Supplementary Information for

Climate-Driven Temperature Changes in the Future Impair China's Terrestrial Carbon Sink Capacity

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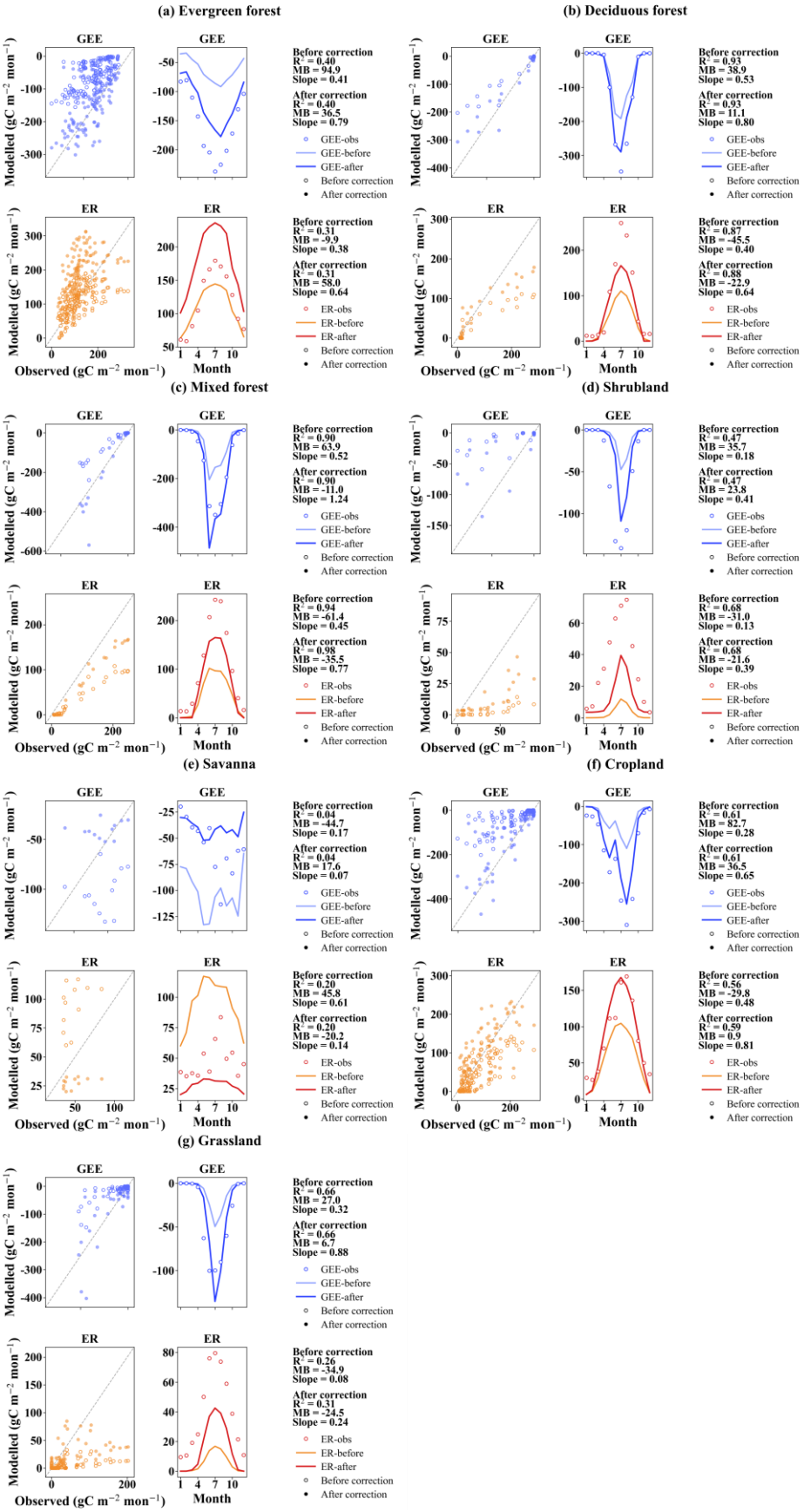


Fig. S1. Comparison of ER and GEE simulated by WRF-VPRM model (default set-up and after calibration) with in-situ observations.

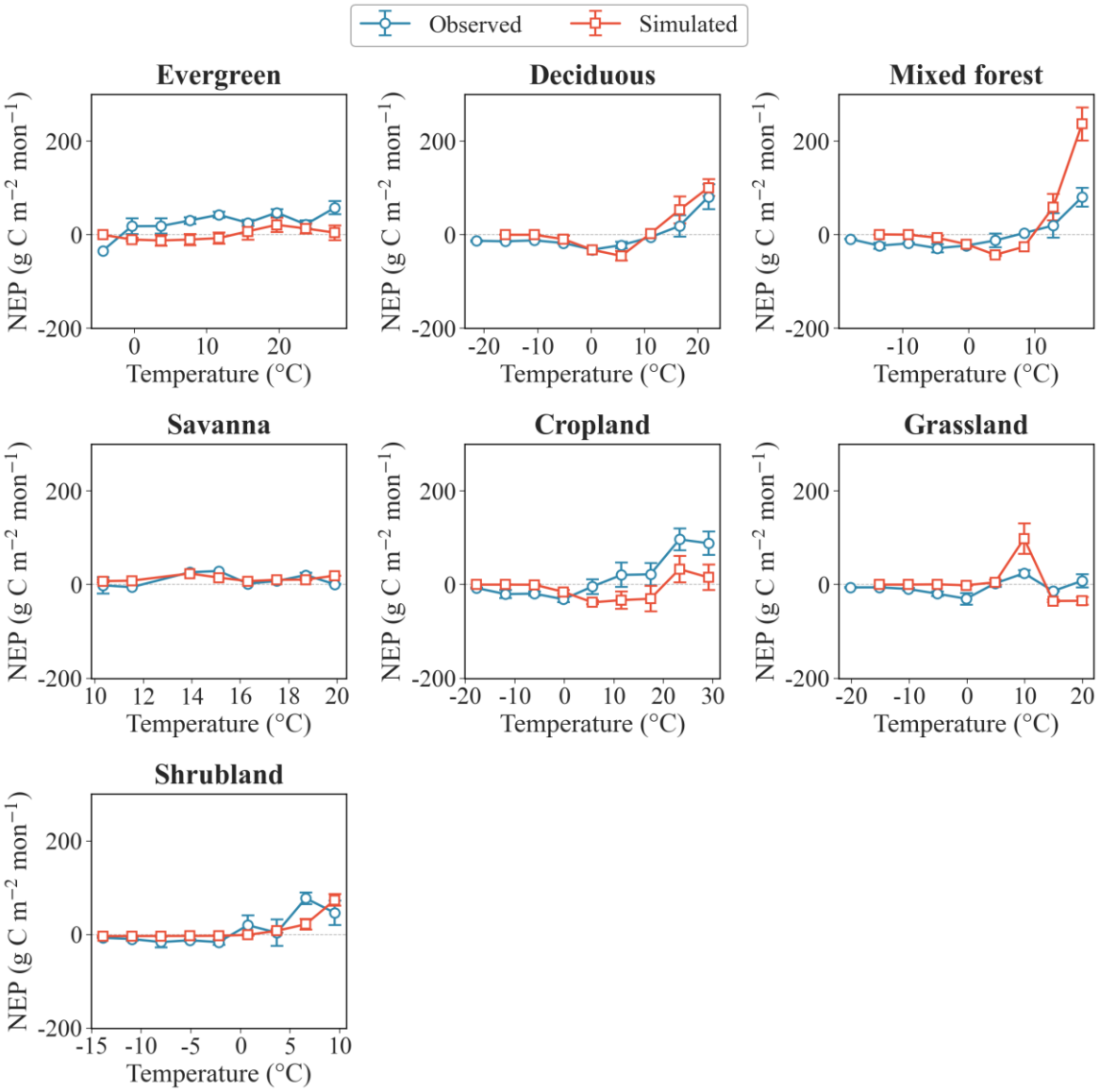


Fig. S2. Modelled and simulated NEP-temperature relationships for 7 vegetation types.

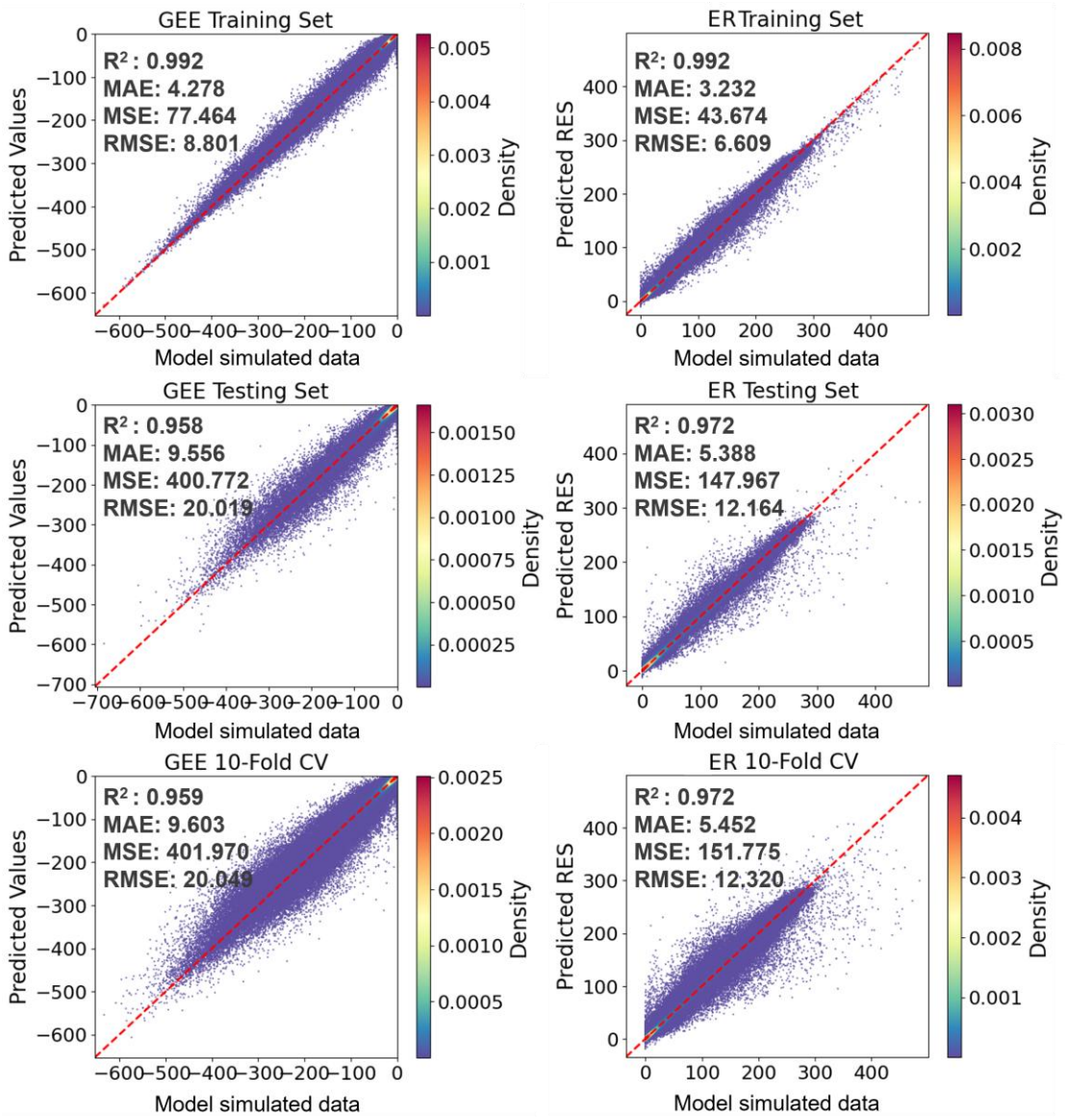


Fig. S3. Scatter plots of XGB predicted and observed values for training and testing sets under 10-fold cross-validation, with point density indicated by color intensity (blue for low density, magenta for high density). Accuracy metrics are shown in the upper left corner of each plot.

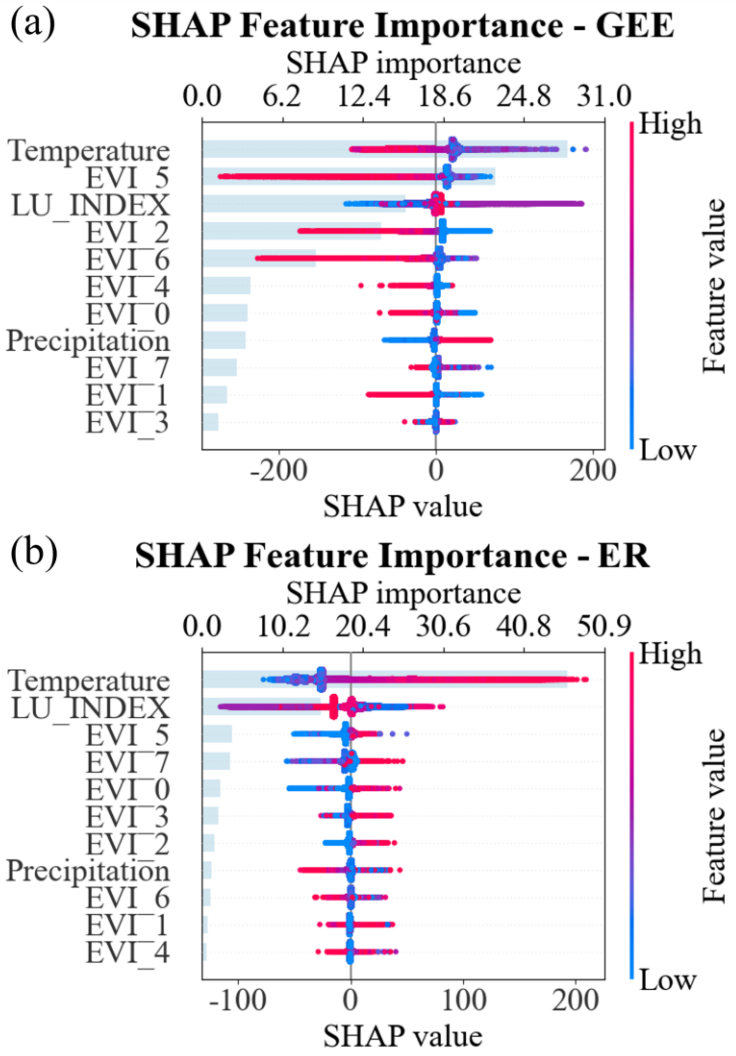


Fig. S4. SHAP-derived impacts of temperature, precipitation, land use and related variables on CO_2 fluxes associated with (a) GEE and (b) ER.

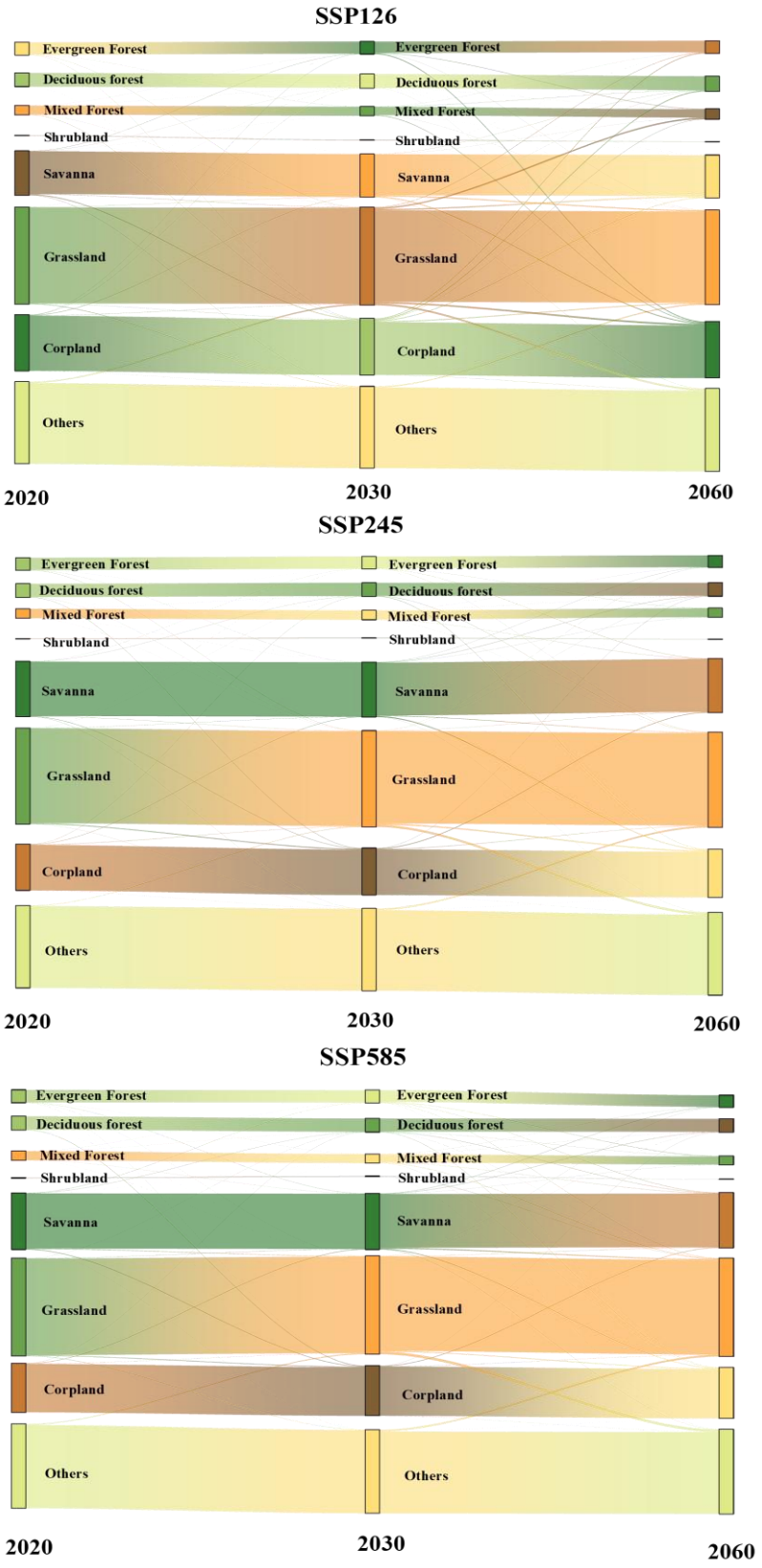


Fig. S5. Land-use transition patterns under different SSP scenarios, illustrating category-to-category conversions across the study period.

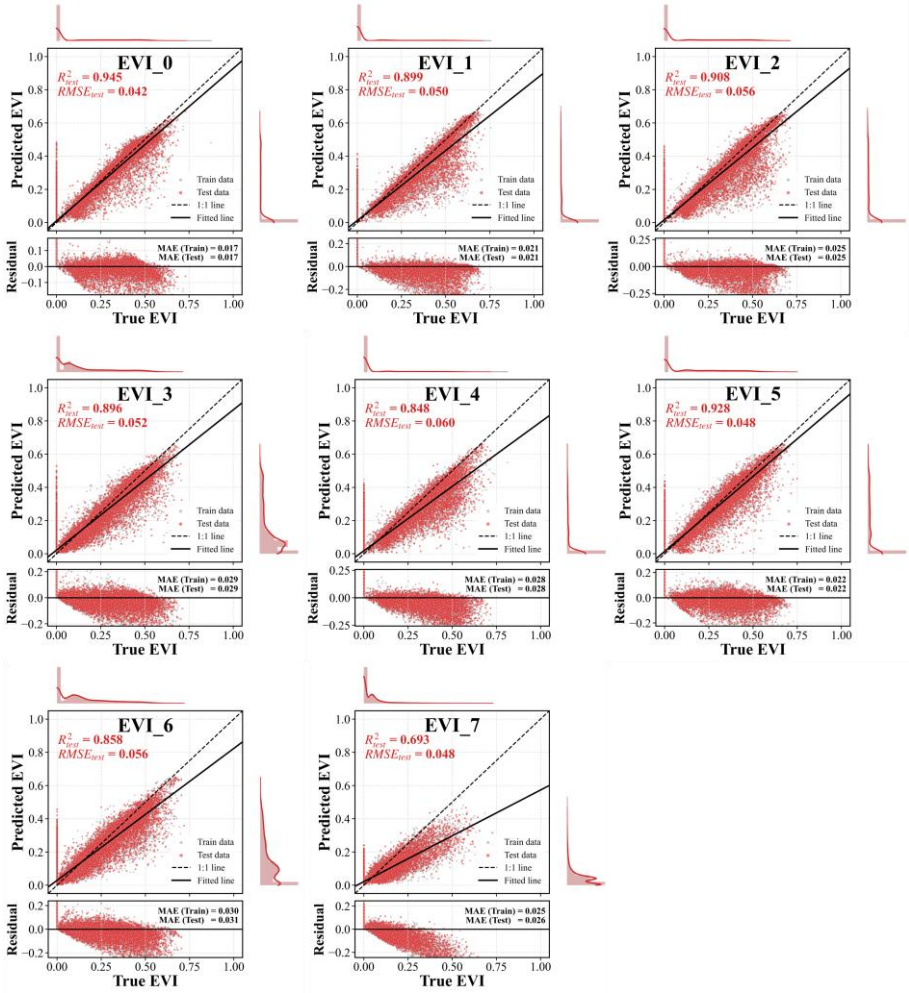


Fig. S6. Test-set observed–predicted scatter plots for monthly EVI component extrapolation models (EVI0–EVI7) under grid-based grouped spatial splitting.

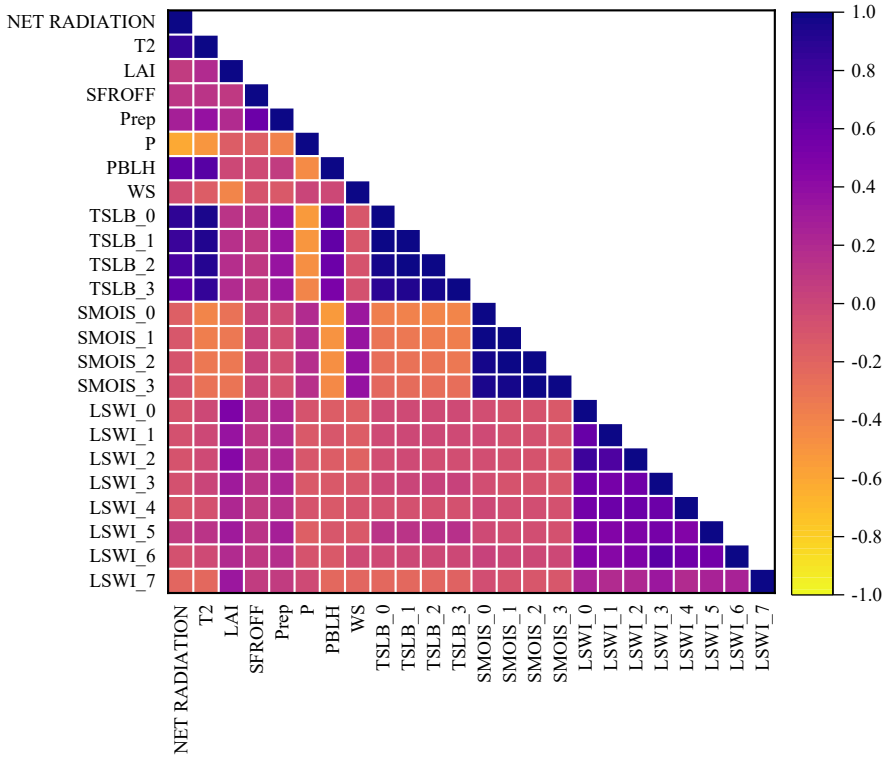


Fig. S7. Correlation heatmap of key meteorological indicators, showing pairwise relationships across the study period.

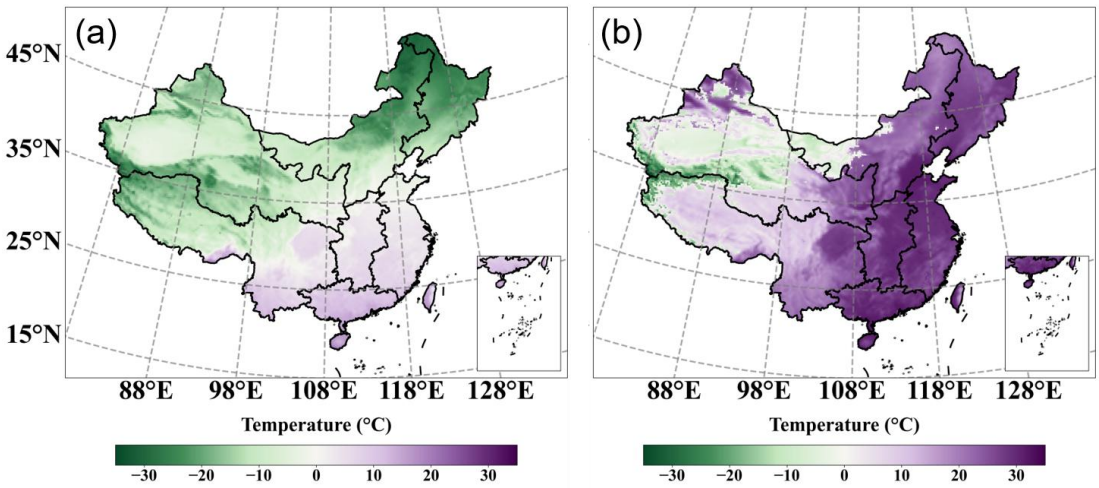


Fig. S8. Spatial patterns of baseline near-surface air temperature across China used for climate zone delineation. (a) Mean temperature for cold zone; (b) Mean temperature for warm zone. These temperature fields underpin the four climatic zones (Zone I–IV) defined in Fig. 4, which are used to interpret temperature-dependent GEE and ER responses via SHAP analysis.

Table S1 ChinaFLUX site information

Vegetation Type	Site Name	Abbreviation	Latitude	Longitude
Evergreen	Xishuangbanna	XSBN	21.90	101.27
	Ailao Mountain	ALM	24.54	101.03
	Qianyanzhou	QYZ	26.73	115.07
	Yan Mountain	YS	40.42	116.66
	Danzhou	DZ	19.55	109.48
	Jinfo Mountain	JFM	29.79	106.44
	Dinghu Mountain	DHM	23.17	112.54
Deciduous	Mao'er Mountain	MEM	45.42	127.67
	Huzhong	HZ	51.78	121.02
Mixed forest	Changbai Mountain	CBM	42.40	128.10
Shrubland	Haibei shrubgland	HB	37.62	101.32
Savanna	Yuanjiang	YJ	23.47	102.18
Cropland	Panjin	PJ	40.94	121.96
	Gucheng	GC	39.13	115.67
	Changling	CL	44.34	123.93
	Jinzhou	JZ	41.15	121.20
	Yucheng	YC	36.95	116.60
Grassland	Ruo'ergai	REG	32.80	102.55
	Dangxiong	DX	30.85	91.08
	Haibei Meadow	HBCD	37.62	101.32
	Inner Mongolia	IM	43.33	116.40

Table S2 Fitted coefficients of the quadratic regression models for ecosystem carbon fluxes across different vegetation types.

Vegetation Type	Flux	a	b	c	R^2
Evergreen		-0.020	6.262	26.705	0.84
Deciduous		0.020	8.162	68.183	0.82
Mixed forest		0.020	6.193	66.874	0.88
Shrubland	ER	0.020	2.829	44.761	0.64
Savanna		-0.020	2.799	-6.540	0.58
Cropland		0.020	3.659	48.082	0.76
Grassland		-0.009	2.670	41.482	0.75
Evergreen		0.200	-12.629	-22.447	0.90
Deciduous		0.050	-11.436	-70.587	0.75
Mixed forest		0.050	-9.708	-76.822	0.74
Shrubland	GEE	0.100	-4.175	-50.823	0.39
Savanna		0.407	-21.669	215.783	0.61
Cropland		0.100	-8.302	-47.206	0.61
Grassland		0.100	-4.413	-43.269	0.62

Notes: The quadratic regression model was expressed as $F=aT^2+bT+c$, where F represents the ecosystem carbon flux (ER/GEE), T is temperature, and a, b, and c are the quadratic, linear, and intercept coefficients, respectively. R^2 indicates the goodness of fit of the regression model.

Table S3 Calibration ratio of empirical parameters derived from observations and simulations

	$\lambda_{obs}/\lambda_{sim}$	$\alpha_{obs}/\alpha_{sim}$
Evergreen forests	1.9	1.7
Deciduous forests	1.5	2.1
Mixed forests	2.4	2.3
Shrubland	2.3	7.1
Savanna	0.4	0.2
Cropland	2.3	1.8
Grassland	2.7	4.7

Table S4 Environmental covariates in the pre-screening phase of this study.

Covariate	Description	Abbreviations	Time	ER-VIF	GEE-VIF
Temperature at 2-meter height	—	T2	2020-2060	33.67	33.67
Precipitation	—	Prep	2020-2060	2.77	2.77
EVI	Evergreen forests	EVI_0	Static	7.12	7.12
	Deciduous forests	EVI_1	Static	5.14	5.14
	Mixed forests	EVI_2	Static	8.38	8.38
	Shrubland	EVI_3	Static	2.94	2.94
	Savanna	EVI_4	Static	3.28	3.28
	Cropland	EVI_5	Static	3.77	3.77
	Grassland	EVI_6	Static	2.26	2.26
	Other LULC	EVI_7	Static	1.22	1.22
LSWI	Evergreen forests	LSWI_0	Static	6.57	6.57
	Deciduous forests	LSWI_1	Static	5.49	5.49
	Mixed forests	LSWI_2	Static	8.35	8.35
	Shrubland	LSWI_3	Static	3.09	3.09
	Savanna	LSWI_4	Static	3.68	3.68
	Cropland	LSWI_5	Static	2.98	2.98
	Grassland	LSWI_6	Static	2.88	2.88
	Other LULC	LSWI_7	Static	1.75	1.75
Soil Temperature of Each Layer	the first soil layer	TSLB_0	Static	333.34	333.34
	the second soil layer	TSLB_1	Static	1281.01	1281.01
	the third soil layer	TSLB_2	Static	1207.86	1207.86
	the fourth soil layer	TSLB_3	Static	191.53	191.53
Soil Moisture of Each Layer	the first soil layer	SMOIS_0	Static	49.32	49.32
Covariate	**Description**	**Abbreviations**	**Time**	**ER-VIF**	**GEE-VIF**
Soil Moisture of Each Layer	the second soil layer	SMOIS_1	Static	181.42	181.42
	the third soil layer	SMOIS_2	Static	151.39	151.39
	the fourth soil layer	SMOIS_3	Static	44.94	44.94
Pressure	—	P	2020-2060	2.14	2.14
Leaf Area Index	—	LAI	Static	4.04	4.04
Wind Speed	—	WS	2020-2060	1.57	1.57

Surface Runoff	—	SFROFF	2020-2060	1.63	1.63
Planetary Boundary Layer Height	—	PBLH	2020-2060	3.76	3.76
Surface Shortwave Radiation Flux	—	SWDOWN	2020-2060	3.14	3.14
Surface Longwave Radiation Flux	—	GLW	2020-2060	25.46	25.46
Land Use/ Land Cover	—	LU_INDEX	Static	5.18	5.18
Background CO2 Concentration	—	CO2_BCK	Static	1.73	1.73
MEIC_CO2	—	MEIC_CO2	Static	1.06	1.06

Table S5. Independent variables used in XGBoost-SHAP model

Description		Abbreviations	VIF
Temperature at 2-meter height		T_2	2.5
Accumulated precipitation		Prep	1.6
Land use		LU_INDEX	2.3
EVI	Evergreen forests	EVI_0	3.7
	Deciduous forests	EVI_1	2.0
	Mixed forests	EVI_2	4.9
	Shrubland	EVI_3	2.5
	Savanna	EVI_4	1.9
	Cropland	EVI_5	2.5
	Grassland	EVI_6	1.7
	Other LULC	EVI_7	1.1

Table S6. Optimal XGBoost Model parameters for both GEE and ER models.

XGBoost Model	Hyperparameter
n_estimators	1116
max_depth	10
learning_rate	0.07
gamma	8
tree_method	hist
random_state	0