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Predicting soil erosion and sediment yield at the catchment scale: scale issues, modelling and understanding

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Understanding the sediment delivery process at the catchment scale is a major challenge in soil erosion research. Many researchers and policy makers face the question which model is most effective and efficient to predict soil erosion and sediment yield under present or future climate, land use and management conditions. Therefore, here we aim to provide an evaluation of the most suitable approach for the prediction of soil erosion and sediment yield at the catchment scale, and provide guidelines indicating the limitations and challenges for interpretation of model results. Based on this, we make suggestions for next steps in model development.
First, we discuss the importance of spatial and temporal scale of observation for erosion assessments, and its implications for model calibration and validation. There is no typical erosion rate or sediment yield for a region, because large local variations occur and soil loss measurements at one spatial or temporal scale are not representative for sediment yield at another scale level. We will illustrate how scale of observation affects erosion and sediment yield assessments, and how this relates to dominant soil erosion and sediment deposition processes.
Second, we provide an evaluation of the effectiveness and efficiency of different model concepts to predict soil erosion and sediment yield at the catchment scale by comparing measured sediment yield data with model output, and by comparing the required model input data. We discuss the strengths and weaknesses of lumped- versus spatially distributed models, and empirical- regression- or physics-based models versus semi-quantitative models. Despite its evident oversimplification, often a negative relation between catchment area (A) and sediment yield (SY) is used to predict SY at the catchment scale. While on average SY decreases with increasing A, there is a very large variation in SY for catchments of the same size. The large spatial and temporal variability in the trend between A and SY implies that prediction of SY based on A alone is troublesome, and that spatially distributed information on land use, climate, lithology, topography and dominant erosion processes is required. On the other hand, many spatially distributed soil erosion models are reductionistic and focus on a selection of erosion and/or sediment transport processes (i.e. sheet and rill erosion). Most of these models do not consider point sources of sediment (e.g. gullies, mass movements, riverbank erosion), sediment transport and deposition. This causes problems when calibrating or validating these models against SY at the catchment scale.
Altogether, it results easier to predict catchment SY than to know where sediments come from and what the dominant erosion processes are. Ideally, a combination of field observations, measurements and modelling is required. The main identified causes for the total error of model predictions, and thus priority issues for future model development, are: 1) input data quality, 2) errors in measured sediment yield, 3) incomplete process description and model structure, 4) dynamic character of land use and the impact of conservation measures.