Global Warming and Agriculture

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(percent and millions of 2005 dollars)

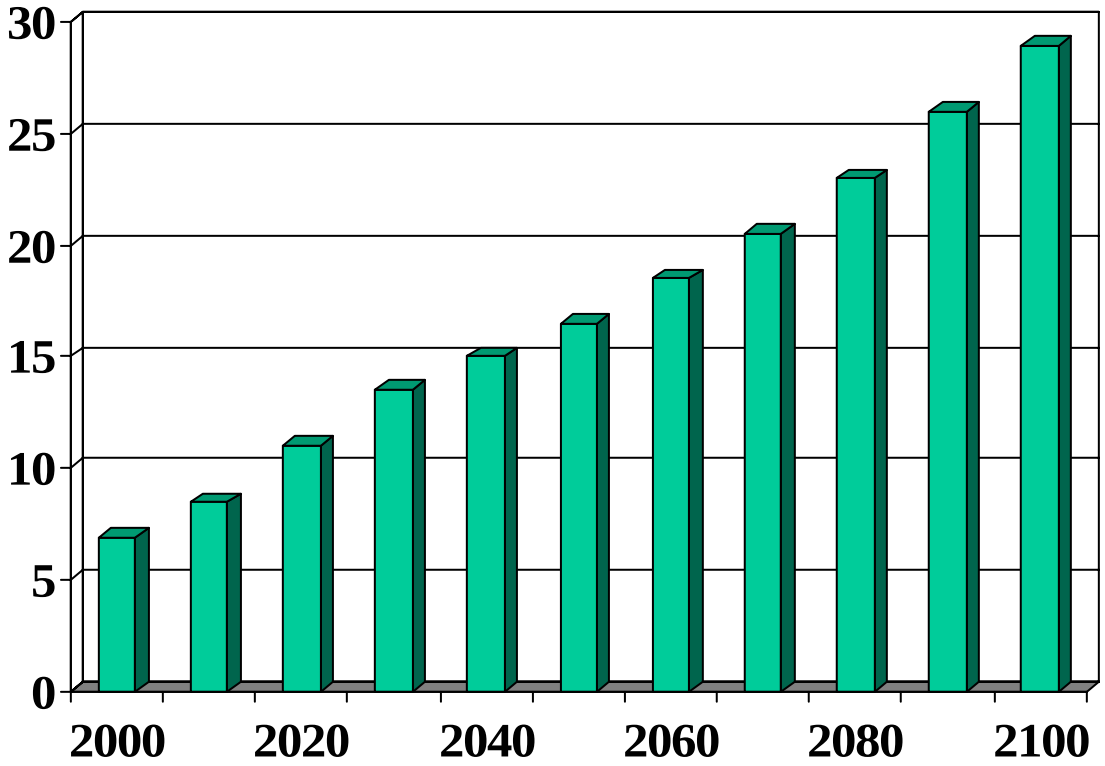
Country/region	Dryland (without carbon fertilization)	Irrigated (without carbon fertilization)	Irrigated share of cropland		Weighted average		Base output (millions of dollars)
			Area	Value	Without carbon fertilization	With carbon fertilization	
Algeria	−66.6	6.3	7.0	27.2	−46.7	−38.7	6,657
Angola	−26.3	−26.2	7.0	27.2	−26.3	−15.2	1,188
Burkina Faso	−16.5	20.9	0.0	0.0	−16.5	−4.0	1,298
Cameroon	−19.1	−31.6	2.0	9.2	−20.3	−8.3	5,499
Democratic Republic of the Congo	−5.5	23.2	1.0	4.8	−4.1	10.2	3,292
Egypt	−50.1	53.5	100.0	100.0	53.5	76.5	13,189
Ethiopia	−31.4	−53.9	0.0	0.0	−31.4	−21.2	2,748
Ghana	−3.0	−41.6	3.0	13.3	−8.2	5.6	2,748
Ivory Coast	−3.6	−74.2	1.0	4.8	−7.0	7.0	3,574
Kenya	8.3	20.8	19.0	53.7	15.0	32.3	2,302
Madagascar	−20.5	−16.4	1.0	4.8	−20.3	−8.3	1,587
Malawi	−33.6	−10.2	2.0	9.2	−31.5	−21.2	651
Mali	−100.0	−11.9	31.0	69.0	−39.0	−29.9	1,645
Morocco	−43.7	−5.5	2.0	9.2	−40.1	−31.1	7,436
Mozambique	−30.6	2.8	5.0	20.7	−23.6	−12.1	1,122
Niger	−100.0	36.3	15.0	46.6	−36.1	−26.5	1,094
Nigeria	−13.7	−1.8	3.0	13.3	−12.1	1.1	15,180
Other Equatorial Africa	1.6	−22.0	1.0	4.8	0.5	15.6	1,429
Other Horn of Africa	−100.0	7.1	1.0	4.8	−94.8	−94.1	20
Other Southern Africa	−52.5	−53.5	1.0	4.8	−52.5	−45.4	619
Other West Africa	−15.6	−100.0	5.0	20.7	−33.2	−23.2	1,832
Senegal	−100.0	−55.2	10.0	35.5	−84.0	−81.6	1,105
South Africa	−51.5	−39.6	11.0	38.0	−47.0	−39.0	6,395
Sudan	−100.0	9.5	4.0	17.1	−81.1	−78.3	6,944
Tanzania	−16.3	−1.1	0.0	0.0	−16.3	−3.7	4,629
Uganda	−1.7	−4.8	6.0	24.0	−2.5	12.1	2,016
Zambia	−48.5	−37.7	3.0	13.3	−47.1	−39.1	1,000
Zimbabwe	−52.4	−15.7	5.0	20.7	−44.7	−36.4	3,018
Total					−18.6	−6.3	100,215
Excluding Egypt					−29.5	−18.9	
Median					−28.9	−18.2	

Sources: Table 5.3 using non-Egypt irrigated model B except for Egypt; World Bank (2006).

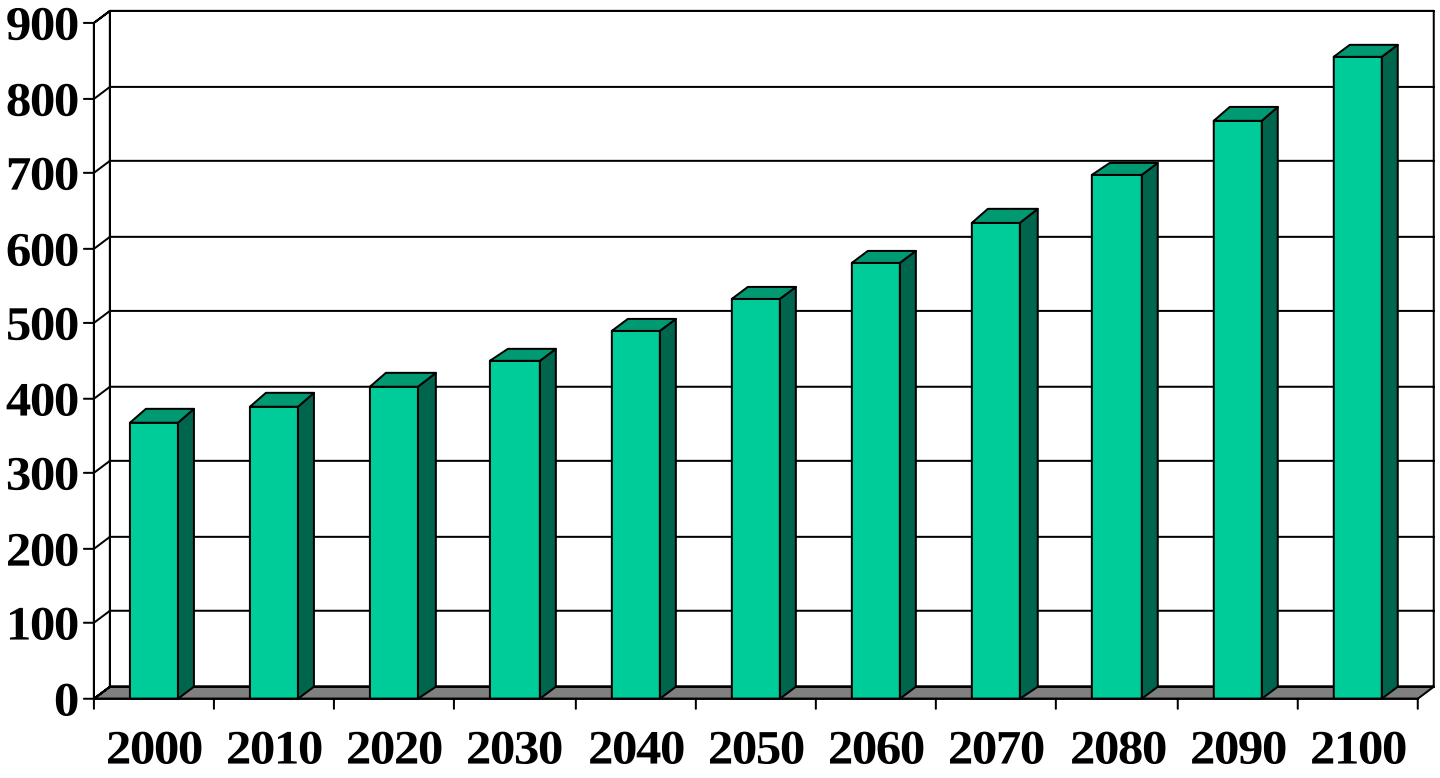
Model	Resolution	Warming for $2xCO_2$ (ºC)
German Climate Research Centre	2.8° x 2.8°	2.6
UK Hadley Centre	2.5° x 3.75°	3.0
Australian Commonwealth Scientif. & Indust. Res. Org	3.2° x 5.6°	3.7
Canadian Centre for Climate Modeling	3.7° x 3.7°	3.6
US Geophysical Fluid Dynamics Laboratory	2.25° x 3.75°	3.4
Japanese Centre for Climate Research Studies (f)	5.6° x 5.6°	3.5

Baseline CO2 Emissions (A2)

(billion tons carbon equivalent)



Baseline CO2 atmospheric concentration (parts per million)



Converting Grid Sizes
(resolution and # of land-based cells)

	Resolution	# of cells
IPCC Actuals, 1961-90	1^o x 1^o	22,156
Typical climate model	3^o x 4^o	1,836
Standardized grid (this study)	2^o x 3^o	3,672

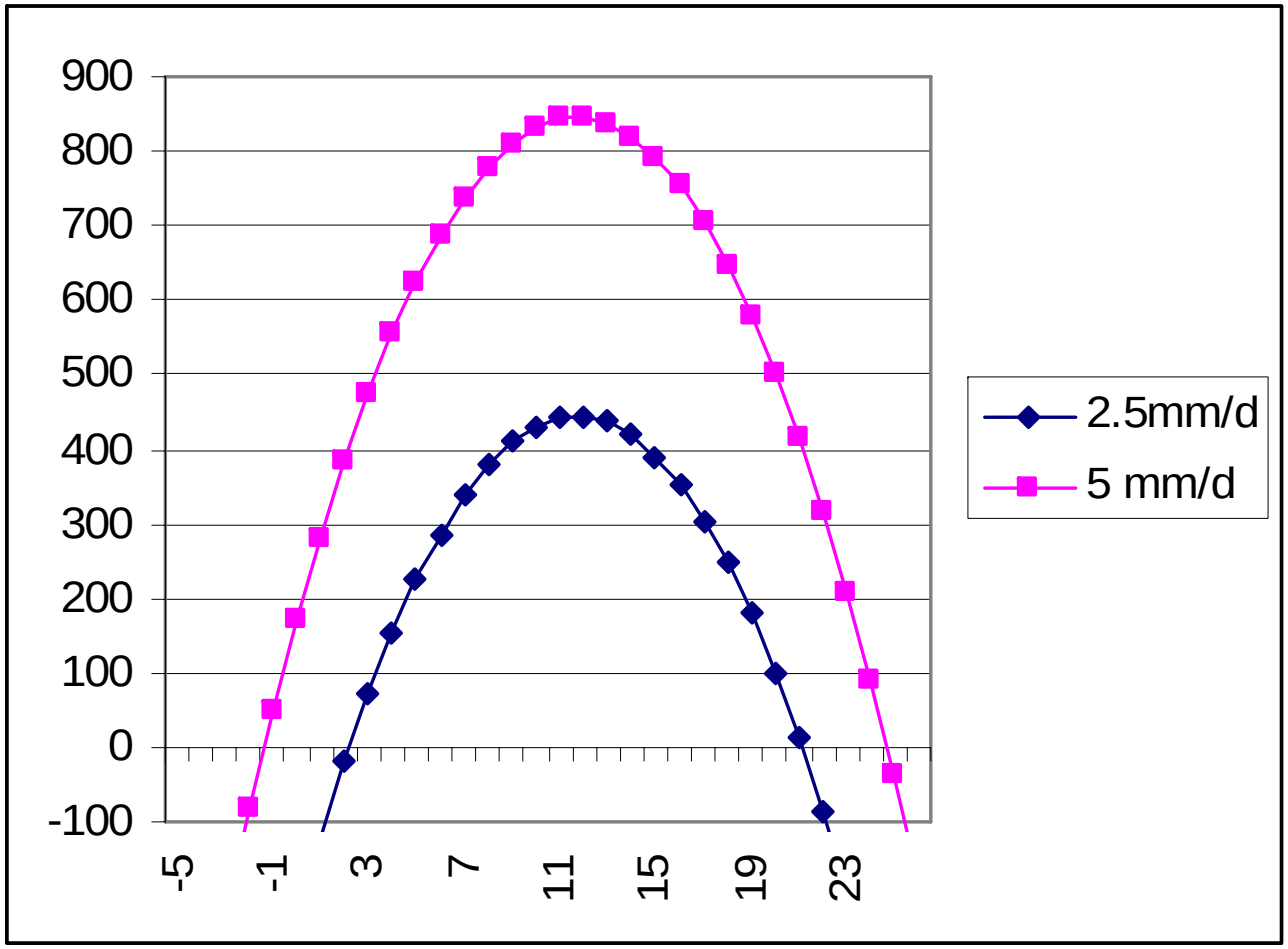
Global Climate Change by 2080s

	Land area weights	Farm area weights
Temperature (^{o}C) (base)	13.15	16.2
Precipitation (mm/d) "	2.20	2.44
Change by 2080s:		
Temperature (^{o}C)	4.95	4.43
Precipitation (mm/d)	0.13	0.07
Precipitation (percent)	5.9%	2.9%

Agricultural Impact Models Used

- Crop Models (18 countries): Rosenzweig-Iglesias
- “Ricardian Models:
  - Mendelsohn-Schlesinger based on US
  - World Bank for Africa, Latin America
  - Mendelsohn-Dinar-Sanghi for India

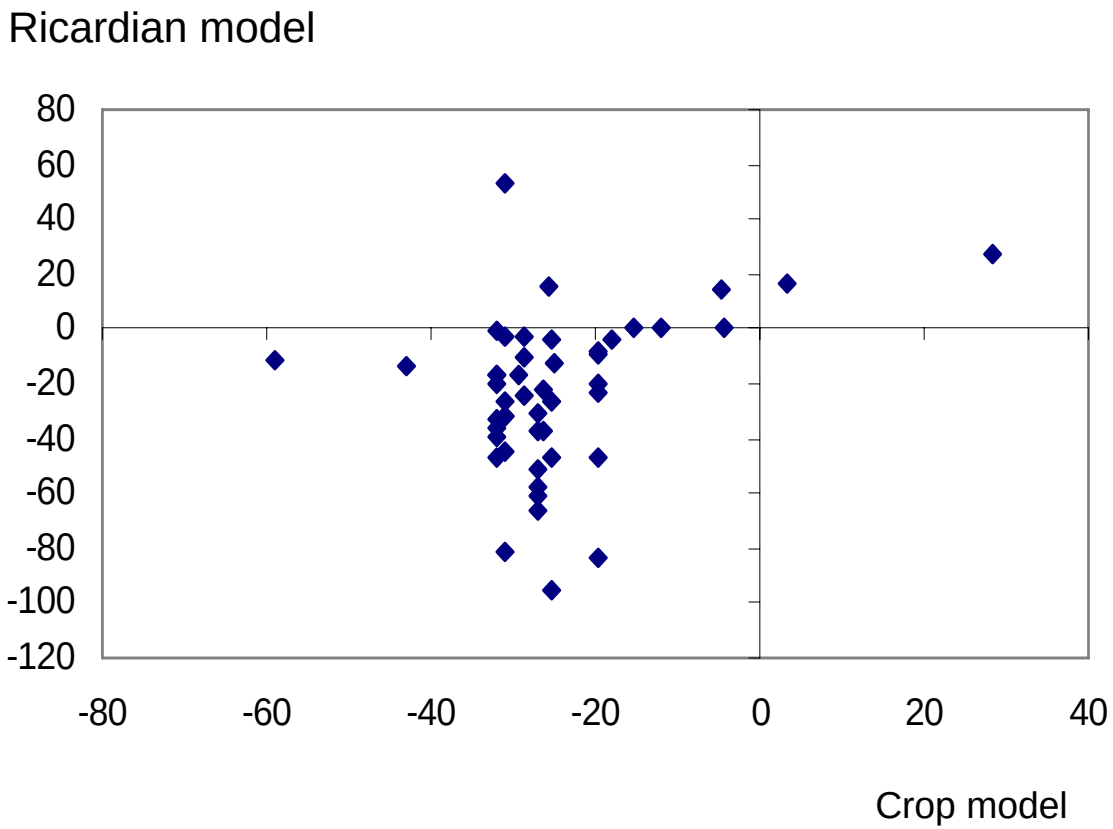
Output per hectare at alternative average temperatures ($ and ^{o}C)



How Much Carbon Fertilization?

- Carbon dioxide is an input into photosynthesis
- Wheat, rice, soybeans, cotton (C3): more response; corn, sugarcane (C4): less
- Early laboratory experiments overstated effect. Open field (FACE) results now show lower impact.
- Estimate: 15% yield boost for 735 ppm

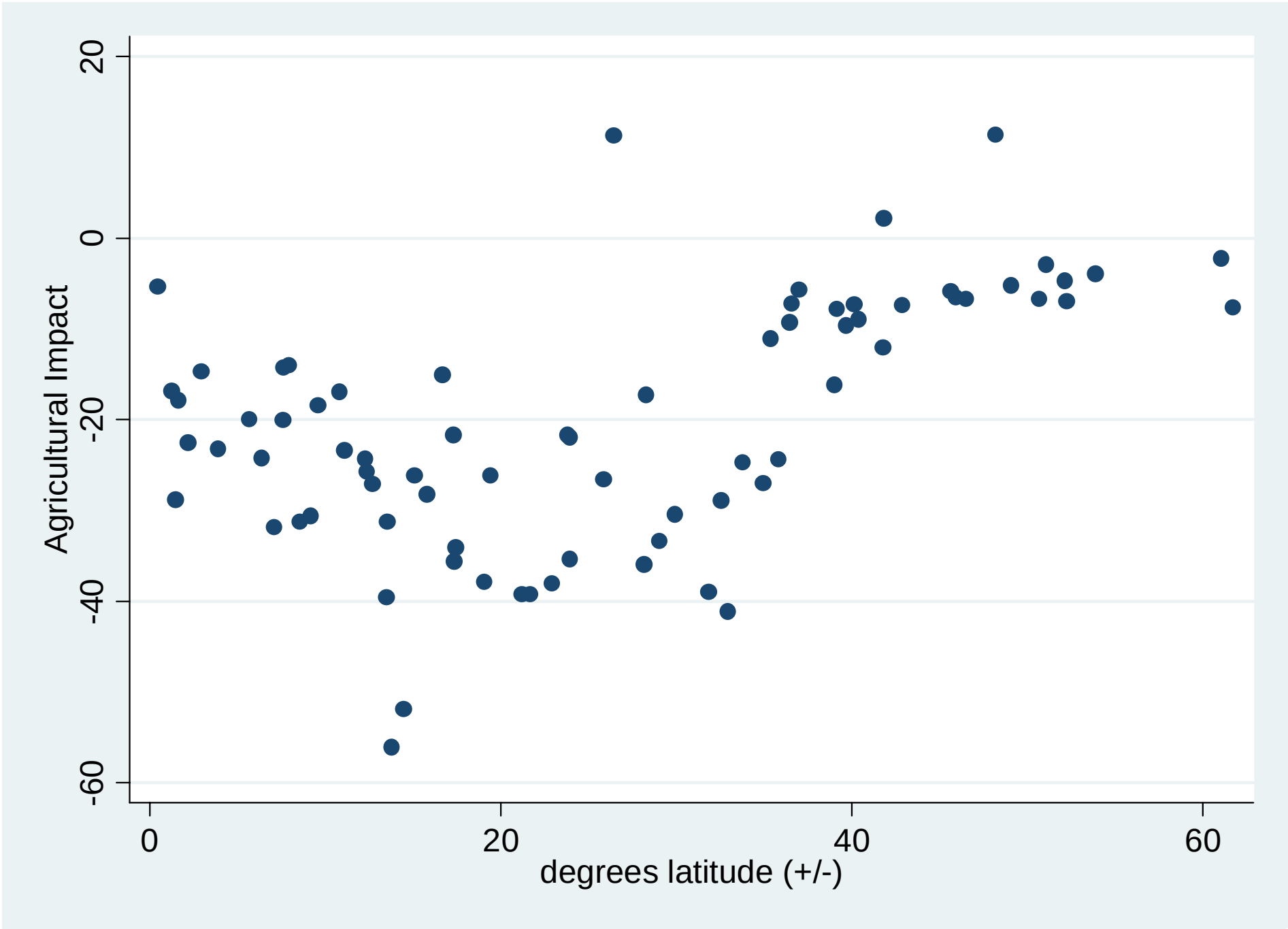
Figure 5.4 Percentage change in agricultural capacity by the 2080s in 47 countries and regions (without carbon fertilization)



Results, selected countries

(percent change in agricultural productivity)

	Ricardian	Crop Model	Weighted Avg	
			w/oCF	w/CF
Argentina	-4	-18.1	-11.1	2.2
Brazil	-5.1	-28.7	-16.9	-4.4
US	4.7	-16.5	-5.9	8.0
SW plains	-11.1	-59.0	-35.1	-25.0
India	-49.2	-27.0	-38.1	-28.8
China	3.8	-12.6	-7.2	6.8
S. central	-18.8	-12.6	-14.6	-1.8

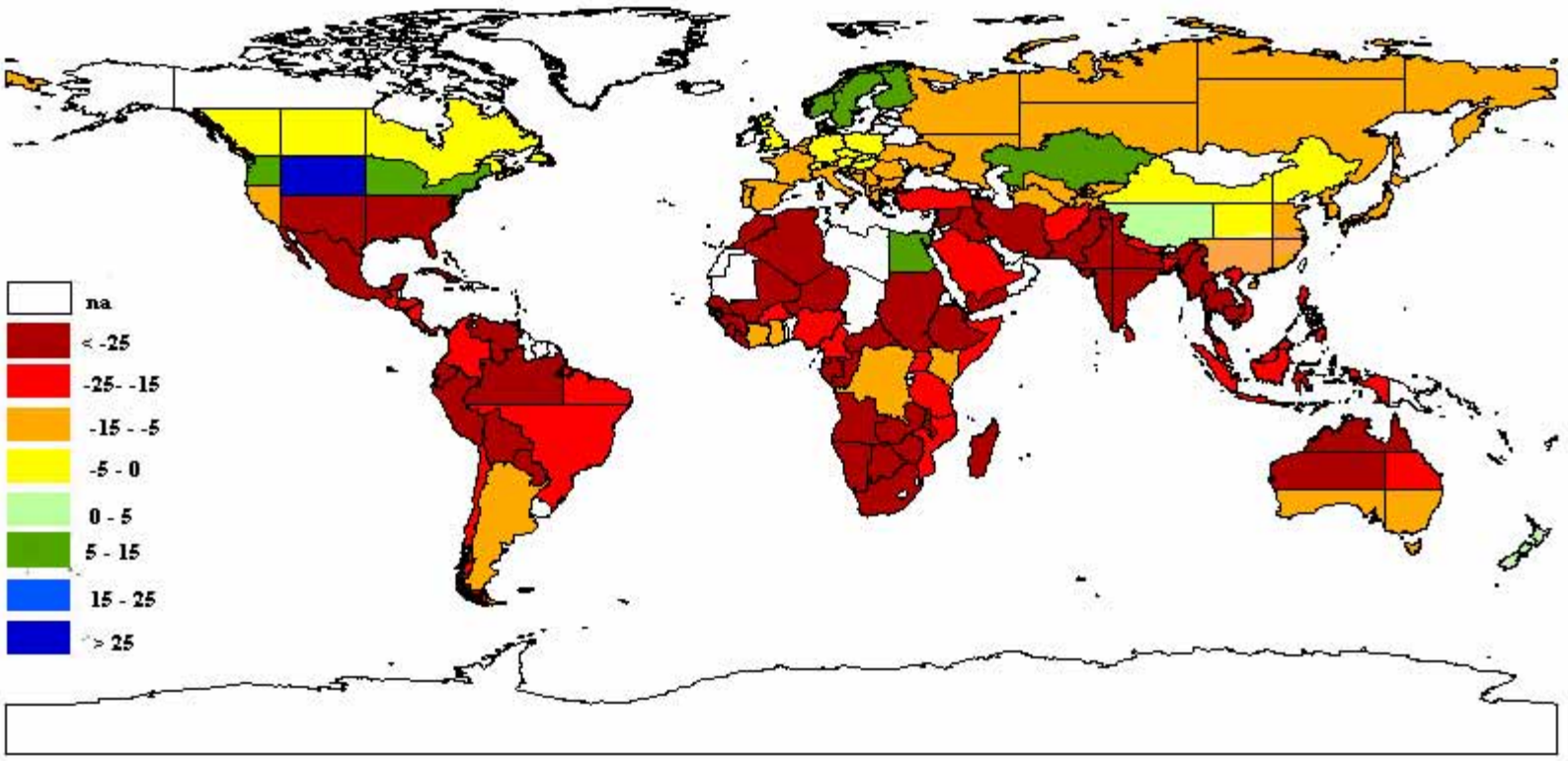

Agricultural Impact
20
0
-20
-40
-60
0
20
40
60
degrees latitude (+/-)

Results, selected countries

(percent change in agricultural productivity)

	Ricardian	Crop Model	Wtd Average	
			w/oCF	w/CF
Mexico	-35.9	-35.1	-35.4	-25.7
Nigeria	-12.1	-24.9	-18.5	-6.3
South Africa	-47.0	-19.8	-33.4	-23.4
Ethiopia	-31.4	-31.1	-31.3	-20.9
Canada	0	-4.3	-2.2	12.5
Spain	-4.5	-11.1	-8.9	4.8
Germany	13.8	-11.1	-2.9	11.7

Impact on Agricultural Productivity without Carbon Fertilization (percent)



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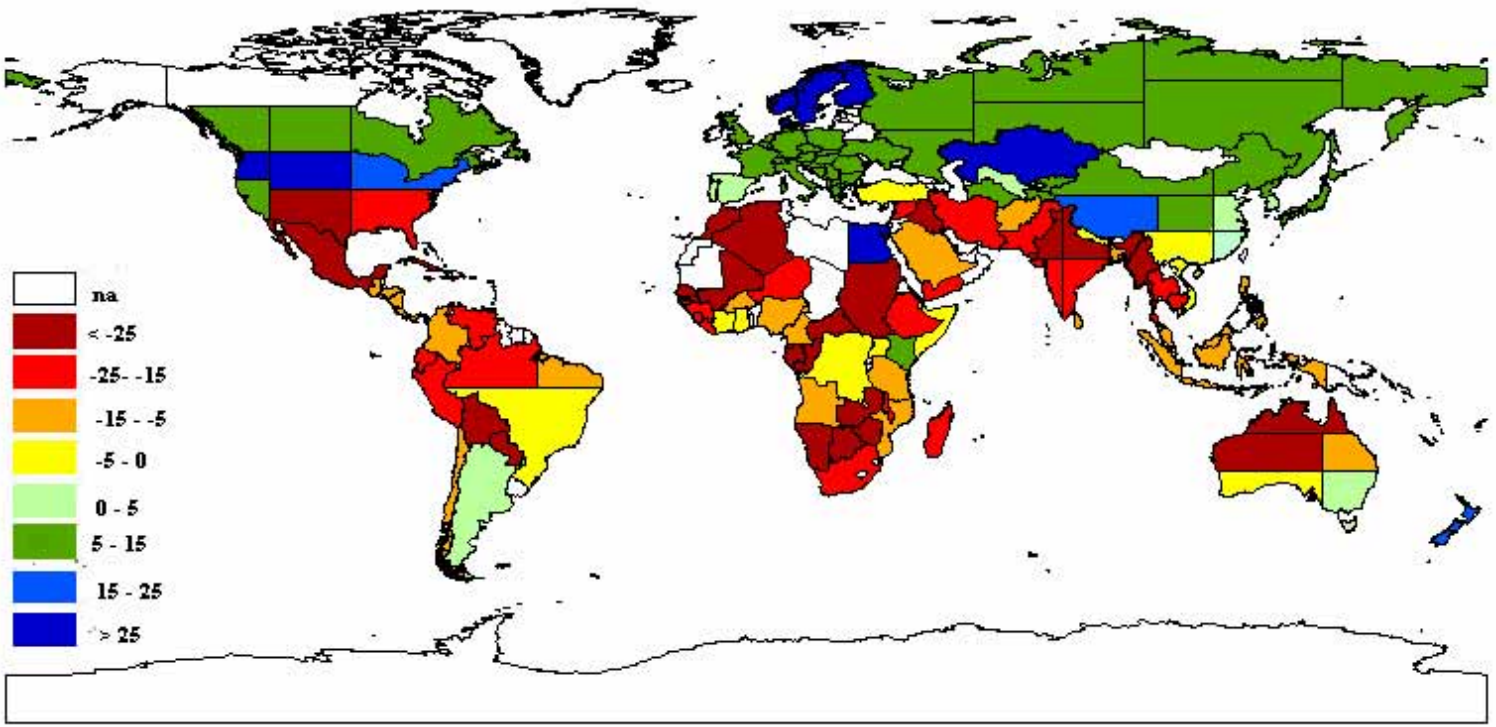


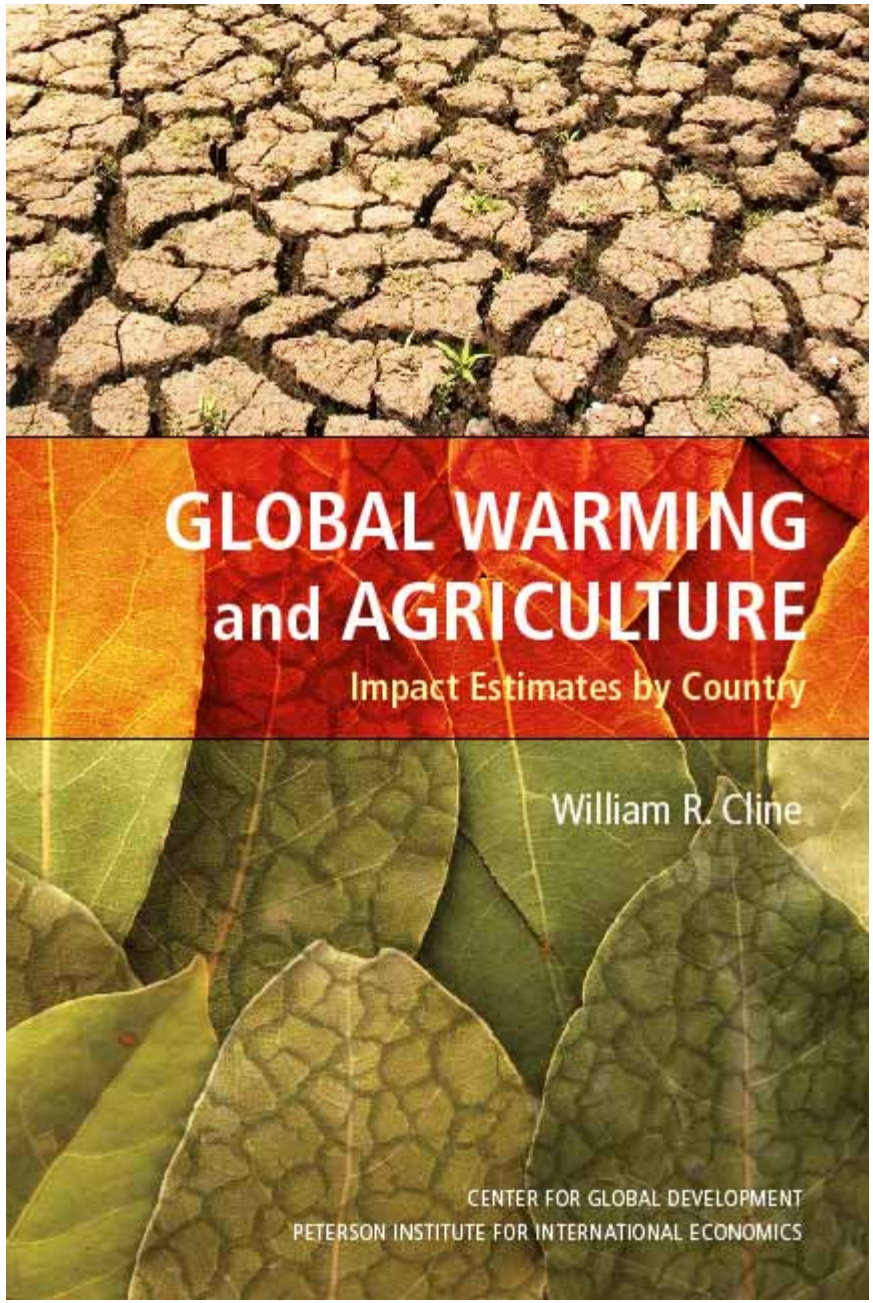
Results by Region

(% change in agricultural productivity)

	w/o CF	w/ CF
World	-15.9	-3.2
Industrial countries	-6.3	7.7
Developing countries exc. Eur.	-21.0	-9.1
Median	-25.8	-14.7
Africa	-27.5	-16.6
Middle East –North Africa	-21.2	-9.4
Asia	-19.3	-7.2
Latin America	-24.3	-12.9

Technological Change is No Panacea

	2004	2085
Population (billion) medium	6.5	10.5
high	6.5	14.7
Per capita ppp income ($)	6,330	14,000
Per capita food consumption (index)	100	163
Food demand (index)	100	260-370
Food supply: technology (index)	100	350
Diversion to energy crops (%)	1	30
Food supply: combined (index)	100	245


GLOBAL WARMING
and AGRICULTURE
Impact Estimates by Country
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