Supplementary Information for

Integration of the Vegetation Phenology Module Improves Ecohydrological Simulation by the SWAT-Carbon Model

Contents of this file

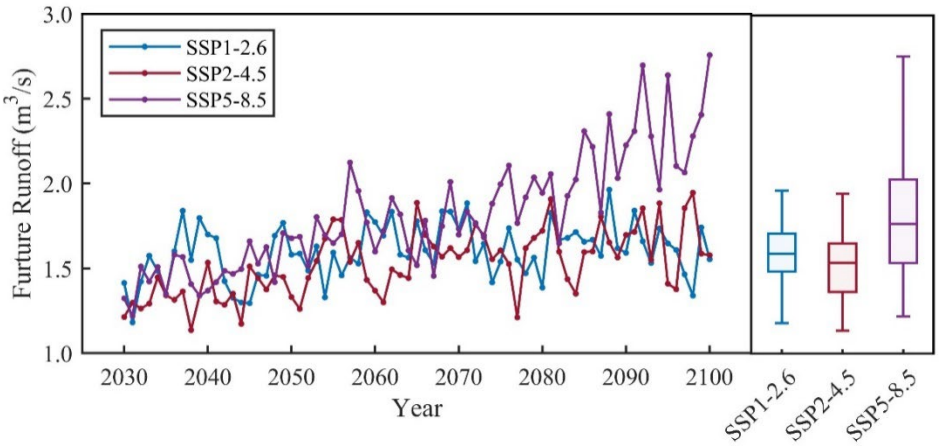
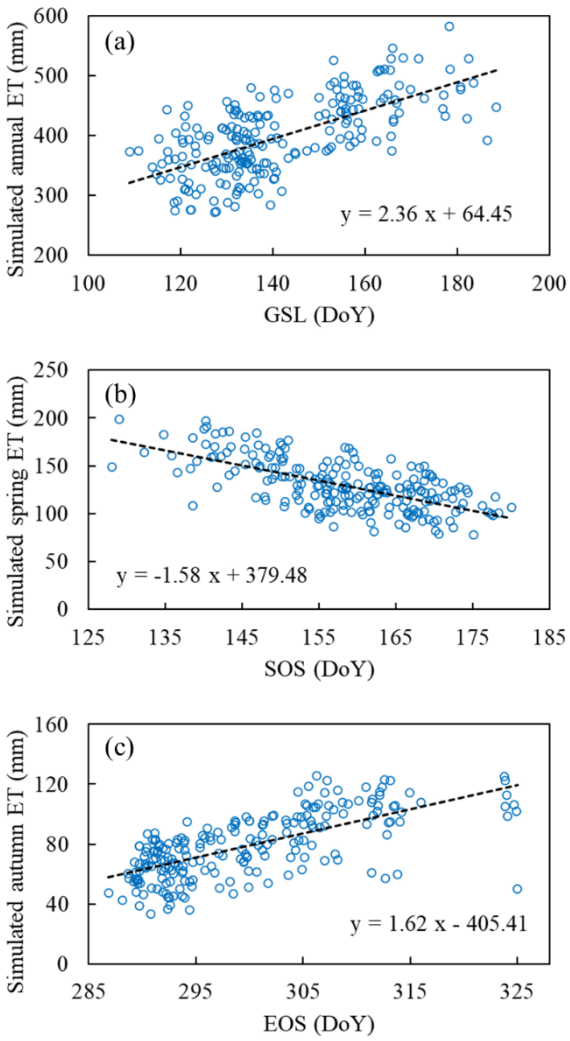


Figure S1: Projection of future runoff during 2030–2100 using the original SWAT-Carbon. The right subplot represents the annual mean runoff. SSP1-2.6, SSP2-4.5 and SSP5-5.8 refer to low emission, moderate and high emissions, respectively, based on the Coupled Model Intercomparison Project Phase 6 (CMIP6) multi-model ensemble.



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13 **Figure S2: Relationship between the phenological variations and sub-basin scales**
14 **evapotranspiration (ET) using modified SWAT-Carbon model.** GSL, growing season
15 length; SOS, start-of-season; EOS, end-of-season; ET, evapotranspiration.

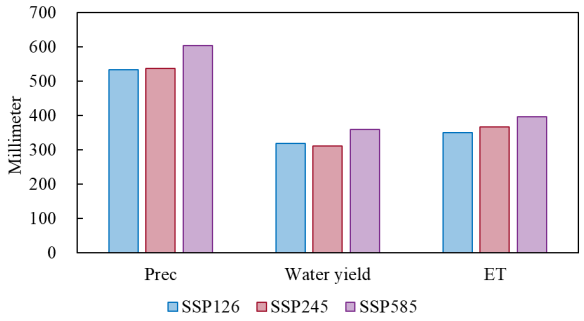

Figure S3: Precipitation, simulated water yield, and ET by modified SWAT-Carbon model from 2030 to 2100 under each emission scenario.

Table S1: Summary of the LAI-related parameters controlling vegetation growth and initial/calibrated values for forest (FRST) and grassland (PAST).

Parameter	Definition (unit)	Calibration values	
		FRST	PAST
ALAI_MIN	Minimum leaf area index (m^2/m^2)	1.099	0.287
BLAI	Maximum potential leaf area index (m^2/m^2)	4.012	4
DLAI	Fraction of PHU when LAI beings to decline	0.850	0.839
FRGRW1	Fraction of PHU corresponding to the 1st point on the leaf area development curve	0.166	0.161
FRGRW2	Fraction of PHU corresponding to the 2nd point on the leaf area development curve	0.809	0.408
LAIMX1	Fraction of BLAI corresponding to the 1st point on the optimal leaf area development curve	0.296	0.636
LAIMX2	Fraction of BLAI corresponding to the 2nd point on the optimal leaf area development curve	0.472	0.984
T_BASE	Minimum temperature for plant growth (°C)	0.855	0.006

Table S2: Summary of the original and modified SWAT-Carbon models' parameters that control runoff with default and calibrated values.

Parameter	Definition (unit)	Scaling type	Range	Original model		Modified model	
				Value	Rank	Value	Rank
CN2	Initial SCS runoff curve number for moisture condition II	multiple	-0.5 – 0.5	0.01	1	-0.12	3
SFTMP	Snowfall temperature (°C)	replace	-5 – 5	1.56	20	1.89	5
SMTMP	Snow melt base temperature (°C)	replace	-5 – 5	-0.18	15	-4.28	17
TIMP	Snow pack temperature lag factor (°C)	relative	0 – 1	0.30	14	0.79	9
ALPHA_BF	Baseflow alpha factor (days)	replace	0 – 1	0.72	8	0.34	7
GW_DELAY	Groundwater delay time (days)	replace	0 – 500	16.60	9	6.09	8
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_20)	replace	0 – 5000	1142.72	5	2882.59	10
GW_REVAP	Groundwater "revap" coefficient	relative	0.02 – 0.2	0.03	12	0.08	21
RCHRG_DP	Deep aquifer percolation fraction	replace	0 – 0.5	0.44	7	0.42	4
CH_N2	Manning's "n" value for the main channel	replace	0.25 – 0.14	0.05	19	0.05	14
SOL_K	Saturated hydraulic conductivity (mm/hr)	multiple	-0.5 – 0.5	-0.38	3	-0.31	6
SOL_AWC	Available water capacity of the soil layer (mm H_2O/mm soil)	multiple	-0.5 – 0.5	-0.003	10	-0.05	16
SOL_BD	Moist bulk density (g cm^{-3})	multiple	-0.5 – 0.5	0.25	2	0.19	1
SOL_Z	Depth from soil surface to bottom of layer (mm)	multiple	-0.5 – 0.5	-0.38	13	0.19	18
HRU_SLP	Average slope steepness	multiple	-0.5 – 0.5	0.23	4	0.50	2
SLSUBBSN	Average slope length (m)	multiple	-0.5 – 0.5	0.04	11	-0.39	12
CANMX	Maximum canopy storage	replace	0 – 15	7.86	22	13.0	13
ESCO	Soil evaporation compensation factor	replace	0 – 1	0.97	6	0.89	11

Table S3: Performance of runoff simulation in different months by modified SWAT-Carbon

Month	R^2		NSE	
	Original	Modified	Original	Modified
June	0.45	0.58	0	0.39
October	0.49	0.79	0.31	0.78
Non-growing season	0.72	0.73	0.19	0.54