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Present and future water resources supply and demand in the Central Andes of Peru: a comprehensive review with focus on the Cordillera Vilcanota

Fabian Drenkhan (1), Christian Huggel (1), Nadine Salzmann (1), Claudia Giráldez (1), Wilson Suarez (2), Mario Rohrer (3), Edwin Molina (4), Nilton Montoya (5), and Fiorella Miñan (6)

(1) University of Zurich, Department of Geography, Zurich, Switzerland (fabian.drenkhan@geo.uzh.ch), (2) National Service of Meteorology and Hydrology of Peru, Senamhi, Lima, Peru, (3) Meteodat GmbH, Zurich, Switzerland, (4) Department of Geography, National University of San Antonio Abad at Cusco, Cusco, Peru, (5) Department of Agriculture, National University of San Antonio Abad at Cusco, Cusco, Peru, (6) CARE Perú, Lima, Peru

Glaciers have been an important element of Andean societies and livelihoods as direct freshwater supply for agriculture irrigation, hydropower generation and mining activities. Peru's mainly remotely living population in the Central Andes has to cope with a strong seasonal variation of precipitations and river runoff interannually superimposed by El Niño impacts. Direct glacier and lake water discharge thus constitute a vital continuous water supply and represent a regulating buffer as far as hydrological variability is concerned.

This crucial buffer effect is gradually altered by accelerated glacier retreat which leads most likely to an increase of annual river runoff variability. Furthermore, a near-future crossing of the 'peak water' is expected, from where on prior enhanced streamflow decreases and levels out towards a new still unknown minimum discharge. Consequently, a sustainable future water supply especially during low-level runoff dry season might not be guaranteed whereas Peru's water demand increases significantly.

Here we present a comprehensive review, the current conditions and perspectives for water resources in the Cusco area with focus on the Vilcanota River, Cordillera Vilcanota, Southern Peru.

With 279 km^2 the Cordillera Vilcanota represents the second largest glacierized mountain range of the tropics worldwide. Especially as of the second half of the 1980s, it has been strongly affected by massive ice loss with around 30% glacier area decline until present. Furthermore, glacier vanishing triggers the formation of new lakes and increase of lake levels and therefore constitutes determining hazardous drivers for mass movements related to deglaciation effects.

The Vilcanota River still lacks more profound hydrological studies. It is likely that its peak water has already been or might be crossed in near-future. This has strong implications for the still at 0.9% (2.2%) annually growing population of the Cusco department (Cusco city). People mostly depend on these water resources but indicate a strong water vulnerability due to a high degree of absolute poverty, 30% and only 67% of access to drinking water. The Vilcanota area has been traditionally the breadbasket for the whole Cusco area. While agriculture is the most important labor sector, a growing export-oriented crop production depends highly on a minimum river streamflow ensuring sufficient water quantity and quality. Hydropower, with 53% of the total electricity nationwide the energy pillar of Peru's economy, might also be heavily affected by diminishing water resources. Nevertheless, improved power plants have to balance out Peru's by 7.5% y^{-1} increasing energy demand. For instance, the Machu Picchu hydropower plant is currently expanded by 100 MW to a full capacity of 190 MW but does not consider future water availability of the Vilcanota River and local impacts for the population.

Our conclusions suggest to focus on an integrative risk-oriented supply-demand water balance model scheme in order to capture the complexity of recent and future water distribution. The integration of both physical and social key variables considering long-term changes in climate-glacier interactions as well as economic and demographic trends, plays a determinant role for the performance quality of that model and future adaptation strategies.