Using Film-Mulched Drip Irrigation to Improve the Irrigation Water Productivity of Cotton in the Tarim River Basin, Central Asia

Jianyu Zhu [1,2], Yaning Chen [1,*], Zhi Li [1], Weili Duan [1], Gonghuan Fang [1], Chuan Wang [1,2], Ganchang He [1,2] and Wei Wei [1,2]

[1] State Key Laboratory of Desert and Oasis Ecology, Key Laboratory of Ecological Safety and Sustainable Development in Arid Lands, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China
[2] University of Chinese Academy of Sciences, Beijing 100049, China
* Correspondence: chenyn@ms.xjb.ac.cn

Supplementary Table S1 Fifteen global climate models (GCMs) used in the study.

Number	Model name	Realizations
1	ACCESS-ESM2	ri1p1f1
2	ACCESS-ESM1-5	ri1p1f1
3	CMCC- ESM2	ri1p1f1
4	EC-Earth3	ri1p1f1
5	FGOALS-g3	ri1p1f1
6	GFDL-ESM4	ri1p1f1
7	INM-CM5-0	ri1p1f1
8	IPSL-CM6A-LR	ri1p1f1
9	KACE-1-0-G	ri1p1f1
10	MIROC6	ri1p1f1
11	MPI-ESM1-2-LR	ri1p1f1
12	MRI-ESM2-0	ri1p1f1
13	NorESM2-MM	ri1p1f1
14	TaiRSM1	ri1p1f1
15	UKESM1-0-LL	ri1p1f2

Supplementary Table S2 Range of crop parameters used in crop model calibration.

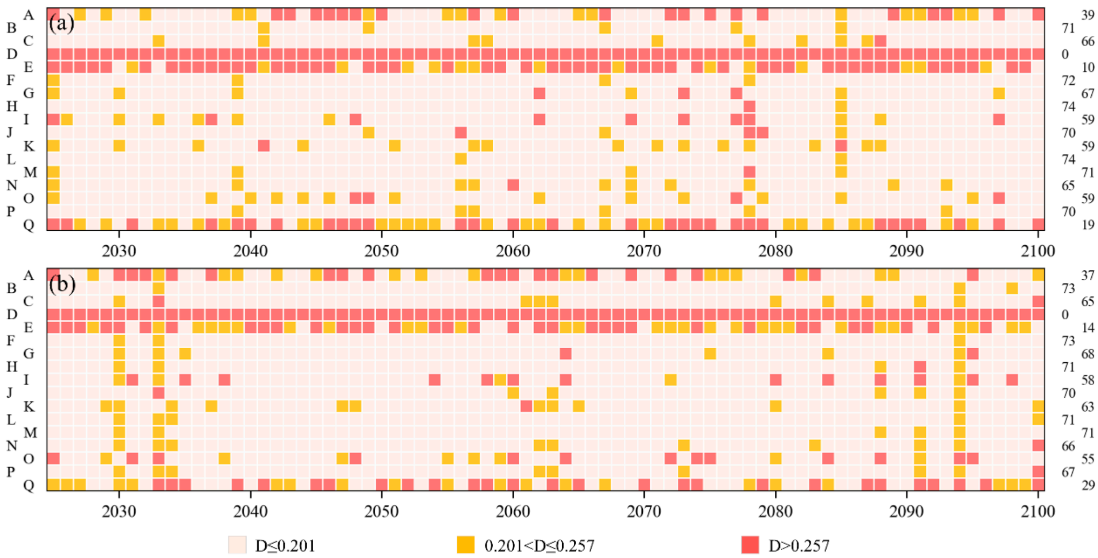
Parameters	Range
Plant density (plants ha^{-2})	60000 - 150000
CC_X (%)	85% - 100%
Canopy growth coefficient (CGC)	0.002 - 0.003
Canopy decline coefficient (CDC)	0.006 - 0.008
HI0 (%)	25% - 40%

Supplementary Table S3 Interpolation methods used in the study and its main parameters.

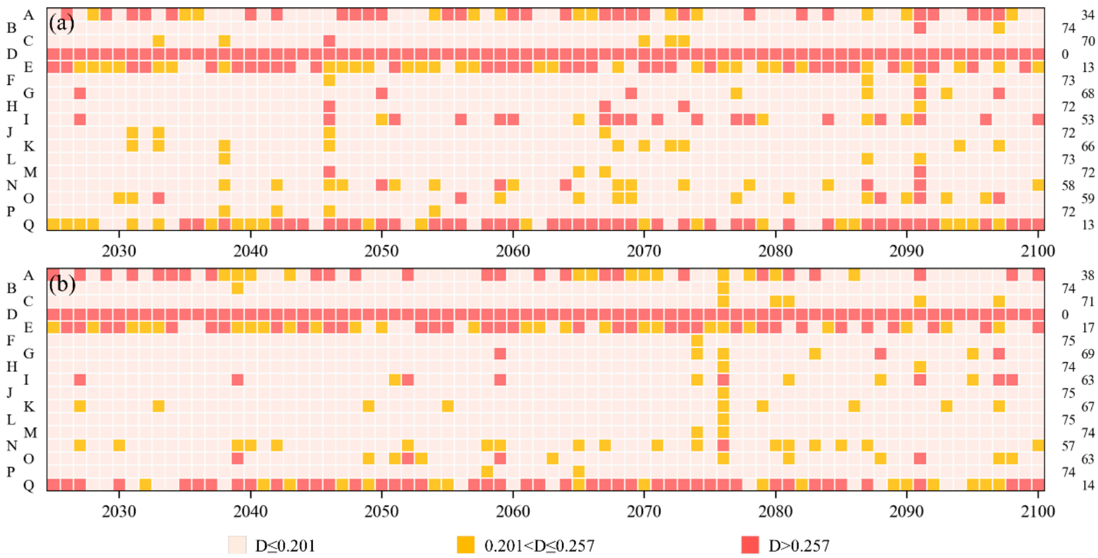
Interpolation Method	Interpolation Main Parameter	
	Main Parameter	parameter values
Global Polynomial Interpolation	Power	1
		2
		3
Inverse Distance Weighting	Power	1
		2
		3
		4
		5
Local Polynomial Interpolation	Power	1
		2
Empirical Bayesian Kriging	Semivariogram model type	Power
		Linear
		Thin plate spline
Ordinary kriging	Semivariogram props	Spherical
		Circular
		Exponential
		Gaussian
		Linear
Universal kriging	Semivariogram props	Linear drift
		Quadratic drift
Radial Basis Functions	Radial Basis Functions	Thin Plate Spline
		Spline With Tension
		Completely Regularized Spline
		Multiquadric Function
		Inverse Multiquadric Function
Spline	Spline Type	Regularized
		Tension

Supplementary Table D4 Seventeen theoretical distributions used in the study.

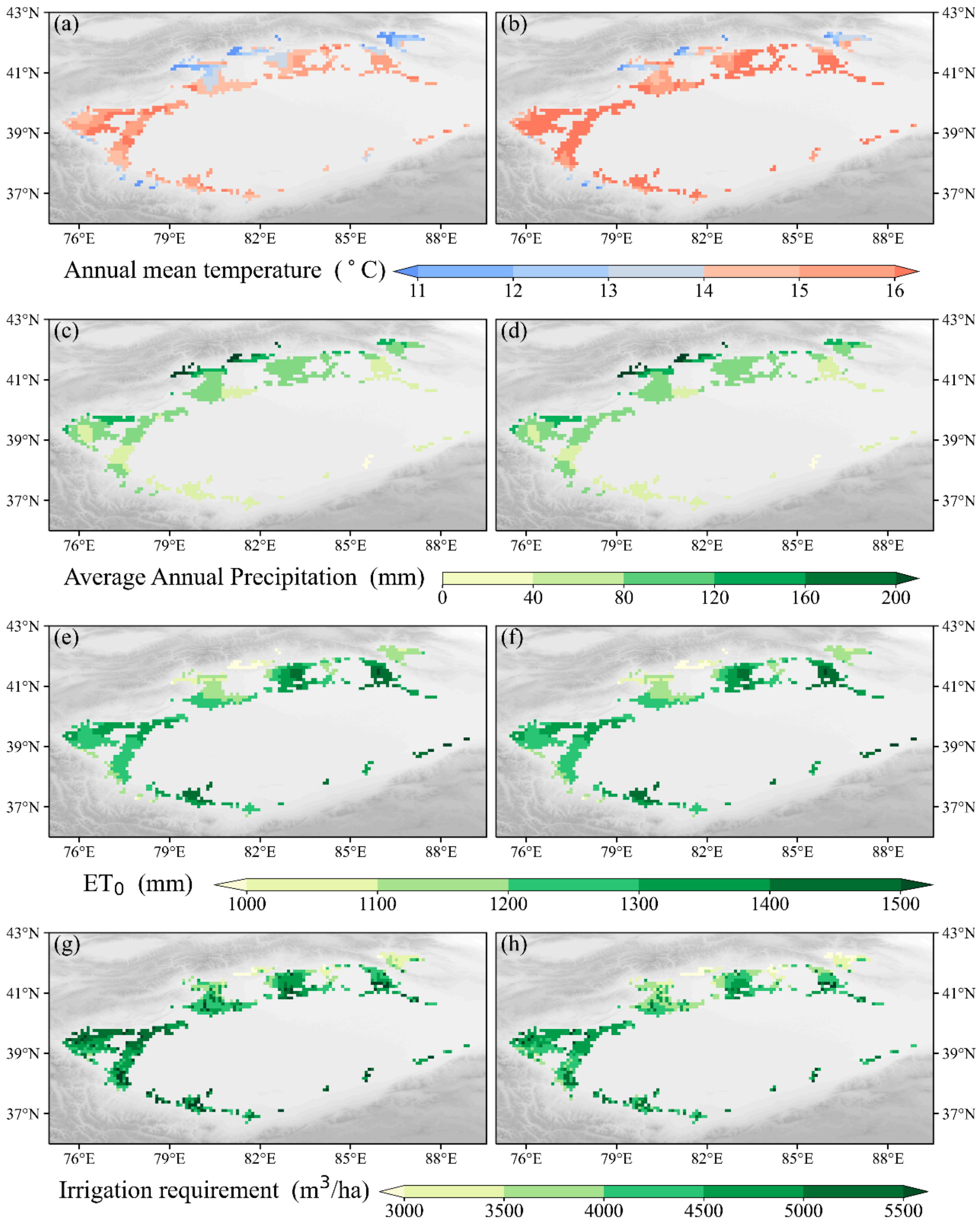
theoretical distribution	The probability density function
Beta	$f(x,a,b)=\frac{\Gamma(a+b)x^{a-1}(1-x)^{b-1}}{\Gamma(a)\Gamma(b)}$
Burr Type XII	$f(x;c,d)=cd\frac{x^{c-1}}{(1+x^{c})^{d+1}}$
Cauchy	$f(x)=\frac{1}{\pi(1+x^{2})}$
Chi-squared	$f(x,k)=\frac{1}{2^{k/2}\Gamma(k/2)}x^{k/2-1}\exp(-x/2)$
Exponential	$f(x)=\exp(-x)$
Exponentially modified Gaussian	$f(x,K)=\frac{1}{2K}\exp(\frac{1}{2K^{2}}-x/K)\mathrm{erfc}(-\frac{x-1/K}{\sqrt{2}})$
f	$f(x,df_1,df_2)=\frac{df_2^{df_1/2}df_1^{df_1/2}x^{df_1/2-1}}{(df_2+df_1x)^{(df_1+df_2)/2}B(df_1/2,df_2/2)}$
log-logistic	$f(x,c)=\frac{cx^{c-1}}{(1+x^{c})^{2}}$
Gamma	$f(x,a)=\frac{x^{a-1}e^{-x}}{\Gamma(a)}$
Johnson's SU	$f(x,a,b)=\frac{b}{\sqrt{x^{2}+1}}\phi(a+b\log(x+\sqrt{x^{2}+1}))$
Laplace	$f(x)=\frac{1}{2}\exp(-\mid x\mid)$
Logistic	$f(x)=\frac{\exp(-x)}{(1+\exp(-x))^{2}}$
log-normal	$f(x,s)=\frac{1}{sx\sqrt{2\pi}}\exp(-\frac{\log^{2}(x)}{2s^{2}})$
Gaussian	$f(x)=\frac{\exp(-x^{2}/2)}{\sqrt{2\pi}}$
The Pearson type III	$f(x,\kappa)=\frac{\mid\beta\mid}{\Gamma(\alpha)}(\beta(x-\zeta))^{\alpha-1}\exp(-\beta(x-\zeta))$
Student's t	$f(x,\nu)=\frac{\Gamma((\nu+1)/2)}{\sqrt{\pi\nu}\Gamma(\nu/2)}(1+x^{2}/\nu)^{-(\nu+1)/2}$
continuous uniform	$f(x)=\frac{1}{b-a},a<x<b$



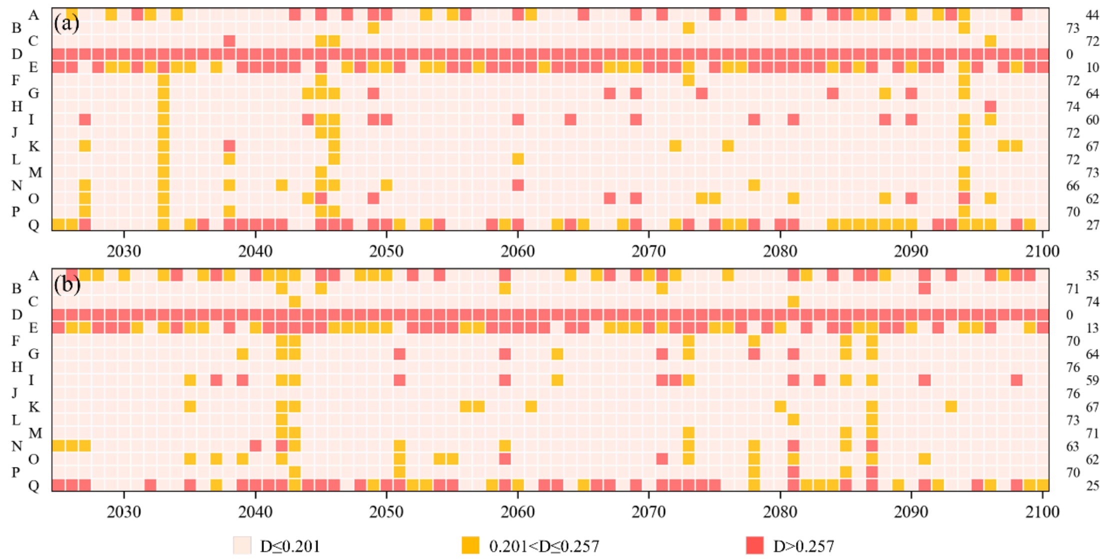
Supplementary Fig. S1. Results of the Kolmogorov-Smirnov test for yield multi-model ensembles under different climate scenarios. (a) SSP245. (b) SSP585. The letters A-Q on the left indicate beta distribution, Burr Type XII distribution, Cauchy distribution, Chi-squared distribution, exponential distribution, exponentially modified Gaussian distribution, f distribution, log-logistic distribution, gamma distribution, su-Johnson's SU distribution, Laplace distribution, logistic distribution, log-normal distribution, Gaussian distribution, Pearson type III distribution, Student's t distribution, and uniform distribution, respectively. The numbers on the right indicate the number of years that met the $\alpha = 0.1$ condition for each distribution when tested. D≤0.201 and 0.201 < D≤0.257 denote that the significance level of $\alpha = 0.1$ and $\alpha = 0.01$, respectively, was met, while D>0.257 indicates that the significance level of $\alpha = 0.01$ was not met. Each test includes the area-weighted average of all pixels in the same year of the 15 models.



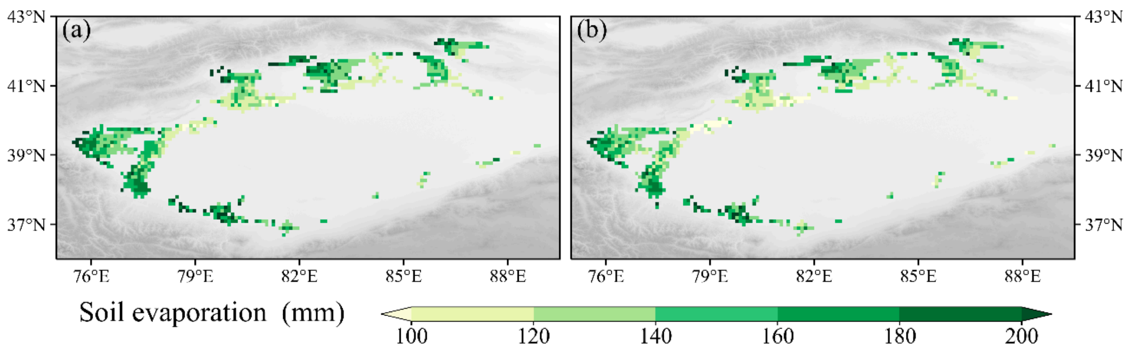
Supplementary Fig. S2. Results of the Kolmogorov-Smirnov test for irrigation water productivity multi-model ensembles under different climate scenarios. (a) SSP245. (b) SSP585. The letters A-Q on the left indicate beta distribution, Burr Type XII distribution, Cauchy distribution, Chi-squared distribution, exponential distribution, exponentially modified Gaussian distribution, f distribution, log-logistic distribution, gamma distribution, su-Johnson's SU distribution, Laplace distribution, logistic distribution, log-normal distribution, Gaussian distribution, Pearson type III distribution, Student's t distribution, and uniform distribution, respectively. The numbers on the right indicate the number of years that met the $\alpha = 0.1$ condition for each distribution when tested. D≤0.201 and 0.201 < D≤0.257 indicate that the significance level of $\alpha = 0.1$ and $\alpha = 0.01$, respectively, was met, while D>0.257 indicates that the significance level of $\alpha = 0.01$ was not met. Each test includes the area-weighted average of all pixels in the same year of the 15 models.



Supplementary Fig. S3. Annual average temperature, annual precipitation, annual reference evapotranspiration, and annual irrigation requirement under flood irrigation conditions in the Tarim River Basin (2025-2100) for different climate change scenarios. (a), (c), (e), and (g) represent the SSP245 scenario, while (b), (d), (f), and (h) represent the SSP585 scenario. (a) and (b) show the annual average temperature, (c) and (d) show the annual precipitation, (e) and (f) show the annual reference evapotranspiration, and (g) and (h) show the annual irrigation requirement under flood irrigation conditions.



Supplementary Fig. S4. Results of the Kolmogorov-Smirnov test for irrigation water productivity multi-model ensembles under different climate scenarios for film-mulched drip irrigation. (a) SSP245. (b) SSP585. The letters A-Q on the left indicate beta distribution, Burr Type XII distribution, Cauchy distribution, Chi-squared distribution, exponential distribution, exponentially modified Gaussian distribution, f distribution, log-logistic distribution, gamma distribution, su-Johnson's SU distribution, Laplace distribution, logistic distribution, log-normal distribution, Gaussian distribution, Pearson type III distribution, Student's t distribution, and uniform distribution, respectively. The numbers on the right indicate the number of years that met the $\alpha = 0.1$ condition for each distribution when tested. D≤0.201 and 0.201 < D≤0.257 indicate that the significance level of $\alpha = 0.1$ and $\alpha = 0.01$, respectively, was, met, while D>0.257 indicates that the significance level of $\alpha = 0.01$ was not met. Each test includes the area-weighted average of all pixels in the same year of the 15 models.



Supplementary Fig. S5. Spatial distribution of soil evaporation for different climate scenarios under flood irrigation. (a) SSP245. (b) SSP585.