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An extended transfer function model for the prediction of nonpoint-source pollutant travel times

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Transfer functions are travel time probability density functions (TT pdfs), which describe the leaching behaviour in a given soil profile. Once they are defined, the output solute concentration at a given time and depth is simply the transfer function convolution with the input concentration signal to the system.

In this work we propose an extended version of Jury's transfer function model (TFM-ext). The proposed model allows to simulate the spatio-temporal distribution of nonpoint-source solutes along the unsaturated zone that: i) integrates a simplified statistical approach with the physically-based soil hydrological parameters; ii) is valid for wide range of applications, both in space and time; iii) is standard and easily replicable; iv) is easy to interpret.

With the assumptions of a) a gravity induced water flow, b) a conservative and nonreactive solute and c) a purely convective flow, ignoring the convective mixing of solute flowing at different velocities and the molecular diffusion, the TT pdf were calculated as functions of the unsaturated hydraulic conductivity k(θ). The strength of the model, despite its important assumptions, is that it derives the TT pdf from a physical quantity, i.e. the hydraulic conductivity function. Moreover, the model extends the transport process to the generic depth z, where information on the hydraulic properties could not be available, assuming a lognormal travel time pdf, whose parameters are scaled according to the generalized transfer function model.

A sensitivity analysis, based on Monte Carlo simulations, to evaluate to which parameters the TFM-ext is more sensitive, was performed. Results shown that θ_s and τ, of the van Genuchten-Mualem model, are the parameter affecting more the mean travel times.

Moreover, in order to validate TFM-ext, an application in the Telesina Valley, a hilly area of 200 km^2 in Southern Italy, was performed. Forty-six soil profiles, completely characterized from the hydrological point of view, were used to evaluate the mean travel times and then compared with the results obtained with a notable physically based model, Hydrus 1D. Two distinct applications were performed: the first with constant upper boundary conditions equal to those applied to the TFM-ext exercise, and the second with real daily variable upper boundary conditions. Results of

both cases gave very high correlation coefficients (above 0.8) and mean absolute errors of 30 and 40 days, respectively.

Eventually, the model was implemented as an operative tool for the groundwater vulnerability assessment within the geospatial Decision Support System developed for LANDSUPPORT H2020 project.