

## Supplementary Materials

# Effects of Climate Change and Human Activities on Streamflow in Arid Alpine Water Source Regions: A Case Study of the Shiyang River, China

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## Test S1: Complementary methods

### SWAT model construction and calibration

To comprehensively assess the simulation performance of the model, we employed a suite of metrics to evaluate the accuracy of the simulation, including: the Nash-Sutcliffe Efficiency (*NSE*) to assess the model's goodness-of-fit, the Coefficient of Determination ( $R^2$ ) to measure the model's ability to explain the variability in the data, the Kling-Gupta Efficiency (*KGE*) which takes into account bias, variance, and correlation, and the Percentage Bias (*PBIAS*) to gauge the degree of deviation between the model's predictions and observed values [1,2]. The relevant formulas (S1–S4) for each metric are as follows.

$$NSE = 1 - \frac{\sum_{i=1}^n (S - M)^2}{\sum_{i=1}^n (S - \bar{M})^2} \quad (S1)$$

$$R^2 = \frac{\left[ \sum_{i=1}^n (M - \bar{M})(S - \bar{S}) \right]^2}{\sum_{i=1}^n (M - \bar{M})^2 \sum_{i=1}^n (S - \bar{S})^2} \quad (S2)$$

$$KGE = 1 - \sqrt{(R-1)^2 + \left( \frac{\sigma_s}{\sigma_o} - 1 \right)^2 + \left( \frac{\bar{M}}{\bar{S}} - 1 \right)^2} \quad (S3)$$

$$PBIAS = \frac{\sum_{i=1}^n (M - S)}{\sum_{i=1}^n S} \times 100\% \quad (S4)$$

where  $M$  represents the simulated value at time  $i$ , and  $\bar{M}$  denotes the simulated average value at time  $i$ .  $S_i$  is the measured value at time  $i$ , with  $\bar{S}$  being the measured average value at time  $i$ . All units are expressed in  $\text{m}^3\text{s}^{-1}$ . The number of time periods is denoted by  $n$ ,  $R$  is the correlation coefficient,  $\sigma_s$  is the standard deviation of the simulated values, and  $\sigma_o$  is the standard deviation of the measured values. Improved simulation performance is indicated by efficiency coefficients (i.e., *NSE*,  $R^2$ , *KGE*) approaching 1 and *PBIAS* values nearing 0.

## Test S2: Complementary tables

**Table S1** Abbreviation Decoding of Nouns.

Abbreviation	Full name	Abbreviation	Full name
LUCC	Land Use/Cover Change	UrL	Urban Land
SWAT	Soil and Water Assessment Tool	UnL	Unutilized Land
NYSK	Nanyingshuiku	HCG	High-coverage Grassland
ZMS	Zamusi	MCG	Medium-coverage Grassland
JST	Jinshatai	LCG	Low-coverage Grassland
GL	Gulang	K	Single land use dynamic degree
WW	Wuwei	LC	Somprehensive land use dynamic degree
MY	Menyuan	NSE	Nash-Sutcliffe Efficiency Coefficient
WSL	Wuqiaoling	R <sup>2</sup>	Coefficient of Determination
MZS	Maozangsi	KGE	Kling-Gupta Efficiency Coefficient
HX	Haxi	PBIAS	Percentage Bias
LG	Longgou	JTR	Jinta River
DEM	Digital Elevation Model	ZMR	Zamu River
CL	Cultivated Land	HYR	Huangyang River
FL	Forest Land	GLR	Gulang River
WB	Water Body	SUFI-2	Sequential Uncertainty Fitting Version 2
		HRUs	Hydrological Response Units

**Table S2** Value of SWAT model parameters.

River	Parameter Name	Fitted_ Value	River	Parameter Name	Fitted_ Value	River	Parameter Name	Fitted_ Value	River	Parameter Name	Fitted_ Value
JT River	v__SMTMP.bsn	1.20	ZM River	v__TLAPS.sub	-6.00	HY River	v__SFTMP.bsn	3.70	GL River	v__TIMP.bsn	0.32
	v__SURLAG.bsn	3.50		v__SLSUBBSN.hru	14.00		v__TLAPS.sub	-4.30		v__SLSUBBSN.hru	41.50
	v__TLAPS.sub	-6.70		v__HRU_SLP.hru	0.30		v__SLSUBBSN.hru	32.00		v__HRU_SLP.hru	0.41
	v__HRU_SLP.hru	0.40		v__CANMX.hru	0.70		v__CANMX.hru	20.00		v__CANMX.hru	0.86
	v__CANMX.hru	0.18		v__ESCO.hru	0.05		v__ESCO.hru	0.44		v__OV_N.hru	0.20
	v__EPCO.bsn	0.02		r__CN2.mgt	0.10		v__ALPHA_BF.gw	0.18		v__ESCO.hru	0.20
	r__CN2.mgt	0.13		r__SOL_BD().sol	0.50		v__RCHRG_DP.gw	0.96		r__CN2.mgt	0.15
	r__BIOMIX.mgt	0.31		r__SOL_AWC().sol	-0.50		r__CN2.mgt	0.13		r__SOL_Z().sol	-0.46
	r__SOL_Z().sol	0.50		v__ALPHA_BF.gw	0.20		r__SOL_Z().sol	0.40		r__SOL_BD().sol	0.15
	r__SOL_BD().sol	0.40		v__CH_K2.rte	42.00		r__SOL_BD().sol	0.38		r__SOL_AWC().sol	-0.15
	r__SOL_AWC().sol	0.30					r__SOL_AWC().sol	0.25		r__SOL_K().sol	0.76
							r__SOL_K().sol	0.75		v__ALPHA_BF.gw	0.90
										v__GWQMN.gw	460.00
										v__CH_N2.rte	0.20
										v__GW_DELAY.gw	300.00

**Table S3** Data Sources and Description.

Data type	Data sources
Land Use and Cover Change (LUCC)	Resource and Environment Science Data Center ( <a href="http://www.resdc.cn">http://www.resdc.cn</a> ) China land use status remote sensing monitoring database dataset in 1990, 2010. (Landsat 8 30m)
Soil Type	Resource and Environment Science Data Center ( <a href="http://www.resdc.cn">http://www.resdc.cn</a> ) Spatial distribution data of soil types in China, 1km, 1995
HWSD	Food and Agriculture Organization of the United Nations ( <a href="https://gaez.fao.org/">https://gaez.fao.org/</a> ), Chinese soil dataset based on the World Soil Database (v1.1), 1 km
Digital Elevation Model(DEM)	Resource and Environment Science Data Center ( <a href="http://www.resdc.cn">http://www.resdc.cn</a> ) DEM data of Shiyang River in 2000 (SRTM 30m)
River and other basic data	National Geographics Center of China ( <a href="http://www.ngcc.cn/ngcc/">www.ngcc.cn/ngcc/</a> ) China Surface Climatological Data Dataset V3.0 ( <a href="https://data.cma.cn/">https://data.cma.cn/</a> )
Temperature data	Extract daily maximum and minimum temperatures data for NYSK, WW, MY, and WSL from 1985 to 2016 according to latitude and longitude
Relative Humidity data	CFSR Global Weather Data ( <a href="https://swat.tamu.edu/data/cfsr">https://swat.tamu.edu/data/cfsr</a> )
Solar Radiation data	Daily data
Wind Speed data	

**Note:** All data were extracted using masking, projected transformations, and resampling procedures. The projection coordinate system utilized was GCS\_WGS\_1984, with a spatial resolution of 30 m × 30 m.

## Test S3: References

1. Janjić, J.; Tadić, L. Fields of application of SWAT hydrological model—a review. *Earth* **2023**, *4*(2), 331-344.
2. Zhang, Z.; Wang, Q.; Guan, Q.; Xiao, X.; Mi, J.; Lv, S. Research on the optimal allocation of agricultural water and soil resources in the Heihe River Basin based on SWAT and intelligent optimization. *Agric. Water Manage.* **2023**, *279*, 108177.