

Table S1. Comparison of carbon-related indicators

Indicator	Direction	Advantages	Limitations
Carbon balance pressure index (CBPI)	Emission–sink imbalance	Integrates emissions and ecological compensation; strong spatial comparability	Not designed for long-term scenario prediction
Total carbon emissions (CE)	Emission scale	Direct and widely available	Ignores ecosystem carbon sinks
Carbon emission intensity	Emission efficiency	Suitable for economic comparison	Underestimates absolute carbon pressure
Per capita carbon emissions	Lifestyle-related emissions	Reflects consumption patterns	Ignores production structure and sinks
Net carbon sink	Net absorption capacity	Highlights ecological contribution	Masks emission-side drivers
Net primary productivity (NPP)	Vegetation productivity	Continuous spatial coverage from remote sensing	Not a direct carbon pressure indicator
Gross primary productivity (GPP)	Carbon uptake flux	Strong process representation	Parameter uncertainty

Table S2. Comparison of analysis methods

Method	Concept	Advantages	Limitations
Geodetector	Spatial stratified heterogeneity	No linear assumption; high interpretability	Does not infer causality
Linear regression	Elasticity estimation	Clear statistical inference	Strong linear assumptions
Geographically weighted regression (GWR)	Spatial non-stationarity	Captures spatial variation	Multicollinearity sensitivity
Random forest	Ensemble learning	Strong nonlinear fitting	Black-box interpretation
XGBoost	Gradient boosting	High predictive accuracy	Complex parameter tuning
Neural networks	Nonlinear mapping	Powerful for flux prediction	High data demand, low interpretability
Method	Core concept	Main advantages	Limitations

Table S3. Interaction between two factors in Sichuan-Chongqing region

Factor A	Factor B	Interaction
X1	X2	Enhance, bi-
X1	X3	Enhance, bi-
X1	X4	Enhance, bi-
X1	X5	Enhance, bi-
X1	X6	Enhance, bi-
X1	X7	Enhance, bi-
X2	X3	Enhance, bi-
X2	X4	Enhance, bi-
X2	X5	Enhance, bi-
X2	X6	Enhance, bi-
X2	X7	Enhance, bi-
X3	X4	Enhance, bi-
X3	X5	Enhance, bi-
X3	X6	Enhance, bi-
X3	X7	Enhance, bi-
X4	X5	Enhance, bi-
X4	X6	Enhance, bi-
X4	X7	Enhance, bi-
X5	X6	Enhance, bi-
X5	X7	Enhance, bi-
X6	X7	Enhance, nonlinear