

Nexus Brief, Nr. 10, March 2023

## Climate, DRR and Environment

# Mountains in a Changing Climate



## Key messages

The mountain regions of the world are home to more than 1 billion people and are distinguished by their geologic characteristics, their biodiversity, their array of cultures, and their vulnerability to climate change. The mountains are warming more rapidly than the lowlands, and the results are threatening mountain ecosystems and the life they support. The rate of change is unprecedented.

The increasing number of extreme precipitation events, to name one example, may trigger more compounding and cascading events. Thus, a hard rain may produce run-off that gathers force as it flows downhill triggering slides and rockfalls that become debris flows that crush whatever is in their path and block river channels, cause dam failures and floods, and destroy infrastructure. Such events are already occurring, and the projected changes in hazards will only increase the risks.

People in the mountains have been adapting to a changing environment throughout history, but the pace of climate change has mountain communities struggling to adapt. The current funding for climate

adaptation in the mountains is not nearly enough to support climate-resilient sustainable mountain development, and mountain communities do not have the resources required for the effort.

Not everything that happens in the mountains stays in the mountains, however, and the consequences of climate change in the mountains affect the lowlands as well. The areas closest to the mountains will feel the effects first, but eventually everyone will. About 2 billion people living in the lowlands depend on freshwater from the mountains. Hydropower development and disruptions in the water cycle in the mountains may threaten the water security of those in the lowlands. Eventually, in light of the 68 per cent of global irrigated agriculture that depends on mountain freshwater, water insecurity may spread throughout the lowlands and lead to widespread food insecurity as well.

In short, we all have a stake in what happens in the mountains, particularly those of us who drink water and eat food. Enlightened self-interest alone could be incentive enough for all of us to work to ensure that no mountain people are left behind.

## Context

### Why this nexus brief

Mountain regions cover one quarter of the world's land surface and are home to more than 1.2 billion people in more than 100 countries, with about one-third of the people living in cities. This nexus brief identifies the challenges to mountain and downstream communities and offers policy responses to meet those challenges.

Hosting rich biological and cultural diversity, mountains provide vital goods and services such as water, food, energy, minerals, and medicinal plants; offer opportunities for tourism and recreation; and embody aesthetic and spiritual values. These ecosystem

services – particularly the provision of freshwater – are crucial not only for mountain regions but for billions of people in downstream areas.

This nexus brief synthesizes the findings of recent publications on mountains and climate change, in particular IPCC Cross-Chapter Paper 5: Mountains (2022) and the OECD Development Co-operation Working Paper: Strengthening climate resilience in mountainous areas (2021). The references appear at the end of this brief, but for the sake of clarity and readability are not cited in the text.

## **Accelerated warming in the mountains**

According to the latest IPCC reports, many mountain regions are experiencing climate change impacts with serious consequences for people and ecosystems – reductions in snow cover extent and duration, loss of glacier mass, thawing of permafrost, increases in the number and size of glacial lakes and changes in seasonal weather patterns – all related to higher temperatures.

The accelerated warming in the mountains, in combination with the large population dependent on mountain services, places mountain regions in a unique and sensitive position in the context of sustainable development under climate change.

## **Compounding hazards and increased exposure**

Compound and cascading events occur when one hazard triggers one or more other hazards. The significant potential harm from common mountain hazards – floods, droughts, extreme weather events, wildfires, earthquakes, volcano eruptions, landslides, avalanches, rockfall or debris flows – multiplies in cascading events, increasing the scale and intensity of hazards. These events can occur over a short or long period, and have resulted in significant damage to ecosystems and infrastructure and in injuries and loss of life and livelihoods.

Mountain topography imposes limits on land use and concentrates development in valleys. Increases in populations and in economic development exacerbate the pressures, and have already resulted in the spread of development into unsafe areas. Inadequate planning fosters this unsustainable practice, which increase the exposure of people and critical infrastructure to natural hazards. In the Himalayas, for example, the prospect of glacial lake outburst floods threatens about two-thirds of the hydropower projects in the region. These physical limitations, population pressures and development failures add to the tensions among competing land uses – settlements, agriculture and infrastructure – and increase the exposure of mountain people.

## **Vulnerability of mountain people**

Sustainable development in the mountains helps countries and regions adapt to climate change, reduce disaster risks and achieve the Sustainable Development Goals. But mountain communities are often left behind economically and politically. While mountain people are adaptive, resourceful and independent, rural mountain communities in developing countries tend to be more vulnerable as a consequence of poverty, marginalisation, lack of economic opportunities, inadequate basic services and infrastructure, and remoteness from centres of power.

More than 90 per cent of the people living in the mountains live in developing countries, and more than 60 per cent live in rural areas where smallholder family farmers and pastoralists work the land. Overall, subsistence agriculture and livestock remain key sources of livelihoods in many mountain regions, with non-agricultural income sources such as remittances, small businesses, sale of medicinal plants, wage labour and tourism also contributing to these economies. To the extent that these activities collide with climate change disruptions and declining ecosystem services, the people become ever more vulnerable. In 2017, about 340 million people living in rural mountain regions in developing countries were vulnerable to food insecurity, a figure that represents 55 per cent of the total rural mountain population.

At the same time, the increasing urban population in many mountain regions, particularly in developing countries, has put considerable pressure on water services and basic amenities for urban dwellers. Large portions of the population reside in informal and low-income settlements where rates of poverty and inequality exacerbate people's vulnerability and exposure to climate-related hazards and environmental pollution.

Mountain communities face challenges in attracting outside investors where sparse populations and the high costs of bringing goods and services to remote areas with limited transport infrastructure undermine the potential return on investment.

## Facts & Figures

### The effects of climate change in the mountains

With few exceptions, mountain glaciers have retreated since the second half of the 19th century, and more than 600 glaciers around the world have disappeared in recent decades. Glaciers will continue to lose mass at least for several decades even if global temperature is stabilised.

As the cryosphere warms, additional snowmelt and glacial meltwater increases water run-off until the point of peak water, after which the availability of water diminishes. The timing of peak water is expected to vary across regions. One study estimates that peak water has already been reached in 82–95 per cent of the glacier areas in the tropical Andes, and in over half the glacier areas in Central Europe and the Caucasus. Citing a study by Rasul et al., the OECD (2021) finds that, “Many glaciers of the Hindu Kush Himalayan region are expected to reach their water peak by the middle of the 21st century.”

The number of extreme precipitation events in mountain regions is likely to increase in the coming years, with potential cascading consequences – floods and landslides – and potential subsequent effects such as dam failures, isolation due to road and rail damage, and supply chain breaks, and with warming between 1.5 °C and 3.0 °C, losses from water-related hazards are projected to increase considerably. The projected changes in hazards will increase the risk and consequences for people, infrastructure and the economies in many mountain regions – more rapidly and more pervasively in South and Central Asia and in north-western South America – but nearly all mountain regions face moderate to high risks at warming of around 2.0 °C.

The increase in wildfires under climate change – in combination with forest degradation and deforestation – can reduce animal populations, diminish air quality, increase soil erosion and landslide risk, and reduce the quantity and quality of freshwater – all with negative effects on human health and well-being.

Energy production in the mountains – especially hydropower – is affected by changes in precipitation and river flow regimes and by landslides. In the Himalayas, for example, recent floods, glacial lake outbursts and landslides led to massive destruction of hydropower infrastructure and significant losses in the energy sector. Energy production assets worth billions of dollars are exposed to changing mountain hazards, while climate change, hydropower development and other human interventions have combined to exacerbate water security problems. With hydropower infrastructure expanding into higher mountain valleys, finding a balance between social and economic development and long-term disaster risk reduction has become an urgent matter.

### Mountain ecosystem services

The OECD (2021) reports that, “Mountains are important biodiversity hotspots, reservoirs for agrobiodiversity, and home to more than 85 per cent of the world’s species of amphibians, birds and mammals. Many of these species are found only in mountainous areas and are highly exposed to climate-related hazards and often extremely vulnerable to warmer temperatures.”

Home to numerous plant and animal species, mountain ecosystems play a crucial role in stabilising slopes, regulating climate and hydrological cycles and supporting livelihoods. Mountain forests play a significant role in disaster risk reduction by buffering settlements and infrastructure against hazards.

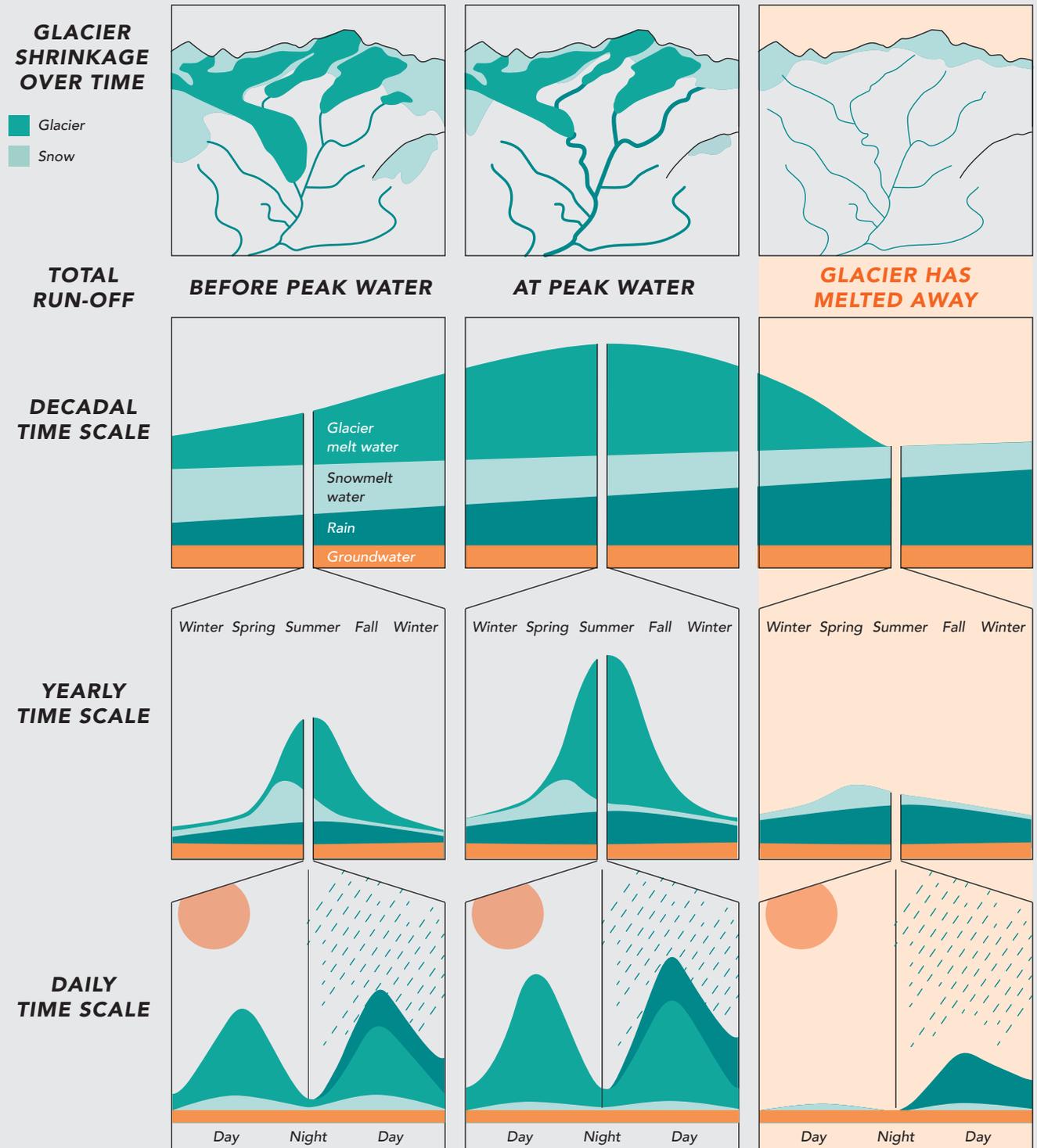
About 2 billion people living in the lowlands depend on freshwater from the mountains, as does 68 per cent of irrigated agriculture worldwide, and current and future hotspots of water scarcity include Central and South Asia, the tropical and subtropical regions of western South America, and south-western North America.

In recent decades, water resources in the lowlands have grown increasingly dependent on mountain areas, a trend that is likely to continue. Lowland areas can expect more severe water scarcity, and some agricultural regions can expect to face risks to their water security.

The downstream economic consequences of diminished ecosystem services also extend beyond agriculture to tourism. The downstream effects of the 2013 flood disaster in Uttarakhand, for example, caused an estimated loss of USD 1.85 billion in the state's tourism sector.

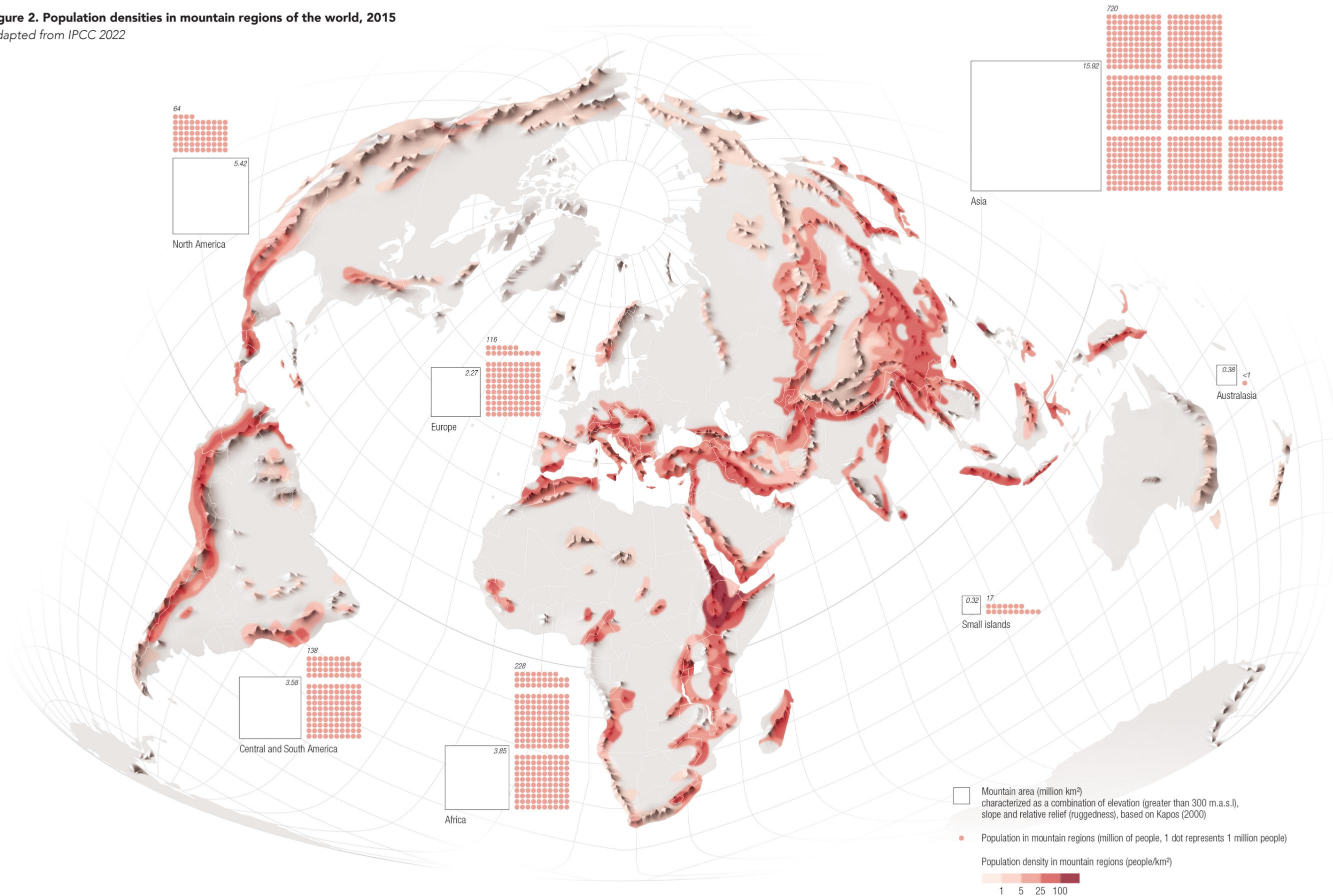
**Figure 1. Changes in run-off in a river basin with shrinking glaciers**

*Adapted from Hock et al. 2019*



**Figure 2. Population densities in mountain regions of the world, 2015**

Adapted from IPCC 2022



## Insufficient adaptation in the mountains

The unprecedented rate of change in the climate in the mountains presents unprecedented challenges to mountain communities with long experience in adapting to a changing environment. In addition, remoteness and economic and political marginalisation further limit the capacity of mountain communities to adapt to climate change. Current levels of resourcing for both adaptation and mitigation are substantially insufficient to support the necessary climate-resilient sustainable mountain development.

At present, the soft limits to adaptation – those related to governance and to the social, economic and political conditions – are the main constraints on adaptation in the mountains. In theory at least, efforts to deal with these underlying conditions can overcome these constraints. Hard limits, on the other hand, may be biophysical – drastic declines in the water supply, for example – and may imply that adaptation will be ineffective and that losses will be inevitable. Where the treeline does not migrate uphill, for another example, the species become restricted in their spatial distribution because their range shrinks at the lower elevation boundary due to temperature rise and because the surface area of mountains decreases with altitude. Both the social and biophysical limits have already been observed, and as climate change goes beyond historical experience, they are likely to become more widespread.

Adaptation can reduce the risks of losses and damages, but adaptation responses to climate-driven impacts vary significantly in terms of goals and priorities, scope, depth and speed of implementation, governance, and the extent of financial and other resources available for implementation. The evidence for the effectiveness of adaptation efforts in the mountains is limited, but a global review of mountain adaptation studies found that 69 per cent of the studies reported evidence that the efforts were reducing risk or vulnerability, while 31 per cent indicated no evidence of this effect.

While the current pace, depth, and scope of adaptation are insufficient to address future risks in mountain regions, particularly at warming levels beyond 1.5 °C, existing adaptation options can address climate risks before the limits to adaptation are reached. The reduction of climate risks will depend in part on our ability to deal with the root causes of vulnerability. Documenting the options that work in mountain contexts and monitoring their effectiveness at reducing key risks strengthens the case for investments in adaptation.

# Policy responses

## **Mainstreaming mountain considerations into national plans**

The United Nations General Assembly proclamation of 2022 as the International Year of Sustainable Mountain Development further underscores the need to increase awareness of the importance of sustainable mountain development and the conservation and sustainable use of mountain ecosystems.

The global policy frameworks most relevant to mountain regions include the Rio conventions on climate, desertification and biodiversity; the Sendai Framework for Disaster Risk Reduction; and the 2030 Agenda for Sustainable Development. In light of the environmental and socioeconomic circumstances in the mountains, and in consideration of the importance of mountain ecosystem services in both the mountains and the lowlands, mountain considerations loom large in the prospects for the ultimate success of the frameworks.

The mainstreaming of mountain-specific challenges into National Adaptation Plans and Nationally Determined Contributions, as well as other national plans linked to global frameworks, is a necessary element in the broad goal of leaving no one behind. Similarly, the mainstreaming of mountain considerations can inform national plans for a green economy or an energy strategy or any plans related to biodiversity or disaster risk reduction. The failure to consider the role of mountains in these endeavours is essentially a guarantee that many people will be left behind.

## **Multisectoral and multi-stakeholder collaboration and cross-sectoral policies**

Water users in upstream and downstream areas often have different and competing interests – the generation of electricity and the irrigation of crops, for example. Stakeholder engagement can help reconcile the differences, but it must be inclusive to be successful, and must work to involve marginalised and vulnerable groups.

An SDC-financed project – Glaciares+ – takes a community-based adaptation approach that integrates traditional knowledge with technical and scientific information to promote climate-resilient livelihoods, reduce the impact of hazards, and build local capacity. This project contributed to the reduction of the risks associated with melting glaciers in the mountains of Peru and to improve water management while pursuing a multisectoral strategy for taking advantage of opportunities opened by retreating glaciers.

In addition, development cooperation experience reveals the benefits of collaboration among scientists, policymakers and practitioners. The SDC-funded Adaptation at Altitude programme, for example, works to provide science–policy exchanges and collaborations, and to generate and share knowledge. The programme has gathered key stakeholders from mountain regions around the world, and maintains a Solutions Portal with case studies offering field-tested solutions to adaptation challenges in mountains.

## Key issues

### Better information for decision-making

Efforts to build resilience in the mountains rely on an understanding of climate risk, and the mapping of the populations, assets and ecosystems exposed to climate-related hazards is a starting point for developing plans and policies. The assessment of vulnerability requires greater investment in the data and information that can improve decision-making on climate resilience and that can help policymakers understand the changes in the water cycle, the dynamics of glacial lakes, and the loss of biodiversity and the associated effects on livelihoods.

Greater investment is also needed for the installation and maintenance of weather stations and observation systems and for the application of hydrometeorological models. More data on weather and climate for remote areas is needed to support early warnings and other disaster risk reduction activities. In addition, landscape-level climate risk assessments can integrate the analyses of multiple hazards and provide insights into the interactions of the hazards.

Another SDC-funded project in Peru – Climandes – worked to improve the reliability of weather and climate forecasts and to develop quality climate services tailored to the agricultural economy of the Andes and to the needs of local decision-makers. The Climandes project connected users and providers of climate services in order to match climate information with user needs, and developed farmers' skills to enable them to make informed decisions. The follow-up BRAVA project is working with the support of Swiss researchers and experts from MeteoSwiss to increase the predictive capabilities of the national authorities and to support co-design of Weather, Water and Climate Services across the region. These projects benefit the local population, including the most vulnerable, and contribute to food security and poverty reduction.

According to the OECD (2021), "Mountain communities are also increasingly using information communication technologies to strengthen their climate resilience. Effective geospatial technologies are also crucial for understanding temporal and spatial

variabilities in the social, economic, geophysical and ecological contexts of mountain areas. Such technologies include geographic information systems, remote sensing and modelling of glacier dynamics."

### Sharing good practices

Mountain areas across the world face similar challenges under climate change, and would benefit from increased international and cross-regional exchange of knowledge and experience, and sharing and peer learning on adaptation measures and solutions. The Adaptation at Altitude programme supported by the SDC facilitates interregional exchange and makes selected and tested climate adaptation solutions for mountain areas available through a Solutions Portal.

Nature-based solutions that support climate change adaptation and disaster risk reduction in mountain areas are finding favour among governments, development cooperation providers, and the private sector. The sustainable management of mountain ecosystems protects the valuable ecosystem services they provide, and builds resilience in both the mountains and the lowlands. Among the ecosystem-based adaptations in wide use in the mountains are afforestation, reforestation and improved forest management to reduce the risks of shallow landslides, and river restoration to reduce the risks of floods.

### Investment in climate resilience and adaptation

Changes in the climate are occurring more rapidly in the mountains than in the lowlands, but mountain regions generally have inadequate resources to devote to climate resilience and adaptation. Governments can improve the enabling environment for mobilising climate financing by providing incentives for private sector investment through public interventions that lower or transfer risk, by mainstreaming climate considerations into national and local budgets and sectoral plans, and by facilitating access to climate finance. The relatively limited access of mountain regions to major adaptation support programmes

indicates an opportunity for mountain countries to increase their climate funding, which may include support from global climate finance instruments such as the Green Climate Fund and the Adaptation Fund.

Another option that may appeal in mountain regions is market-based payment for ecosystem services, an instrument that is increasingly used across the globe to finance the conservation of nature.

**Figure 3. Strategies for successful adaptation**



## Raising awareness

People living in the mountains are well-aware of the hazards they face, but may not be knowledgeable of the role of climate change or of the assistance available to them. Raising their awareness may result in the collaboration of civil society organisations and local government, the benefits of which may include the combining of traditional knowledge and scientific research in the development of adaptation strategies. The people living downstream also have a real stake in disaster risk reduction and climate change adaptation in the mountains, and raising their awareness of the relationship between the mountain ecosystems and the downstream benefits may help build support for adaptation in the mountains.

## Leaving no one behind

With more than 90 per cent of the people who live in the mountains living in developing countries, and more than 60 per cent living in rural areas that experience poverty, marginalisation, lack of economic opportunities, inadequate basic services and infrastructure, and remoteness from centres of power, the feeling of being left behind might be all too common. And when people flee the disasters and environmental changes occurring in the mountains by migrating to urban centres or abroad in search of better income, the ones who stay behind to look after the family homes are most often the women, children and elderly – those most vulnerable to disasters.

## Relevance for development cooperation

The myriad mountain hazards and the potential for cascading events warrant the attention of development cooperation, but the additional consideration of the number of downstream people who rely on mountain ecosystem services makes the case for development assistance particularly compelling.

### SDC engagement

The Swiss Agency for Development and Cooperation has a long history of supporting sustainable mountain development. In its strategic framework, the thematic section Climate, Disaster Risk Reduction and Environment puts specific emphasis on sustainable mountain development. The primary focus of SDC support is on knowledge-sharing, global and regional policy mainstreaming, improved data and monitoring of mountain issues, and disaster risk reduction. Switzerland also provides financial contributions to mountain organisations and networks such as the International Centre for Integrated Mountain Development and the Mountain Partnership (supported through the Swiss Federal Office for Agriculture).

### Adaptation at Altitude – Taking Action in the Mountains



The Adaptation at Altitude programme co-funded by the SDC aims to support mountain communities and those working with them by improving data availability and knowledge of appropriate CCA and DRR strategies in the mountains, and transferring that knowledge through science-policy platforms to inform decision-making in national, regional and global policy processes.

[The Adaptation at Altitude Solutions Portal](#) supports the sharing and transfer of knowledge on interventions that are helping reduce vulnerability and climate risks in the mountains. The Portal provides easy access to information on tried, tested, and replicable climate adaptation solutions, making these solutions easier to find, explore and appraise for everyone working in this area.

### **Strengthening State Strategies for Climate Actions, India**

The Global Climate Risk Index 2019 ranks India among the countries most vulnerable to climate change. Aware of this fact, the Government of India has encouraged all its states to develop their climate change action plans with consideration of all relevant sectors. Since 2014, the SDC project has assisted multiple Indian Himalayan States in these efforts through technical assistance with Swiss and national expertise. In a first phase, national guidelines for the management of glacial lake outburst floods (GLOFs) were developed and CHF 4.4 million from India's national Adaptation Fund were leveraged for climate actions.

In its second phase, the project focuses on the implementation of climate actions such as the development of a pilot early warning system for GLOFs and pilot sites to test an innovative approach that integrates the management of springs and surface water. Through close collaboration and capacity-building with four states (Uttarakhand, Sikkim, Manipur and Himachil Pradesh), the national government and other key stakeholders, the project builds showcases for replication across the 12 Indian Himalayan states, supports policy uptake and shares results at the national, regional and global levels.

### **Cryospheric Observation and Modelling for improved Adaptation in Central Asia (CROMO-ADAPT)**

The CROMO-ADAPT project builds on a previous SDC-supported project on glacier monitoring in Central Asia and uses high-quality cryospheric data to provide information for policymaking, planning, and implementation of adaptation measures in the water and risk management sectors in Central Asia to increase the resilience of local populations to climate change.

The project will set up locally managed and sustained cryospheric monitoring networks that provide steady and reliable data to national, regional and global databases. It will also strengthen national institutions in Kyrgyzstan,

Tajikistan and Kazakhstan so they can provide user-oriented cryospheric climate information services to basin planning and disaster risk management authorities as a means of creating awareness and informing policy and planning on medium- and long-term consequences of climate change. The project will also increase the capacity of national and subnational basin planning and disaster management authorities in Kyrgyzstan and Tajikistan to plan adaptation measures and facilitate investments that respond to long-term cryospheric changes.

### **Building regional adaptive capacity and resilience to climate variability and change in vulnerable sectors in the Andes (BRAVA)**

The SDC is implementing the BRAVA project in collaboration with the already existing World Meteorological Organization-implemented project, Enhancing Adaptive Capacity of Andean Communities through Climate Services (ENANDES). ENANDES is supporting Chile, Colombia and Peru, and will provide additional support to Peru as well as to Argentina, Bolivia and Ecuador. ENANDES/BRAVA will strengthen climate resilience by increasing the countries' capacity to provide weather, water and climate services in support of improved climate-related socioeconomic outcomes and reduced losses associated with hydrometeorological hazards.

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