# GLACIER PRESERVATION IN PAKISTAN

## Challenges, Strategies and the Way Forward

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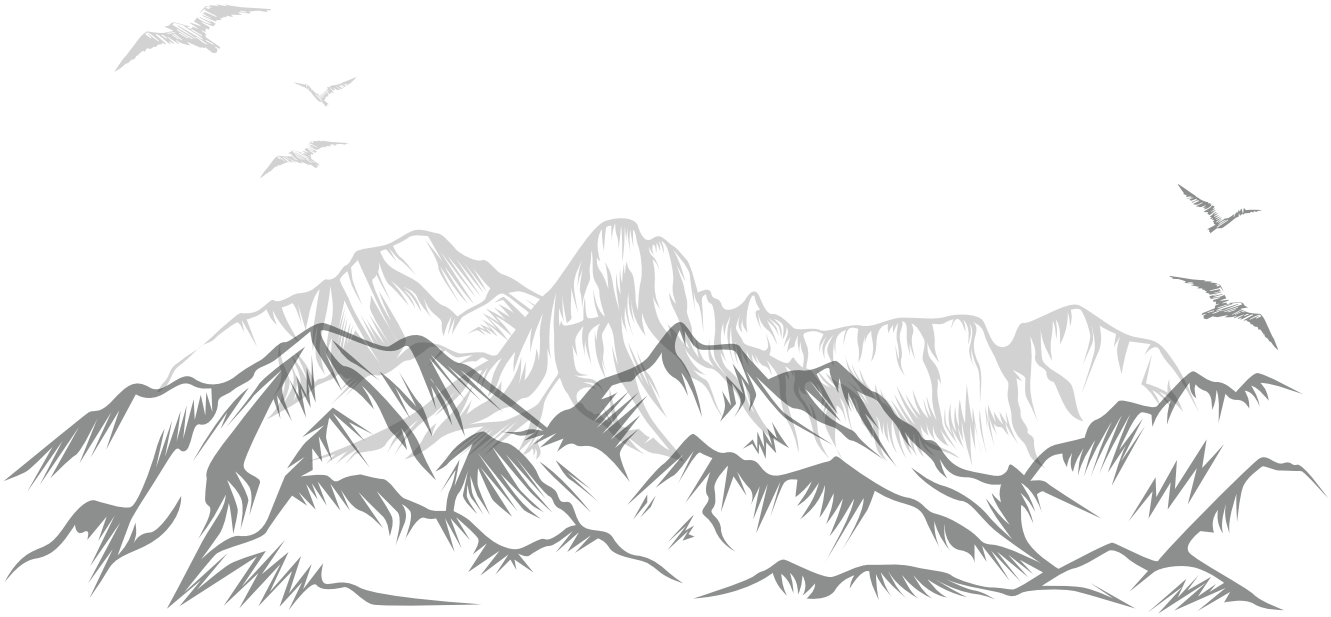

# GLACIER PRESERVATION IN PAKISTAN: Challenges, Strategies and the Way Forward

## 1 Introduction

### 1.1 Overview of World Water Day 2025 and Earth Hour 2025 Themes

Every year on March 22, the world observes World Water Day, a global campaign to promote sustainable water resource management and highlight the value of freshwater sources. The **World Water Day 2025's** theme is **Glacier Preservation**, emphasizing the urgent need to save glaciers as vital freshwater resources that support economies, communities, and ecosystems. In an effort to promote energy conservation and increase awareness of climate change, **Earth Hour 2025**, invites people, groups, and communities to turn off non-essential lights for an hour. The call for glacier preservation is in line with this year's Earth Hour, demonstrating the connection between water conservation and climate action.

### 1.2 Importance of Glacier Preservation for Water Security and Climate Resilience

Glaciers are one of the most visible indicators of climate change, with rising global temperatures accelerating their retreat. The preservation of glaciers is critical for ensuring long-term water security, particularly in regions heavily dependent on glacial meltwater. In Pakistan, the Himalayan and Karakoram glacier systems form the backbone of the Indus River Basin, supplying up to 80 per cent of the river's flow during the dry season. These glaciers not only provide water for drinking, irrigation, and hydropower but also support biodiversity and maintain ecological balance in the region.

The accelerated melting of glaciers presents significant and multifaceted risks, including the heightened occurrence of glacial lake outburst floods (GLOFs), disruptions in established hydrological regimes, and the progressive depletion of long-term freshwater reserves (Lutzow et al., 2023). These threats critically jeopardize the well-being and economic stability of millions of individuals, particularly those residing in the upper and lower reaches of the Indus Basin—an essential lifeline for water security, agriculture, and ecosystem sustainability in the region. The conservation of glaciers is, therefore, an indispensable strategy in fortifying climate resilience, ensuring the continuity of freshwater supplies, and mitigating the far-reaching socio-economic repercussions of anthropogenic climate change (Immerzeel et al. 2020).

Across the vast and ecologically significant High Mountain Asia (HMA) region encompassing diverse glacial landscapes from Afghanistan to the eastern Tibetan Plateau the rate of glacier mass

loss has accelerated at an alarming pace (Bolch et al., 2019). This intensifying trend underscores the broader cryospheric response to climate change, with significant implications for regional hydrology, ecosystem stability, and human livelihoods (IPCC, 2021).

In Pakistan's Karakoram range, earlier observations revealed a unique anomaly in glacial dynamics, where ice loss appeared comparatively subdued commonly referred to as the "Karakoram anomaly" (Dimri, 2021). However, recent scientific assessments indicate that even this once-resistant subregion has now succumbed to the overarching trajectory of glacial decline. The transition toward sustained ice loss across the Karakoram aligns with global trends, reinforcing concerns about diminishing water reserves, disruptions in seasonal meltwater flow, and heightened risks associated with glacial hazards

### 1.3 Objectives of the Working Paper

This working paper aims to:

- Utilize Earth Hour and World Water Day as a platform to get people and groups involved in group efforts to protect glaciers.
- Emphasize the fundamental importance of glaciers as a vital source of freshwater in Pakistan.
- Present evidence-based strategies for glacier preservation, including nature-based solutions, technological innovations, and community-based conservation efforts.

## 2 Role of Glaciers in the Indus Basin Hydrology and Water Supply

### 2.1 Background

Pakistan's primary water supplies originate from the glaciated headwaters and snowfields of the Indus Basin rivers, supplemented by monsoon runoff and groundwater aquifers (Immerzeel et al., 2019). Within the Hindu-Kush-Karakoram (HKK) region of the Himalayas, snow and glacier melt contribute between 50–80% of the typical river flows in the Indus system, while monsoon rains on the plains provide the remaining portion (Bolch et al., 2019). Approximately 268 million people in the Indus Basin depend on snow and glacier meltwater from the Karakoram and western Himalaya for agriculture, industry, hydroelectric power generation, and domestic consumption (IPCC, 2021). The Upper Indus River basin, spanning over 13,000 km², is home to more than 5,000 glaciers, which serve as vital reservoirs of freshwater (Hewitt, 2005). Throughout the 21st century, projections indicate a global decline in the volume of water stored within snow and glacier systems, though regional patterns of accumulation and depletion exhibit significant variability (Shrestha & Aryal, 2011). Increasing concerns regarding climate change, glacier retreat in the Himalayas, and their critical role in sustaining South Asian rivers underscore the need for further

research. These challenges highlight existing gaps in scientific knowledge and water management strategies regarding the significance of mountain headwaters and their hydrological influence (Immerzeel et al., 2019).

The varying timing of water availability has become an emerging challenge in Pakistan, significantly impacting water distribution and agricultural cycles (Immerzeel et al., 2019). Snow and glacier melt serve as the primary contributors to the base flow of the Indus River, playing a crucial role in sustaining water supply during dry months (Bolch et al., 2019). However, recent shifts in seasonal melt patterns are altering provincial water distribution, creating disparities in demand. For instance, Punjab requires water later in the season for wheat sowing, whereas Sindh needs water earlier, leading to growing tensions over water allocation (IPCC, 2021). These hydrological shifts underscore the need for comprehensive climate adaptation policies and sustainable water management strategies to mitigate conflicts among stakeholders (Hewitt, 2005).

## 2.2 Impact of Climate Change on Glacier Melting and Associated Risks

The water cycle is becoming more variable due to climate change, which also makes flows and water supplies less predictable. A silent disaster is taking place in the breathtaking scenery of Northern Pakistan. The Himalayan, Karakoram, and Hindu Kush glaciers are melting at an alarming rate as a result of rising temperatures. Glacial lakes have therefore formed, glistening among the rocky landscape like precious gems. These glacial lakes provide a serious risk of flooding, which could wreak havoc on the region and its inhabitants. A tragedy is looming over more than seven million people. The Indus River, which flows the entire length of the nation, overflowed its banks and became a huge inland lake during the floods of 2022. According to a World Weather Attribution (WWA) research, climate change caused by humans may have contributed up to **50 per cent** more intense rainfall during Pakistan's floods in 2022. In comparison to 1970, the global glaciers have lost almost **26,000 kilograms** of ice per square meter as of 2023. Recently, this downward trend has accelerated, contributing about **1,000 kilograms per square meter** to the annual loss of glaciers (World Weather Attribution, 2022).

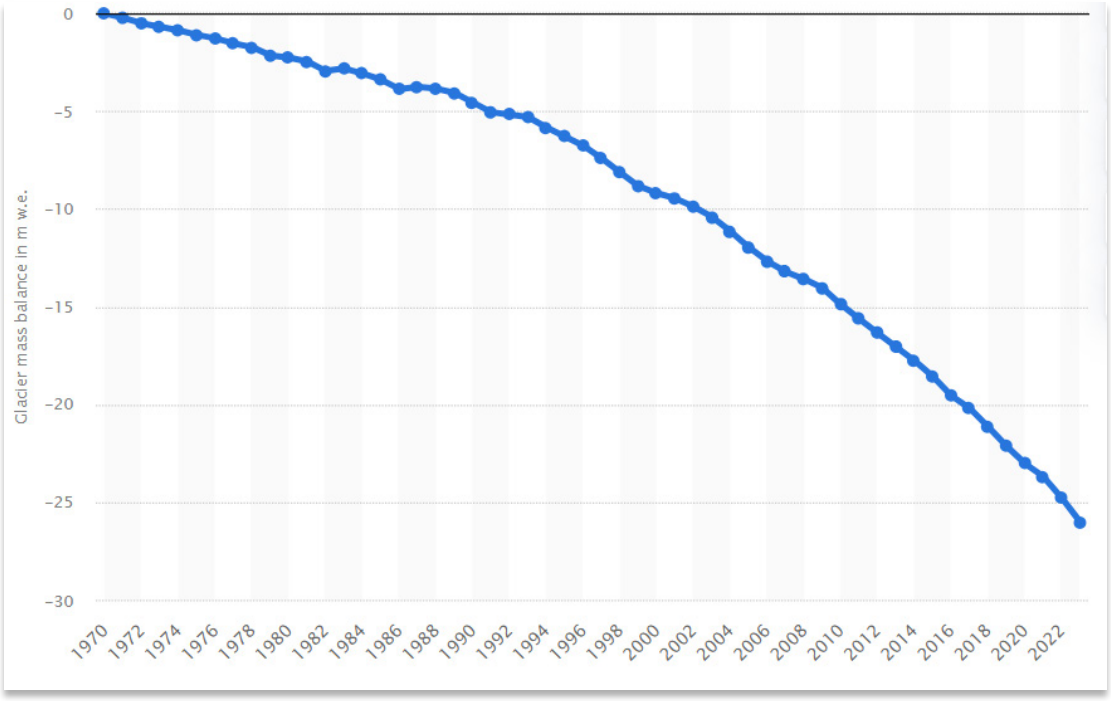


**Figure 1 global glaciers melt from 1970 to 2023 (Statista, n.d.).**

Pakistan is home to more than 7,000 glaciers, more than anywhere else on Earth outside the poles. The Indus is mostly reliant on snowmelt and glacial melting, whereas other rivers in Pakistan depend on rainfall. Global warming, however, is causing the majority of Pakistan's glaciers to retreat. The Indus will reach **"peak water"** by 2050 if temperatures keep rising, at which point flows would start to decrease. In addition, the Indus is under tremendous strain due to the growing need for agriculture and hydropower. Thousands of glacial lakes are being formed as a result of the glaciers melting quickly due to rising global temperatures brought on by climate change. According to the Government, **33 of these lakes**, all of which are part of Pakistan's breathtaking Himalaya, Hindu Kush, and Karakoram Mountain ranges, could collapse, spilling millions of cubic meters of water and debris in a matter of hours, as was the case in Hassanabad. This year has already seen at least 16 of these heatwave-related glacial lake outburst floods, compared to an average of five or six annually (Intergovernmental Panel on Climate Change, 2022). The European Rhône River serves as an example of how glacier meltwater controls river temperatures, therefore promoting aquatic life and energy generation. The cooling impact of glaciers, however, is lessened as they continue to recede, which makes river temperatures even higher. This is a serious problem, especially for nuclear power reactors that use river water to cool. As an example of how glacier melt has far-reaching effects even for areas far from glacial zones, the rising water temperatures, which in some cases approach the crucial threshold of 30°C, endanger aquatic ecosystems and force the closure of energy infrastructure (U.S. Geological Survey, 2024).

## 2.3 The Melting Giants: Climate Change Impacts on the Himalayan and Karakoram Glaciers

In contrast to the comparatively stable Karakoram glaciers, the Himalayan glaciers have been losing mass at an accelerated rate in recent decades. The Himalayan and Karakoram glacier meltwater runoff is expected to peak in the next decades under a variety of climate change scenarios. Although the size, timing, and rate of the glacial run-off peak and subsequent drop are unknown, run-off will decrease as the glaciers in both mountain ranges recede after the peak. As the glaciers' moderating effect diminishes, basin run-off regimes will become more rain-dominated, which will likely make droughts and floods more severe. Current and proposed hydropower infrastructure downstream is at risk because to the recent increase in the frequency of GLOFs and runoff floods, which may grow even more in the upcoming decades. The rate of glacier loss would slow down under a climate change scenario with lower emissions, giving more time for response. There would be significant socioeconomic advantages to this route.

# 3 Ongoing Projects for Glacier Preservation and Disaster Risk Mitigation

Given the severity of the situation, the Government of Pakistan, in collaboration with the UNDP and the Green Climate Fund, is carrying out a comprehensive project called **Scaling-up of Glacial Lake Outburst Flood (GLOF) Risk Reduction in Northern Pakistan**. This project aims to reduce the risks associated with GLOFs and assist communities in maintaining traditional methods of conserving water in the northern valleys, such as avalanche harvesting, glacier grafting, and ice stupas. The goal is twofold:

- to safeguard local communities; and
- to provide early warnings of potentially catastrophic flood events.

By the end of 2024, the Pakistani government aimed to install 250 engineering structures strategically positioned across the impacted areas. They consist of irrigation channels, check dams, and gabion walls, all of which are intended to control and redirect the massive amounts of water that pose a threat to land and life.

Up to 157,259 people, 51 per cent of them are women and girls, are benefiting from the 230 small-scale infrastructure projects and 172 irrigation channels that have been completed. The project is investing in the creation of strong disaster management policies in addition to building hydraulic structures. Federal and provincial institutions, as well as people in 24 of Northern Pakistan's most vulnerable valleys, have received support thus far. They will now create a structure for efficient crisis response and coordination. 13,687 persons have benefited from the installation of 14 gauges and sensors and two automated weather stations in Gilgit Baltistan.

Amid the devastating effects of rapid glacial melt brought on by climate change, the Asian Development Bank (ADB) today announced a new regional program called **Glaciers to Farms** that will support sustainable water use and food security in Pakistan, the South Caucasus, and Central Asia. Along with investments in agriculture and water, the program will help communities that are at risk from glacier melt, especially in mountainous areas. ADB is building climate-resilient infrastructure and early warning systems in the Hindu Kush Himalaya. The bank is strengthening resilience across whole river basins in monsoonal South and Southeast Asia.

# 4 Mitigation Strategies to Tackle Climate Change Impacts on Glaciers

### 1. Climate Change Mitigation

The primary driver of glacier melting is rising global temperatures. Transitioning to renewable energy sources (solar, wind, and hydropower), enhancing energy efficiency, and introducing carbon pricing mechanisms can significantly curb emissions. Additionally, advocacy for and alignment with international climate agreements such as the Paris Agreement play a crucial role in collectively reducing emissions on a global scale (United Nations Development Programme, 2024).

### 2. Protection of Glacial Watershed and Sustainable Land Use

Establish protected areas to preserve fragile glacier-fed ecosystems, regulate land use, and minimize human impact on vulnerable regions. Promote sustainable land-use practices such as agroforestry, soil conservation techniques, and reforestation to reduce soil erosion and sedimentation in glacier-fed rivers, which can accelerate glacier melt (International Union for Conservation of Nature, 2025).

### 3. Community-Based Adaptation and Water Management

Develop adaptive water management systems to cope with the changing availability of glacial meltwater by improving water storage infrastructure, rainwater harvesting, and equitable water distribution systems. Simultaneously, build the capacity of local communities through disaster preparedness training, livelihood diversification, and community-based early warning systems to enhance their resilience against climate-induced water shortages and extreme weather events (International Federation of Red Cross and Red Crescent Societies, 2020).

### 4. Glacier Protection and Research

Implement eco-tourism guidelines to regulate tourism activities in glacier regions and prevent physical damage to ice bodies. Support long-term glacier monitoring programs using remote sensing, satellite technology, and field surveys to assess glacier mass balance and predict future melting trends (International Union for Conservation of Nature, 2025).

### 5. Nature-Based Solutions and Ecosystem Restoration

Restore degraded riparian zones along glacier-fed rivers to prevent erosion and sedimentation, which threaten downstream water quality. Encourage traditional glacier preservation methods such as glacier grafting and ice stupas, which help retain water during winter for use in drier months (National Centers for Coastal Ocean Science, 2025).

### 6. Disaster Risk Reduction Infrastructure

Construct gabion walls, check dams, and artificial drainage systems to mitigate the risk of GLOFs and manage excess runoff. Invest in automatic weather stations and community-based early warning systems to provide timely flood alerts (United Nations Office for Disaster Risk Reduction, 2023).

### 7. Advanced Remote Sensing for Glacial Lake Monitoring

Use satellite-based and aircraft-based remote sensing technology to monitor the development and growth of glacier lakes. Also, determine which lakes are at high risk of unexpected eruptions as a result of glacier melt and warming temperatures (Sharma, Prakash, & Thakur, 2024).

### 8. Engineering Solutions for Water Storage and Flood Absorption

To reduce the risk of unexpected outbursts, conduct specialized engineering evaluations to evaluate structural modifications such spillways and drainage channels for controlled water release from glacier lakes. To improve flood management capability, investigate the viability of building downstream reservoirs to absorb floodwaters, as has been done effectively in areas like the Alps. In order to improve natural water absorption, stabilize ecosystems, and increase overall flood resilience, support these efforts by reinforcing riverbanks and floodplains with nature-based solutions, such as reforestation and wetland restoration (HUESKER, 2025).

### 9. Policy and Governance

Formulate and implement national and regional climate adaptation plans that prioritize glacier protection, water resource management, and disaster risk reduction. Encourage sustainable industrial practices that reduce carbon emissions and limit environmental degradation in glacier-fed river basins (U.S. Environmental Protection Agency, 2024).

### 10. International Cooperation and Funding

Collaboration with global partners like UNDP, Green Climate Fund (GCF), and Adaptation Fund to mobilize financial resources for glacier conservation projects. Facilitate knowledge-sharing through partnerships with international institutions working on glacier preservation and climate adaptation (UNESCO, 2025).

### 11. Technological Solutions

Explore innovative technologies such as artificial glaciers, glacial blankets, or reflective cover sheets to slow down glacier melting. Invest in remote sensing technologies for early warning and monitoring of glacier mass balance and GLOF risks (Travers, 2023).

## 4.1 Short-Term Potential for Academic Research and Policy Initiatives

### 1. Scientific Research and Data Utilization

Supported by a wealth of climate-related data and an established water monitoring system, Pakistan's huge glacial covering and reasonably accessible topography offer a solid basis for glacier study. Nonetheless, issues with coordination and accessibility among stakeholders persist, which restricts the efficient use of the resources that are available. Improved data management techniques and more institutional cooperation can improve knowledge of glacial and hydrological changes, resulting in better water management and climate adaption plans.

### 2. Investing in Local Expertise and Human Capital

Although Pakistan's top colleges produce competent graduates, many of them do not have the opportunity to contribute to national solutions. Policymakers should place a high priority on research funding and competitive remuneration for early-career scientists in order to retain expertise and allow them to tackle important environmental issues. Furthermore, resources can be allocated towards expanding research capabilities and creating practical solutions for sustainable environmental management by utilizing already-existing global databases and remote sensing technology without incurring additional expenses.

### 3. Broader Environmental and Global Impact

In addition to disrupting the Indus Basin, the melting of Pakistan's glaciers would raise the sea level globally, causing serious environmental hazards. Continued glacier loss might have serious effects on coastal towns like Karachi, such as increasing floods and rising sea levels. Pakistan's glacier retreat is a national and worldwide issue, highlighting the pressing need for effective climate action and international collaboration to lessen its severe effects.

# 5 Way Forward and Conclusion

South Asia's melting glaciers highlights how urgently we must all work to combat climate change. Proactive actions in the area could yet stop irreversible loss, unlike in North America and Europe, where many glaciers have already recovered. A comprehensive and cooperative strategy that incorporates community-based solutions, legislative interventions, and scientific research is needed to address the problem of glacier melt. It is critical that efforts to mitigate climate change be given top priority going forward by significantly cutting greenhouse gas emissions and pushing for better international climate commitments. To deal with the shifting hydrological patterns brought on by glacier retreat, it will be essential to improve adaptive water resource management and local people' resilience.

Protecting glacial ecosystems can be greatly aided by investments in natural solutions like watershed restoration and local glacier preservation techniques. Furthermore, catastrophe risk reduction and preparedness will be enhanced by encouraging sustainable tourism, advancing scientific research, and putting early warning systems into place. To successfully implement these policies, governments, civil society, and foreign partners must work together. We can create the foundation for a more resilient and sustainable future for glacier-fed ecosystems and populations by encouraging collaboration, building local capacity, and fusing traditional knowledge with modern technology. Glacier preservation is a societal issue rather than an individual one. Although it is not feasible to directly stop glacier melting, significant legislative changes, international collaboration, and sustainable land-use practices might lessen additional loss. To protect glacier habitats and guarantee long-term water security in the area, it will be essential to invest in nature-based solutions, strengthen early warning systems, and improve community resilience.

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