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Can rainfall simulation data be used to parameterize a dynamic infiltration model?

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Soil erosion models need detailed runoff and infiltration data as input. This hydrological information can be deduced from empirical relationships or from physically based models.

Physically based models have the advantage of allowing dynamic simulation of infiltration and runoff and a physically based model can be expected to have a wider application domain than a purely empirical relationship: while physically based models also need calibration and validation they have a key advantage in that they allow a dynamic approach and may explicitly account for variations in rainfall duration and intensity. On the other hand they may be less successful in prediction as compared to an empirical regression model as the latter may be optimally fitted to the experimental data used for calibration.

Here we investigate to what extent it is possible to use rainfall simulation data to derive meaningful parameterizations for the dynamic Green-Ampt (GA) infiltration model and the performance of this process-based model is compared with that of an empirical, regression-based model (RM). We use a unique dataset consisting of 350 simulations carried out over a period of 6 years in Central Belgium to evaluate and compare the performance of both model types.

The GA model was calibrated to the observed cumulative infiltration curve by direct fitting of the model parameters. The GA model was calibrated using 1 to 3 model parameters: (i) only effective hydraulic conductivity, Ke,, (ii) Ke and time to ponding, tp and (iii) initial and final effective hydraulic conducitity (Ki and Kf) and a rate constant describing the dependency of K on time.

In all cases an excellent fit with experimental data was obtained: increasing the number of parameters only marginally increased model efficiency (from a mean ME of 0.97 to 0.996). However, fitting model parameter values to observed state variables such as soil cover or crusting state was clearly better when only one model parameter was used.

The runoff coefficient at 10, 20, 30 minutes and the final runoff coefficient after ca. 45 minutes was then predicted by means of the one-parameter GA model. The prediction of the final runoff coefficient with the GA model was compared to the runoff coefficient predicted by the RM model With respect to the prediction of the final runoff coefficient on summer crops the model efficiency of the GA model and the RM model during calibration were very similar (ME=0.43). As expected, the RM model performed better during the calibration phase (ME=0.53). The models could not be successfully calibrated for winter crops, however.

We therefore conclude that the use of a process-based infiltration model is preferable to a regression based approach. Although an RM model may fit experimental data better, this does not seem to result in better predictive capabilities and the use of a dynamic, process-based model offers more flexibility. It does not only allow to predict the final runoff coefficient, but also the evolution of rainfall infiltration trough time. A one-parameter calibration of the GA model was clearly superior to the use of 2 or 3 parameters.

Although the use of a process-based model offers more flexibility, this does not imply that results can be more easily transferred from one location to another. We did not obtain meaningful results when using pedotransfer functions from the literature to determine parameter values. Thus, even when a process-based model is used, local model calibration appears to be a necessity.