Comparison of different estimation techniques to quantify groundwater recharge in Pirna, Germany

Technische Universität Dresden, Institute of Waste Management and Contaminated Site Treatment, Pirna, Germany

www.tu-dresden.de/uw/inowas

BACKGROUND

- Spatial and temporal **recharge estimation difficult** because of **soil heterogeneity** and **influence of vegetation**
- Numerical models are data-intensive, specific parameters are hard to measure and can only be estimated→ high uncertainty in parameter estimation
- Empirical models use less and easier obtainable parameters → alternative to numerical models?

OBJECTIVES

- **Comparison of Open Source models** which use **different model approaches** and have **varying complexity** to estimate natural groundwater recharge at Pirna test field site, Germany
- Selection of suitable models which will then be integrated into a web-based Decision Support System (DSS) developed for the sustainable management of groundwater

METHODS

- Model complexity covers numerical (HYDRUS 1D) and physically-based empirical models (SWB, DPM, HELP3)
- Approaches: distributed surface models (SWB, DPM) and unsaturated zone point models (HYDRUS 1D, HELP3)
- For comparison of physical background, estimation of unsaturated soil properties, evapotranspiration, runoff and recharge used in the applied models see Table 1

Table 1. Attributes of various codes used in this study, *SCS: Soil Conservation Service curve number

Code	Source	Physical background	Soil properties	Evapotrans-piration	Runoff	Recharge
SWB -Modified Thornthwaite-Mather Soil-Water-Balance Code	Dripps 2003	Soil water balance approach	Soil-water retention table (Thornthwaite-Mather)	Thornthwaite-Mather	SCS*	Residual of soil water balance equation
DPM -Deep Percolation Model	Vaccaro 2007	Water-budget approach	Saturated hydraulic conductivity	Jensen-Haise	approximation of Darcy flow for saturated soils and saturation excess	Residual of soil water balance equation (below root zone)
HELP3 (quasi 2D) -Hydrologic Evaluation of Landfill Performance	Schroeder et al. 1994	Water-routing	Brooks-Corey-Burdine Model	Penman	SCS*	Gravity drainage (Darcy-Buckingham for unsaturated flow)
HYDRUS-1D	Simunek et al. 1998	Numerical (1D Richards eq.)	Van Genuchten-Mualem Model	Hargraeves	Precipitation exceeds infiltration capacity	Drainage (Richards equation)

STUDY AREA

- Modeling was performed at Pirna test field site, located adjacent to the Elbe river (Fig. 1)
- Sediments consist mainly of fluvial deposits ranging from fine sand to coarse gravel (Fig. 2)
- Climate: Mean yearly precipitation 872 mm, mean yearly temperature 9ºC

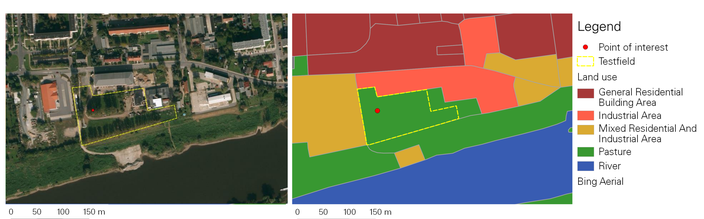

Figure 1. Left Satellite image (Microsoft, 2015) and right land use in Pirna, Germany including the test field and the point of interest for groundwater recharge estimation. Microsoft, 2015: Bing Maps, http://binged.it/1yvoHn5, retrieved 31 March 2015.

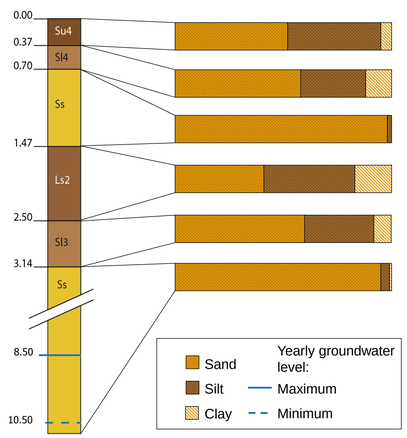

Figure 2. Schematic soil profile inferred from drilling including yearly groundwater table fluctuations and distribution of soil classes

RESULTS AND DISCUSSION

- **„Wet“ year** (2009-2010):
  - Precipitation 40% above yearly mean
  - Recharge between **28 %** and **70 %** of total annual **precipitation** depending on used model (Fig. 3, Fig.4, Table 2)
- **„Dry“ year** (2013-2014):
  - Precipitation 44% below yearly mean
  - Recharge only between **0 %** and **22 %** of total annual **precipitation** depending on used model (Table 2)

→ Groundwater recharge estimations are **highly variable** between the **different applied codes** and the **years** modeled

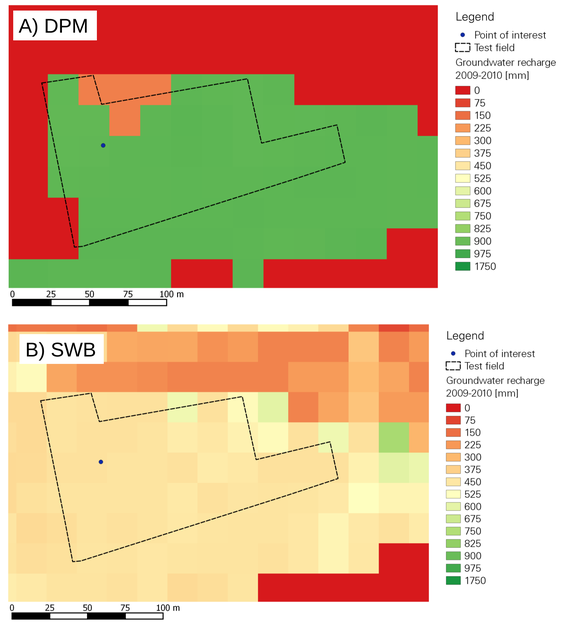

Figure 3. Groundwater recharge for hydrological year 2009-2010 calculated with A) DPM and B) SWB

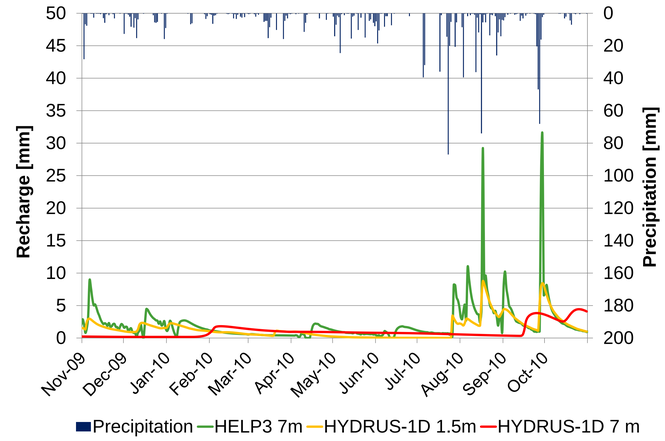

Figure 4. Daily recharge for hydrological year 2009-2010 for the unsaturated soil zone models HELP3 (7 m) and HYDRUS-1D (1.5m and 7m)

Table 2. Comparison modelling results [mm] for all used models (HELP3, HYDRUS-1D; SWB, DPM) for A) 2009-2010 and B) 2013-2014

A) Hydrological year 2009-2010

Model	Precipi-tation	Runoff	Evapotrans-piration	Recharge	%*
HELP3 (7 m)	1227	71	414	760	62
HYDRUS-1D (1.5 m)		5	704	541	44
HYDRUS-1D (7 m)				376	31
SWB		23	565	339	28
DPM	1311[1]	0	398	915	70

B) Hydrological year 2013-2014

Model	Precipi-tation	Runoff	Evapotrans-piration	Recharge	%*
HELP3 (7 m)	495	0.0	389	109	22
HYDRUS-1D (1.5 m)		0.4	482	2	0.4
HYDRUS-1D (7 m)				72	15
SWB		0.0	513	0	0.0
DPM		0.0	424	68	14

* Percentage of recharge to annual precipitation
[1] Difference in annual precipitation caused by rounding

OUTLOOK

- As a next step further models will be applied and field experiments (tracer tests) will be conducted at the test field site to compare the estimated groundwater recharge with measured values.

CONTACT

Jana Ringleb, Jana Sallwey and Catalin Stefan
Technische Universität Dresden
Institute of Waste Management and Contaminated Site Treatment
Pratzschwitzer Str. 15, 01796 Pirna, Germany
Tel. +49 3501 530046; Email: jana.ringleb@tu-dresden.de

Funded by
Federal Ministry of Education and Research