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Uncertainty in Predicting Soil Hydraulic Properties at the Hillslope Scale with Pedotransfer Functions

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An effective representation of soil hydraulic properties and their spatial variability is of prime importance for hydrological studies, especially those applied to environmental and land-use planning problems. Pedotransfer functions (PTFs) are being developed as simplified methods to estimate soil hydraulic properties that represent an alternative to direct measurements. PTFs express soil water retention and hydraulic conductivity characteristics as function of basic soil properties, such as texture, oven-dry bulk density, porosity, and organic carbon content, which are currently measured on soil cores sampled at widely spaced points. One important, but scarcely pondered issue concerns to how precise could be PTF predictions when using input data that are extrapolated from sampled locations. Using the PTFs of Vereecken (Vereecken et al, 1999) and HYPRES (Wosten et al., 1990), the objectives of this study are to quantify the uncertainty in PTFs spatial predictions at hillslope scale as related to the sampling density, due to (i) the variability exhibited by the input soil physico-chemical properties and (ii) PTF model bias. Soil physical, chemical, and hydraulic properties have been collected along a hillslope transect in the Agri River Basin (Basilicata, Italy), at 45 locations spaced of 50 m. Spatial structure of the basic soil properties across the hillslope have been identified by analyzing the correlation with terrain attributes, the semivariograms and their cross-variograms. The method proposed is based on a stochastic generation of patterns of soil variables using sequential Gaussian simulation. Gstat on R (Pebesma, 2004) is then used to generate multiple equally probable images of residuals of soil properties, consistent with the estimated spatial structure and conditioned to the measured soil core properties. Firstly, twenty simulations have been generated on a fine grid and that one, which best reproduced the statistics of the measured data, is selected for the subsequent analyses. The resultant array (named the full set) covers an area 2200 m long and 900 m width, including the point observations along the transect. The full set has been sampled according to three grid resolutions: 50 m, 100 m and 200 m. Therefore, three sets of 100 stochastic images of the original full set, conditioned respectively to three sample grids, have been generated by sequential simulation. Soil water content (swc) at three matric potentials of -10, -100, and -10000 cm is computed for the full set as well as for the 100 images employing both PTFs HYPRES and Vereecken. Results are evaluated by computing patterns of estimation errors and statistical indices (such as mean and root mean squared errors), whereas probability distributions of these statistics are derived for each sampling density. The results show that accuracy of PTF spatial predictions does not improve significantly with increasing sampling resolution. Moreover, PTF model bias (estimated by comparing the simulated values to those measured along the transect) is not significant compared to the uncertainty associated with the variability of the basic soil properties.