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Link between groundwater storage and landscape changes in mountainous areas: the Kahule Khola watershed (Nepal)

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In many watersheds of various sizes, the role played by groundwater to sustain river flow is still misunderstood. This is the case in mountainous areas where geological features as fractures, altered or unaltered bedrocks and steep slopes notably play an important role for storing groundwater into the subsurface. The groundwater support to low flows was considered for a long time as a minor contribution, due to the steep slopes in those areas. But in Nepal, it is estimated that 2/3 of the volume of rivers comes from the exfiltration of groundwater through resurgences. Though several attempts were made with numerical modelling based on data monitoring and field surveys to quantify river-groundwater exchanged fluxes, some ambiguities remain. Especially regarding the impact of landscape change in a mountainous topography. The aim of this work is to characterize the subsurface infiltration, recharge, and storage mechanisms of a mountainous hydrogeological system in the Himalayas using field investigations and numerical modelling. In the Kahule Khola watershed (Nepal), a steep catchment of 33 km² whose altitudes range between 1000 and 3500 masl, various field experiments were made to identify groundwater pathways into the altered subsurface and to catch the river/groundwater interactions: seismic and electric surveys (ERT), infiltration tests, physical and isotopic measurements of springs/streams and the water tracking on the surface with loggers installed along gullies in the overall watershed. The region is submitted to intense rainfall as monsoon, intercalated by dry periods in which the river flow is still sustained. Moreover, by closing ancient fractures and opening new ones, earthquakes can deviate springs and change the surface water/groundwater pathways. This contributes to reshaping the landscape. However, the spatial and temporal contribution of groundwater to maintain a baseflow in the river is not quantified yet, in space and time. The ERT data from a time-lapse realized before and after monsoon show a deep alteration zone with a shallow humid layer of 10 m thick at least all year long under the slopes. Areas of low resistivity reveal infiltration zones and preferential flow paths. These areas are recharged in the wet season and drained in the dry season. At the surface, we estimate an average hydraulic conductivity at saturation of $3,5.10^{-5}$ $m.s^{-1}$ in 150 cm depth which suggest an infiltration rate higher than the average rainfall rate (~3000 $mm.year^{-1}$). In order to quantify the groundwater storage into the subsurface, a numerical

groundwater model in 2D has been developed (Python) and is able to simulate and quantify the water storage dynamics of a spatial and temporal pre-defined domain. The data measured on the field will be used to define the initial conditions of future scenarios.