The Status of Glaciers in the Hindu Kush–Himalayan Region

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The Status of Glaciers in the Hindu Kush–Himalayan Region

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The Hindu Kush–Himalayan (HKH) region encompasses a mountainous area of more than 4,192,000 km^2 in the countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The region is one of the most dynamic, fragile, and complex mountain systems in the world as a result of tectonic activity and the rich diversity of climates, hydrology, and ecology. This high region is the freshwater tower of South Asia; it has the highest concentration of snow and glaciers outside the polar regions, giving it the name the "Third Pole." Meltwater from the snow and glaciers feeds the 10 largest river systems in Asia, which together support some 1.3 billion people in their downstream basins.

Many glaciers in this region are retreating, leading to concerns that, over time, they 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, amount, and type of precipitation; and glacial behavior and dynamics across the region, that it remains challenging to determine exactly how retreating glaciers will affect water supply in each location (National Research Council 2012). A long-term consistent glacier database is needed to support assessments of glacier status across the region and understanding of climate change impacts on glaciers as well as for climate and hydrological monitoring.

This inventory is a welcome addition to our knowledge of glaciers in the HKH, which resulted from work by the International Centre for Integrated Mountain Development (ICIMOD) with partner institutes in the region to build a regional database of HKH glaciers since the late 1990s. This publication presents a comprehensive account of the number and status of glaciers across the whole region, organized by major basins and sub-basins.

What makes this study so valuable is that it is based on a single data type collected over a short time span, which reduces the errors introduced by using multiple data types over extended periods. The present inventory used Landsat 5-MSS and Landsat 7-ETM+ images from 2005 $\pm$ 3 years. The best images in this period were selected, that is, those with the least snow cover and no clouds. The SRTM (Shuttle Radar Topography Mission) Digital Elevation Model (DEM) at a spatial resolution of 90 m was used to derive crucial glacier parameters such as hypsometry, minimum/median elevation, and equilibrium line altitude (ELA). A semiautomatic methodology was adopted to delineate glaciers by using an object-based image analysis approach, which relied primarily on the normalized difference snow and ice index (NDSI). A similar approach was used to identify and quantify debris-covered portions of glaciers. Eleven attribute parameters were assigned to each glacier, including hydrological identification code (ID), location (latitude/longitude), area, elevation, aspect, average slope, mean glacier thickness, estimated ice reserve, and morphological classification.

I was happy to see that each glacier was assigned a unique ID, which was assigned at the center of each glacier polygon based on the approach of the Global Land Ice Measurements from Space (GLIMS), based at the National Snow and Ice Data Centre (NSIDC) in Boulder, Colorado (http://nsidc.org/). These IDs will help scientists, land managers, government officials, and concerned citizens to find individual glaciers and compare the glacier parameters from this study to past and future studies to evaluate potential changes over time.

A total of 54,000 individual glaciers were identified, with an overall area of 60,000 km^2 and an estimated 6000 km^3 of ice reserves. Thus, 1.4% of the HKH region is glaciated, and the total ice reserves are equal to roughly three times the annual precipitation over the region. The average size of individual glaciers was relatively small (1.1 km^2), but most of the ice reserves are found in the larger glaciers as a result of the nonlinear volume-area relationship. The largest individual glacier was the Siachen glacier in the Karakoram Mountains in the Indus basin, with an area of 926 km^2.

There was a large variation in the range of elevations covered by glaciers, with the lowest glacier terminus identified at 2409 m in the Indus basin and the highest glacier at 8806 m in the Koshi basin. Overall, the largest glaciated area concentration was found at altitudes of 5000–6000 m. These hypsometric relationships are the most important contribution of this inventory, because they provide insight into the sensitivity of glaciers to changes in climate. Moreover, this study provides detailed hypsometric curves at the sub-basin level for all the major river basins outside the region in China.

The data generated in this study, including the attribute information, is being made publically available and can be used by decision-makers, scientists, and governments for different fields of application. The intent is to make the data available through a web portal accessible at http://geoportal.icimod.org/HKHGlacier/, which allows easy access, spatial subsetting, and online analysis. However, at the time of this

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review, the data were not yet available at that site.

Realistic, accurate, and comprehensive assessments of the future availability and vulnerability of the water resources in the HKH region are not possible until the existing glaciological regime of these mountains is better defined, and the current relationship between snow, glaciers, and streamflow is evaluated in quantitative terms. To date, this comprehensive goal has not been addressed in a coordinated and systematic manner, which has led to controversies on the rate of glacial retreat and consequent impacts on water security in the region. This inventory can now serve as a baseline that provides the first coordinated and systematic evaluation of the glacier resources in this region, and will lead to a large improvement in our understanding of the vulnerability of water resources in the region to changes in climate. The open approach and the use of a transparent methodology by the editors will help in avoiding future misunderstandings related to changes in the HKH glaciological system and the potential impacts on water security for rivers of high Asia.

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