Supplemental material to: The impact of calibration strategies on future evapotranspiration projections: a SWAT-T comparison of three hydrological modeling approaches in West Africa

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1 Plant growth modeling with SWAT-T

In SWAT/SWAT-T, the plant growth is computed with the approach of the Environmental Policy Impact Climate (EPIC) model (Arnold et al., 1998), where LAI is a primary vegetation attribute (Neitsch et al., 2011). The plant growth is divided into a growing phase, a period of maturity (growing is halted to a constant LAI), a leaf senescence phase (natural decrease of LAI), and a dormancy phase (plant phenology is stopped to a constant LAI) in SWAT/SWAT-T. The growing phase is initialized by the start of the growing cycle. In SWAT, plant growth is triggered by the accumulation of heat units per day, i.e., based on the daily average temperature the plant experiences. Plant growth in the tropics is however governed by the water availability in the soils rather than the daily temperature (Jolly and Running, 2004). Alemayehu et al. (2017) thus modified the plant growth trigger of the SWAT2012 version and implemented an automatic start of the growing phase. In SWAT-T, plant growth is triggered by the soil moisture index $S_{smi} = P_a/E_0$, where P_a and E_0 are the aggregated precipitation for a user-defined time window (here $5d$). An S_{smi} threshold to start the growing has to be defined (here 0.5). If the computed index is greater than the defined one, the plant starts to grow. To avoid false starts of the new growing cycle, the end of the dry season (SOS1, here October) and the beginning of the rainy season (SOS2, here January) also have to be specified (Alemayehu et al., 2017). The growing phase is controlled by the optimal leaf area development curve:

$$fr_{LAI_{mx}} = \frac{fr_{PHU}}{fr_{PHU} + exp(l_1 - l_2 \cdot fr_{PHU})}, \tag{1}$$

where $fr_{LAI_{mx}}$ is the fraction of the maximum LAI of a plant to the fraction of the potential heat units (PHUs) for the plant; fr_{PHU} is the fraction of the PHUs in the current day of the growth cycle; and l_1 and l_2 are shape coefficients. For optimal conditions, the plant grows until a user–defined maximum LAI (LAI_{mx}) is reached:

$$\Delta LAI_i = (fr_{LAI_{mx},i} - fr_{LAI_{mx},i-1}) \cdot LAI_{mx} \cdot (1 - exp(5 \cdot (LAI_{i-1} - LAI_{mx}))), \tag{2}$$

where $fr_{LAI_{mx}}$ is the fraction of LAI with respect to LAI_{mx}. LAI_i for a given day i is the sum of the prior LAI_{i-1} and the growth change $LAI_i = LAI_{i-1} + \Delta LAI_i$.

The optimal plant growth in SWAT/SWAT-T can be regulated by water, temperature, nitrogen, or phosphorous stress. The water stress (s_w) is directly related to the actual plant transpiration and the total water uptake. The temperature stress (s_t) is calculated based on user–defined base and optimal plant growth temperature T_{base} and T_{opt}, respectively. Nitrogen and phosphorous stresses (s_n and s_p, respectively) are used to describe insufficient nutrient supply. The actual plant growth is constrained by the plant growth factor γ_{reg}:

$$\gamma_{reg} = 1 - Max(s_w, s_t, s_n, s_p). \tag{3}$$

The actual LAI $\Delta LAI_{act,i}$ added on a day i is calculated as:

$$\Delta LAI_{act,i} = \Delta LAI_i \cdot \gamma_{reg}. \tag{4}$$

The growing phase transitions to maturity if enough heat units have accumulated ($fr_{PHU} = 1$), where LAI remains constant. In the maturity phase, plant transpiration and water uptake continue. The leaf senescence starts as soon as a user–defined fraction of PHU ($DLAI$) is reached. In the original SWAT version, the LAI decline depends on the fraction fr_{phu} of day i and can rapidly drop to zero. The leaf senescence is described as:

$$LAI_{act,i} = LAI \cdot r \text{ , with } r = \frac{1 - fr_{phu,i}}{1 - DLAI} \text{ , if } fr_{phu,i} \geq DLAI. \tag{5}$$

Strauch and Volk (2013) addressed the rapid drop of leaf area and modified the implemented plant module in SWAT accordingly. The LAI decline is thereby computed using a logarithmic approach:

$$LAI_{act,i} = \frac{LAI_{max} - LAI_{min}}{1 + exp(-12 \cdot r + 6)} \text{ , if } fr_{phu,i} \geq DLAI, \tag{6}$$

where LAI_{max} and LAI_{min} refer to the maximum and minimum LAI parameters $BLAI$ and $ALAI\_MIN$, respectively. The logarithmic LAI decline of Strauch and Volk (2013) is also implemented in SWAT-T (Alemayehu et al., 2017). After the leaf senescence phase, the plant growth enters dormancy and the new growing cycle starts depending the soil moisture index.

References

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