Supplement of

A field-validated surrogate crop model for predicting root-zone moisture and salt content in regions with shallow groundwater

Zhongyi Liu et al.

Correspondence to: Zailin Huo (huozl@cau.edu.cn) and Tammo Siert Steenhuis (tss1@cornell.edu)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.
**SUPPLEMENTARY MATERIAL**

**S1 Potential evaporation and transpiration**

As a critical budget term of hydrological cycle, the evapotranspiration has great influence on soil moisture content and crop growth. The reference evapotranspiration \( (\text{ET}_0) \) is calculated by FAO-56 Penman-Monteith method (Allen et al., 1998).

\[
\text{ET}_0 = \frac{0.408 \Delta (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_2)}
\]  

(S1)

where \( \Delta \) is the slope of vapor pressure curve (kPa°C\(^{-1}\)), \( R_n \) is the net radiation at the reference grassland (alfalfa) surface (MJ (m\(^2\) · d\(^{-1}\)), \( G \) is the soil heat flux (MJ (m\(^2\) · d\(^{-1}\)), \( \gamma \) is the psychrometric constant (kPa°C\(^{-1}\)), \( T \) is the mean air temperature (°C), \( u_2 \) is the wind speed (m s\(^{-1}\)), \( e_s \) and \( e_a \) are the saturation vapor pressure and actual vapor pressure (kPa). The potential evapotranspiration \( (\text{ET}_p) \) of crop is calculated as:

\[
\text{ET}_p = K_c \times \text{ET}_0
\]  

(S2)

where \( K_c \) is the crop coefficient but the meaning of this \( K_c \) is not the same as the \( K_c \) that described by (Allen et al., 1998). In this study, the calculation of \( K_c \) is referred to the studies of Sau et al., (2004) and DeJonge et al., (2012).
\[ K_c = 1.0 + (K_{cmax} - 1.0) \times \frac{LAI}{LAI_{max}} \]  

where \( LAI \) is the leaf area index, \( LAI_{max} \) is the maximum LAI value, and \( K_{cmax} \) is the possible \( K_c \) with largest leaf area index.

The evapotranspiration includes soil evaporation and crop transpiration. Here, the potential evapotranspiration was partitioned to potential evaporation \( (E_p) \) and potential transpiration \( (T_p) \) according to the study of (Ritchie et al., 1972). The ratio of \( E_p \) to \( T_p \) is according to the crop development stage of the leaf canopy occupied, expressed as \( \tau \),

\[ \tau = \exp\left[-(K_b)(LAI)\right] \]  

\[ E_p = \tau \times ET_p \]  

\[ T_p = ET_p - E_p \]  

where \( K_b \) is the dimensionless canopy extinction coefficient.

**S2 Equations used to calculate phonological parameters in EPICS taken from EPIC**

The phonological development of crop in the EPIC model (Williams et al., 1989) is based on daily heat unit accumulation.

**Crop growth**

The crop height can be calculated with equation:

\[ H_t = H_{mx} \sqrt{HUF_t} \]  

where \( H_t \) is the crop height (cm) on day \( t \) since seeding (cm), \( H_{mx} \) is the maximum crop height (cm) and \( HUF_t \) is the heat factor on day \( t \). \( HUF_t \) is equal to

\[ HUF_t = \frac{HUI_t}{HUI_t + \exp(\alpha_1 - \alpha_2 HUI_t)} \]  

Where \( \alpha_1 \) and \( \alpha_2 \) are crop parameters and \( HUI_t \) is the heat unit index of day \( t \), ranging
from 0 at seeding to 1 at physiological maturity.

\[ HUI_t = \frac{\sum_{k=1}^{t} HU_k}{PHU} \quad (S9) \]

where PHU is the potential heat units required for crop maturity and \( HU_k \) is the value of heat unit on day \( k \) after seeding that can be expressed as:

\[ HU_t = \left( \frac{T_{mx,t} + T_{mn,t}}{2} \right) - T_b \quad (S10) \]

where \( T_{mx,t} \) is maximum temperature (°C) and \( T_{mn,t} \) are the minimum temperature (°C) and \( T_b \) is crop-specific base temperature (°C).

**Leaf Area Index (LAI)**

The leaf area index (LAI) is the function of heat units, crop stress and crop development stages. The LAI can be calculated from the emergence to the start of leaf area decline:

\[ LAI_t = LAI_{t-1} + \Delta LAI_t \quad \text{for} \ t \geq t_{\text{deline}} \quad (S11) \]

where

\[ \Delta LAI_t = (\Delta HUF_t)(LAI_{mx})(1 - \exp[5(LAI_{t-1} - LAI_{mx})]) (REG^{0.5}) \quad (s12) \]

From the start of leaf decline to the end of the growing season, the equation used to estimate LAI can be expressed as

\[ LAI_t = LAI_0 \left[ \frac{1 - HUI_t}{1 - HUI_0} \right]^{ad} \quad \text{for} \ t > t_{\text{deline}} \quad (s13) \]

\[ REG_t = \min(WS_t, TS_t) \quad (s14) \]

\[ WS_t = \frac{T_{at}}{T_{pt}} \quad (s15) \]

\[ TS_t = \sin \left[ \pi \left( \frac{T_{mean,t} - T_b}{T_0 - T_b} \right) \right] \quad (s16) \]

where \( REG \) is the minimum crop stress factor and \( LAI_{mx} \) is the maximum leaf area index,
ad is an exponent that governs LAI decline rate for crop, HUI$_0$ is the HUI value when LAI starts declining and LAI$_0$ is the actual largest LAI. WS is the water stress factor, $T_a$ is the actual transpiration, $T_p$ is the potential transpiration. TS is the plant temperature stress factor, $T_{mean}$ is the average daily temperature, $T_b$ is the base temperature, $T_o$ is the crop optimal temperature.

**Root Growth**

The root length is simulated as the function of heat units and the maximum root depth. And usually the crop root length will be maximum before the mature stage. The root depth can be calculated by:

\[
RD_t = RD_{t-1} + \Delta RD_t 
\]

\[
\Delta RD_t = 2.5 \times RD_{mx} \times (\Delta HU F_t) \quad RD_t \leq RD_{mx} \tag{s18}
\]

\[
RD_t = RD_{mx} \quad RD_t > RD_{mx} \tag{s19}
\]

Where $\Delta RD_t$ is the variation of root depth at day $t$ (cm), $RD_{mx}$ is the maximum crop root depth (cm).
REFERENCES

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M.: Crop evapotranspiration. Guidelines for computing crop water requirements-FAO Irrigation and Drainage Paper 56, FAO, Rome. 1998

Delonge, K. C., Ascough, J. C., Andales, A. A., Hansen, N. C., Garcia, L. A., Arabi, M.: Improving evapotranspiration simulations in the CERES-Maize model under limited irrigation. Agr Water Manage, 115: 92-103. http://doi.org/10.1016/j.agwat.2012.08.013. 2012.

Williams, J., Jones, C., Kiniry, J., and Spanel, D.: The EPIC Crop Growth Model. T. ASAE, 32:479-511. 1989.

Sau, F., Boote, K., Bostick, W., Jones, J., Minguez, M.: Testing and improving evapotranspiration and soil water balance of the DSSAT crop models. Agron. J., 96: 1243-1257. https://doi.org/10.2134/agronj2004.1243. 2004.

Ritchie, J.T.: Model for Predicting Evaporation from A Row Crop with Incomplete Cover. Water Resour Res,8(5): 1204-. https://doi.org/10.1029/WR008i005p01204.1972.