Appendix

Appendix A. Calculations of $\mathrm{LAI_{sun}}$ and $\mathrm{LAI_{shd}}$.

We refer to Chen *et al.* (1999), Liu *et al.* (1999) and Norman (1982) for calculating $\mathrm{LAI_{sun}}$ and $\mathrm{LAI_{shd}}$, such that:

$$\mathrm{LAI_{sun}} = 2\cos\theta\left(1-\exp\left(-0.5\times\Omega\times\mathrm{LAI}/\cos\theta\right)\right) , \quad \text{(A1)}$$

$$\mathrm{LAI_{shd}} = \mathrm{LAI} - \mathrm{LAI_{sun}} , \quad \text{(A2)}$$

$$\theta = \frac{\pi}{8} + \frac{3}{4}\theta_{\mathrm{n}} , \quad \text{(A3)}$$

$$\begin{aligned}\cos\theta_{\mathrm{n}} = {} & \sin\left(-23.45\times\frac{\pi}{180}\cos\left(\frac{360\left(\mathrm{DoY}+10\right)}{365}\right)\right)\sin\varphi \\ & +\cos\left(-23.45\times\frac{\pi}{180}\cos\left(\frac{360\left(\mathrm{DoY}+10\right)}{365}\right)\right)\cos\varphi\end{aligned} , \quad \text{(A4)}$$

where θ and θ_{n} denotes the mean solar zenith angle during the daytime and solar zenith angle at noon (rad); DoY denotes the Julian day; and φ denotes the local latitude (rad).

Appendix B. Calculations of Q_{sun} and Q_{shd}.

We refer to Norman (1982), Chen *et al.* (1999) and Liu *et al.* (1999) for obtaining Q_{shd} and Q_{sun} in the daytime:

$$C = 0.07\times\Omega\times Q_{\mathrm{dir}}\times\left(1.1-0.1\mathrm{LAI}\right)\times\exp\left(-\cos\theta\right), \quad \text{(B1)}$$

$$Q_{\mathrm{dif\_under}} = Q_{\mathrm{dif}}\times\exp\left(-0.5\times\Omega\times\mathrm{LAI}/\cos\overline{\theta}\right) , \quad \text{(B2)}$$

$$\cos\overline{\theta} = 0.537 + 0.025\mathrm{LAI} , \quad \text{(B3)}$$

$$Q_{\mathrm{shd}} = \left(Q_{\mathrm{dif}} - Q_{\mathrm{dif\_under}}\right)/\mathrm{LAI} + C , \quad \text{(B4)}$$

$$Q_{\mathrm{sun}} = Q_{\mathrm{dir}}\frac{\cos\alpha}{\cos\theta} + Q_{\mathrm{shd}} , \quad \text{(B5)}$$

where C denotes the multiple scattered radiation (μmol m^{-2} s^{-1}); Ω denotes the clumping index of vegetation, 0.9 is used for crops; Q_{dir} and Q_{dif} denote the direct and diffuse solar radiation in the daytime (μmol m^{-2} s^{-1}); θ denotes the daytime mean solar zenith angle; $Q_{\mathrm{dif\_under}}$ denotes the daytime radiation under canopy (μmol m^{-2} s^{-1}); $\overline{\theta}$ denotes the solar zenith angle for radiation transmission; α denotes the inclination angle of leaves ($\pi/3$). The following equations, referring to Black *et al.* (1991); Chen *et al.* (1999); Liu *et al.* (1999), was adopted to calculate Q_{dir} and Q_{dif}:

$$R = \frac{Rg}{R_0}, \tag{B6}$$

$$\frac{Rg_{\text{dif}}}{Rg} = \begin{cases} 0.13 & , R \geq 0.8 \\ 0.943 + 0.734R - 4.9R^2 + 1.796R^3 + 2.058R^4 & , R < 0.8 \end{cases}, \tag{B7}$$

$$Q_{\text{dif}} = Q \cdot \frac{Rg_{\text{dif}}}{Rg}, \tag{B8}$$

$$Q = k_{\text{q}} \cdot Rg \cdot \frac{Hr_{day}}{24}, \tag{B9}$$

$$Q_{\text{dir}} = Q - Q_{\text{dif}}, \tag{B10}$$

where R_0 is the daily extraterrestrial solar radiation (W m^{-2}); R denotes the atmosphere transmissivity; Rg denotes the daily global solar radiation (W m^{-2}); Rg_{dif}/Rg denotes the proportion of diffuse solar radiation to the global solar radiation; k_{q} is a factor to scale solar radiation to PPFD (2.0 μmol J^{-1}); Q_{dif}/Q denotes the fraction of diffusion radiation calculated according to Black *et al.* (1991). R_0 is calculated referring to Duffie *et al.* (2013):

$$R_0 = \frac{1}{\pi} S_0 \cdot \left(\cos\varphi \cdot \cos\delta \cdot \sin\omega_{\text{set}} + \omega_{\text{set}} \cdot \sin\varphi \cdot \sin\delta\right), \tag{B11}$$

$$\omega_{\text{set}} = \arccos\left(-\tan\varphi \tan\delta\right), \tag{B12}$$

where S_0 denotes the solar constant (1367 W m^{-2}); ω_{set} denotes the hour angle of sunset (rad).

Appendix C

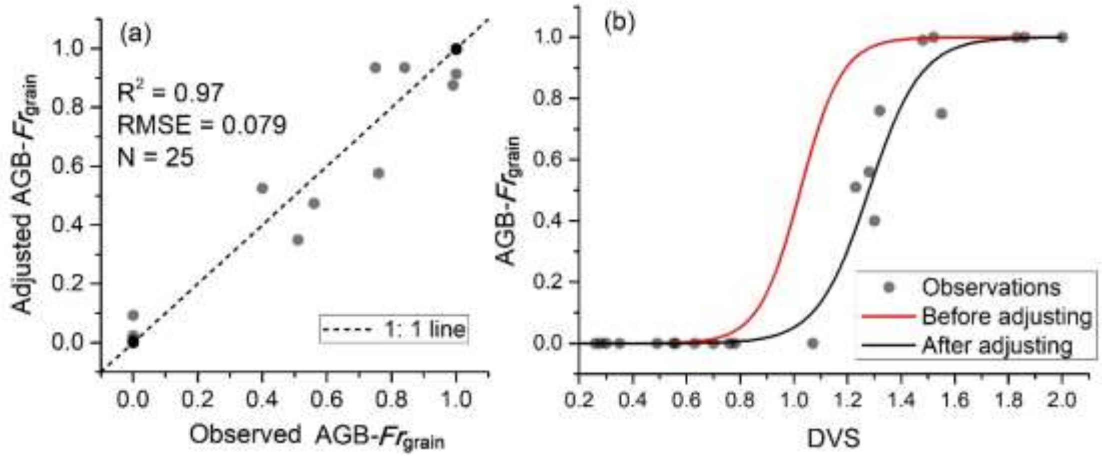

Figure C1 Observed aboveground biomass (AGB) based Fr_{grain} (AGB-Fr_{grain}) *vs*. the calculated values (a), and a comparison between the AGB-Fr_{grain} curve before and that after adjusting (b). The AGB-Fr_{grain} indicates the photosynthetic production that is used for grian-filling, in proportion to the total aboveground biomass. The observed AGB-Fr_{grain} were retrieved from Hao *et al.* (2016). Some points having the same value overlap in the figure. R denotes the correlation coefficient and RMSE denotes the root mean standard error. Superscript "**" implies the correlation is significant at the 0.01 level (similarly hereinafter).

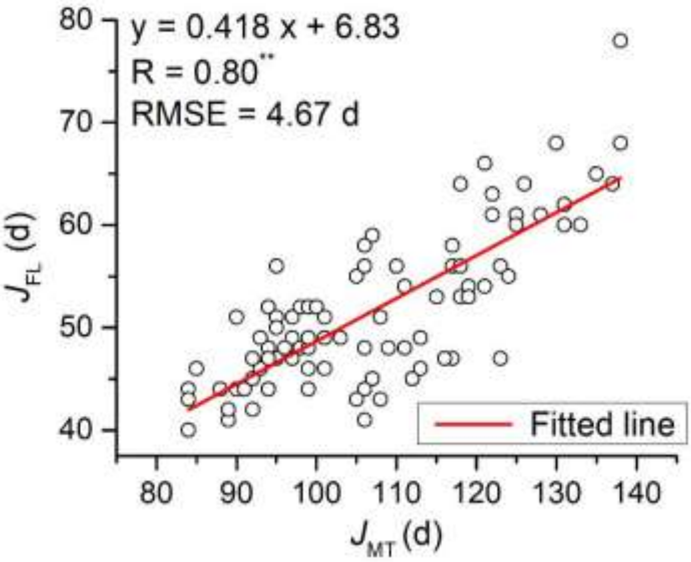

Figure C2 An estimate of the number of days for maize developing from emerging to flowering (J_{FL}) in terms of the length of growing seasons (J_{MT}). A total of 94 samples are available.

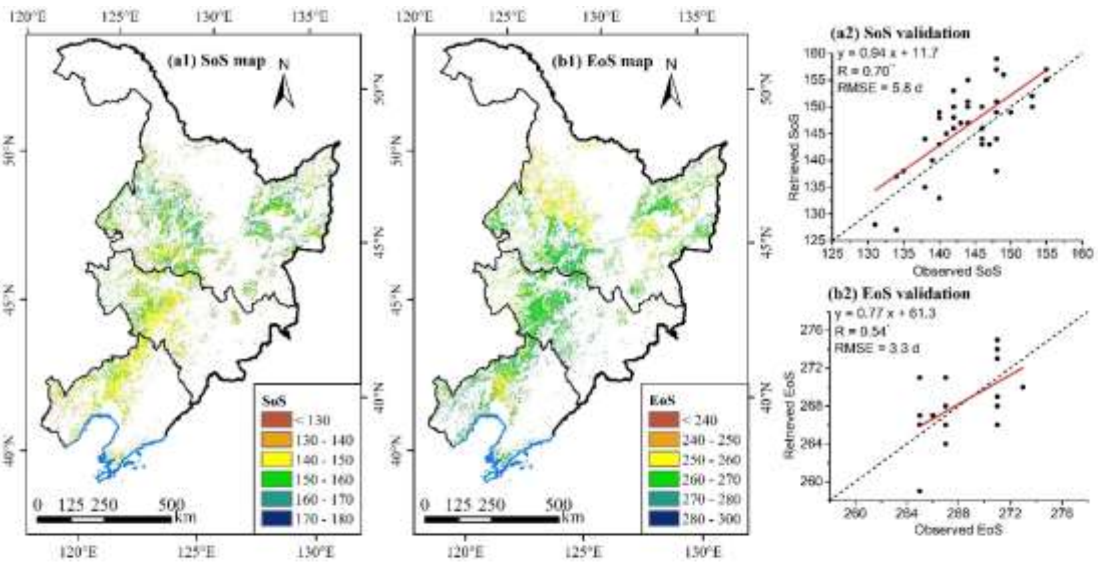

Figure C3 The maps of RS-retrieved emerging and maturity DoY values of maize (a1 and b1) over the study region and the comparison against the site-observations (a2 and b2). The legend for boundaries shows in Figure 1.

Appendix D. Abbreviations and variables

Abbreviations or variables	Descriptions
A_n	Net photosynthesis rate
A_v, A_e, A_s	Rubisco, potential electron transport and export limited photosynthesis rates respectively
c_a	Partial pressure of CO_2 in the atmosphere
CGM	Crop growth model
c_i	intercellular partial pressure of CO_2
De_x	Daily senescence rate of organ "*x*"
dM	Dry matter change
DMCS	Data-model coupling strategy
dM_x	Daily change in the dry matter of organ "*x*"
DVS	Development stage
EM	Crop emerging stage
EVI	Enhanced vegetation idex
FL	Crop flowering stage
$f_N(N)$	Restrictive function of nitrogen supply
Fr_x	Fraction of daily photosynthesis product allocated to organ '*x*'
$g(g_{st})$	Stomatal conductance measured in μmol m^{-2} s^{-1}
GDD	Growing degree days
GDD1 and GDD2	GDD required for crop developing from emerging to flowering and from flowering to maturity, respectively
$GDD_{leafLife}$	GDD from leaf span to the start of leaf senescence
GPP	Growth primary productivity
g_{st}	Stomatal conductance measured in m s^{-1}
HI	Harvest index
Hr_{day}	Length of daytime in hours
Hr_S	Daily sun duration hours
J_{FL} and J_{MT}	Number of days required for crop developing from emerging to flowering and from emerging to maturity, respectively
LAI	Leaf area index
LAI_{shd} and LAI_{sun}	Leaf area index of shaded and sunlight leaves
LUE	Light use efficiency
M_C	Mole mass of carbon (12 g mol^{-1})
M_{grain}	Dry matter of the grain
M_{leaf}	Dry matter of leaf
MT	Crop maturity stage
NECP	Northeast China Plain
P_{atm}	Atmosphere pressure
Pr_{ann}	Mean annual precipitation

Q	Photosynthetically active radiation (PAR) on the leaf surface
Q_{10}	Temperature sensitivity parameter of respiration reflecting the increments of respiration rate with an increase of temperature by 10℃
R_0	Extraterrestrial solar radiation
PRYM–Maize	A Process-based and Remote sensing crop Yield Model for Maize
R_d	Dark respiration
Rg	Global solar radiation
R_g	Growth respiration rate
R_{gas}	mole constant of gas
r_m	Maintenance respiration coefficient, $r_{m,grain,}$ $r_{m,leaf,}$ $r_{m,stem}$ and $r_{m,root}$ denotes the r_m values for grain, leaf, stem and root, respectivley.
R_m	Maintenance respiration rate
RS	Remote sensing
R_{total}	Daily total respiration rate
swc	Soil water content
T	Temperature
t_0	Current day
$T_{a,daily}$	Daily temperature
T_{base}, T_o and T_m	The base, optimum and maximum temperature for crop developments
T_{eff}	Effective temperature
t_{EM}, t_{FL} and t_{MT}	Dates for emerging, flowering and maturity, respectively
T_R	Daily temperature range
ts	Temporal scale
V_m	Maximum carboxylation rate
V_{m25}	Maximum carboxylation rate at the temperature of 25℃
WUE	Water use efficiency
ε	Intrinsic quantum efficiency
ε_m	Maximum value for ε