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Quanitification of sustainable hydropower potential in the Upper Indus basin

Sanita Dhaubanjar[1,2], Arthur F. Lutz[2], David Gernaat[3], Santosh Nepal[1], Saurav Pradhananga[1], Sonu Khanal[4], Arun Bhakta Shrestha[1], and Walter Immerzeel[2]

[1]International Center for Integrated Mountain Development (ICIMOD), Lalitpur 44700, Nepal
[2]Faculty of Geosciences, Universiteit Utrecht, Utrecht 3584 CB, Netherlands
[3]PBL Netherlands Environmental Assessment Agency, The Hague 2500 GH, Netherlands
[4]FutureWater, Wageningen 6702 AA, Netherlands

Considering the lack of a comprehensive assessement of hydropower potential in the Upper Indus basin, we developed and implemented a systematic framework to explore four different classes of hydropower potential. Our framework uses high-resolution discharge generated by a coupled cryosphere-hydrology model as the bio-physical boundary conditions to estimate theoretical potential. Thereafter, diverse context-specific constraints are implemented stepwise to estimate the technical, economic and sustainable hydropower potential. The successive classes of hydropower potential integrate considerations for various water demands under the water-energy-food nexus, multiple geo-hazard risks, climate change, environmental protection, and socio-economic preferences. We demonstrate that the nearly two thousand Terawatt-hour of theoretical potential available annualy in the upper Indus can be misleading because a majority of this is technically and economically not viable. Even smaller potential remains if we account for the various sustainability constraints that vary spatially. Our concept of the sustainable hydropower potential enables decision makers to look beyond the energy sector when selecting hydropower projects for development to achieveenergy security under the Sustainable Development Goal 7 (SDG7).The generated portfolio of sustainable hydropower projects is superior to the current portfolio based on outdated studies because our method looks beyond theoretical possibilities and excludes projects that conflict with management objectives under other SDGs. The spatial maps with potential and the cost curves for hydropower production provide a science-based knowledge base for hydropower development in the Indus basin. Our method could similarly be adapted to inform hydropower development in other basins across the globe.