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Supplement of

Estimation of temporal and spatial variations in groundwater recharge in unconfined sand aquifers using Scots pine inventories

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Supplement

Equations used in calculating different components of evapotranspiration

Transpiration:

$$L_v E_{tp} = \frac{\Delta R_n + \rho_a \cdot c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)} \quad \text{(A1)}$$

where R_n is net radiation, ρ_a is air density, c_p is the specific heat of air, e_s is the vapor pressure at saturation, e_a is the actual air vapor pressure, r_a is the aerodynamic resistance, Δ is the slope of the saturated vapor pressure-temperature curve, γ is the psychrometer constant, and r_s is surface resistance.

The aerodynamic resistance (r_a) for transpiration was calculated as:

$$r_a = \frac{ln\left(\frac{z_{ref} - d}{z_0}\right)}{k^2 \cdot u} \quad \text{(A2)}$$

where z_{ref} is the reference height of the measurements, d is the displacement height, z_0 is the roughness length, k is von Karman's constant, and u is wind speed.

Surface resistance (r_s) was estimated with Eq. 6:

$$r_s = \frac{1}{max(LAI \cdot g_l; 0.001)} \quad \text{(A3)}$$

where g_l is the leaf conductance given by the Lohammar equation (see e.g. Lindroth, 1985).

Soil evaporation:

$$L_v E_{tp} = \frac{\Delta (R_n - q_h) + \rho_a \cdot c_p \frac{(e_s - e_a)}{r_{as}}}{\Delta + \gamma\left(1 + \frac{r_{ss}}{r_{as}}\right)} \quad \text{(A4)}$$

where q_h is the soil surface heat flux, r_{as} is the aerodynamic resistance of soil, and r_{ss} is the surface resistance of soil.

The aerodynamic resistance of the soil (r_{as}) is calculated as Eq (8):

$$r_{as} = r_{alai} \cdot LAI + \frac{1}{k^2 \cdot u} \cdot ln\left(\frac{z_{ref} - d}{z_{0M}}\right) \cdot ln\left(\frac{z_{ref} - d}{z_{0H}}\right) \cdot f(R_{ib}) \quad \text{(A5)}$$

where r_{alai} is an empirical parameter, z_{0M} and z_{0H} are surface roughness lengths for momentum and heat, respectively, and $f(R_{ib})$ is a function governing the influence of atmospheric stability.

The surface resistance for soil (r_{ss}) is given by:

$$r_{ss} = \begin{matrix} r_\Psi \cdot log(\Psi_s - 1 - \delta_{surf}); & \Psi_s > 100 \\ r_\Psi (1 - \delta_{surf}); & \Psi_s \leq 100 \end{matrix} \quad \text{(A6)}$$

where r_Ψ is an empirical coefficient, Ψ_s is the water tension in the uppermost soil layer, and δ_{surf} is the mass balance at the soil surface (see Jansson and Karlberg, 2004).

Lake evaporation:

$$E_{lake} = K_E \cdot v_a \cdot (e_s - e_a) \qquad \text{(A7)}$$

where K_E is mass transfer coefficient [$ML^{-1}T^{-2}$], v_a is wind speed [$L\ T^{-1}$], e_s [$ML^{-1}T^{-2}$] is saturated vapor pressure at lake water surface temperature, and e_a [$ML^{-1}T^{-2}$] is air vapor pressure. The mass transfer coefficient (K_E) represents the efficiency of vertical water transport from the evaporating surface and it can be treated as a function of lake size:

$$K_E = 1.69 \times 10^{-5} \cdot A_L^{-0.05} \qquad \text{(A8)}$$

where A_L is lake surface area [km^2]

The groundwater recharge study area has lakes of variable size, from less than 1 ha to 25 ha (Fig. 1). Lake size variability was included in the total recharge calculation by randomly selecting a A_L value (from the range 1-25 ha) in Eq. (8) when calculating lake evaporation, and thereby groundwater recharge in model cells with lakes.