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Parameterisation of a soil detachment model using rainfall simulation experiments

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Soil particle detachment is a key process affecting water erosion, since it determines the amount of sediment that is potentially transferred to surface water bodies. Detachment of soil particles depends on various factors such as hydro-meteorological forcing, soil hydraulic and mechanical properties, type of crop and tillage practice. As with most other sub processes that determine water erosion, particle detachment is only directly observable at small scales within laboratory and field experiments. Process-based numerical erosion models are thus used for extrapolating these findings from the plot scale to the scale of small catchments in order to quantify sediment yields.

The objective of this study is to derive and parameterise a detachment approach that balances simplicity and necessary process complexity to be implemented in a process-based erosion model applicable at the scale of small catchments. In the proposed model the attacking forces of rainfall (characterised as momentum flux of rainfall) and overland flow (characterised as shear stress) are combined and related to the detachment rate. The resisting forces of the soil are characterised by two empiric parameters: a) erosion resistance f_{crit}, which is a threshold of the attacking forces that has to be exceeded to initiate particle detachment and b) erodibility parameter p_1, which represents the linear increase of the detachment rate once the erosion resistance is overcome. The empiric parameters of the detachment model are determined for cultivated loess soils using two different data sets from rainfall simulation experiments. On the one hand, data from laboratory experiments that were carried out under varying conditions of rainfall and overland flow using identically prepared loess soil samples (published by Schmidt, 1996) were used to determine p_1. On the other hand, data from 58 rainfall experiments performed on 24 m^2 plots in the Weiherbach catchment (Southwest Germany) were used to determine the erosion resistance f_{crit} for varying soil conditions. For the procedure of determining f_{crit}, we assumed the erodibility parameter p_1 to be constant for the conventionally tilled silt loam soils in the Weiherbach catchment and exclusively varied the erosion resistance parameter f_{crit} to characterise particle detachment for the different field experiments. This approach ensured that determination of f_{crit} was a well posed problem with a unique solution to facilitate the prediction and regionalisation of the resistance of the soil against detachment. We found evidence that cultivation was the first order control of the erosion resistance: Crops that are cultivated in rows were strongly susceptible to detachment because runoff is channelled along the intermediate areas of plant rows. Mean erosion resistance was thus minimal for these sites. For bare soils we found a strong correlation between the erosion resistance, surface roughness and clay content.