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Development of pedotransfer functions to estimate annual groundwater recharge rates in countries of the Arab region

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1. Introduction

Quantitative water resources management on a regional scale often requires reliable estimates for annual values or long term means of the groundwater recharge rate. To avoid high costs of field measurements empirical equations or "hydro-pedotransfer functions" (HPTFs) are needed, based on input variables that can be determined easily or are available from existing databases. The same methodology as applied within the framework of the new Hydrological Atlas of Germany was used to develop similar equations for countries of the Arab region. For this purpose a simulation model of the soil water balance, based on the FAO56 approach, and the CLIMWAT database were used. Simulations were carried out for eight countries, six kinds of land use and varying soil hydrological properties.

2. Methodology

2.1 Methods examplary applied for the Hydrological Atlas of Germany

- 4 soils, varying in the available water capacity (Ss, Sl3, Ls3, Ut3)
- 5 kinds of land use (cereals, sugar beets, pastureland, coniferous forest, deciduous forest)
- 16 climatic regions of Germany
- 5 different groundwater tables

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simulation runs for 57.600 years on a daily basis

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multiple regression statistics

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pedotransfer functions for estimating percolation rates

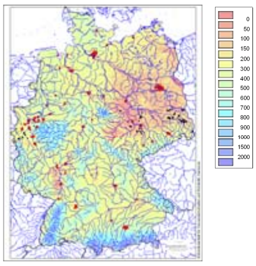

Fig. 1: Mean annual percolation rates [mm] in Germany

2.2 Methods applied to develop similar equations for the Arab region

- 5 soils, varying in the available water capacity (40 - 200 mm)
- 6 typical kinds of land use from the Mediterranean environment
- 188 meteorological stations from 8 countries (Fig. 3)
- no groundwater affected soils with capillary rise
- fixed amount of surface runoff

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2.820 simulation runs

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multiple regression statistics

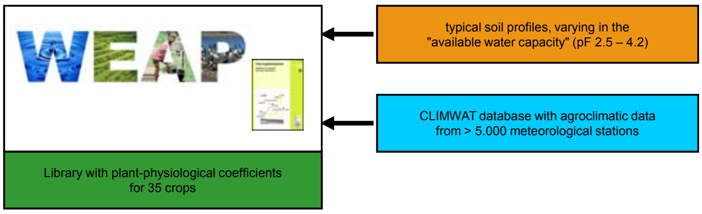

Fig. 2: Data sources for CROPWAT applications

Fig. 3: Meteorological stations, available from the CLIMWAT database

3. Results

Tab. 1: General conditions and summarized results for all cases under consideration

Land use type	Length of growing season	Sowing/ planting date	Period of potential evaporation	Statistically significant input variables for estimating GWR	Correlation coefficient
Winter wheat - no irrigation -	240 days	1st Nov	155 days	Prec, awc	$r^2 = 0.957$
Barley - no irrigation -	160 days	1st Dec	225 days	Prec, awc	$r^2 = 0.967$
Olives - no irrigation -	270 days	1st Mar	125 days	Prec, awc	$r^2 = 0.951$
Winter wheat under irrigation	240 days	1st Nov	160 days	Prec, ETpot, Irrig	$r^2 = 0.989$
Citrus trees under irrigation	365 days	(whole year)	60 days	Prec, ETpot, Irrig, awc	$r^2 = 0.957$
Vegetables under irrigation	100 days	1st Apr	285 days	Prec, ETpot, Irrig, awc	$r^2 = 0.999$

(ETact = actual evapotranspiration; GWR = groundwater recharge; Prec = precipitation; ETpot = potential evapotranspiration; Irrig = Irrigation; awc = available water capacity)

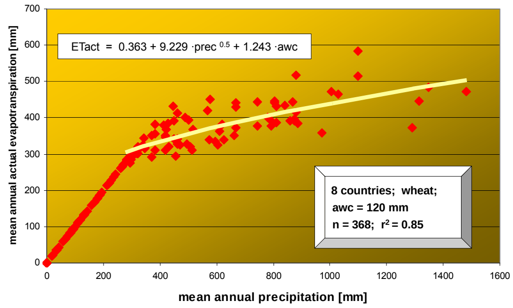

Fig. 4: Fitting a regression model to actual evapotranspiration rates of winter wheat

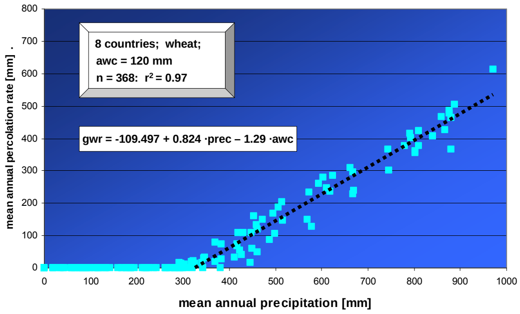

Fig. 5: Fitting a regression model to groundwater recharge rates under winter wheat

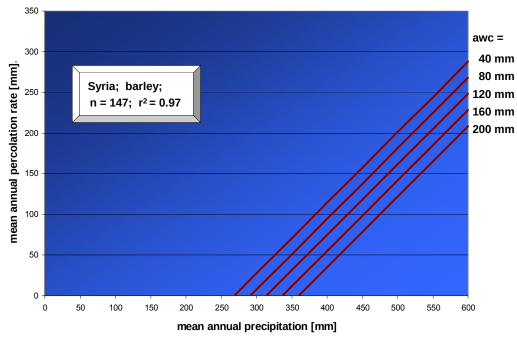

Fig. 6: Nomogram for estimating groundwater recharge in case of different soil physical properties

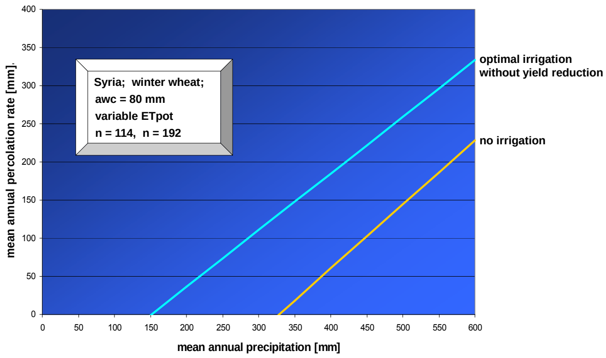

Fig. 7: Nomogram for estimating groundwater recharge in case of different irrigation practices

4. Outlook / need for action:

- The amount of surface runoff has to be known and is not simulated by the model or empirically estimated.
- Results are not valid for groundwater affected soils with shallow water tables and capillary rise towards the root zone.
- No distinction was made so far between different irrigation techniques and their varying degree of efficiency ("wetted fraction").
- Prediction models have to be furthermore validated and continuously improved on the basis of available measurements from test sites.