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Prediction of the Long-Term Groundwater Recharge by Hydropedotransfer Functions

Key words: Evapotranspiration, groundwater recharge, hydropedotransfer functions

Long-term groundwater recharge R is given by

$$R = P - E_a \qquad (1)$$

P average annual precipitation
E_a average annual average evapotranspiration

To estimate E_a, Bagrov has proposed the differential equation

$$\frac{dE_a}{dP} = 1 - \left(\frac{E_a}{E_p}\right)^b \qquad (2)$$

where b is a coefficient related to the availability of soil water and E_p is potential evapotranspiration. The Bagrov equation restricts evapotranspiration to the availability of either water or energy. E_a is accessible by

$$P = \int_0^{E_a} \frac{1}{1-(E_a/E_p)^b} dE \qquad (3)$$

and was successfully used by Glugla al. (1971, 2003).

To estimate b, a transfer function

$$b = c_1 W_a^{c_2} + c_3 \exp\left(c_4 q_{\max}\right) + c_5 \frac{C_s}{P_s - E_{p,s}} \qquad (4)$$

is used that considers climatic conditions (P, E_p), maximum plant available soil water (W_a), water supply by capillary rise from groundwater table, and the simultaneity of water and energy supply. An attempt was made to consider the effect of anaerobiosis on actual evapotranspiration.

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Data basis

The simulation model SWAP was used to generate a data basis comprising 30year simulation periods of 3 different weather stations, 14 soil texture classes and 4 levels of groundwater depth, in total 4050 simulation years. The only crop considered here was grass of 12 cm height covering the soil surface completely over the entire year.

Limitations of the Bagrov method

There are two different conditions where the Bagrov method fails.

(A) Because of the underlying assumption that infiltrated soil water be available to evapotranspiration, the method requires the residence time of infiltrated water in soil to be sufficient to make water available to evapotranspiration. (B) The second limitation holds for plains under dry climatic conditions where the aquifer is recharged by groundwater inflow from regions with precipitation excess. Since Eq. (3) restricts actual evapotranspiration to precipitation, it should not be used for wetlands where E_a is enhanced by capillary rise from the groundwater table so much that it might exceed the local precipitation leading to groundwater depletion.

To cope with conditions (B), a statistic prediction equation was set up which is given by

$$\frac{E_a}{E_p} = c_{10} + c_{11} P_s + c_{12} q_{\max}^{c_{13}} + c_{14} W_a \qquad (5)$$

Eq. (10) predicts the relation E_a/E_p using the long-term average of summer precipitation (April to September), P_s. The remaining variables keep their meaning as explained above.

Results

To find the parameters of the transfer function, Eq. (4) was substituted into Eq. (3) and the standard error of the predicted actual evapotranspitration was minimized. Eq. (3) predicts the actual evaporanspiration with a standard error of 1.55 cm**.**

Eq. (5) predicts groundwater recharge with a standard error of $RMSE = 2.58$ cm. The coefficient of correlation between SWAP-simulated and predicted groundwater recharge is $r = 0.975$.

Calculations may be performed using a computer code available at http://www.small-scale-hydrology.de

References

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