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Unraveling the Illgraben sediment cascade

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Quantification of the volumes of sediment removed by rock–slope failure and debris flows and identification of their coupling and controls are pertinent to understanding mountain basin sediment yield and landscape evolution. This study captures a multi-decadal period of hillslope erosion and channel change following an extreme rock avalanche in 1961 in the Illgraben, a catchment of high scientific interest in the Swiss Alps due to its extremely high debris-flow dominated sediment yield. We analyzed photogrammetrically-derived datasets of hillslope and channel erosion and deposition along with climatic and seismic variables for a 43-year period from 1963 to 2005. Based on these analyses we identify and discuss (1) patterns of hillslope production, channel transfer and catchment sediment yield, (2) their dominant interactions with climatic and seismic variables, and (3) the nature of hillslope–channel coupling and implications for sediment yield and landscape evolution in this mountain basin. Our results show an increase in the mean hillslope erosion rate in the 1980s from 0.24 ± 0.01 m yr^{-1} to 0.42 ± 0.03 m yr^{-1} that coincided with a significant increase in air temperature and decrease in snow cover depth and duration, which we presume led to an increase in the exposure of the slopes to thermal weathering processes. This is indicated by a significant increase in the number of days of subzero air temperature and no snow cover. Conversely, there was no increase in precipitation or seismic activity that would explain the increase in erosion rate. However, the combination of highly fractured slopes close to the threshold angle for failure, and multiple potential triggering mechanisms, means that it is difficult to identify an individual control on slope failure. This is illustrated by our analysis of the 1961 rockfall event, which failed to reveal an individual trigger of the failure given both extreme meteorological conditions and seismic activity in the weeks leading up to the event. On the other hand, the variable rate of channel change over the study period was strongly related to variables influencing runoff. A period of particularly high channel erosion rate of 0.74 ± 0.02 m yr^{-1} (1992–1998) coincided with an increase in the frequency and magnitude of intense rainfall events.

Hillslope erosion rate exceeded channel erosion rate on average, indicative of a downslope-directed coupling relationship between hillslope and channel. This is in contrast to the more commonly reported upslope-directed coupling relationship in which channel incision sets the rate of hillslope erosion. This study therefore demonstrates the first order control of rock–slope failure on catchment sediment yield and landscape evolution.