ELECTRONIC SUPPLEMENTS

LIST OF FIGURES AND TABLES IN THIS FILE
Figures S1 to S4
Tables S1 to S5

LITERATURE CITED

Shen Z., Kusano E, Chien H, Koyama O (2014) Predictive analysis of nitrogen balances resulting from the production and consumption of livestock products in the Huang-Huai-Hai region, China. Japan Agric Res Q 48:331–342.

Taylor KE, Stouffer RJ, Meehl GA (2012) An Overview of CMIP5 and the experiment design. Bull Amer Meteor Soc 93:485–498.

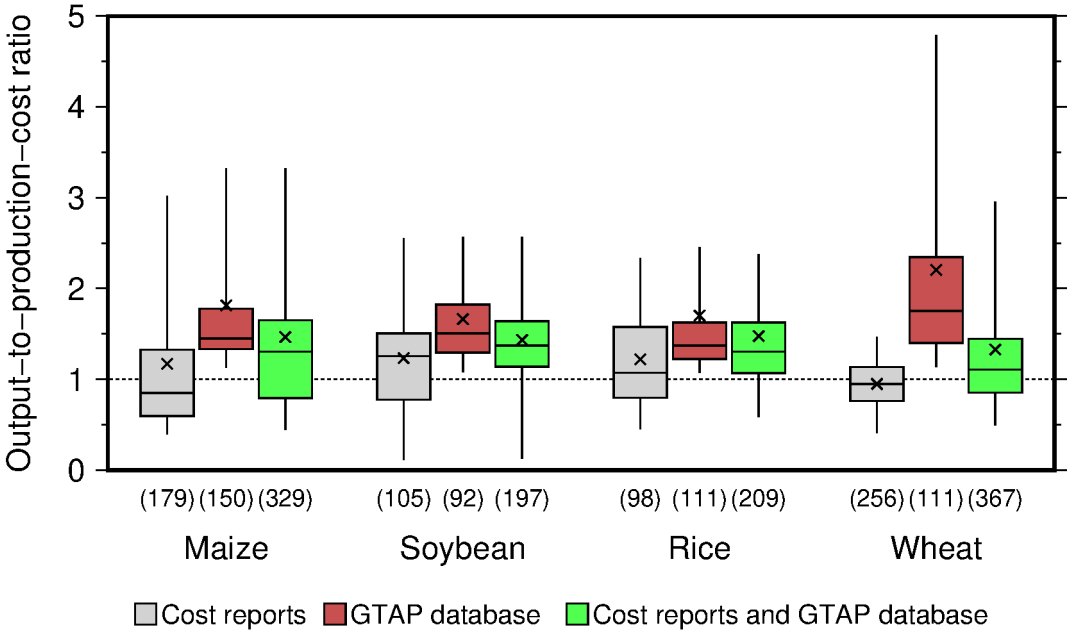

Fig. S1. The output-to-production-cost ratio calculated from the different data sets. Numbers in parentheses indicate the country-year samples. Box plots indicate the mean (cross), with the 25% to 75% (box) and 5% to 95% (vertical line) confidence intervals. The horizontal lines indicate the median. When the GTAP database reports production costs for a region, an identical regional value is commonly assigned to countries that are located within that region.

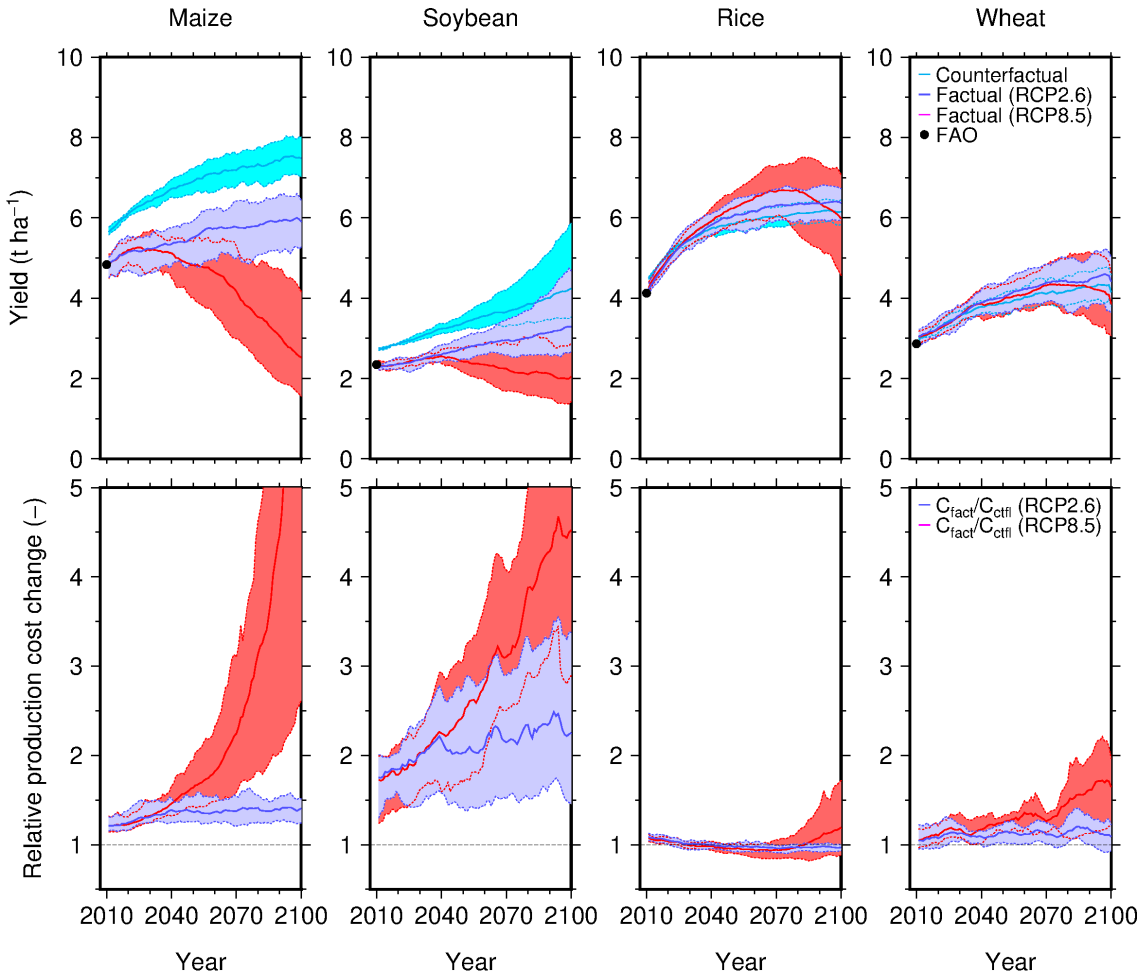

Fig. S2. Projected global decadal mean factual and counterfactual yields under the low (RCP2.6) and high (RCP8.5) emissions scenarios and associated changes in production cost relative to what would occur without climate change. For the relative production cost changes presented here (C_{fact}/C_{ctfl}), the maintenance of the current output-to-production-cost ratio was not considered for explanatory purposes. The solid lines indicate the ensemble mean, and the shaded areas with dotted lines denote the 90%-probability interval consisting of 50 scenarios (5 climate models × 5 socioeconomic scenarios × 2 production cost models (the cross-sectional and panel specifications)). In the upper panels, the black circles indicate the FAO-reported yields averaged over 2001–2010.

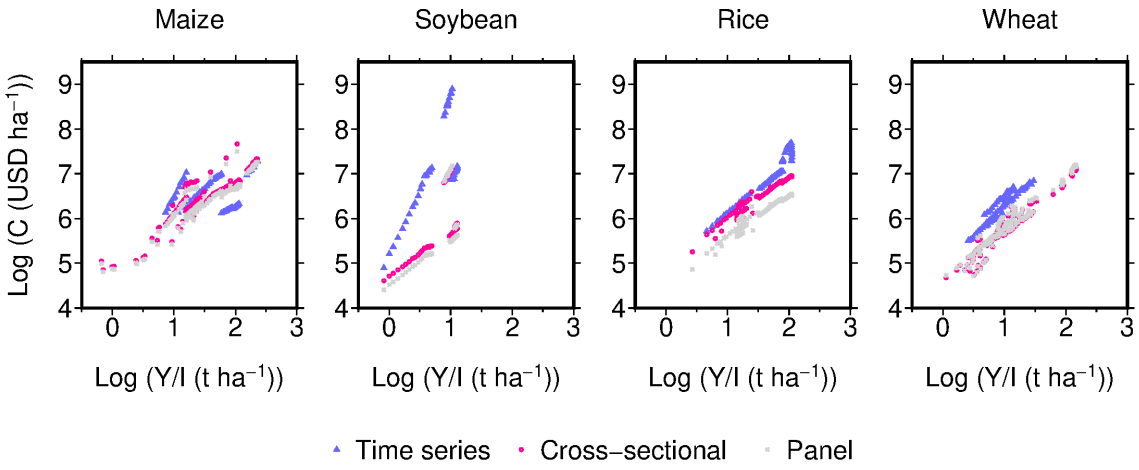

Fig. S3. The country decadal mean yield divided by the climate change impacts on yield used as the input to the production cost models (*Y*/*I* on the x-axis) and the country annual production cost simulated by the production cost model (*C* on the y-axis). The results from the time-series, cross-sectional and panel specifications for the countries where all three specifications are available are presented.

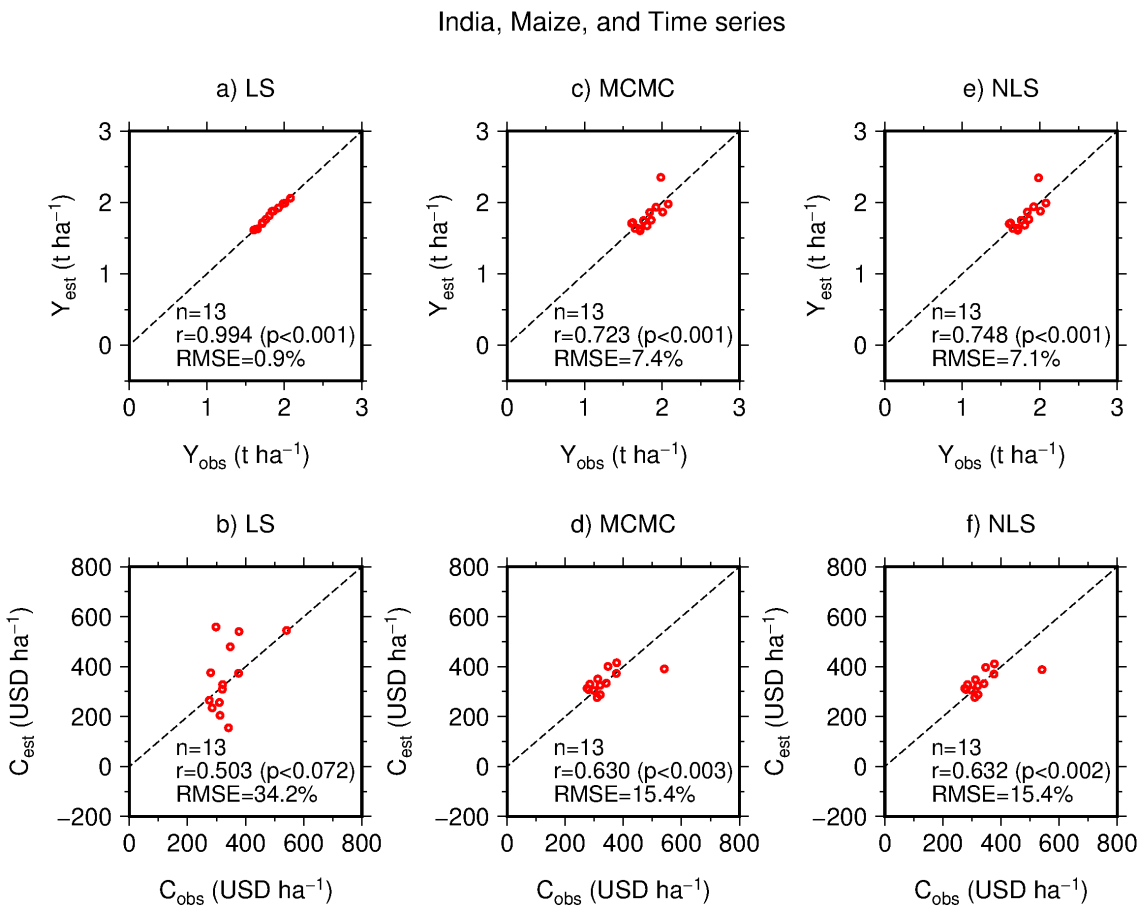

Fig. S4. The correspondence between the reported and reproduced yields and production costs for the three different calibration methods. LS denotes the least squares method; MCMC denotes the Markov-Chain Monte Carlo method; and NLS denotes the nonlinear least squares method. The sample size (n), correlation (r), p-value and root-mean-squared error normalized against the mean of the reported data (RMSE) are presented. The data presented here are taken from the time-series specification of the production cost model for maize in India for explanatory purposes.

Table S1. The country-crop combinations considered in this study.

Countries	Maize	Wheat	Rice	Soybean
Afghanistan		X		
Algeria		X		
Angola	X			
Argentina	X	X		X
Australia		X		
Bangladesh			X	
Brazil	X	X	X	X
Cambodia			X	
Canada	X	X		
China	X	X	X	X
Congo (Democratic Republic of)	X			
Egypt		X		
Ethiopia	X	X		
France	X	X		
Germany		X		
Ghana	X			
Hungary	X			
India	X	X	X	X
Indonesia	X		X	
Iran		X		
Iraq		X		
Italy		X		
Japan			X	
Kazakhstan		X		
Kenya	X			
Madagascar			X	
Malawi	X			
Mexico	X			
Morocco		X		
Mozambique	X			
Myanmar			X	
Nepal			X	
Nigeria	X		X	
Pakistan	X	X	X	
Philippines	X		X	
Poland		X		
Romania	X	X		
Russian Federation	X	X		
South Africa	X			
Spain		X		
Syrian		X		
Tanzania	X			
Thailand	X		X	
Turkey		X		
Uganda	X			
Ukraine	X	X		

United Kingdom		X		
United States	X	X	X	X
Uzbekistan		X		
Vietnam	X		X	
Zambia	X			
Zimbabwe	X			

Table S2. The sources of reported production costs for individual countries. The sample size indicates the number of years with effective data within the indicated period.

Crop	Country	Sample size	Period	Source(s)
Maize	Austria	2	2006-2007	b, c
	Brazil	11	2000-2010	l
	Bulgaria	1	2010-2010	b, c
	Canada	20	1991-2010	m
	China	20	1991-2010	d
	France	12	1999-2010	
	Greece	12	1999-2010	b, c
	Hungary	2	2006-2007	
	India	13	1998-2010	e, f
	Italy	12	1999-2010	b, c
	Nepal	13	1995-2010	i
	Philippines	7	2004-2010	g
	Poland	5	2006-2010	
	Portugal	12	1999-2010	b, c
	Slovak	4	2006-2010	
	Spain	12	1999-2010	
	United States	20	1991-2010	j
	Zambia	1	2010-2010	k
Soybean	Brazil	11	2000-2010	l
	Canada	17	1991-2007	m
	China	20	1991-2010	d
	India	13	1998-2010	e, f
	Japan	12	1999-2010	a
	Philippines	12	1999-2010	g
	United States	20	1991-2010	j
Rice	Brazil	7	2004-2010	l
	China	20	1991-2010	d
	India	13	1998-2010	e, f
	Japan	20	1991-2010	a
	Nepal	11	1996-2010	i
	Philippines	7	2004-2010	h
	United States	20	1991-2010	j
Wheat	Austria	1	2010-2010	b, c
	Brazil	11	2000-2010	l
	Bulgaria	2	2009-2010	b, c
	Canada	20	1991-2010	m
	China	20	1991-2010	d
	Czech	5	2006-2010	
	Denmark	12	1999-2010	
	Estonia	5	2006-2010	
	Finland	12	1999-2010	b, c
	France	12	1999-2010	
	Germany	12	1999-2010	
	Greece	12	1999-2010	

	Hungary	5	2006-2010	
	India	13	1998-2010	e, f
	Ireland	1	2010-2010	b, c
	Italy	12	1999-2010	
	Japan	12	1999-2010	a
	Latvia	5	2006-2010	b, c
	Lithuania	5	2006-2010	
	Nepal	11	1996-2010	i
	Poland	5	2006-2010	
	Romania	2	2009-2010	
	Slovak	5	2006-2010	b, c
	Spain	12	1999-2010	
	Sweden	12	1999-2010	
	United Kingdom	12	1999-2010	
	United States	20	1991-2010	j

Sources:

a. Ministry of Agriculture, Forestry and Fisheries, Agricultural Products Production Cost Statistics, http://www.maff.go.jp/j/tokei/kouhyou/noukei/seisanhi_nousan/
b. European Commission, EU Cereal Farms Economics – FADN Report 2008, http://ec.europa.eu/agriculture/rica/pdf/sa0202_cereals_2008.pdf
c. European Commission, EU Cereal Farms Report 2013 Based on FADN data, http://ec.europa.eu/agriculture/rica/pdf/cereal_report_2013_final.pdf
d. National Development and Reform Commission, National Agricultural Products Cost-Income Statistics Compilation [see Shen et al. (2014) for details]
e. Ministry of Agriculture, Cost of Cultivation of Principal Crops in India 2007 (1996-2003), https://eands.dacnet.nic.in/costofcultivation.pdf (accessed in 2016)
f. Ministry of Agriculture, Cost of Cultivation of Principal Crops in India 2014/15, http://mospi.nic.in/statistical-year-book-india/2014/177 (accessed in 2017)
g. CountrySTATA, Production Cost of Corn, and Soybean, http://countrystat.psa.gov.ph/selection.asp (Accessed in 2016)
h. CountrySTATA, Production Cost of Rice, http://countrystat.psa.gov.ph/?cont=10&pageid=1&ma=Q20CPCOP (Accessed in 2016)
i. Government of Nepal Ministry of Agriculture Development Department of Agriculture, Cost, Production and Price Spread of Cereal Crops in Nepal: A Time Series Analysis 2071/2072, http://mrsmp.gov.np/files/download/Cost,%20Production%20and%20Price%20Spread%20of%20Cereal%20Crops%20in%20Nepal-A%20Time%20Series%20Analysis%202072.pdf (accessed in 2017)
j. U.S. Department of Agriculture, Commodity Costs and Returns, http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx
k. MACO/CSO. 2010. Crop Forecast Survey, Jointly Implemented by the Ministry of Agriculture and Cooperatives and Central Statistical Office. Lusaka: Government of Zambia.
l. The National Supply Company (CONAB), Production Cost Estimated, https://www.conab.gov.br (accessed in 2016)
m. Statistics Canada, Agriculture Statistics Index, Historical Total Costs of Crop

Production, https://www.gov.mb.ca/agriculture/markets-and-statistics/statistics-tables/pubs/cop-incl-labour.pdf (accessed in 2016)

Note:
When per ton production cost value was reported, it was adjusted to be per hectare value by multiplying average yield. If average yield was not available within report, then the FAO country average yield was used instead. Values reported in local currency were converted into constant 2005 USD using the consumer price index and exchange rate obtained from International Monetary Fund (https://www.imf.org/external/np/ds/matrix.htm; accessed in 2016).

Table S3. The posterior distributions for the coefficients in the time-series, cross-sectional and panel specifications of the production cost model. The uniform prior distribution of (0, 1) for A, (0, 1) for α and (0.001, 2) for β were used. For the time-series model, only three countries where all four crops considered here are grown (China, India and the United States) are presented.

Crop	Production cost model type	Posterior average (90% credible interval)		
		A	α	β
Maize	Time series (China)	0.1668 (0.0102, 0.8401)	0.8605 (0.8206, 0.9582)	0.0576 (0.0117, 0.2457)
	Time series (India)	0.1917 (0.0106, 1.3105)	0.5836 (0.3664, 0.8095)	0.1592 (0.0153, 0.7633)
	Time series (United States)	0.0344 (0.0110, 0.0859)	0.5498 (0.2574, 0.8618)	0.1168 (0.0244, 0.2663)
	Cross-sectional	0.9816 (0.0996, 1.9092)	0.9131 (0.8654, 0.9471)	0.0803 (0.0171, 0.1434)
	Panel	1.0015 (0.1173, 1.9078)	0.9088 (0.8633, 0.9464)	0.0798 (0.0160, 0.1431)
Soybean	Time series (China)	0.4016 (0.2193, 0.5801)	0.3345 (0.2336, 0.3948)	0.0176 (0.0063, 0.0285)
	Time series (India)	0.0657 (0.0243, 0.1094)	0.5922 (0.5157, 0.7345)	0.0263 (0.0107, 0.0511)
	Time series (United States)	0.0813 (0.0125, 0.4041)	0.2877 (0.1545, 0.6180)	0.1510 (0.0153, 0.2444)
	Cross-sectional	1.0177 (0.1176, 1.8935)	0.9048 (0.8554, 0.9462)	0.0796 (0.0162, 0.1429)
	Panel	1.0009 (0.0935, 1.8958)	0.9091 (0.8573, 0.9463)	0.0787 (0.0177, 0.1417)
Rice	Time series (China)	0.0437 (0.0113, 0.1235)	0.6324 (0.4648, 0.8185)	0.0554 (0.0128, 0.1456)
	Time series (India)	0.9850 (0.1123, 1.8832)	0.8999 (0.8549, 0.9450)	0.0800 (0.0170, 0.1427)
	Time series (United States)	0.1164 (0.0169, 0.5207)	0.3063 (0.1235, 0.5436)	0.1545 (0.0210, 0.2619)
	Cross-sectional	1.0132 (0.0923, 1.9231)	0.9079 (0.8709, 0.9453)	0.0807 (0.0171, 0.1434)
	Panel	1.0206 (0.1060, 1.9145)	0.9077 (0.8705, 0.9455)	0.0796 (0.0157, 0.1428)
Wheat	Time series (China)	0.0291 (0.0103, 0.0792)	0.6417 (0.4261, 0.8057)	0.0475 (0.0128, 0.1141)
	Time series (India)	0.0762 (0.0108, 0.2608)	0.6989 (0.4619, 0.8112)	0.0404 (0.0116, 0.1429)
	Time series (United States)	0.3572 (0.0108, 1.7566)	0.7542 (0.6403, 0.9453)	0.1654 (0.0116, 0.7880)
	Cross-sectional	1.0209 (0.1059, 1.9117)	0.9048 (0.8605, 0.9459)	0.0816 (0.0176, 0.1434)
	Panel	1.0076 (0.1147, 1.8977)	0.8939 (0.8623, 0.9187)	0.0441 (0.0132, 0.0761)

Table S4. List of the GCMs and modeling groups obtained from the CMIP5 multimodel ensemble data set [Taylor et al. (2012)] for this study.

GCM name	Modeling group
GFDL-ESM2M	NOAA Geophysical Fluid Dynamics Laboratory
IPSL-CM5A-LR	Institut Pierre-Simon Laplace
HadGEM2-ES	Met Office Hadley Centre
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
NorESM1-M	Norwegian Climate Centre

Table S5. Analysis of variance results for the projected decadal mean yield change, adaptation cost, residual damage and cost of climate change for the individual countries and crops. Three countries (the United States, China and India) where all four crops and all three specifications of the production cost model are available are examined.

Variable	Df	Mean square error							
		Yield impact		Adaptation cost		Residual damage		Cost of climate change	
2041-2050									
Emissions	3	20.3	***	1375		350	***	2542	
Climate model	4	41.2	***	58497	***	1622	***	47678	***
Socioeconomic	4	2	*	2478		1		2590	
Cost model	2	0		388737	***	232	***	407928	***
Country	2	1931.5	***	725685	***	2080	***	796980	***
Crop	3	1338.6	***	575768	***	6018	***	591593	***
Residuals	3581	0.7		5022		26		4959	
2091-2100									
Emissions	3	5370	***	6977		20902	***	23042	
Climate model	4	2583	*	366097	***	7881	***	371279	***
Socioeconomic	4	2102	*	45933		337	**	52446	
Cost model	2	0		2166455	***	177		2205742	***
Country	2	8190	***	3418230	***	3680	***	3511857	***
Crop	3	7432	***	3163380	***	37131	***	3346489	***
Residuals	3581	818		34395		99		34117	

The point (.), single asterisk (*), double asterisk (**) and triple asterisk (***) indicate significance at the 10%, 5%, 1% and 0.1% levels, respectively.