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21st century Himalayan hydropower: Growing exposure to glacial lake outburst floods?

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Primary energy demand in China and India has increased fivefold since 1980. To avoid power shortages and blackouts, the hydropower infrastructure in the Hindu Kush-Himalaya region is seeing massive development, a strategy supported by the policy of the World Bank and in harmony with the framework of the Kyoto Protocol. The targeted investments in clean energy from water resources, however, may trigger far-reaching impacts to downstream communities given that hydropower projects are planned and constructed in close vicinity to glaciated areas. We hypothesize that the location of these new schemes may be subject to higher exposure to a broad portfolio of natural hazards that proliferate in the steep, dissected, and tectonically active topography of the Himalayas.

Here we focus on the hazard from glacial lake outburst floods (GLOF), and offer an unprecedented regional analysis for the Hindu Kush-Himalaya orogen. We compiled a database of nearly 4,000 proglacial lakes that we mapped from satellite imagery; and focus on those as potential GLOF sources that are situated above several dozen planned and existing hydropower plants. We implemented a scenario-based flood-wave propagation model of hypothetic GLOFs, and compared thus simulated peak discharges with those of the local design floods at the power plants. Multiple model runs confirm earlier notions that GLOF discharge may exceed meteorological, i.e. monsoon-fed, flood peaks by at least an order of magnitude throughout the Hindu Kush-Himalaya.

We further show that the current trend in hydropower development near glaciated areas may lead to a >15% increase of projects that may be impacted by future GLOFs. At the same time, the majority of the projects are to be sited where outburst flood modelling produces its maximum uncertainty, highlighting the problem of locating minimum risk sites for hydropower. Exposure to GLOFs is not uniformly distributed in the Himalayas, and is particularly high in rivers draining the Mt. Everest and Lulana regions of Nepal and Bhutan, respectively. Together with the dense, cascading sequence of hydropower stations along several river networks in these areas, the combination of GLOFs and artificial reservoirs in steep terrain may result in increasing threats to downstream communities.

Hydropower stations are infrastructural investments with minimum design lives of several decades, and our results suggest that their planning should be orchestrated with projected changes in glacier response to future climate change. Our data underline the preponderance of glacial lakes in areas with high glacial retreat rates and a commensurate exposure of hydropower stations to GLOFs. To ensure sustainable water resources use at minimum risk implications for on-site downstream communities, potential changes in GLOF hazard should be taken seriously when planning hydropower stations in the Hindu Kush-Himalaya.