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Modelling floodplain sediment storage times using simulated river channel changes

Christopher Feeney (1), Richard Chiverrell (1), Hugh Smith (2), James Cooper (1), and Janet Hooke (1)

(1) University of Liverpool, School of Environmental Sciences, Liverpool, United Kingdom (c.j.feeney@liverpool.ac.uk), (2) Landcare Research, Palmerston North, New Zealand

Constraining sediment storage times is important for catchment management. Floodplains store significant quantities of fine sediments (particles <2 mm in diameter) and potentially harmful contaminants which can adversely affect water quality when released into rivers via erosion. Mean sediment storage times can be estimated by dividing an estimated mass by an average erosion rate. This assumes equal probability of erosion with respect to sediment age and that the probability distribution of storage times decays exponentially. However, if erosion is restricted to an active, recently (re)formed floodplain area in the centre of the valley floor, and areas closer to the valley edge are undisturbed, the storage time distribution will decay sharply, reflecting preferential removal of younger and retention of older sediments. Furthermore, it is unclear how different environmental conditions such as vegetation cover will influence sediment storage behaviour. Our aim is to determine whether sediment removal from floodplain storage is dependent upon age. Here, we present a method of quantifying sediment storage behaviour from channel changes simulated using CAESAR-Lisflood. We track the timing of deposition and erosion in valley floor DEM cells over 1000 years, creating a unique time-series of sediment fluxes for every cell that has been occupied by the channel at least once. Age is calculated as time since deposition and storage time as the age recorded when sediment is eroded. Non-linear regression models are fitted to storage time distributions and compared with the exponential model. We model the age-dependent probability of erosion (erosion hazard) by dividing storage time probability density functions (PDFs) by age PDFs and test the effect on modelled storage time distributions of recording age and storage times at different time intervals (10, 20, 50 and 100-year). We apply this procedure to nine model runs covering three vegetation cover scenarios (forested, grass covered and unvegetated) and three valley floor reaches. For most simulations, regardless of sampling interval, the simulated storage time distribution decay is steeper than the exponential model predicts, and erosion hazard decreases with increasing age. This suggests that some sediments, and any associated contaminants, are released from the floodplain into receiving rivers after a much shorter period of storage than predicted when dividing floodplain mass by sediment removal rate. Total erosion is greatest for grass and unvegetated conditions and there is generally less bias towards erosion of younger floodplains than under forest cover. Sampling at 50 and 100-year intervals results in better fits for the exponential model to simulation data. For at least one scenario, as time interval length increased from 10 to 100 years, the exponential model switched from being the worst to the best fitting model. This apparent sensitivity results from preferential removal of young sediment being recorded less frequently under 100-year time intervals and suggests that it is possible to derive contrasting conclusions from the same simulation depending on how data are sampled.