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Prognosis of groundwater recharge by means of the simulation tool PCSiWaPro® under the conditions of climate change

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Recent studies showed that varying atmospheric conditions as a result of climate change have a significant impact on the magnitude and time variable development of groundwater recharge. Essentially there are two driving factors that influence groundwater recharge: the temporal distribution of precipitation, and the saturation processes resulting from capillary effects in the unsaturated soil zone. Water balance processes can accurately be modelled by using the Richards' equation for transient flow, together with the Van-Genuchten/Luckner approximation describing hysteresis relationships between water contents and pressure heads in the soil. Precipitation distributions, as boundary conditions for the unsaturated model, can be generated from climate data measurements using statistical analysis tools. These synthetic time series reflect both the real climate conditions in a given model area, as well as statistical variations of rainfall by implementing characteristics of a predefined probability distribution. Depending on the kind of distribution, the resulting time series can represent both annual rainfall variations as well as long-term climate changes.
The Institute of Waste Management and Contaminated Site Treatment of the TU Dresden has developed two software programs that help estimate these two driving forces for groundwater recharge. WettGen is a weather generator using a Weibull distribution and Markov chain approximations to create synthetic climate time series. These are applied as an upper boundary condition for PCSiWaPro®, a numerical finite element simulation tool solving the Richards' equation for water balance and a convection dispersion equation for contaminant. The result of this coupled simulation is an outflow at the lower boundary of the PCSiWaPro® model, which can be interpreted as a recharge rate for the underlying aquifer.
Considering that climate change scenarios for Germany predict longer dry periods and an increase of extreme precipitation events, simulations showed that groundwater recharge rates tend to decrease. This is due to the fact that during extreme events the maximum infiltration rate is reached much sooner than for rain periods with a lower intensity and a longer duration, leading to higher rates of surface runoff.
Current advancements of the existing modelling components include a more accurate estimate of groundwater recharge, which will be achieved by taking into account the interactions between unsaturated soil zone processes and groundwater processes. To implement this, a coupling between PCSiWaPro® and a groundwater simulation software, PCGeofim® by IBGW Leipzig, is currently being worked on. This will not only enhance the accurate estimation of groundwater recharge, but it will also give new insights into which effects different time series of precipitation have on the transport of contaminations through the unsaturated soil zone, and into the groundwater.