Geophysical Research Abstracts
Vol. 13, EGU2011-3159, 2011
EGU General Assembly 2011

Estimation of future groundwater recharge using climatic analogues and HYDRUS-1D

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Scenarios of future precipitation and temperature data are needed for a number of hydrological and environmental applications. For example, surface disposal facilities of nuclear waste are supposed to be present in the landscape for several millenia. The Belgian Agency for Radioactive Waste and Enriched Fissile Materials (Ondraf/Niras) aims to develop such a facility in Dessel (North-East of Belgium). Assessing the long-term performance of such a facility involves estimation of future infiltration or groundwater recharge rate on the scale of a catchment, for alteration of recharge may affect the local groundwater flow and dispersion of contaminants in the environment. The objective of this study is to provide an estimate of groundwater recharge rate in the vicinity of the Dessel site for the next few millenia.

In absence of RCM data for a sufficiently far future, we use climatic analogues and 1-D modelling of the soil-plant-atmosphere system to quantify groundwater recharge for a sequence of future climate states. The following contrasting climate states are considered (based on Köppen-Trewartha classification): DO (maritime temperate – the present-day climate in Dessel, Belgium), Cs/Cr (subtropical with dry summers/no rainfall seasonality), EO (boreal, cold without permafrost) and FT (tundra, cold with permafrost).

Available estimates of future temperature and precipitation often extend until AD 2100 only (e.g. IPCC scenarios of climate change). For the longer term, possible sequences of future climate states have previously been defined that are applicable to the study area (Bioclim, 2003).

Using criteria including altitude, distance to moisture source, and atmospheric circulation system, potential analogue stations were collected for each climate state Cs/Cr and EO/FT. Among these, the two stations displaying the least devation from median statistics of temperature and precipitation were chosen, while the two stations having the lowest and highest precipitation record were also included to account for variability within a climate class.

Analogue stations provided time series (30 years) of precipitation, temperature, wind speed and relative humidity. This allowed to calculate potential evapotranspiration and to perform Hydrus-1D (Simunek et al., 2005) simulations for the different climates. Simulations were performed on sandy soils (podzol) characteristic of the study area with a grassland cover.

A constant 1-m deep groundwater table was taken as bottom boundary condition for the calculations with the current-day DO climate. However, the validity of this bounday condition is questionable under different climate conditions. An alternative is to use a deep drainage boundary condition in which the imposed drainage is a function of pressure head at the bottom of the profile (Hopmans and Stricker, 1989). This boundary condition was parameterised with piezometric data of the study area, and being an intrinsic property of the soil, was then applied to other climate states.

Starting from the reference recharge value of 306 mm/y (DO climate class, constant groundwater level at 1 m depth), the future recharge simulated for other climate states was:
* 275 mm/y for the Cs/Cr climate of the Gijon (Spain) analogue station, which was chosen because its precipitation amount and seasonality are more in accordance with the predictions of the IPCC for the near future applied to Belgium.
* 96 mm/y for the FT/EO climates. Based on geological observations, it is inferred that low infiltration rates prevailed in the study area in past cold climate periods. No representative analogue station was chosen among the

EO analogues because they presented a too high variability. Instead, Sisimiut (Greenland) analogue station was chosen as the best representative analogue station for both the EO and FT climate classes.

Applying these recharge values to the sequence of climate states defined for the next few millenia gives insights into the future soil water balance and groundwater recharge, although significant uncertainty is unavoidable given the time scale considered.

References.

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