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Analysing the spatio-temporal organization of sediment dynamics at the hillslope scale using a process based erosion model

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The morphology of soil covered hillslopes tends to a characteristic convex-concave shape. In hilly landscapes, where erosion rates do not exceed the weathering rates of bedrock material, the form of hillslopes is convex near the hilltop and becomes increasingly planar further downslope with the steepest descent in the middle of the slope. This typical shape is the result of long term erosion and sediment redistribution processes driven by a topographic gradient and climatic forcing. Erosion rates depend on slope, soil properties, vegetation cover and rainfall/runoff rates. The morphology of hillslopes is thus the result of a trade-off between all these parameters controlling the relation of detachment, transport and deposition rates of sediments as well as feedback mechanisms on the driving gradient. Sediment flux increases with increasing slope but higher sediment transport rates deplete the driving gradient and thus reduce sediment export. We hypothesize that sediment export is maximized under the condition of maintaining the driving gradient and that this trade-off implies a typical shape and steepness of slopes.

We used the process based model CATFLOW-SED to verify this hypothesis and to better understand the spatio-temporal organisation of sediment dynamics at the hillslope scale. CATFLOW-SED is a continuous, dynamic, spatially distributed model. Soil water dynamics is described by the Richards equation, including an effective approach for preferential flow that is numerically solved by an implicit mass conservative Picard iteration. Evaporation and transpiration is simulated, using an advanced approach based on the Penman-Monteith equation. The model simulates overland flow as sheet flow using the diffusion wave equation. Soil detachment is related to the attacking forces of rainfall and overland flow. The detachment rate further depends on the model parameter erosion resistance, which is characterized by soil properties, land use and management practice. Transport capacity and deposition are quantified using the equation of Engelund and Hansen (1967) and the sinking velocity of grain size fractions. For the model runs, we used data of the Weiherbach catchment located in a hilly loess region in Southwest Germany.