Supplementary

Table S1. Parameter setting for spring maize and summer maize.

(light red)	Same as the parameter for one-year corn from X. Liu et al. (2016)
(light blue)	Same as the parameter for one-year corn from Z. Zhang et al. (2020)
(light yellow)	Same as the parameter for spring wheat from Z. Zhang et al. (2023)
(light grey)	Based on winter wheat study from Y. Zhang et al. (1991)
(light green)	Recalibrated with the station/satellite data

Parameter	Maize		Wheat	Physical meaning
	Spring	Summer	Winter	
GDDTBASE	10		0	Base temperature for GDD accumulation
GDDTCUT	30		30	Upper temperature for GDD accumulation
GDDS1	50		150	GDD from seeding to emergence
GDDS2	625		790	GDD from seeding to initial vegetative
GDDS3	1000		1190	GDD from seeding to post vegetative
GDDS4	1103		1600	GDD from seeding to initial reproductive
GDDS5	1555		2010	GDD from seeding to physical maturity
C3PSN	0		1	Indicator for C3 plant (1) or C4 plant (0)
KC25	30		30	CO_2 Michaelis-Menten constant at 25 °C
AKC	2.1		2.1	Q10* base for KC25
KO25	3.E4		3.E4	CO_2 Michaelis-Menten constant at 25 °C
AKO	1.2		1.2	Q10* base for KO25
AVCMX	2.4		1.5	Q10* base for VCMX25
VCMX25	60		80	Maximum rate of carboxylation at 25 °C
BP	4.E3		1.E4	Minimum leaf conductance
MP	4		9	Slope of conductance-to-photosynthesis
QE25 [(1)]	0.08		0.12	Quantum efficiency at 25 °C
Q10MR	2.0		2.0	Q10* base for maintenance respiration
LEFREEZ	268		268	characteristic T for leaf freezing
DILE_FC_S5	0.5		0.5	Coefficient for temperature leaf stress death
DILE_FC_S6	0.5		0.5	
DILE_FW_S5	0.2		0.2	Coefficient for water leaf stress death
DILE_FW_S6	0.2		0.2	
FRA_GR	0.2		0.2	Fraction of growth respiration
LF_OVRC_S5	0.2		0.05	Fraction of leaf turnover
LF_OVRC_S6	0.3		0.05	
ST_OVRC_S5	0.12		0.05	Fraction of stem turnover
ST_OVRC_S6	0.06		0.05	
RT_OVRC_S5	0.12		0.12	Fraction of root turnover
RT_OVRC_S6	0.06		0.06	

LFMR25	0.8		0.8	Leaf maintenance respiration at 25 °C
STMR25	0.05		0	Stem maintenance respiration at 25 °C
RTMR25	0.05		0	Root maintenance respiration at 25 °C
LFPT_S3	0.36	0.4	0.45	Fraction of carbohydrate flux to leaf
LFPT_S4	0.2	0.3	0.55	
LFPT_S5	0.1		0	
LFPT_S6	0.1		0	
STPT_S3	0.24	0.2	0.4	Fraction of carbohydrate flux to stem
STPT_S4	0.5	0.2	0.45	
STPT_S5	0.4	0.3	0.4	
STPT_S6	0	0.2	0.3	
RTPT_S3	0.4	0.3	0.15	Fraction of carbohydrate flux to root
RTPT_S4	0.3	0.5	0.0	
RTPT_S5	0.2	0.2	0.1	
RTPT_S6	0.1	0	0.1	
GRAINPT_S5	0.4	0.4	0.5	Fraction of carbohydrate flux to grain
GRAINPT_S6	0.8	0.7	0.6	
LFCT_S6 (2)	0		0.0005	Carbohydrate translocation from leaf to grain
STCT_S6 (2)	0		0.001	Carbohydrate translocation from stem to grain
BIO2LAI (3)	0.023	0.020	0.008	Leaf area per living leaf biomass

*Q10 means the rate increases by a 10°C temperature increases

(1) The QE25 parameter is increased following the removal of the great-overestimated and non-water-sensitive assumption 'FVEG=0.95'. This removal significantly decreases the radiation intercepted by vegetation, consequently imposing light limitations when calculating photosynthesis. Since the crop model adopts the same photosynthesis function as other non-crop vegetation in the Noah-MP, for simplicity, we opt to raise the crop quantum efficiency to achieve higher photosynthesis without affecting other vegetation types.

(2) Carbohydrate translocation from leaf and stem to grain, which typically occurs during the reproductive stages, has been sometimes overlooked. However, we found it is necessary to include it when predicting the wheat yield in the highly productive NCP (Huang et al., 2020; Ma et al., 2006).

(3) The average station BIO2LAI is calculated to be 0.02 for maize and 0.01 for winter wheat approximately. However, the BIO2LAI varies a lot during different stages and different quadrats, which requires slight recalibration around that station value. The final 0.023 for spring maize is similar to the 0.025 calibrated by (Yu et al., 2022) in northeast China.

The recalibration process:

The recalibration starts from crop-stage identification, since it relies purely on the accumulated GDD and is less affected by other crop parameters. The GDD-related parameters are retrieved from Z. Zhang et al. (2020) and Zhang et al. (1991), and then validated with the heading date and maturity date retrieved from the satellite data (Luo et al., 2020). The crop stage comprises the pre-planting stage, three vegetative stages (emergence, initial vegetative, post-vegetative), two reproductive stages (initial reproductive, post-reproductive), and finally, one maturity stage. During the vegetative stage, a majority of carbohydrates are allocated to the leaves and stems, while in the reproductive stage, the allocation shifts towards the grain.

Next, the general growth rate including BIO2LAI can be extracted from the station data, and the Maximum rate of carboxylation at 25 °C (VCMX25) can also be estimated using the monthly satellite data of Gross Primary Product (GPP) and LAI, since the photosynthesis rate and the LAI are approximately linearly related, especially on sunny days when the canopy temperature is around 25°C (He et al., 2023). Instead of the linearly interpolated data from WRF pre-processing, both GPP and LAI that we adopted are initially derived from MODIS products but have undergone further post-processing to generate a more continuous monthly pattern (Wang et al., 2020; Yuan et al., 2020), and will be considered as the observation (OBS). Furthermore, the AVCMX, which represents the crop sensitivity to the temperature, can be determined by the gradient of biomass accumulation (Huang et al., 2022), especially in spring and autumn with greater temperature changes. For maize, the values of VCMX25 and AVCMX have simply followed the previous studies, while BIO2LAI is subject to recalibration, as its necessity of recalibration has been demonstrated by Yu et al. (2022).

Following the establishment of the general photosynthesis rate, we proceed to fine-tune the distribution of carbohydrates among the leaf, stem, and grain compartments, based on the annual cycle of leaf mass and stem data obtained from the station data. Any remaining carbohydrates are allocated to the root. In cases where the recalibration of the distribution scheme alone does not yield satisfactory predictions, adjustments to the turnover and translocation rates are implemented. Additionally, the crop yield will be validated through comparisons with remotely sensed estimations from Gorgan et al. (2022).

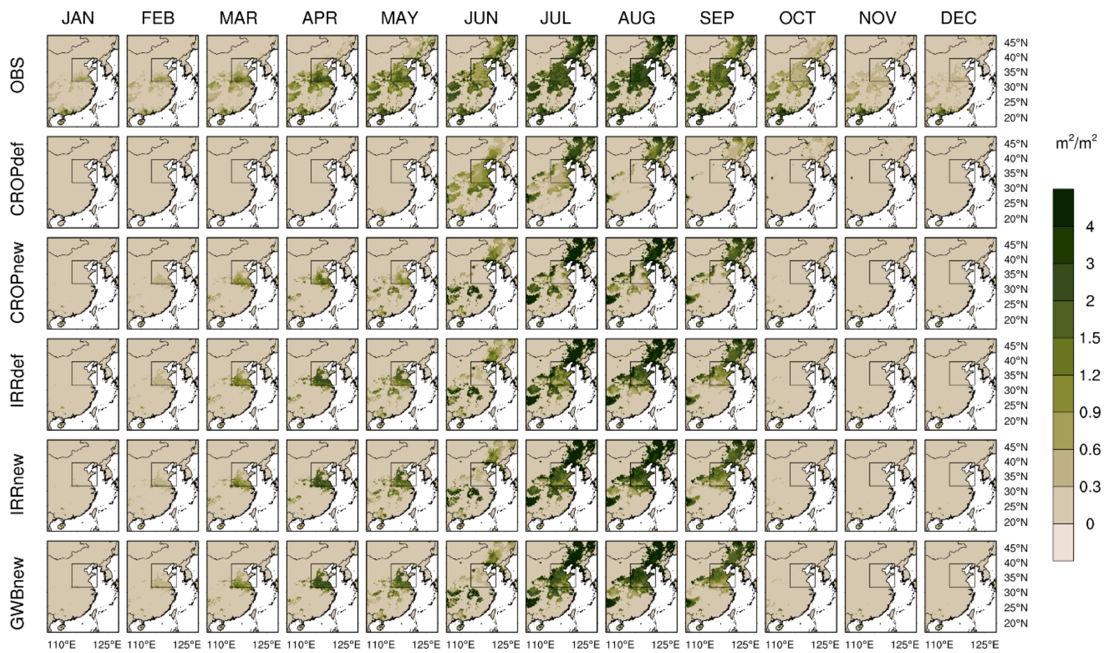

Figure S1. Monthly LAI pattern of the satellite observation, default crop model only, and after all modification and integration. This is an extended version of Fig. 8.

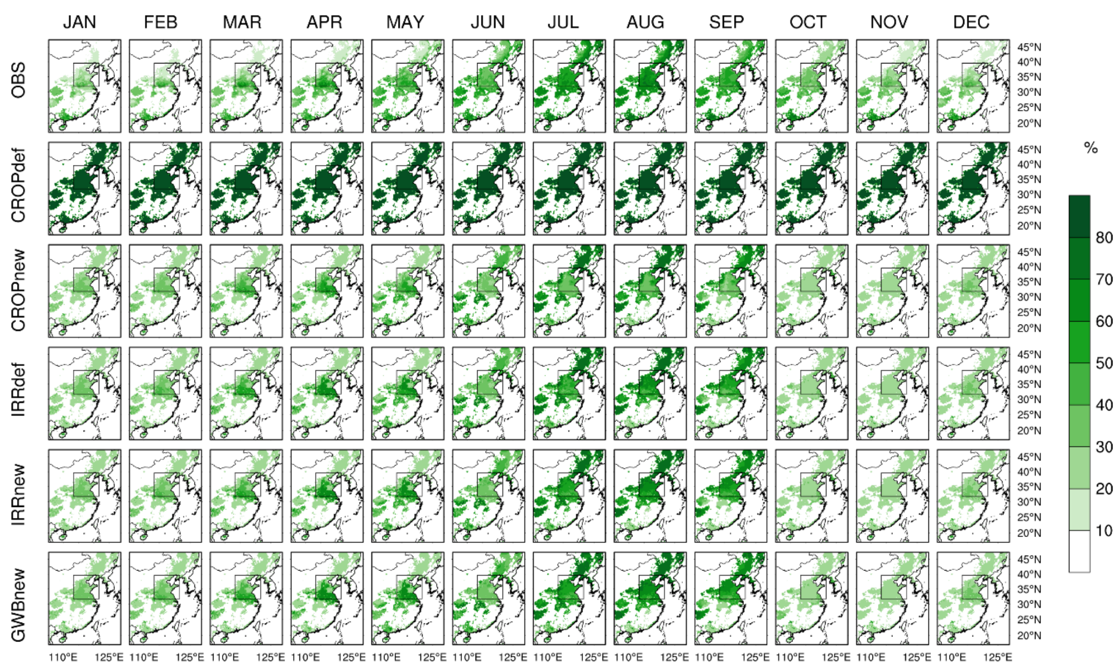

Figure S2. Similar to Fig. S1 but for FVEG. Notice that in the default crop model (CROPdef) all FVEG is fixed to 95%.