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A dynamic, network scale sediment (dis)connectivity model to reconstruct historical sediment transfers and river reach sediment budgets

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Sediment transport and connectivity are key factors for the functioning of fluvial eco-systems, and variations to these drivers deeply affect the geomorphology of the river system. Given that lags often occur in river systems, these changes may appear displaced in time and space from the disturbances that generated them. Modelling sediment (dis)connectivity and its reaction to anthropic pressures with a network-scale perspective is thus necessary to increase the understanding of river processes, to quantify real impacts and estimate future evolutionary trajectories. The CASCADE model (Schmitt et al., 2016) is a sediment connectivity model developed to address this type of research question: it combines concepts of network modelling with empirical sediment transport formulas to quantitatively describe sediment (dis)connectivity in river networks.

In this work, we present a new version of the CASCADE model which expands on the original model by featuring a dynamic simulation of sediment transport processes in the network (D-CASCADE). This new framework describes sediment connectivity in term of transfer rates through space and time. It takes into consideration multiple factors that can affect sediment transport, such as spatial and temporal variations in water discharge and river geomorphological features (i.e., river gradient and width), different sediment grainsizes, sediment entraining and deposition from and in the river bed and interactions between materials coming from different sources.

We apply the new D-CASCADE on the Bega River, New South Wales, Australia, which due to anthropic alterations post European colonization after 1850 including large-scale deforestation, removal of riparian vegetation and swamp drainage, has experienced significant alteration to the character and behaviour of streams, widespread channel erosion and massive sediment mobilization (Fryirs and Brierley, 2001). Our objective is to reproduce the historical sediment transfers that occurred across the network and associated river reach sediment budgets. First, we reconstructed the pre-settlement geomorphic features of the river network and the past hydrology from historical observations and expert-based reconstruction, and then modelled the sediment transport processes in the network in the last two centuries introducing the different

drivers of change observed historically in the proper chronological sequence. Due to the uncertainty in the reconstruction of the historical conditions, multiple scenarios have been used.

The D-CASCADE model successfully reproduces the timing and magnitude of the major sediment transfers of the last two centuries in the Bega River network from headwaters swamps to lowland river reaches and associated channel geomorphic adjustments. Using the knowledge acquired by these historical simulations, the model was also applied to provide estimations on future trajectories of sediment transport and sediment budgets at the river reach scale.

With this research, we demonstrate the potential of the new D-CASCADE model to simulate and quantify at the network-scale sediment transport events generating information on sediment budget transfers from a single event to historical trajectories of the last centuries. Such knowledge paves the way to aid predictions of future impacts of basin-scale management measures and can support decision-making when designing sediment management strategies or river restoration initiatives.