree cultivation can lead to increased soil erosion and reduced soil water infiltration.

Mountain soils develop under harsh climatic conditions. They differ significantly from lowland soils, as they are shallower and more vulnerable to erosion. Such soils are easily and often degraded by various human activities, especially removal of vegetation that exposes the bare soil. The recovery of degraded soils and thus ecosystems at high elevations is slow.

At the ecosystem level, most of the options for addressing the impacts of changes in the cryosphere and high mountains involve conserving or restoring ecosystem functionality to maintain or enhance ecosystem services at local to regional scales through nature-based solutions (NbS) or EbA. These approaches are now commonly seen as an adaptation component in the nationally determined contributions of many mountain countries around the world.

Regional perspectives

Sub-Saharan Africa

Of continental Africa's land area, 20% is classified as mountains with an elevation over 1,000 metres above sea level (masl), with 5% rising above 1,500 masl. East Africa is the most mountainous region in Africa. The mountain regions are characterized by high levels of biodiversity; they provide ecosystem services, including water resources, to millions of people. In tropical and subtropical Sub-Saharan Africa, mountains have favourable environmental conditions and resources compared with the generally drier surrounding lowlands.

Agricultural production and food security within mountain regions and downstream lowlands are critically dependent on mountain waters. The degradation of mountain ecosystems reduces their ability to store and supply water downstream. This is particularly the case with deforestation of critically important montane forests.

Considering farming is the principal livelihood in the mountains of Sub-Saharan Africa, improving agricultural practices to reduce land degradation (soil conservation) is of critical importance. Promoting EbA (e.g. reforestation and conservation of montane forests reducing soil erosion) can enhance water retention and aquifer recharge and diminish the risk of natural hazards.

There are high population growth rates and density in the mountains of the region, with widespread poverty and a lack of alternative and resilient livelihoods. In many areas, the mountains are more densely populated than the lowlands.

Europe and Central Asia

Mountain ranges are the source of water for many rivers in Europe and Central Asia. Alpine snow and glacial melt ensure a slow release of water to downstream areas. However, climate change is leading to earlier seasonal snow-melt and smaller glaciers, thereby threatening the availability of water in the summer season. This has serious consequences for populations in downstream basins.

Water from the Alps is vitally important to large parts of Europe. Hydropower generation is the main reason for water abstraction, while other uses include industrial purposes, agricultural irrigation and snow-making.

The Carpathian Mountains are home to approximately 30% of European flora. Their semi-natural habitats such as mountain pastures and hay meadows are of great ecological and cultural importance.

Across the mountains of Central Asia, upstream countries experience energy shortages in winter and would like to expand their hydropower production, while downstream countries are largely dependent on water from the mountains for their agricultural production in the summer. These conflicting seasonal demands lead to political tensions among the riparian countries.

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*Alpine glaciers are
disappearing at an
alarming rate*

The improvement and exchange of knowledge and information, the strengthening of regional cooperation, the strengthening of in-country capacities on the cryosphere and mountain water management, and the raising of awareness and involvement of key stakeholders in developing and implementing action plans are needed.

Latin America and the Caribbean

Mountains occupy about one-third of the territory in Latin America and the Caribbean. They produce more water flow per land area than any other continent. Glaciers across the region are experiencing a significant overall reduction in volume, with several having disappeared entirely.

Water originating in the mountains is essential for producing high-value agricultural crops like coffee and cocoa. Mountain waters also generate most of the region's hydroelectric power, providing energy for cities and smaller communities downstream, as well as remote villages in mountain areas.

The mountain areas in Latin America and the Caribbean are being increasingly affected by climate change and human activities. Water-related social conflicts have occurred in high-elevation areas of Andean countries, many of which can be attributed partially to mining activities, which can negatively affect the availability of water for downstream users.

In response, several countries have enacted policies and laws to protect these critical ecosystems. However, some systems have already surpassed critical thresholds, making it crucial to promote adaptive measures such as NbS (e.g. reforestation), cropping techniques and expanding water collection infrastructure. To implement these measures effectively, well-targeted funding, robust monitoring, capacity-building and inclusive governance frameworks are needed, fostering dialogue and inclusion of local communities to apply the best available practices adapted to local contexts in the mountain regions.

Asia and the Pacific

The Asia–Pacific region contains some of the world's highest mountains and most extensive glacier systems. This so-called Third Pole stores more ice and snow than any other region outside the Antarctic and Arctic. It is the origin of more than ten river systems that are vital for sustaining nearly 2 billion individuals in the river basins of Central, Northeast, South and Southeast Asia. The Third Pole is also one of the most biologically diverse and ecologically fragile areas in the world, and is home to a variety of cultures.

Alpine glaciers in the region are disappearing at an alarming rate, often faster than the global average. Over the long term, reduced water flows and increased droughts are expected to jeopardize food, water, energy and livelihood security in the Hindu Kush Himalaya region.

Energy use, environmental degradation and human activity are contributing to risks in other ways, with black carbon, heavy metals and persistent organic pollutants showing an increasing presence in the Third Pole.

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*There is a need
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infrastructure in
high mountain
areas*

Collaboration on engaging the diverse stakeholders and sectors affected by the trends is essential. Glacial melt and water-related crises must be addressed by strengthened adaptation measures, integrated water resources management (IWRM) and synergistic solutions for climate, nature and pollution, supported by transboundary collaboration, regional dialogue, advocacy and awareness-raising.

Arab region

The mountain areas of the Arab region are often overlooked, despite the important role they play in providing water resources and other ecosystem services. They are home to thriving communities and centres of economic activity for tourism, agriculture and industry, which are often reliant on the ever-dwindling availability of freshwater resources, resulting in a reduced amount of renewable water per capita.

Meltwater can serve a crucial role for the agricultural sector, particularly in sustaining crops during the summer when precipitation is limited. Some aquifer-fed springs within the Arab region are primarily recharged from snow-melt. In Mount Lebanon and the Atlas Mountains, seasonal snowfall and overall precipitation are expected to decrease, affecting snow cover duration and depth and availability of freshwater resources. These projected reductions in snow cover signal an overall decrease in water supply, specifically during the dry season when it is most needed for irrigation. Water, sanitation and hygiene services may also be affected by reduced overall water resources in the long term.

Managed aquifer recharge is one adaptation measure that could be employed. Water harvesting could be used in the winter to mitigate the decrease in water availability in the summer resulting from climate change impacts on mountain areas in the Arab region, including the loss of snowpack.

Knowledge- and capacity-building

The high variability in mountain climate, topography, geology and vegetation – all of which influence the movement of water through the landscape – creates an exceptional need for representative hydrometeorological networks and robust information systems.

The sparseness of cryosphere monitoring in mountain regions exacerbates uncertainties in hydroglaciological predictions, enhancing the risk of water resources mismanagement. To understand cryospheric changes and improve the sustainability of mitigation and adaptation approaches, there is a need for expansion of the observational infrastructure in high mountain areas, and also for data to be open access.

Engagement and meaningful collaboration with Indigenous Peoples and local communities, with their prior informed consent, and the willingness to learn from stewardship of water systems evolved over generations will improve the collective ability to respond to changing mountain cryospheric and downstream hydrological conditions.

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Institutional capacity can encompass the time and resources necessary to bring diverse people and perspectives together. Collaborative governance models often imply trade-offs that, while advantageous to society in the long term, may be undesirable to current beneficiaries from the status quo.

Participation in citizen science projects can provide valuable avenues for public engagement with the local environment, improve scientific literacy and encourage research careers. Collaboration between research organizations and community groups, where researchers develop the methods, education and training, is a common approach to ensure this requirement is met. In this process, locals should provide input on project scope to ensure the knowledge outcomes meet their community needs.

Governance and finance

The role of water governance in mountains has not received as much attention as in lower-lying lands, on which there has been a large amount of work, such as through IWRM.

International policy frameworks offer promising support to water governance and adaptation to climate-related changes in the mountains. Treaties and conventions are relevant enablers to promote cooperation and implementation at the mountain region scale.

Most large rivers originate in mountain areas and often cross international borders. Transboundary water governance, based on a 'basin-level view' that considers mountain waters, can provide benefits to riparian countries. Regional cooperation among countries, including river basin governance initiatives, is an important mechanism for advancing climate adaptation in mountains. However, conflict between national interests within transboundary water agreements and the ineffectiveness of institutions to navigate coordination within the local context has hindered effective cooperation.

The management of mountain waters takes place primarily within country borders, through national legislation, policy and strategies. In some cases, national policies for water, agriculture, industry and energy are developed to favour low-lying regions of river basins, for instance, to serve more populous areas. National policies may often not fully reflect water sectoral issues within the mountains; rather, they tend to focus on mountains as sources for downstream users.

Development in mountains is generally more costly and difficult than in lowlands due to the rugged terrain and poor accessibility, restrictions on economies of scale, long distance from seaports and economic centres, and poorly developed industrial and service sectors. Costs related to transport, infrastructure, goods and services increase with elevation and isolation. These need to be considered in policy and financing, with calls for mountain-specific policies and programmes in national and global development plans.

Climate adaptation finance and private sector inclusion and contribution are key enablers for achieving the adaptation potential in mountains. While substantial funding is potentially available for investment in sustainable development in mountain regions, access to major support programmes has been relatively limited. This indicates a significant response option is underutilized. More specifically, innovative and affordable international, regional, national and local funds should be mobilized to support water, agriculture and energy planning and infrastructure investments.

Coda

Mountains provide life-sustaining fresh water to billions of people and countless ecosystems. As the world's water towers, their critical role in sustainable development cannot be ignored.

Actions must be taken to better understand and protect these fragile environments, increasingly threatened by climate change and unsustainable human activities.

Because nothing that happens in mountains stays in mountains.

In one way or another, ***we all live downstream.***

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This publication is produced by UNESCO WWAP
on behalf of UN-Water.

Cover artwork by Davide Bonazzi
Design and layout by Marco Tonsini

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<https://doi.org/10.54679/UTAH5608>



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UNESCO World Water Assessment Programme
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We acknowledge with gratitude the financial support provided
by the Government of Italy and Regione Umbria.

