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Controls of hillslope-channel coupling on bed material grain size in a semi-arid catchment

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Hillslope-channel coupling has been shown to be an important control on sediment supply. It can affect the calibre and amount of sediment reaching the channel, and therefore, the texture of the bed material. In coupled reaches colluvial input greatly alters the bed material grain size and may suppress any pattern of downstream fining. In decoupled reaches, floodplains buffer hillslope sediment supply and the channel grain size distributions evolve autogenically. In semi-arid catchments hillslope-channel coupling is further complicated by infrequent, short-lived and spatially-variable rainfall events which lead to uneven hillslope erosion patterns and discontinuous sediment transport in the ephemeral channels. In this paper we explore the relationships between the downstream changes in hillslope-channel coupling, the grain-size variation on the river bed and the resultant sediment transport characteristics within an ephemeral channel and the hillslope sediment delivery.

Detailed topographic valley cross sections and hillslope, floodplain and channel particle sizes were collected from 30 locations along a 15-km dry, ephemeral-river reach in the Rambla Nogalte, Spain. We investigated the longitudinal variation in grain-size distributions on the hillslopes, floodplains and on the channel bed in order to determine a grain-size 'signal' of the degree of coupling and its spatial persistence. Results show that various aspects of the bed material grain size distribution (d10, d50, d90, sorting) oscillate with distance downstream and there is no downstream fining. The coarser fraction in the channel (d90) correlates with the median coupled hillslope grain size in the corresponding cross section and there is a downstream variation related to the presence or absence of floodplains and to the entry of some tributaries.

Channel sediment transport modelling was carried out using a transport equation based on a modified Engelund-Hansen formula sensitive to bed material grain-size distribution. A range of observed channel flow depths obtained from the literature for that catchment, were used to simulate fractional transport and to estimate a reach-scale sediment budget which is analysed in the context of longitudinal patterns in grain sizes and hillslope-channel coupling. Hillslope sediment transport modelling was carried out in order to investigate the effect of hillslope-channel coupling on coarse-sediment delivery. A discrete particle-based model was developed and applied to the measured valley cross sections. The model is hydrologically driven and uses flow hydraulics to calculate particle transport. Results show that coupled slopes allowed direct transmission of sediment to the channel and the texture of the transported sediment is affected by factors such as slope profile. Floodplains were found to buffer sediment transport from the hillslope, preventing sediment from reaching the channel. Most sediment was deposited at the interface between the hillslope and floodplain and the change in slope gradient between the hillslope and floodplain was found to be the major control on sediment deposition, storage and texture.

The combined field, statistical and modelling approach for analysing bed material grain-size responses to hillslope and channel sediment transport, provides new insights into the role of hillslope-channel coupling on the spatial patterns of sediment fluxes and transport in semi-arid catchments.