Compound hazards pose increased risk to highly populated regions in the Himalayas

September 13 2021

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Most of the research concerned with hazards like flooding, landslides, or wildfires describes only one hazard at a time, but the Intergovernmental Panel on Climate Change's latest assessment report states that

anthropogenic climate change is increasing the likelihood of compound hazards—events where more than one hazard interact with multiplicatively destructive consequences. A recent study has found that current urbanization trends in the Himalaya are exposing more and more people to risks from increasingly destructive compound hazards.

In a paper published in the journal *Science of the Total Environment*, a global team of researchers led by Jack Rusk, a Master of Environmental Management student at the Yale School of the Environment, found that only a small proportion of the Himalaya region is susceptible to compounding threats from multiple hazards, yet almost half of the region's population is concentrated in that high-risk area.

The paper, entitled "Multi-hazard susceptibility and exposure assessment of the Hindu Kush Himalaya," shows that current patterns of urbanization are putting people in harm's way while less hazardous landscapes remain more sparsely populated. "Our sobering realization is that urbanization processes are concentrating human settlement in these relatively smaller but highly hazardous areas," says Karen C. Seto, Frederick C. Hixon Professor of Geography and Urbanization Science at Yale School of the Environment and a co-author of the study. In mid-elevation valleys in the Hindu Kush region, the same conditions that correspond to multi-hazards are also major sites of urban growth.

Compounding hazards in the Himalaya take many forms. For example, climate change is causing more frequent and intense wildfires, which contribute to landslides by destabilizing slopes. Those landslides can dam waterways swelling from increased precipitation and glacial melt, leading to catastrophic flooding when the dam breaks. And high-magnitude earthquakes, like the 2015 Gorkha earthquake in Nepal, can trigger landslides and floods together. The reality of compounding multi-hazards suggests that connections between hazards may be as impactful as any single hazard alone.

"It's often stated that the Himalaya is a high-risk environment," says Rusk. "But the difficulty of working across such a large area meant that patterns of risk weren't previously understood. Contrary to studies that describe the entire region as highly hazardous, our study shows that the highest risk areas are relatively small."

Understanding these patterns of risk would not have been possible without a big data approach that connected on-the-ground observations of floods, wildfires, and landslides with satellite data collected from high in the atmosphere. Relatively few hazard incidents are documented in the Himalaya, so the team used machine learning techniques to infer patterns in the distribution of hazards from historical hazard information and environmental conditions described by satellite data. For floods, landslides, and wildfires, ten environmental conditions were tested. The results showed that multi-hazard risk was often concentrated in relatively hotter mid-elevation valleys with wet soils. Based on 2019 population estimates, this study shows over 36 million people (49% of the region's population) living in areas highly susceptible to multi-hazards.

The migration and mobility patterns shaping urbanization in the region are motivated by factors other than hazard risk, study co-author Sara Shneiderman, associate professor at the School of Public Policy and Global Affairs/Institute of Asian Research and the Department of Anthropology at the University of British Columbia, says.

"Urbanization in the Himalaya is driven by social processes as people seek economic, educational, and political opportunities," says Shneiderman. "As people move across the region in search of sustainable livelihoods, they are tending to settle in areas at risk of compounding hazards."

To reduce the tragic risks associated with compounding multi-hazards, approaches to risk reduction must continue to evolve. The

interdisciplinary team of authors balanced a quantitative modeling approach with the insights of social scientists who live or have worked extensively in the region.

Co-author Mark Turin, associate professor in the Institute for Critical Indigenous Studies and the Department of Anthropology at the University of British Columbia and former Yale Himalaya Initiative Director, notes the uniquely broad and interdisciplinary approach taken by Rusk and the research team.

"This study brings together transboundary approaches—pursuing issues as they move across political borders—with innovative transdisciplinary methodologies. I see much potential in integrating granular, site-specific ethnographic knowledge with broader scale computational and machine learning tools in service of complex research questions like those addressed in this paper."

Building from this expertise, the paper emphasizes that effective disaster risk reduction must span from very large to very small scales. At the smallest scale, risk reduction strategies should consider the knowledge of individual residents. "Residents in multi-hazard environments," the paper states, "have detailed knowledge of multi-hazard processes, and their knowledge should be central to mitigation planning efforts."

At larger scales, Amina Maharjan, Senior Specialist (Livelihoods and Migration) at the International Centre for Integrated Mountain Development (ICIMOD) in Nepal, underscores the need for this transboundary study to motivate transboundary collaboration for disaster risk reduction: "Often in this region, disasters cross administrative and international boundaries, so disaster mitigation and risk reduction require a transboundary approach—saving lives and livelihoods are a humanitarian concern for which countries in the region must collaborate without delay."

More information: Jack Rusk et al, Multi-hazard susceptibility and exposure assessment of the Hindu Kush Himalaya, *Science of The Total Environment* (2021). DOI: 10.1016/j.scitotenv.2021.150039

Provided by Yale University