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Sediment transfer dynamics in the Illgraben

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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. We analyzed photogrammetrically-derived datasets of hillslope and channel erosion and deposition along with hydroclimatic variables from the Illgraben, an active debris flow catchment in the Swiss Alps, spanning 1963 – 2010. Two events in the recent history of the catchment make it particularly interesting and challenging to study: a large rock avalanche in 1961, which filled the channel with sediment, and the construction of check dams along the channel in the late 1960s and 1970s. We aimed to (1) identify the nature of hillslope-channel coupling, (2) identify the dominant controls of hillslope sediment production, channel sediment transfer and total sediment yield, (3) observe the response of the channel system to the 1961 rock avalanche and check dam construction, and (4) develop a conceptual model with which to investigate sediment transfer dynamics in various scenarios, including the absence of check dams along the channel.

The study captures a multi-decadal period of channel erosion in response to the 1961 rock avalanche, punctuated by shorter cut-and-fill cycles that occur in response to changes in hillslope sediment supply and changes in transport capacity. Hillslopes eroded rapidly at an average rate of 0.34 myr^{-1}, feeding the channel head with sediment. A near doubling of hillslope erosion in the 1980s coincided with a significant increase of air temperature and reduction in snow cover duration and depth, whilst precipitation variables did not change significantly. We find that the main influence of check-dam construction on channel sediment transfer was an initial reduction in sediment transport and a drop in debris flow activity between 1963 and 1986. After 1986 sediment storages in the channel were filled and debris flow activity resumed. During this time hillslope erosion exceeded channel erosion by 0.14myr^{-1} indicating that hillslopes eroded independently of channel incision. Channel sediment transfer was transport-limited at the scale of the study as suggested by the aggradation of the channel in periods of very high hillslope flux and its apparent relation to variables connected to runoff generation such as precipitation and snowmelt.

We have developed a conceptual model of sediment transfer based on our data set with which to investigate sediment transfer dynamics in a probabilistic sense. A stochastic sediment input from the hillslopes is generated from our magnitude-frequency model of landslides. Sediment is fed into a hillslope storage component, where a fraction is redeposited in long-term storage. Sediment in short-term storage is subsequently fed into the channel system and is only removed given a transport event (rainfall or snowmelt) of sufficient magnitude *and* sufficient available sediment. Transport events are generated stochastically using a weather generator. We calibrate the model with available data. Despite its simplicity the model reproduces the storage and discharge behavior of the channel system observed over the study period and enables us to test the sensitivity of the system to different parameters and system structures.