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Simple hydrological modelling with scarce data in high mountain regions: a case study in the upper Vilcanota basin, Peru

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Glaciers in the Tropical Andes are known for their buffering function in water supply, especially during the dry season (May – October). They supply water for different uses like agriculture, households and hydropower production. However, glaciers are retreating and many are projected to disappear in the mid to long term, with significant consequences for local populations and economy. It is likely that the related changes in streamflow seasonality, due to the lack of a glacier melt contributions during the dry season, will considerably affect several water use sectors, which depend on year-round continuous discharge.

In the Vilcanota River in southern Peru, water resource related research has recently been promoted by joint projects of the international cooperation and the Peruvian government under a climate change framework. This catchment contains the Cordillera Vilcanota, the second largest glaciated mountain range in Peru and the tropics worldwide. While most of the studies on tropical glaciers and related runoff have been developed in the Cordillera Blanca and the Santa catchment (northern Peru), little is known for the Cordillera Vilcanota region.

As in many other mountainous regions, high mountain conditions with complex topography and related variations of climatic variables are contrasted with scarce data availability. Existing studies have evaluated changes in glaciers, climate and future development of new landscapes. However, a comprehensive assessment of the current and future water availability is still missing.

To overcome these issues we applied a simple hydrological model proposed by Temez (1977) for the upper Vilcanota basin in a monthly time step. This lumped model is able to estimate surface runoff, including groundwater flow. We integrated a simple glacier runoff contribution scheme based on glacier surface area and seasonally varying melt rates. Input data like precipitation and temperature were obtained from the Peruvian gridded precipitation and temperature data set PISCO$_2$.1 (SENAMHI). Evapotranspiration was estimated applying the FAO ETo calculator based on maximum and minimum temperature. Surface groundwater recharge was estimated based on infiltration rates.

The model was calibrated in the Sibinacocha sub catchment, a contributor to the Vilcanota River, were streamflow measurements exist. Later we applied the calibrated parameters to five other small sub catchments with glacier influence. To assess the impact of glacier retreat on runoff, we changed the glacier surface according to previous studies based on freezing level height, anticipating glacier extents in 2050 and 2100 under RCP2.6 and RCP8.5, respectively. Climate variables other than temperature remained static.

Our findings show that glacier contribution currently represents between 30 to 50% of the total runoff, increasing to 60% during the dry season. At the end of the century, a scenario with complete glacier retreat (RCP8.5), implies a water availability reduction of up to 40 million m3 during one hydrological year. This simple approach provides new information in a region with few measurements and provides relevant information to decision makers and planners for the anticipation of future water availability and adaptive long-term water resource management.

Témez, J. R. (1977). Modelo Matemático de trasformación “precipitación-escorrentía.” Asociación de Investigación Industrial Eléctrica (ASINEL). Madrid, España.