Appendix for:

Implications of climate mitigation for future agricultural production

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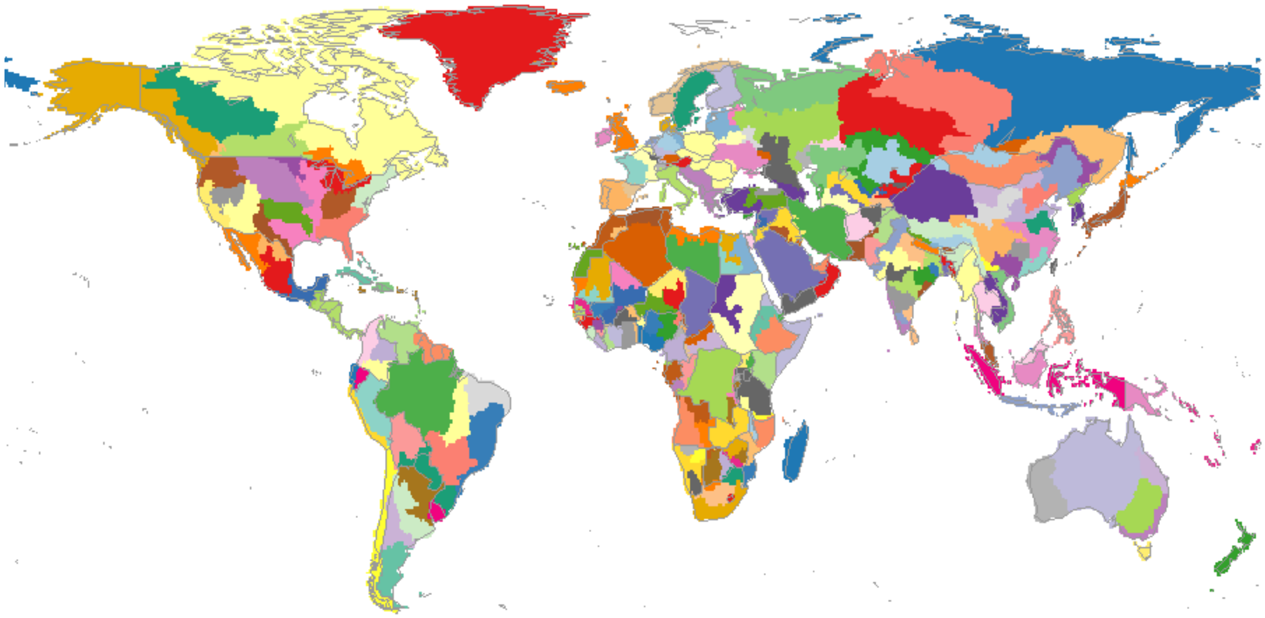

Figure S1: Spatial delineation of Food Production Units (FPU) for which climate change impacts are computed here. For aggregation of grid-specific crop yield simulations, we assume static cropland areas based on MIRCA2000 (Portmann *et al.*, 2010). Colors have no meaning but simply delineate the spatial units.

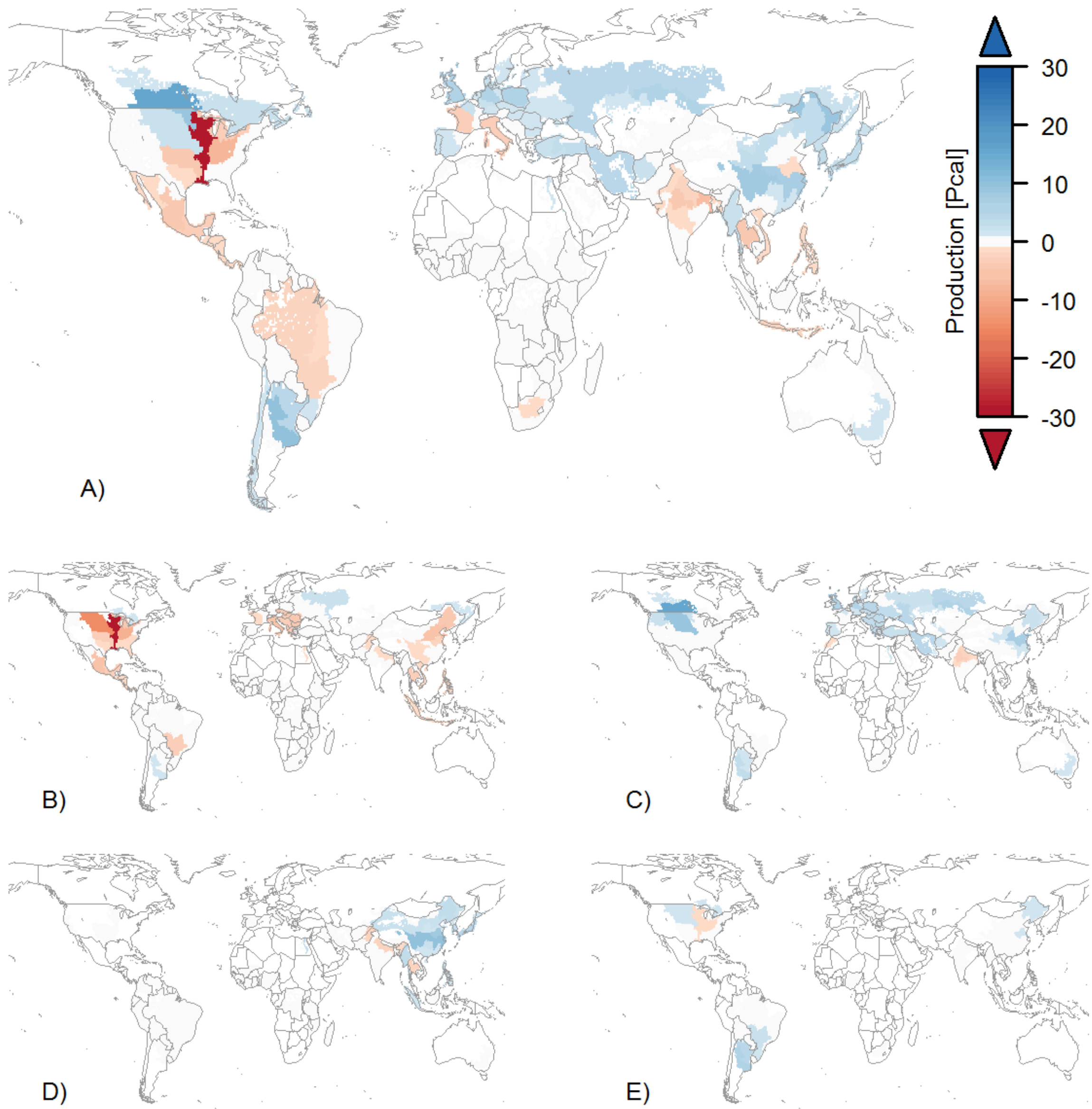

Figure S2: As figure 1 but for absolute changes in production (Pcal) per FPU.

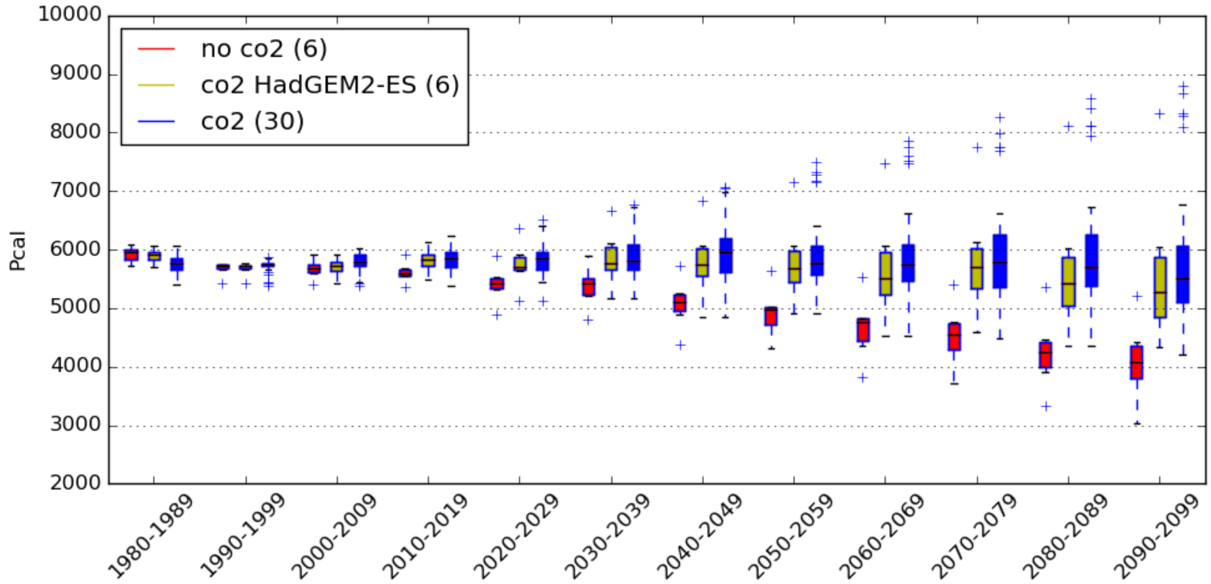

Figure S3: Total production of maize, wheat, rice and soy (measured in Pcal) for current cropland areas for RCP 8.5. Blue bars display the full GCMxGGCM ensemble for the assumption of fully effective CO_2 fertilization. Yellow bars are as the blue bars, but for one GCM (HadGEM2-ES) only. Red bars are as the yellow bars, but for the assumption of ineffective CO_2 fertilization. Bars display the interquartile range (IQR) and whiskers extend to the max/min of the ensemble, ignoring outlier points that lie further than 1.5 time IQR beyond the IQR Outliers are depicted as crosses. Positive outliers are from LPJ-GUESS which typically has the least strong climate change impact projections strongest response to CO_2 fertilization and negative outliers are typically from PEGASUS.

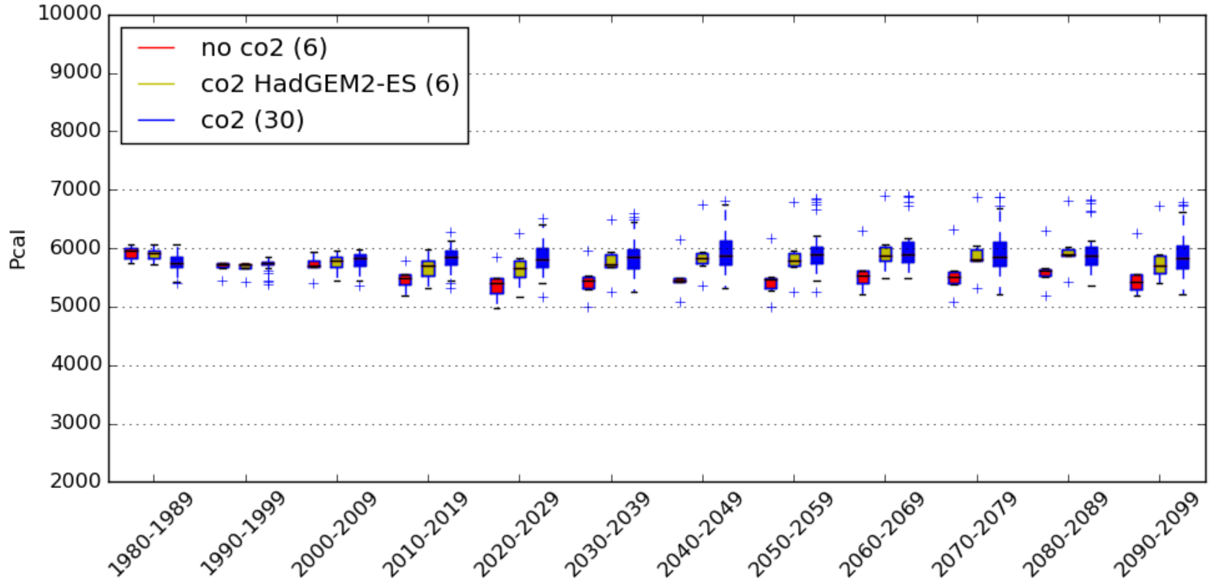

Figure S4: As figure S3 but for RCP 2.6.

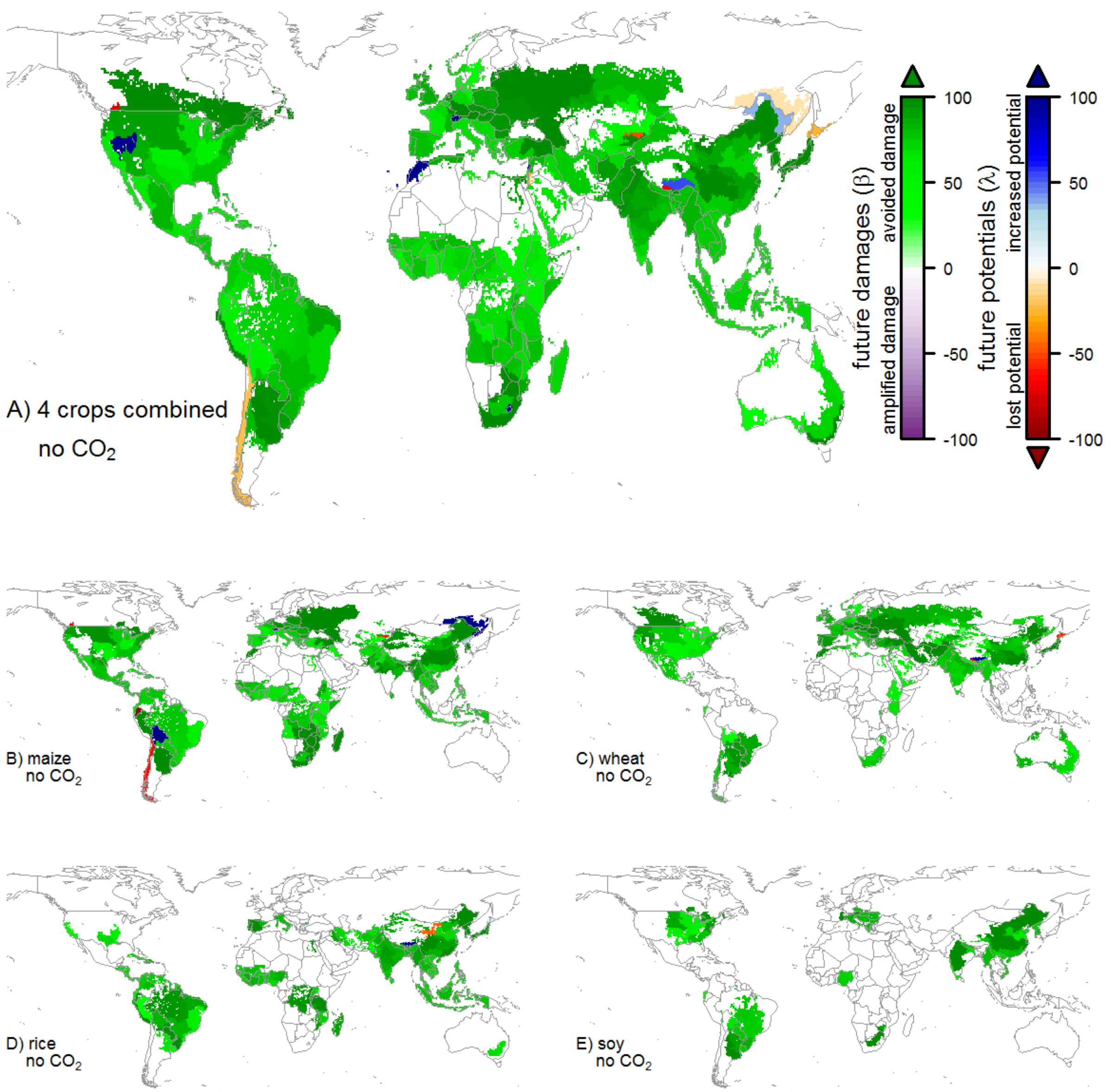

Figure S5: Effects of climate mitigation on agricultural productivity as in figure 3, but assuming no effectiveness of CO_2 fertilization. This figure is based on only one GCM (HadGEM2-ES) for limited data availability for the assumption of ineffective CO_2 fertilization. Green (avoided damages) and blue (gained potentials) areas profit from climate mitigation.

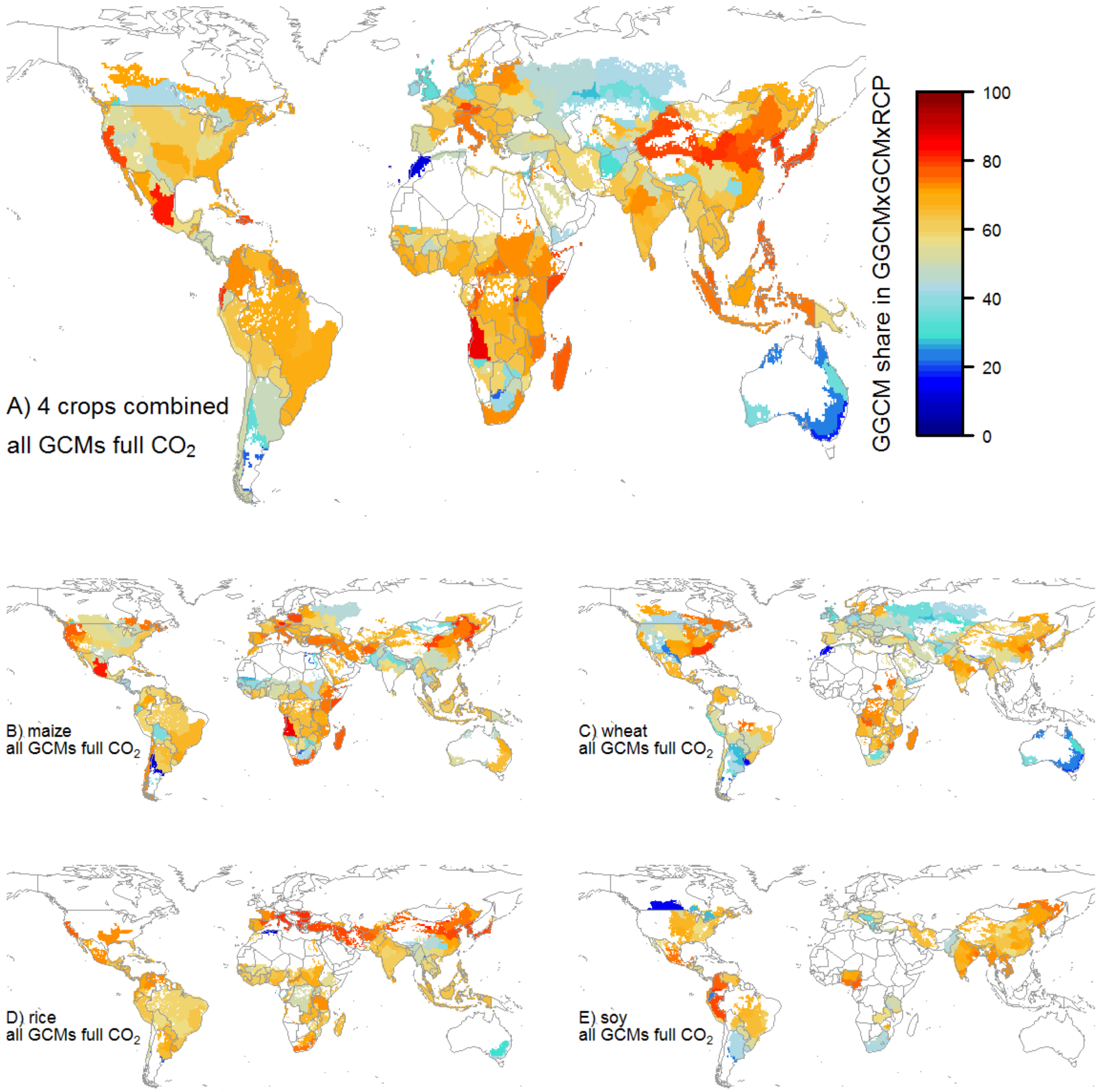

Figure S6: The share of GGCM-induced uncertainty per FPU in the full scenario ensemble assuming full CO_2 fertilization effectiveness (5 GCMs x 6 GGCMs x 2 RCPs) as also presented in Table S4 for the global aggregation. The CO_2-induced uncertainty is not included here, as this ensemble is only available for the assumption on full CO_2 fertilization effectiveness.

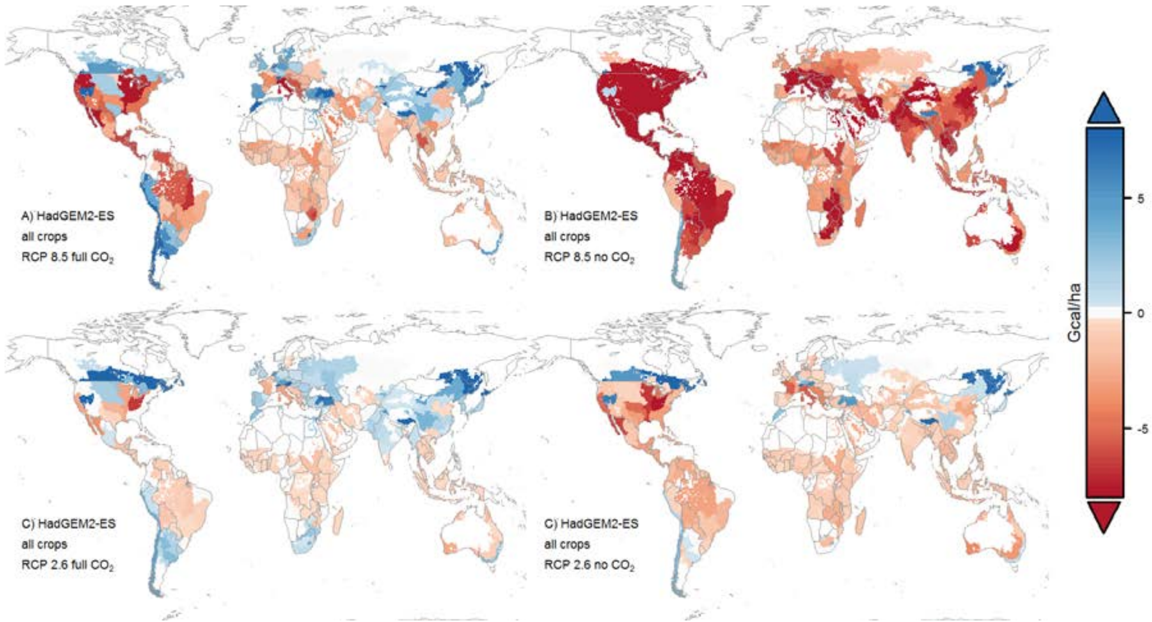

Figure S7: Effects of CO_2 fertilization on agricultural productivity for the median projection of all GGCMs for HadGEM2-ES only. Panel A corresponds to panel A in Figure 1 but is for HadGEM2-ES only, panel C corresponds to panel A in figure 2 but also for HadGEM2-ES only. The panels on the right (B, D) show the climate change impacts on agricultural productivity if CO_2 fertilization is assumed to be inefficient under RCP 8.5 (top) and RCP 2.6 (bottom). Values are computed at FPU level but are displayed only for regions currently cropped.

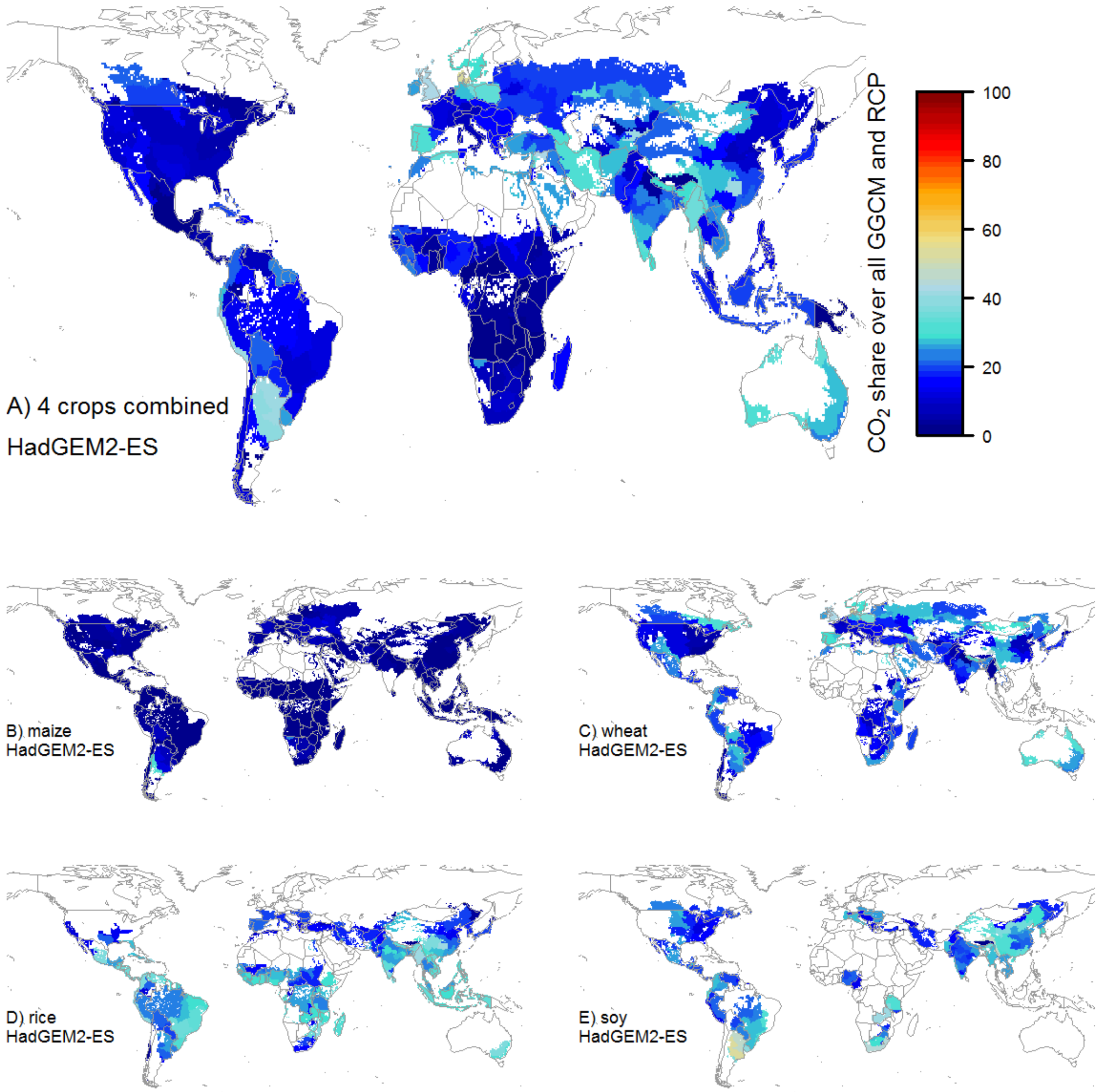

Figure 8: The share of CO_2-induced uncertainty per FPU in the HadGEM2-ES scenario ensemble (6 GGCMs x 2 RCPs x 2 CO_2) as also presented in Table S3 for the global aggregation. The GCM-induced uncertainty is not included here, as this ensemble is only available for HadGEM2-ES.

Table S1: Model characteristics and setup. Modified from (Rosenzweig *et al.*, 2014)

	EPIC	GEPIC	LPJ-GUESS	LPJmL	pDSSAT	PEGASUS
Type[1]	Site-based	Site-based	Ecosystem	Ecosystem	Site-based	Ecosystem
CO_2 effects[2]	RUE, TE	RUE, TE	LF, SC	LF, SC	RUE (for wheat, rice, maize) and LF (for soy)	RUE
Stresses[3]	W, T, H, A, N, P, BD, AL	W, T, H, A, N, P, BD, AL	W, T	W, T	W, T, H, A, N	W, T, H, N, P, K
Fertilizer application[4]	automatic N input (max 200 kg ha-1 yr-1) PK (national stat. IFA) dynamic application	NP (national stat: FertiSTAT), dynamic application	na	na	SPAM, dynamic application	NPK (national stat. IFA), annual application
Calibration	Site-specific (EPIC 0810)	Site-specific and global	Uncalibrated	Global	Site-specific (DSSAT)	Global
Parameters	Na	F HI_{pot} (for maize and rice)	na	LAImax HI αa	Na	β
Evaluation	(Izaurralde *et al.*, 2006; Schneider *et al.*, 2007; Balkovič *et al.*, 2013; Mitter *et al.*, 2015; Williams *et al.*, 1989)	(Liu *et al.*, 2007; Gaiser *et al.*, 2010; Folberth *et al.*, 2012; Izaurralde *et al.*, 2006; Liu, 2009)	(Bodin *et al.*, 2014; Lindeskog *et al.*, 2013)	(Bondeau *et al.*, 2007; Fader *et al.*, 2010; Waha *et al.*, 2013; Waha *et al.*, 2012)	(Jones *et al.*, 2003 and references therein; Glotter *et al.*, 2014)	(Deryng *et al.*, 2014; Deryng *et al.*, 2011)

Notes for abbreviations (na = not applicable)**:**

(1) site-base crop model; GAEZ: Global agro-ecological zones; ecosystem: global ecosystem model

(2) Elevated CO_2 effects: LF: Leaf-level photosynthesis (via rubisco or quantum-efficiency and leaf-photosynthesis saturation; RUE: Radiation use efficiency; TE: Transpiration efficiency; SC: stomatal conductance

(3) W: water stress; T: temperature stress; H: specific-heat stress; A: oxygen stress; N: nitrogen stress; P: phosphorus stress; K: potassium stress; BD: bulk density; AL: aluminum stress (based on pH and base saturation)

(4) Fertilizer application, timing of application; NPK annual application

Table S2: Models' key physiological process implementations. Modified from (Rosenzweig *et al.*, 2014)

Model	Leaf area developmen[1]	Light interception[2]	Light utilisation[3]	Yield formation[4]	Stresses involved[5]	Type of heat stress[6]	Crop phenology[7]	Type of water stress[8]	Evapo-transpiration[9]	Soil water dynamic[10]	Root distribution over depth[11]	Soil CN model[12]	CO_2 effects[13]	CO_2 levels[14]
EPIC	D	S	RUE	HI_{ws} Prt B	W T H A N P BD AL	V	T(HU) V O	E	PM	10	LIN W	C N B(1) P(6)	RUE, TE	380 ppm
GEPIC	D	S	RUE	HI_{ws} Prt B	W T H A N P BD AL	V	T(HU) V O	E	PM	5	LIN W	C N B(1) P(6)	RUE, TE	364 ppm
LPJ-GUESS	D	S	P-R	HI_{ws}	W T	NA	T V	E	PT	2	LIN	NA	LF, SC	379 ppm
LPJmL	PS	S	P-R	HI_{ws}	W T	NA	T V	E	PT	5	EXP	NA	LF, SC	370 ppm
pDSSAT	D	S ; Soy: D	RUE; soy: P-R	Gn	W T H A N	V R F	T V DL O	E	PT	4	EXP	C N P(3)	RUE, TE, soy: LF, TE	330 ppm
PEGASUS	D	S	RUE	Prt	W T H N P K	V F	T(HU)	E	PT	3	NON	NA	RUE TE	369 ppm

Notes for abbreviations (NA where not applicable)**:**

(1) D: Dynamic simulation based on development and growth processes; PS: prescribed shape of LAI curve as function of phenology, modified by water stress & low productivity

(2) S: Simple approach: D: Detailed approach

(3) RUE: Simple (descriptive) radiation use efficiency approach; P-R: Detailed (explanatory) gross photosynthesis – respiration

(4) Yield formation depending on: HI: fixed harvest – index; B: total (above – ground) biomass; Gn: number of grains and grain growth rate; Prt: partitioning during reproductive stages; HIws: HI modified by water stress

(5) W: water stress; T: temperature stress; H: specific-heat stress; A: oxygen stress; N: nitrogen stress; P: phosphorus stress; K: potassium stress; BD: bulk density; AL: aluminum stress (based on pH and base saturation)

(6) V: vegetative (source); R: reproductive organ (sink); F: number of grain (pod) set during the flowering period

(7) Crop phenology is a function of: T: temperature; DL: photoperiod (day length); O: other water/nutrient stress effects considered; V: vernalization; HU: Heat unit index

(8) E: ratio of supply to demand of water; S: soil available water in root zone

(9) PM: Penman – Monteith; PT: Priestley –Taylor

(10) number of soil layers

(11) LIN: linear; EXP: exponential; NON: no roots-just soil depth zone; W: actuals water depends on water availability in each soil layer

(12) C model; N model; P(x): x number of organic matter pools; B(x): x number of microbial biomass pools

(13) Elevated CO_2 effects: LF: Leaf-level photosynthesis (via rubisco or quantum-efficiency and leaf-photosynthesis saturation; RUE: Radiation use efficiency; TE: Transpiration efficiency; SC: stomatal conductance

(14) Concentration levels assumed for simulations with static [CO_2] for simulations with assumed ineffective CO_2 fertilization

Table S3. As Table 1 but across both assumptions on CO_2 fertilization effectiveness. The assumptions on CO_2 fertilization effectiveness is important for the overall uncertainty in results but typically depends on the RCP and the GGCM implementation and thus mainly shows in the cross-interaction terms with these.

	All crops	Maize	Wheat	Rice	Soy
CO_2 share [%]	23.8	5.2	43.2	27.5	33.5
GGCM share [%]	40.1	59.7	14.6	31.7	31.0
RCP share [%]	15.7	23.7	11.3	3.4	9.1
CO_2xRCP share [%]	8.1	1.6	15.0	10.1	10.8
GGCMxRCP share [%]	6.5	9.1	5.4	6.8	4.0
CO_2xGGCM share [%]	3.8	0.5	7.1	13.8	7.7
CO_2xRCPxGGCM share [%]	2.1	0.2	3.4	6.7	3.8
Standard Deviation [Pcal]	882	377	220	276	114

Table S4: ANOVA results for all GCMs, assuming full CO_2 fertilization, describing the shares of overall variance explained by the GCMs, GGCMs, the RCPs and their interaction in percent. The Standard Deviation [Pcal] indicates how variable projections are across RCPs, GCMs and GGCMs.

	All crops	Maize	Wheat	Rice	Soy
GCM share [%]	7.2	6.6	13.3	2.0	7.6
GGCM share [%]	71.7	62.9	59.6	72.0	70.7
RCP share [%]	0.0	9.5	3.9	4.1	1.3
GCMxRCP share [%]	2.4	2.2	4.7	0.9	1.8
GGCMxRCP share [%]	16.7	12.4	13.4	20.6	15.7
GCMxGGCM share [%]	1.6	5.0	2.9	0.4	2.4
GCMxRCPxGGCM share [%]	0.4	1.4	2.2	0.2	0.5
Standard Deviation [Pcal]	780	298	170	292	111

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