Geophysical Research Abstracts
Vol. 21, EGU2019-9155, 2019
EGU General Assembly 2019

Socioeconomic impacts and losses from deglaciation-driven changes in mountain hydrology

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About one sixth of the World's population directly depends on water of snow and ice melt from major mountain ranges. Particularly in (semi)arid regions, where human vulnerability towards water scarcity is quite high, mountains play an important role as virtual water towers for human livelihoods. In the Tropical Andes, year-round streamflow from glaciers buffers seasonal and local water scarcity and discharge variability. However, this sub-region is among the most vulnerable mountain areas worldwide due to strong impacts from glacier shrinkage. In the Santa river basin (Western Andes of Peru), the Cordillera Blanca glaciers, which represent the largest tropical glacier coverage worldwide, have reduced by about 38% in area between 1962 and 2016 to about 450 km^2. The vanishing of large ice bodies has serious implications for timing and quantity of upstream-downstream water use, which at the same time is under strong transformation. Rising water demand due to the growth of irrigated agriculture ($\sim$3500 km^2), population ($\sim$646,000) and hydropower capacity (73 MW) is already challenging and expected to further exacerbate the pressure on water resources and socioenvironmental systems in the basin within the next decades. This situation of most likely increasing water scarcity, coupled with a lack of water governance and high human vulnerabilities, bears high conflict potentials with negative feedbacks for socioeconomic development in the Santa basin and beyond.

While a growing number of research in the Santa and other tropical basins covers topics of impacts from climate change and glacier shrinkage on river hydrology, little progress has been made so far to quantify water demand, related trends and to integrate potential future trajectories of socioeconomic development in hydrological models. Furthermore, coupled assessments including the estimation of economic losses for multiple sectors of water use related to glacier shrinkage and changes in river streamflow represent an important shortcoming. In this context, we are developing an integrative hydrological impact model at unprecedented scales. Therefore, current (1981-2016) and future (2030-2100) water availability in the Santa basin are analyzed within a lumped water balance framework at monthly scale. The estimated future water volume released due to deglaciation effects is then quantified by different metrics and converted into potential financial and socioeconomic impacts and losses through a coupled economic assessment for the main sectors of water use (agriculture, households and hydropower). Therefore, different scenarios are used which provide a broad range of the magnitude of glacier and water volume changes and associated economic impacts. Additionally, the damage potential of outburst floods from current and possible future lakes is considered. In a last step, the feasibility of measures for hydro-economic risk reduction is discussed. Our research represents an important progress in integratively assessing hydrology, economy and climate change aspects in the Tropical Andes. Furthermore, it provides support for future decision-making in a context of increasing water scarcity, strong data scarcity and, thus, high uncertainties. The proposed hydro-economic model framework builds an important basis for integrated and adaptive water resources planning which includes risk reduction and water storage options in the context of long-term water management.