EGU22-861
https://doi.org/10.5194/egusphere-egu22-861
EGU General Assembly 2022

A modified USLE-based approach combined with sediment delivery module to estimate soil loss and reservoir sedimentation rates in Alpine basins

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Reservoir sedimentation constitutes a major issue worldwide and a long-lasting priority for dam managers, especially when hydropower, and hence profit, is involved. Commonly, the problem of excessive sedimentation is attributed to failed prediction of the sediment supply from the upland basin prior to the construction of dams, namely to the underestimation of sediment inflow to the reservoir.

The sediment input in the Rio di Pusteria reservoir (South Tyrol, Italy) between two consecutive sediment flushing operations in June 2014 and May 2019, was determined by obtaining the volumetric difference between very high resolution (0.25 m) reservoir bathymetries conducted after the flushing of 2014 and before the flushing of 2019. The sediment yield in the reservoir during the latter period was found to be 453,783 t.

To calculate the sediment yield in the reservoir, we have applied a gridded seven-factor Universal Soil Loss Equation (USLE) combined with a Sediment Delivery Ratio (SDR) module in a high resolution (2.5 m) GIS environment, which enabled an accurate representation of the rapidly shifting Alpine topography. An additional factor for coarse fragments was added to the conventional six-factor USLE to account for the non-erodible part of the basin. This is of great importance as the USLE-based models are criticized to produce extreme erosion rates in uplands and mountain areas. The topographic factor, LS, was refined by the use of a fine scale DEM and the slope length factor, L, was adjusted to the Alpine terrain by means of a regulating threshold. The proposed SDR module does not rely on one but on several physiographic, topographic and hydrologic characteristics of the basin. Finally, the rainfall erosivity factor, R, was determined in two different ways, one representing the rainfall climatology of the study area and one the specific rainfall conditions of the study period, hence the application of the model in two distinct configurations.

The application of the combined USLE-SDR model resulted in five-year reservoir sedimentation rates of 439,279.2 t and 589,520.5 t, with deviations from the measured sediment yield of 3.3% and -25.5%. Excluding very high altitudes with glaciers and perennial snow, we consider the proposed modeling approach ideal for upper lands and mountainous areas such as the Alps.