Supplemental information

Constraints and potentials of future irrigation water availability on agricultural production under climate change

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Models

Table S1: GGCM models contributing the present analysis along with the primary contact for this work and institutional affiliation.

Crop model	Institution	# crops	Contact
pDSSAT	University of Chicago	4	Joshua Elliott
PEGASUS	University of East Anglia	3	Delphine Deryng
GEPIC	EAWAG	4	Christian Folberth
LPJmL	PIK	13	Christoph Müller
LPJ-GUESS	Lunds University	4	Stefan Olin
EPIC	Boku/ IIASA	15	Erwin Schmid

Table S2: GHM models contributing the present analysis along with the primary contact for this work and institutional affiliation.

Water model	Institution	PIrrUse?	Contact
LPJmL	PIK	Yes	Dieter Gerten/ Markus Konzman
VIC	Norwegian Water Resources and Energy Directorate	Yes	Ingjerd Haddeland
H08	National Institute for Environmental Studies Japan	Yes	Yoshimitsu Masaki
WaterGAP	Kassel University	Yes	Martina Flörke
MacPDM	University of Reading/ University of Nottingham	No	Simon N. Gosling
WBM	CUNY	Yes	Balazs Fekete
MPI-HM	Max-Plank-Inst. For Meteorology	Yes	Tobias Stacke
PCR-GLOBWB	Utrecht University	Yes	Yoshihide Wada
DBH	IGSNRR, China	No	Qihuong Tang
MATSIRO	University of Tokyo	No	Yusuke Satoh

Parameterizations of irrigation event algorithms

Most of the models participating use a method that can be summarized in terms of 4 parameters:

1. IMDEP: depth of soil moisture considered
2. ITHRL: critical lower soil moisture threshold to trigger irrigation event
3. ITHRU: upper soil moisture threshold to stop irrigation
4. IREFF: irrigation application efficiency

EPIC-type models use the following parameterization

1. BIR: water stress in crop to trigger automatic irrigation
2. EFI: irrigation efficiency - runoff from irrigation water
3. VIMX: maximum of annual irrigation volume
4. ARMX: maximum of single irrigation volume allowed
5. ARMN: minimum of single irrigation volume allowed

Table S3: Irrigation parameters for GGCMs.

Model	IMDEP (cm)	ITHRL (%)	ITHRU (%)	IREFF (%)
pDSSAT	40	80	100	75
pDSSAT (rice)	30	50	100	100
LPJmL	300[1]	90	100	Varies[2]
PEGASUS	40	90	100	100
LPJ-GUESS	200[1]	90	100	100

Table S4: Irrigation parameters for EPIC-based GGCMs.

Model	BIR (%)	EFI (%)	VIMX (mm)	ARMX (mm)	ARMN (mm)
EPIC	90	100	500	50	20
GEPIC	90	100	2000	1000	0.01

Estimating global PIrrUse from for all crops from GGCM outputs

For this analysis we consider 16 of the most important global crop types (including grass/pasture). Because of the extreme diversity of global agriculture however, it is not possible to include all crops that are important for irrigation in all regions. In total, the 16 crops simulated by at least one global crop model account for 85.5% of the global irrigated areas recorded in MIRCA2000. For the remaining crop-types, which are dominated by the general categories "Others annual" and "Others perennial," we assume areas equipped for irrigation demand irrigation according to the ***median*** irrigation demand among the seven simulated crops that constitute the highest total fraction of global irrigation (Fig. S1). Table S5 shows a detailed breakdown of the crops simulated, the number of models used to simulate each, and the fraction of global irrigated area in all MIRCA land-cover types (simulated or not).

Table S5: Fraction of global irrigated area (according to MIRCA 2000) in each of the simulated (by at least one global crop model) and non-simulated crop-types represented in MIRCA.

Simulated (# GGCMs)			Not simulated	
Rice	0.247	(5)	Other annual	0.061
Wheat	0.227	(6)	Other perennial	0.049
Maize	0.115	(6)	Potatoes	0.014
Cotton	0.062	(1)	Citrus	0.013
Fodder grasses	0.045	(2)	Vine	0.006
Sugar cane	0.039	(2)	Date palm	0.003
Soybeans	0.023	(6)	Rye	0.001
Pulses*	0.021	(2)	Coffee	0.001
Barley	0.017	(1)	Cocoa	0
Peanuts	0.014	(2)	Oil palm	0
Canola	0.013	(2)		
Sorghum	0.013	(1)		
Millet	0.007	(2)		
Sugar beet	0.006	(1)		
Sunflower	0.005	(2)		
Cassava	0	(2)		

* LPJmL simulates 'field pea' and EPIC simulates 'dry bean'; here we consider these both as representing general legumes

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[1] LPJ-type models use a root-access weighted mean soil moisture down to a depth of 3m.

[2] LPJmL uses country specific values for IREFF, ranging between 29.4% (e.g. Mexico, Pakistan, etc.) and 85.5% (e.g. Israel, Jordan etc.). These consist of a conveyance efficiency (transporting to the field) and a field application efficiency [cite http://www.pik-potsdam.de/research/publications/pikreports/summary-report-no-104].

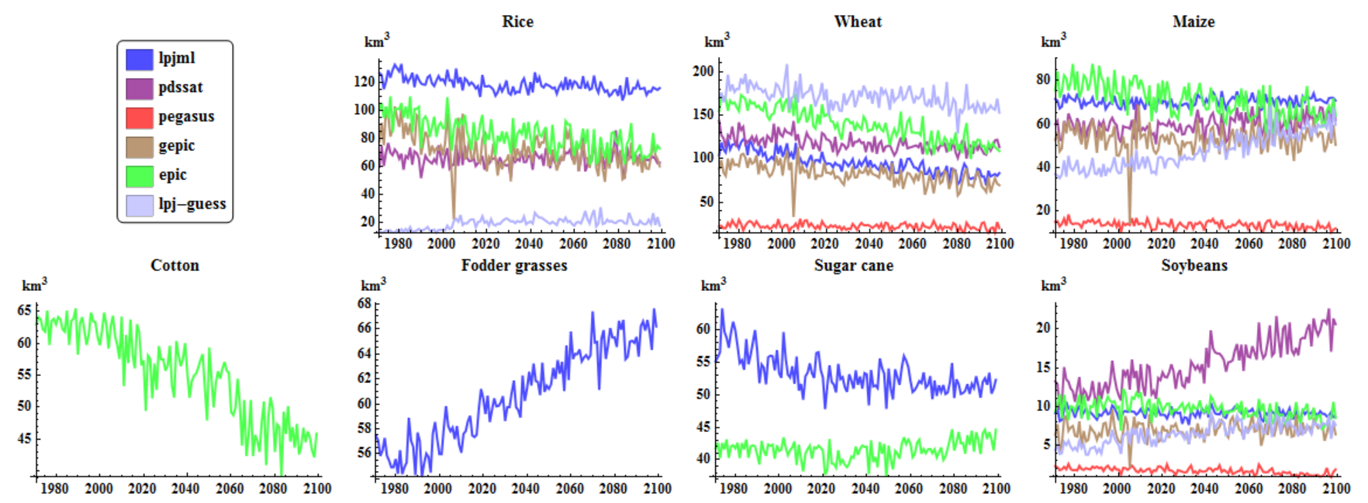

Figure S1: Global PIrrUse from 1971-2099 for the top 6 irrigated annual crops and perennial grasses. All six GGCMs are shown for HadGEM2-ES, RCP 8.5.

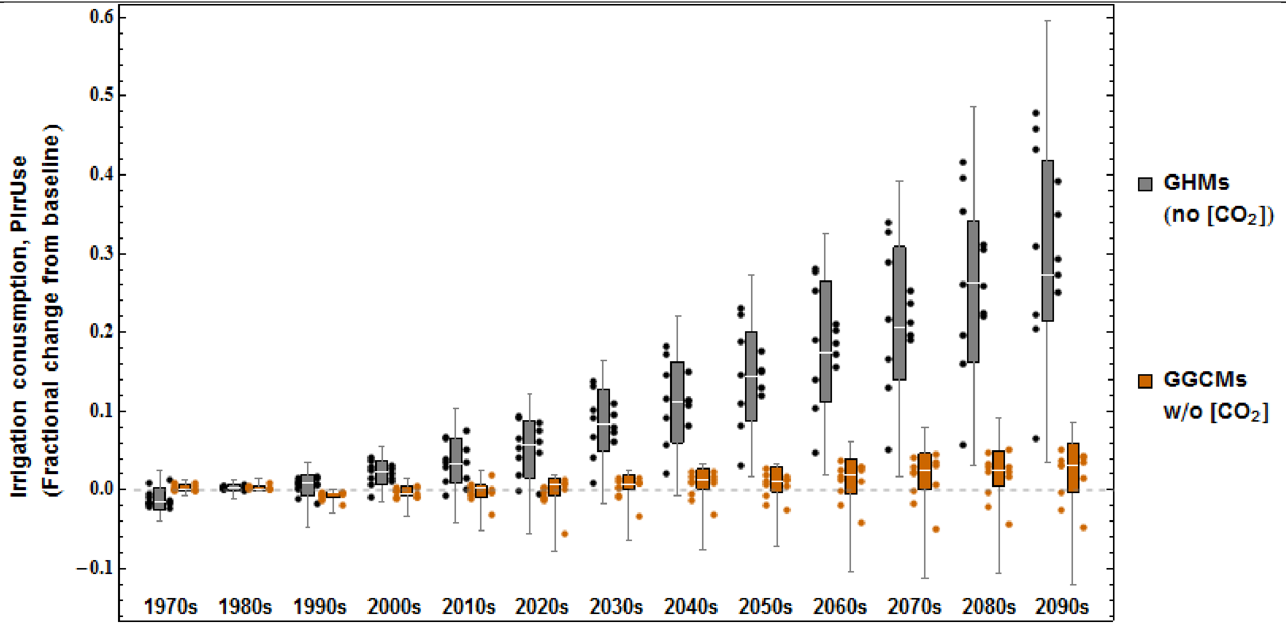

Figure S2: Partial reproduction of Figure 1 with results shown explicitly for each model type in the ensemble. Points to the left of each bar are results for each impact model (GHM or GGCM) averaged over all 5 GCMs. Points to the right of each bar are results for each GCM averaged over all impact models (GHM or GGCM). Variability in PIrrUse among GHMs is about twice as large as variability among GCMs, where the variability in estimates of PIrrUse from is comparable between GCMs and GGCMs.

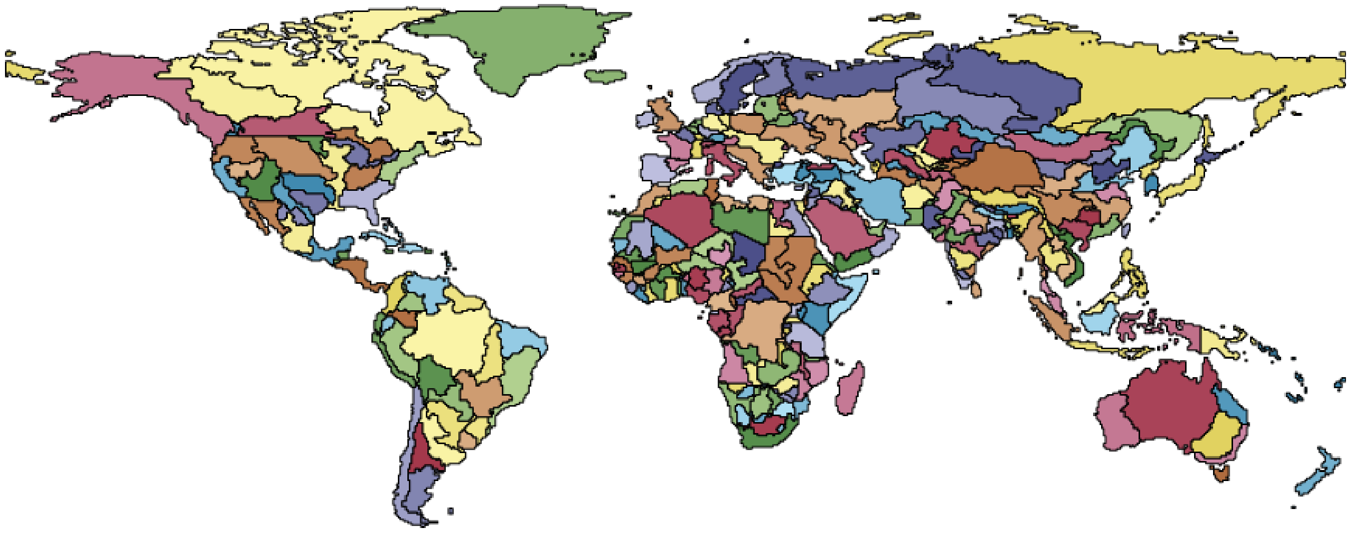

Figure S3: Map of 309 global food producing units (FPUs), composites of river basins and economic regions following Cai and Rosegrant (2002) with modifications by Kummu et al. (2010).

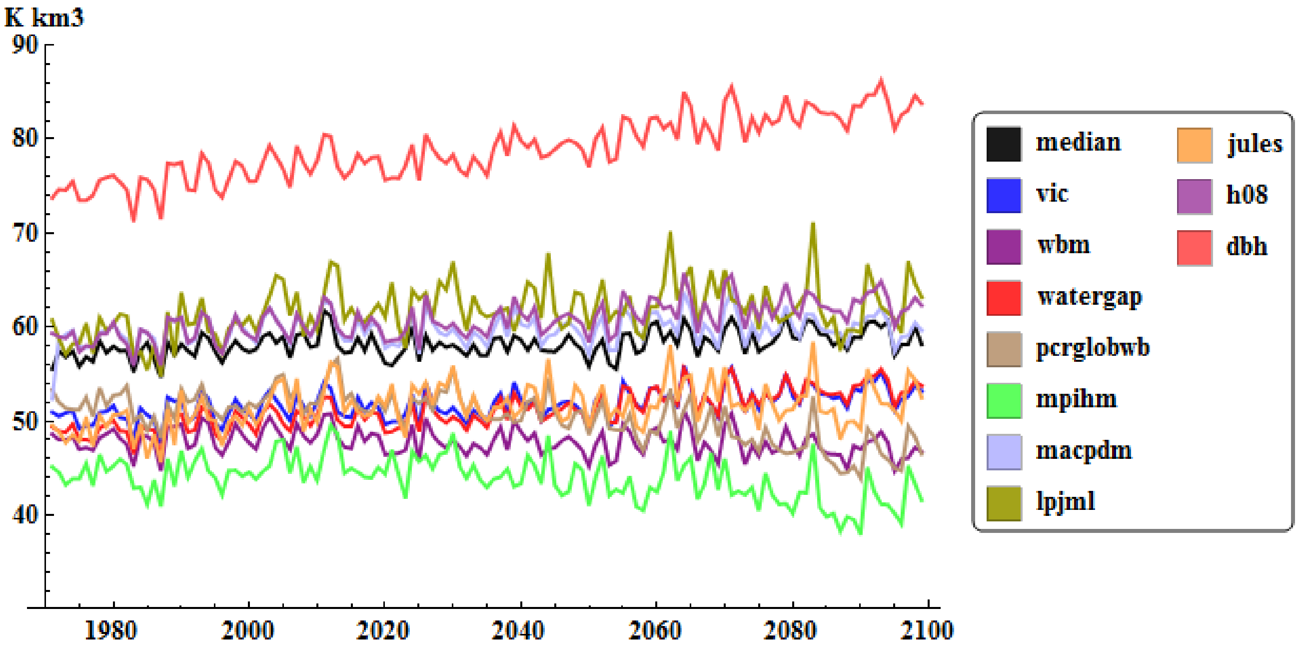

Fig S4: Global total blue water runoff from 11 water models averaged over all GCMs/ RCP8.5.

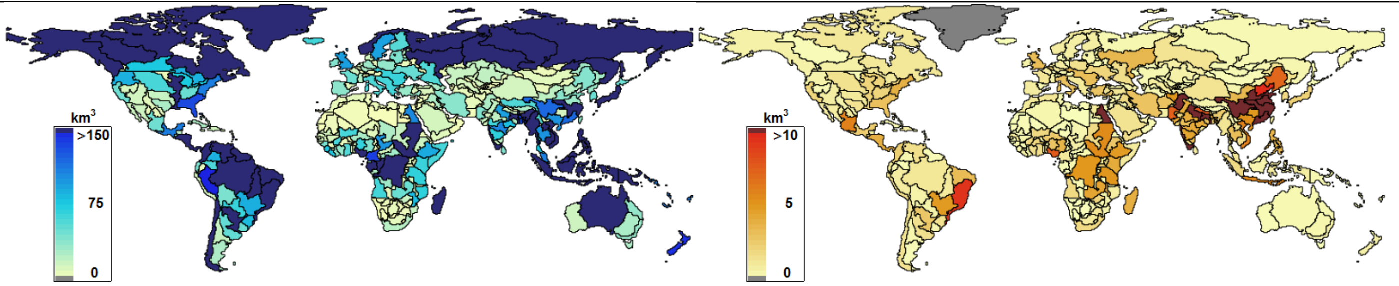

Figure S5: **Left:** end-of-century (2070-2099) renewable water available for human use (median of all GCM × GHM combinations) assuming 40% of available blue water runoff is potentially extractable for human use. **Right:** end-of-century demand for water for non-agricultural human uses, including domestic, industrial, energy generation, and livestock sector water demand under SSP2, as estimated by WaterGAP.

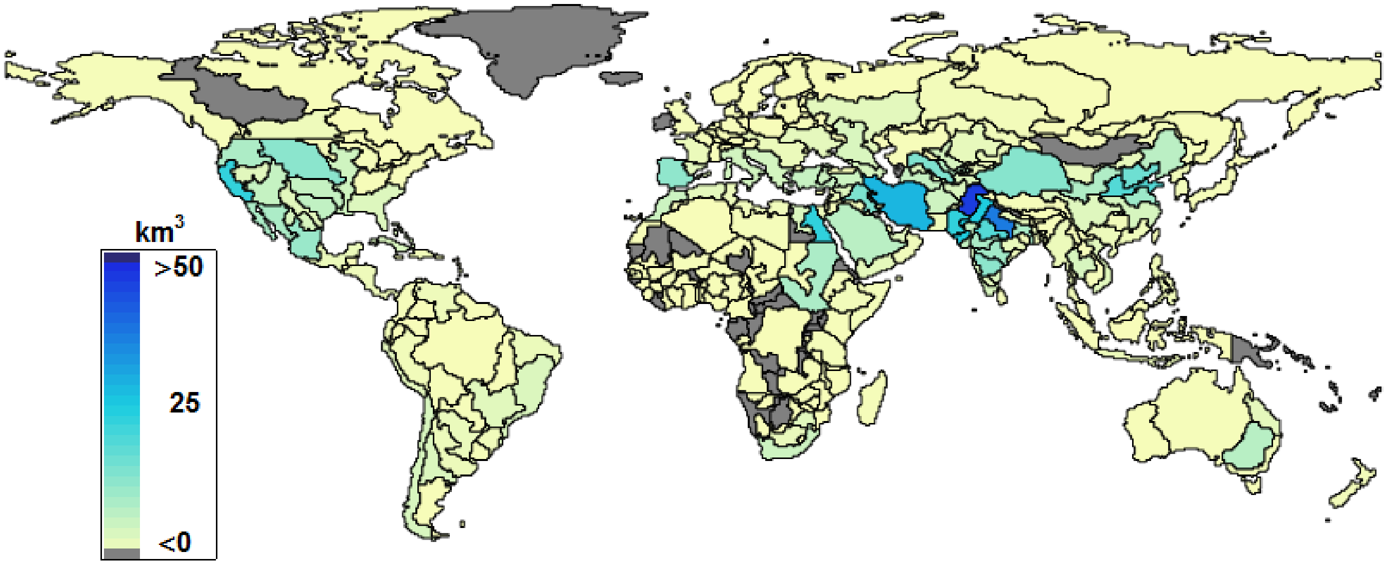

Fig S6: Total PIrrUse for each FPU for the median of all 30 GCM × GGCM combinations over the historical period, 1980-2010.

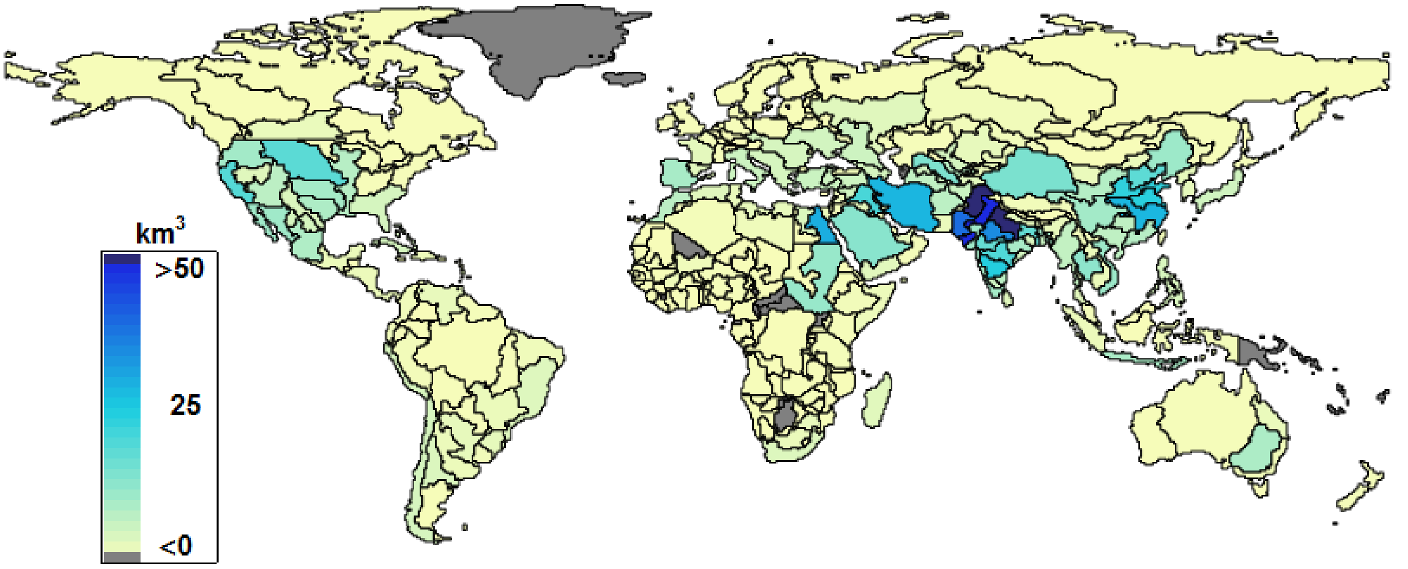

Fig S7: Total PIrrUse for each FPU for the median of all 35 GCM × GHM combinations over the historical period, 1980-2010.