



Supplement of

Machine-learning-constrained projection of bivariate hydrological drought magnitudes and socioeconomic risks over China

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Table S1. Classification of drought and threshold values of the drought events. Two drought indexes, TWSA-DSI and SRI, both follow this classification.

Drought Classes	Drought Index (DI)
No Drought	DI>-0.5
Mild Drought	-1.0< DI≤-0.5
Moderate Drought	-1.5< DI≤-1.0
Severe Drought	-2.0< DI≤-1.5
Extreme Drought	DI≤-2.0

Table S2. Seven candidate distributions to the marginal distributions of drought duration and severity.

Candidate distributions	Probability density functions
Gamma	$f(x) = \frac{x^{\alpha-1}}{\beta^\alpha \Gamma(\alpha)} e^{-\frac{x}{\beta}}$
Generalized Extreme Value	$f(x) = \exp\left\{-\left[1 + \gamma\left(\frac{x-\mu}{\sigma}\right)\right]^{-\frac{1}{\gamma}}\right\}$
Inverse Gaussian	$f(x) = \frac{\sqrt{\lambda}}{\sqrt{2\pi x^3}} \exp\left\{-\frac{\lambda(x-\mu)^2}{2\mu^2 x}\right\}$
Log-normal	$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left\{-\frac{(\ln x - \mu)^2}{2\sigma^2}\right\}$
Normal	$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\}$
Pearson type-III	$f(x) = \frac{\beta^\alpha}{\Gamma(\alpha)} (x - a_0)^{\alpha-1} e^{-\beta(x-a_0)}$
Weibull	$f(x) = \frac{k}{\lambda} \left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^k}$

Table S3. Affiliation of acronyms and their full names in this study.

	Acronyms	Full names
Drivers	CMIP6	Coupled Model Intercomparison Project phase Six
	SSP	Shared Socioeconomic Pathways
	ISIMIP3b	Intersectoral Impact Model Intercomparison Project 3b
	GCM	Global Climate Model
	ECMWF	European Center for Medium Weather Forecasting

	ERA5	Fifth generation ECMWF Atmospheric Reanalysis of the global climate
Meteorological variables	<i>RH</i>	Relative Humidity
	<i>SH</i>	Specific Humidity
	<i>ps</i>	Near surface air pressure
	<i>pr</i>	Precipitation
	<i>srsds</i>	Surface Downwelling Shortwave Radiation
	<i>srlsds</i>	Surface Downwelling Longwave Radiation
	<i>T_{2m}</i>	2-meter Temperature
	<i>T_d</i>	Dew-point Temperature
Hydrological models	GR4J	Génie Rural à 4 paramètres Journalier
	HBV	Hydrologiska Byråns Vattenbalansavdelning
	HMETS	Hydrological Model of École de Technologie Supérieure
	SIMHYD	Simple lumped conceptual daily rainfall-runoff
	XAJ	Xinjiang
Statistical & Machine learning methods	SCE-UA	Shuffled Complex Evolution
	BIC	Bayesian Information Criterion
	MANOVA	Multivariate Analysis of Variance
	RNN	Recurrent Neural Network
	LSTM	Long Short-Term Memory neural network
	RM	Random Forest
	HTM	Hybrid Terrestrial Model
Supporting test data	GRACE	Gravity Recovery and Climate Experiment
	GRACE-FO	GRACE Follow-On
	TWS	Terrestrial Water Storage
Statistical indicators	KGE	Kling-Gupta Efficiency
	JRP	Joint Return Period
Drought indicators	SRI	Standardized Runoff Index
	TWS-DSI	TWS based Drought Severity Index