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REPORT IN BRIEF

Himalayan Glaciers

Climate Change, Water Resources, and Water Security

Scientific evidence shows that most glaciers in South Asia's Hindu Kush Himalayan region are retreating, but the consequences for the region's water supply are unclear, this report finds. The Hindu Kush Himalayan region is the location of several of Asia's great river systems, which provide water for drinking, irrigation, and other uses for about 1.5 billion people. Recent studies show that at lower elevations, glacial retreat is unlikely to cause significant changes in water availability over the next several decades, but other factors, including groundwater depletion and increasing human water use, could have a greater impact. Higher elevation areas could experience altered water flow in some river basins if current rates of glacial retreat continue, but shifts in the location, intensity, and variability of rain and snow due to climate change will likely have a greater impact on regional water supplies.

The Himalayan region, which covers eight countries across Asia, is home to some of the world's largest and most spectacular glaciers. The melt-water generated from these glaciers each summer supplements the rivers and streams of the region, including several of Asia's great river systems such as the Indus, Ganges, and Brahmaputra.

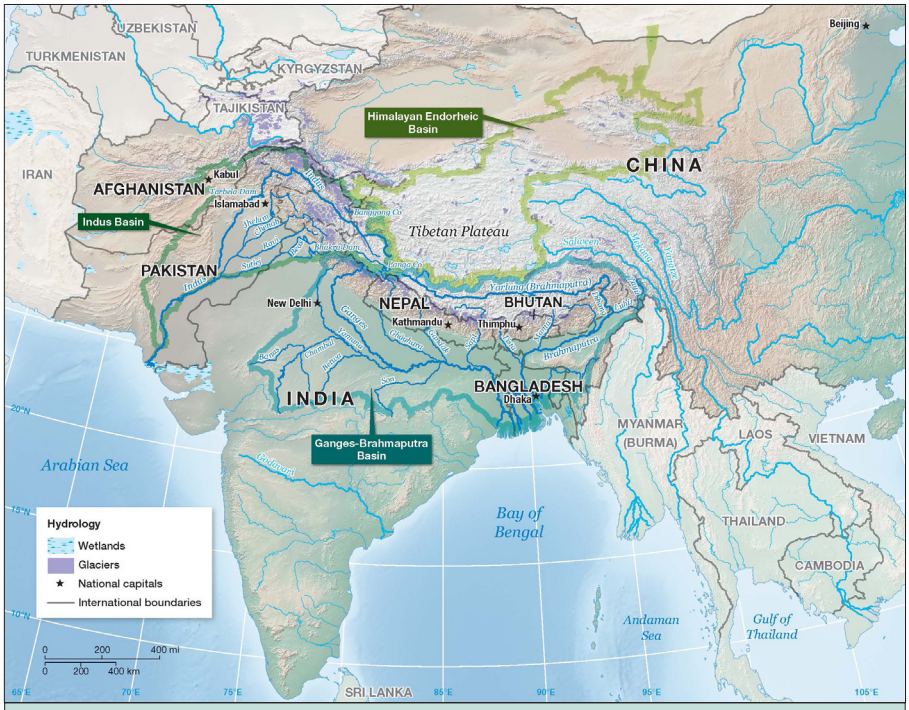

Figure 1. Extending over 2000 kilometers across the Asian continent and including all or part of Afghanistan, Bangladesh, Bhutan, China, India, Nepal, and Pakistan, the Hindu Kush Himalayan region is the source for many of Asia's major river systems, including the Indus, Ganges, and Brahmaputra.

Rising temperatures due to climate change are causing glaciers worldwide to shrink in volume and mass, a phenomenon known as glacial retreat (see Box 1). Scientific evidence shows that most glaciers in the Himalayan region are retreating, leading to concerns that, over time, the glaciers of the Hindu Kush Himalayas will dwindle in size until normal glacier melt can no longer contribute to the region's water supply each year.

Although the entire Himalayan climate is changing, the region is so vast and so varied—including variations in climate; the timing,

Box 1. Understanding Glacier Melt and Retreat

Glaciers grow and shrink as seasons change over the course of each year. Glacier mass is lost when summer temperatures cause glacier melting, and mass is added when precipitation such as snow and rain freezes. When a glacier is in steady state with the climate, glacier melt is offset when precipitation freezes, and overall glacier mass and volume stay about the same. Glacier retreat occurs when rising temperatures caused by climate change lead to permanent decreases in glacier mass and volume. This image shows plateau glaciers with glacier lakes at Gangrinchemzoe Pass in Bhutan. Source: USGS

amount, and type of precipitation; and in glacial behavior and dynamics across the region—that it remains challenging to determine exactly how retreating glaciers will affect water supply in each location. Furthermore, it is likely that the contribution of glacier meltwater to water supply in the Hindu Kush Himalayan region may have been overestimated in the past, for example, by not differentiating between the contributions to water supply of meltwater from glaciers and meltwater from snow.

Regional Climate Variations Affect Glacial Retreat

Glaciers in the eastern and central regions of the Himalayas appear to be retreating at rates that have accelerated over the past century and are comparable to those in other parts of the world. In the western Himalayas, glaciers are more stable and may even be increasing in size. Although historical climate data about the region is sparse, scientists are fairly confident about projections of future temperature increases. There is more uncertainty in projections of future changes in precipitation, but shifts in the location and intensity of snow and rain could also affect the rate of glacial retreat.

Estimating Effects of Glacial Retreat on Water Supply

The contribution of glacier melt to water supply varies across the region and is highly seasonal (see Figure 2). Furthermore, due to factors including the remoteness and political instability of some parts of the Hindu Kush Himalayas, hydrological field data from the region is sparse. Recently, researchers have sought to identify scientific gaps and important geographical nuances associated with the hydrology of the region. The research suggests glacier meltwater contributes less to the Hindu Kush Himalayan region's water supply than previously thought. For example, modeling showed that in Nepal, the glacial meltwater contribution to tributaries to the Ganges varies from approximately 20 percent in the Budhai Gandaki basin to approximately 2 percent in the Likhu Khola basin.

Overall, retreating glaciers over the next several decades are unlikely to cause significant changes in water availability at lower elevations, which depend primarily on monsoon rains. However, for high elevation areas, current glacier retreat rates, if they continue, could alter streamflow in some basins.

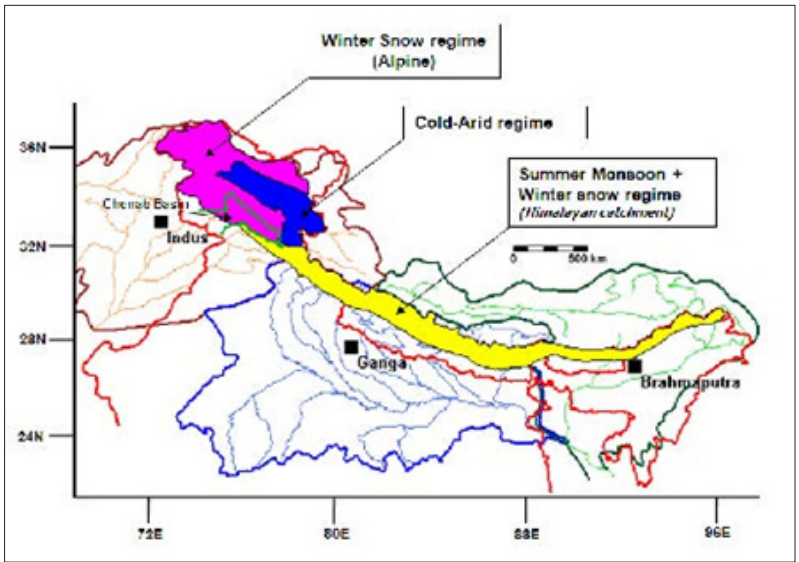

Figure 2. The Hindu Kush Himalayan region is so vast that there are great variations in climate, hydrology, glacier behavior, and the timing of precipitation. At the base of the foothills of the Himalayas, the climate is tropical, while at higher elevations there is permanent ice and snow. There are also variations from the west, where rainfall is scarce year round and most precipitation falls in the form of snow each winter; to the east, where most precipitation falls as heavy monsoon rains each summer.

Assuming annual precipitation in the form of snow and freezing rain remains the same, the loss of water stored as glacial ice will likely not change the amount of meltwater that supplements rivers and streams each summer.

Glacial meltwater can act as a buffer against the hydrologic impacts of a changing climate, such as drought. Insight on this process can be drawn from regions where there is a greater amount of data on the contribution of glacial melt to water supply. For example, during the 2003 European drought, glacial meltwater from the Alps contributed about three times more water to the Danube River than the 100 year average. Thus, water stored as glacial ice could serve as the Himalayan region's hydrologic "insurance." Although retreating glaciers would provide more meltwater in the shorter term as glaciers shrink, the loss of glacier insurance could become problematic over the longer term.

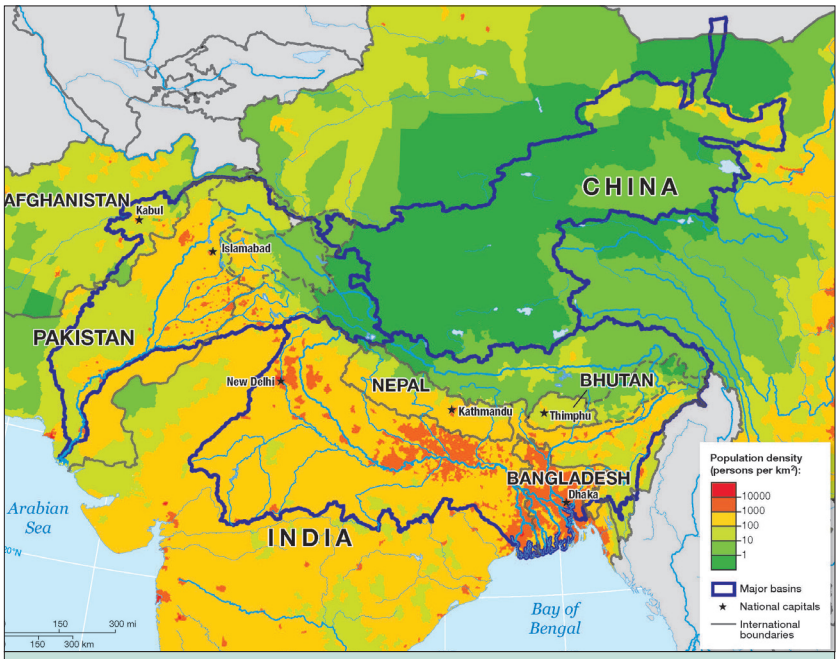

Figure 3. The Hindu Kush Himalayan region contains some of Earth's most densely populated areas, and some of the planet's most sparsely inhabited regions.

Groundwater is an integral part of the Hindu Kush Himalayan region's hydrology, although uncertainties about its contributions to water supply are great. It is clear that groundwater is already being depleted in many areas, with evidence that in the central Ganges Basin, overdraft of groundwater is likely to have an earlier and larger impact on water supplies than foreseeable changes in the supply of glacial meltwater.

There have been concerns that pulses of increased meltwater generated as glaciers retreat could cause flooding in downstream communities. Although it is unlikely that glacial retreat in the Hindu Kush Himalayan region would lead to flows of water large and rapid enough to cause flooding, the region does face other physical hazards. These include flash flooding due to extreme precipitation, flooding due to monsoon rainfall, and flooding that is caused when water dammed by a glacier or sediment is rapidly released due to failure of the dam.

Water Use and Water Security

Social changes in the Hindu Kush Himalayan region, such as changing patterns of water use and water management decisions, are likely to have at least as much of an impact on water demand as environmental factors do on water supply. Many of the region's river basins are already water stressed, and with projections of rapid population growth over the next few decades, water stress could be intensified. Water scarcity will likely affect the rural and urban poor most severely, as these groups have the least capacity to adapt to changing environmental and social conditions by moving to new locations as needed.

Although existing demographic methods do not allow for fine-grained projections of population growth at specific locations, it is predicted that the region will become increasingly urbanized as cities expand to absorb migrants in search of economic opportunities. As living standards and populations rise, water use will likely increase—for example, as more people eat diets rich in meat, more water will be needed for agricultural use. The effects of future climate change could further exacerbate water stress.

Water resources management and the provision of clean water and sanitation is already a challenge in the Hindu Kush Himalayan region. The changes in climate and water availability warrant small-scale adaptations with effective, flexible management that can adjust to the changing conditions. The adequacy and effectiveness of existing water management institutions, which focus on natural hazards and disaster reduction, provide an indicator of how the region will likely cope with changes in water supply.

Although the history of international river disputes suggests that cooperation is more likely than violent conflict, current political disputes in the region

could complicate the process of reaching agreements on resource disputes. Changes in the availability of water resources could play an increasing role in political tensions, especially if existing water management institutions do not better account for the social, economic, and ecological complexities of the region.

Figure 4. Due to factors including the remoteness and political instability of some parts of the Hindu Kush Himalayas, hydrological field data from the region is sparse. Here, researchers trek across the Guliya ice cap on the Tibetan Plateau after a snowstorm. Source: Lonnie Thompson, The Ohio State University

Adapting to Uncertainty: The Need to Monitor

A paucity of data about current and emerging conditions of glacier retreat and the hydrologic system of the Hindu Kush Himalayan region has led to an incomplete understanding of current conditions, the extent to which climate change will generate new conditions, and how the region's population will adapt to this change. More effective management of water resources will require a greater understanding of how each management option would affect downstream users, and its potential negative consequences. To implement adaptive management techniques, it will be necessary to monitor the impacts of water management policies and make adjustments as required. The capacity of governments and institutions to adapt to climate change will vary across the region. That means it will be important to expand monitoring programs that gather information on glacier mass balances, streamflow, and water quality in the Hindu Kush Himalayan region. More detailed, consistent, and accurate data on demographics, and on water supply, demand, and scarcity are also needed.

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The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Intelligence Community. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

EXPERT CONSENSUS REPORT

For more information, contact the Board on Atmospheric Science and Climate at (202) 334-3062 or visit http://dels.nas.edu/basc. Copies of *Himalayan Glaciers: Climate Change, Water Resources, and Water Security* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.