Geophysical Research Abstracts
Vol. 21, EGU2019-7400, 2019
EGU General Assembly 2019

Understanding socio-hydrological systems in a context of climate and socio-economic change: Santa river basin, Peru

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Water resources management in catchments with important contributions from glacier and snow melt face large challenges under current and future climate and global change. Regions with pronounced dry seasons and high glacier runoff contributions such as in Central Asia or in the Andes of South America have been identified as particularly vulnerable in this context. Adequate management of water resources necessarily requires knowledge of both, water supply and demand, and their interlinkages and spatio-temporal dynamics. Water demand related understanding and consideration, however, is typically limited, especially in many developing countries and remote mountain regions that suffer from data scarcity.

Here we analyze spatio-temporal dynamics of past and future water supply and demand according to various scenarios of climate and socio-economic change for the Santa river catchment, extending from the glacierized peaks of the Cordillera Blanca to the arid Pacific coast of Peru. For this purpose we collected and compiled large amounts of data, related to temperature and precipitation, glaciers, river runoff, small and large-scale agriculture, hydropower and domestic water use. We conducted interviews with local stakeholders to define the driving factors of socio-economic change, develop future scenarios and evaluate their effects on water demand, availability and management. Applying the cross-impact-balance analysis (CIB), we developed three scenarios for further analysis and validation through a participatory process involving local experts and stakeholders of the study region. To analyze the spatio-temporal dynamics of water resources we applied a semi-distributed hydrological modeling framework, integrating water supply and demand at a previously unprecedented level of detail. This balance model eventually allows us to integratively evaluate different water management and adaptation options against various climate and socio-economic change scenarios and uncertainties.

We found that glacier melt contributes more than 50%to Santa river runoff during the dry season in upstream parts of the catchment, with sustained high contributions further downstream in the arid coastal areas with large and highly irrigation-dependent agro-export industries – a more significant amount than previously thought. As a consequence of glacier shrinkage, future decades will see a strong reduction in dry season runoff, with an important difference of magnitude between low- and high-emission scenarios. Large-scale agriculture and hydropower are economically the most powerful water users with the highest dependence on water resources. Water management in the upper catchment is deficient (e.g. lacking governance) and inefficient (e.g. high non-revenue water), and conflicts are latent and acute among upstream and downstream users. Our research of the socio-hydrological system identifies major management challenges due to seasonally and locally declining water supply and rising water demand, thus potentially exacerbating existing competition over water. Increased attention in water governance and inclusive decision-making mechanisms will be key to prevent and resolve social conflicts. More socio-hydrologic research is needed, including improved hydro-climatic and socio-economic monitoring and more in-depth understanding of the trends, complexities and intertwining of water supply-demand systems and multiple users' perspectives, including better quantifying and reducing uncertainties. Joint knowledge generation spaces between science, policy and society of the region should be further promoted.