Quantifying uncertainty in soil hydraulic parameters for the dual porosity model using null-space Monte Carlo method - implications for uncertainty in potential groundwater recharge estimation

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Estimating groundwater recharge is important to sustainably manage water resources and assess their vulnerability to pollution. Numerical water flow and tracer transport models of the vadose zone have been widely used to estimate potential groundwater recharge under different soil surface and climate conditions. Nevertheless, these parameter-based models require a large number of model parameters and input data. Uncertainty in these model parameters thus can result a large uncertainty in groundwater recharge estimation.

Inverse modeling is conventionally used to estimate model parameters, which could often lead to non-unique solutions. Monte-Carlo (MC) methods generate many different parameter sets which can be used by the model to match the observed data with some acceptable level of mismatch instead of a single ‘‘best’’ estimated parameter set.

This study was carried out in the over-exploited Indo-Gangetic alluvial plains of Punjab, India under grass cover to understand natural recharge, where its high water demand is causing a significant drawdown of the groundwater in the alluvium aquifer.

Time series soil moisture content (SMC) data and tritium tracer profile data have been used to estimate soil hydraulic parameters and solute transport parameters in order to predict potential groundwater recharge. Single and dual-porosity models of water flow and solute transport, implemented in HYDRUS 1D computer program, were used to calculate potential recharge from SMC and tracer profile data, both sequentially and simultaneously. Potential recharge was predicted for 1000 randomly generated parameter sets using a null-space Monte-Carlo method (NSMC) proposed by Tonkin and Doherty (2009) and implemented in the parameter estimation software PEST. NSMC is calibration constrained and significantly reduces computational cost as compared to other MC methods.

Results indicate that when soil hydraulic parameters were estimated from SMC alone, the parameter set could not predict tracer transport behavior, though a better fit to SMC was obtained, calling for a cautioned approach to estimate recharge from SMC alone.

Histograms for certain soil hydraulic parameters obtained from non-linear uncertainty analysis display bi-modal characteristics for the dual porosity model implying that the data are from different sets of population representing different retention and hydraulic conductivity functions. Majority of predicted recharge (50%) on the other hand showed a narrow range of 0.002 cm to 0.2 cm in contrast to previously reported recharge prediction of 4.1cm to 16.1 cm as calculated from tritium mass balance approach for Punjab, India (Datta and Goel, 1977). This shows that recharge calculated from vadose zone tritium profile assuming piston flow is significantly overestimated. Hence, quantifying uncertainty in predicted recharge could help in proper management of groundwater resources.

References

Tonkin, M., and Doherty, J.(2009), Wat.Res.Res.,45,W00B10. Datta, P.S., and Goel, P.S.(1977), Nordic.Hydrol.,8, 225-236.

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