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A probabilistic framework for the cover effect in bedrock erosion

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Bedrock erosion rates in mountain rivers are driven by impacting bedload particles and are modulated by two conflicting affects. Rising sediment flux leads to an increasing number of impacts and thus larger erosion rates (the tools effect). However, when sediment supply gets too large, sediment particles sit on the bed protecting it from impacts and thereby decreasing the erosion rate (the cover effect). Previous flume experiments and numerical models have predicted a wide range of formulations for the relationship between sediment flux and sediment cover. Here, we propose a simple probabilistic framework to mathematically describe the cover effect, in which the development of cover is as a function of the probability of sediment deposition on bedrock or sediment-covered areas of the bed. The framework can incorporate empirical or modelling results and provides a neat link to process interpretations. We compare model predictions with results from both a cellular automaton model of grain dynamics, and from flume experiments. The framework is able to reproduce many of the observed behaviours, and thus provides a way of unifying the range of different results that have previously been reported. Further, we present a simple first order model for the dynamic evolution of bed cover over time that could be incorporated into channel morphodynamic models.