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

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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 (ET_0) is calculated by FAO-56 Penman-Monteith method (Allen et al., 1998).

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (S1)$$

where Δ is the slope of vapor pressure curve (kPa℃$^{-1}$), 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)$^{-1}$), γ is the psychrometric constant (kPa℃$^{-1}$), T is the mean air temperature (℃), u2 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 (ET_p) of crop is calculated as:

$$ET_p = K_c \times ET_0 \quad (S2)$$

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).

$$K_c = 1.0 + (K_{cmax} - 1.0) \times \frac{LAI}{LAI_{max}} \tag{S3}$$

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 τ,

$$\tau = exp[-(K_b)(LAI)] \tag{S4}$$

$$E_p = \tau \times ET_p \tag{S5}$$

$$T_p = ET_p - E_p \tag{S6}$$

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:

$$H_t = H_{mx}\sqrt{HUF_t} \tag{s7}$$

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

$$HUF_t = \frac{HUI_t}{HUI_t + exp(\alpha_1 - \alpha_2 HUI_t)} \tag{s8}$$

Where α_1 and α_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.

$$HUI_t = \frac{\sum_{k=1}^{t} HU_k}{PHU} \tag{S9}$$

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:

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

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

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:

$$LAI_t = LAI_{t-1} + \Delta LAI_t \quad for\ t \geq t_{deline} \tag{S11}$$

where

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

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

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

$$REG_t = min(WS_t, TS_t) \tag{s14}$$

$$WS_t = \frac{T_{at}}{T_{pt}} \tag{s15}$$

$$TS_t = sin\left[\frac{\pi}{2}\left(\frac{T_{mean,t} - T_b}{T_0 - T_b}\right)\right] \tag{s16}$$

where REG is the minimum crop stress factor and LAI_{mx} is the maximum leaf area index, ad is a 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_0 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;

$$RD_t = RD_{t-1} + \Delta RD_t \tag{s17}$$

$$\Delta RD_t = 2.5 \times RD_{mx} \times (\Delta HUF_t) \qquad RD_t \leq RD_{mx} \tag{s18}$$

$$RD_t = RD_{mx} \qquad RD_t > RD_{mx} \tag{s19}$$

Where $\Delta\mathrm{RD}_\mathrm{t}$ 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.