Regional Economic and Environmental Impacts of Agricultural Adaptation to a Changing Climate in the United States

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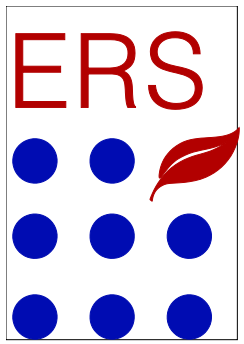

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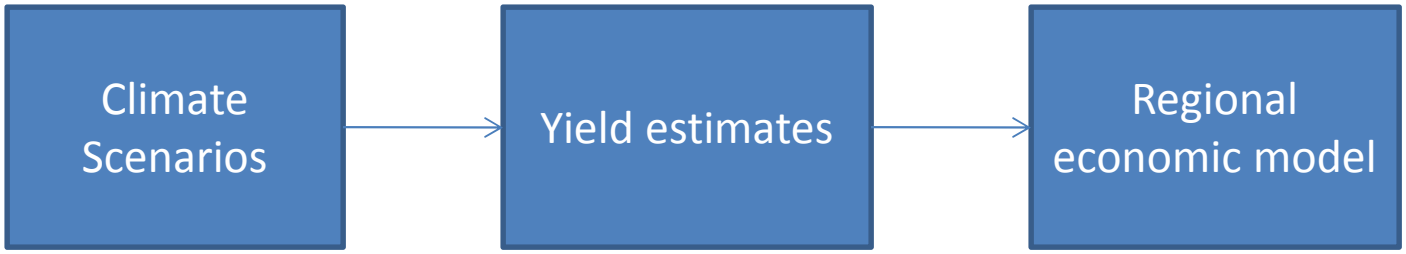
What is the issue?

- Prevailing climate conditions have determined crop and production practice suitability and preference
- The regional variability in anticipated changes to climate will influence crop production and economic choices, thereby changing crop distribution, prices and incomes
  - Which regions are most robust and which are most sensitive to climate-induced yield shifts?
- In addition to changes in temperature and precipitation, climate change may also induce changes in irrigation water supply and pest prevalence (among other factors) that will influence crop yields.

How do we define adaptation?

- Farmers have historically adjusted to changes in demand for crops, new technological developments, a changing policy environment, and pressure from development
- We do not attempt to project new technology, market trends or policies, nor assess their potential contribution to future US agriculture
- Adaptation is restricted to shifts in prevailing crop distribution and production practices that affect land use, national markets, and environmental consequences

Analysis Method



- No climate change Baseline
- 4 climate change scenarios

- Baseline and climate-change yields computed using EPIC (biophysical crop growth simulation model)
- Sensitivity analysis (pest prevalence, drought tolerance)

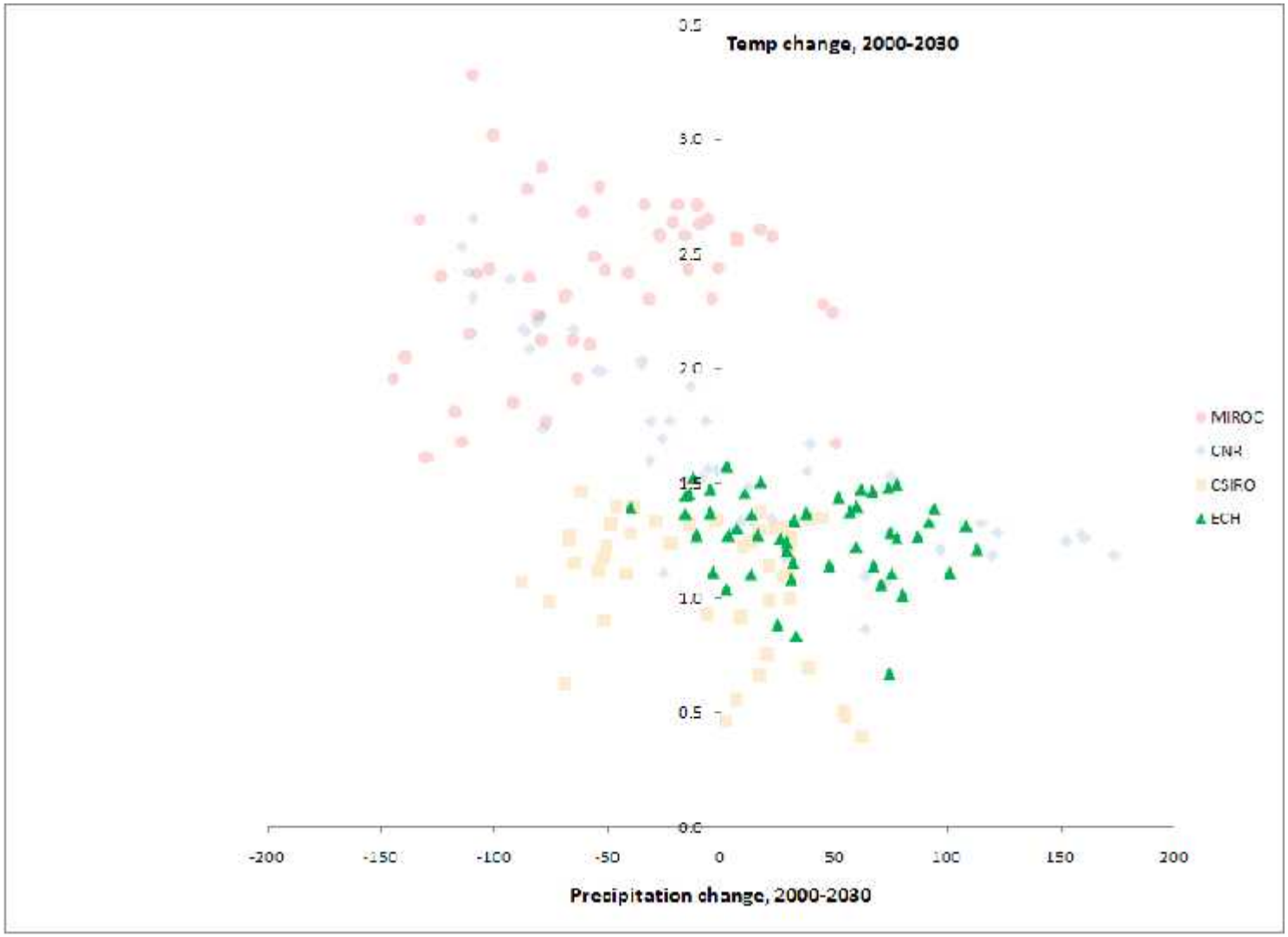
- REAP – Regional Environment and Agriculture Programming model
- USDA baseline partially extended to 2030

Climate change scenarios

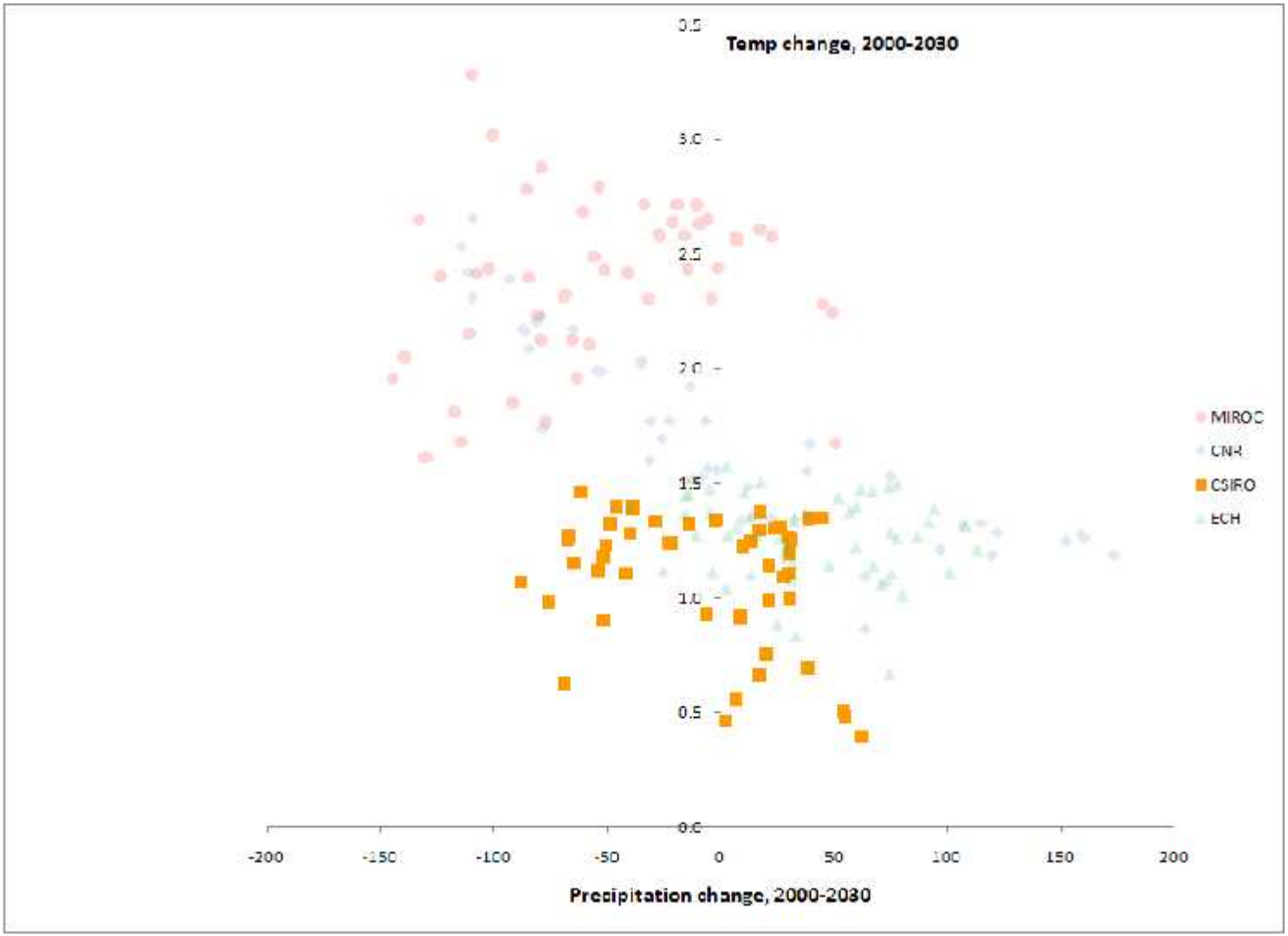
Model Name	Label	Institution	Reference
CNRM-CM3	CNR	Météo-France/Centre National de Recherches Météorologiques, France	Déqué et al. (1994)
CSIRO-Mk3.0	CSIRO	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	Gordon et al (2002)
ECHam5	ECH	Max Planck Institute for Meteorology, Germany	Roeckner et al (2003)
MIROC3.2	MIROC	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	K-1 Developers (2004)

- These scenarios are not exhaustive of the range of potential climate change in the US
- Downscaled precipitation, Tmax and Tmin, with points representing non-agricultural land removed
- The scenarios do have differing temperature and precipitation shift characteristics

Scenario regional weather changes



Scenario regional weather changes



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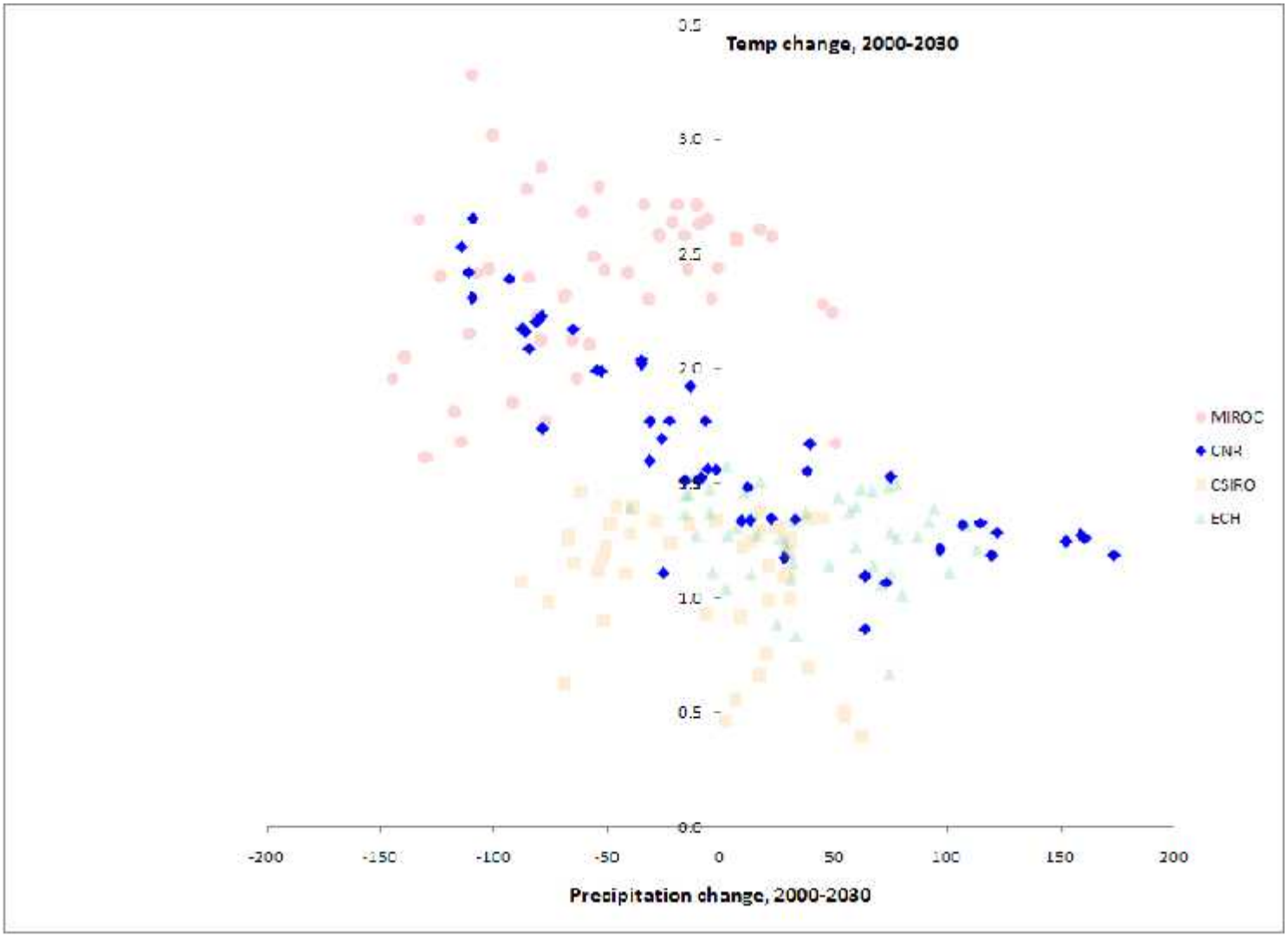

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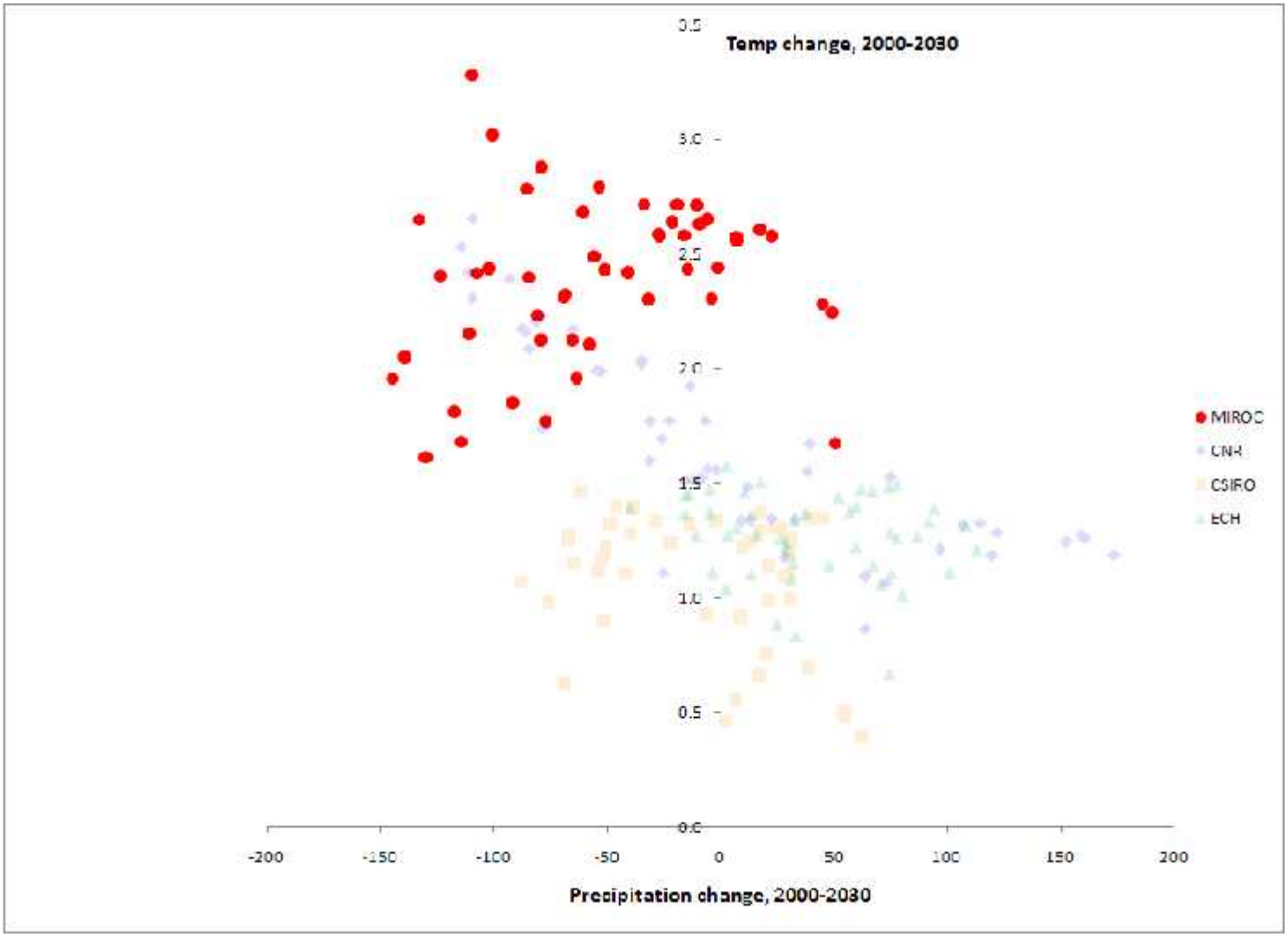


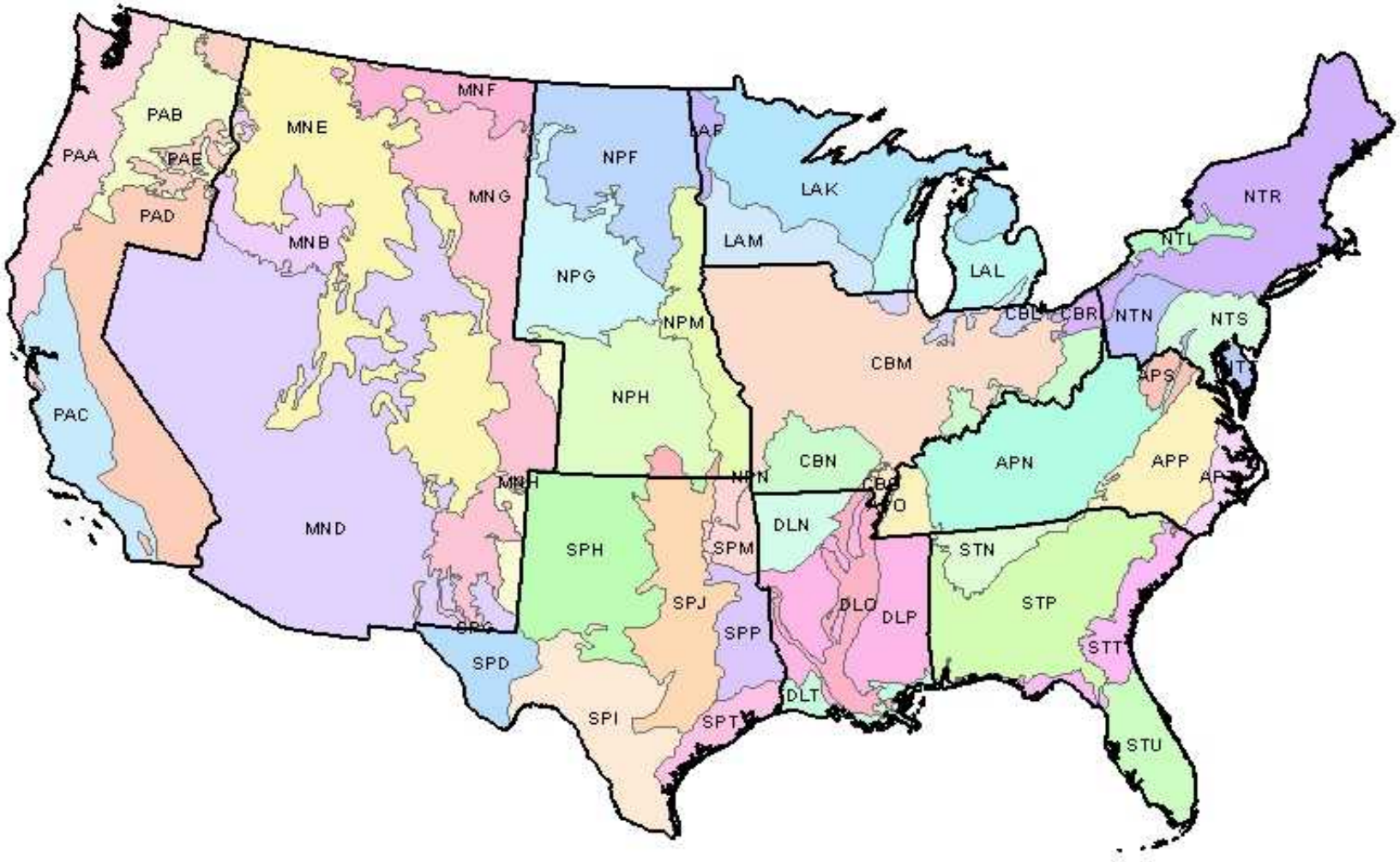
Estimating crop yields

- EPIC uses monthly weather data as a seed for generating daily weather over the simulation period
- Atmospheric CO_2 changes from 381 ppm to 450 ppm
- EPIC computes for a given soil/rotation/tillage combination: crop yields, input use, and nutrient fate
- There are a large number of parameters in EPIC that are likely to be affected by climate change besides temperature and precipitation

REAP Summary

- Regional Environment and Agriculture Programming (REAP) model
  - U.S. production and use for major field crops, livestock and processed products
  - 50 agricultural production regions
    - Intersection of USDA Farm Production Regions and Land Resource Regions
    - Generally homogenous units that have similar production and cost conditions within each region
  - Data from ARMS, NRI, Ag Census, EPIC and ERS estimates
  - Integrates crop, livestock and agricultural products via supply/demand functions and livestock rations
  - Explicit relationship between production practice (rotation, tillage, fertilizer), crop yields and environmental measures

REAP regions

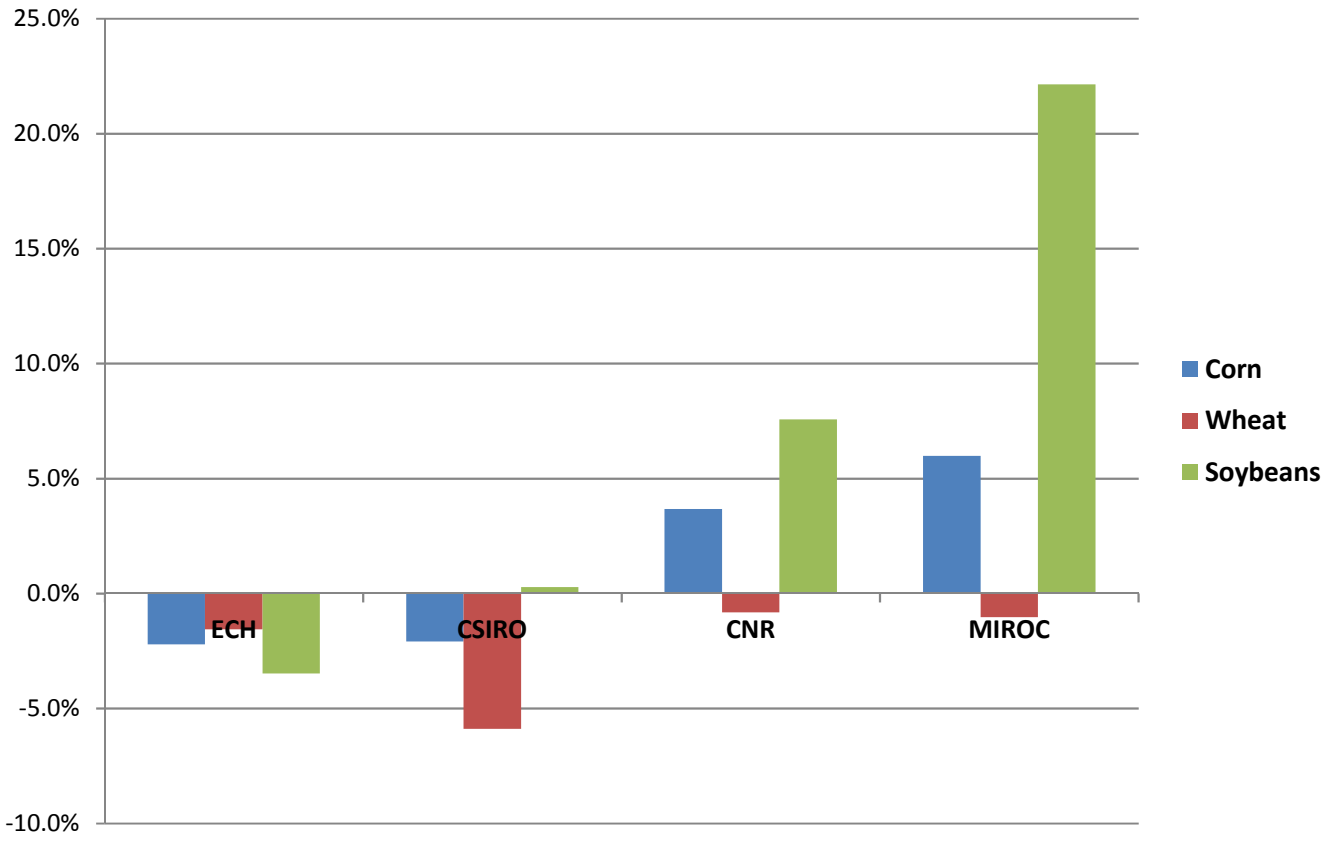


Cases for analysis

- Four Climate change adaptation scenarios

- For each climate change scenario, we examine:
  - Consequences of not adapting
  - Additional impacts of expected changes in pest prevalence
  - Impacts of adopting drought-tolerant crop varieties

Crop price change from Baseline



Climate change scenarios:

National acreage change

	ECH	CSIRO	CNR	MIROC
Total Acres	0.6%	0.6%	0.2%	1.0%
Corn	1.7%	2.8%	3.0%	4.2%
Wheat	-1.1%	-0.2%	1.0%	0.8%
Soybeans	1.4%	1.0%	-2.8%	-1.8%
Other Crops	-0.1%	-1.5%	-0.2%	0.5%

National production change

	ECH	CSIRO	CNR	MIROC
Corn	1.8%	1.8%	-2.1%	-3.8%
Wheat	2.8%	10.7%	1.5%	1.9%
Soybeans	7.6%	-0.5%	-15.5%	-26.9%

Regional change from Baseline Total Planted Acres

ECH
0.6%

CNR
0.2%

CSIRO
0.6%

MIROC
1.0%

Regional change from Baseline Corn Acres

ECH
1.7%

CNR
3.0%

CSIRO
2.8%

MIROC
4.2%

Regional change from Baseline Soybean Acres

ECH
1.4%

CNR
-2.8%

CSIRO
1.0%

MIROC
-1.8%

Regional change from Baseline Wheat Acres

ECH
-1.1%

CNR
1.0%

CSIRO
-0.2%

MIROC
0.8%

Crop acreage change across CNR scenario

	Total	Corn	Soy	Wheat	Cotton	Other
NT	-0.5	-0.1	-0.1	0.0		-1.3
LA	-1.3	-0.9	-0.5	0.1		1.3
CB	1.3	0.3	0.3	0.1	0.2	1.2
NP	1.2	1.4	0.4	-0.3		0.2
AP	0.2	0.0	-0.1	0.0	1.5	0.3
SE	0.3	0.0	0.1	0.0	-0.3	0.7
DL	0.7	-0.2	0.9	0.0	-0.7	1.3
SP	1.3	0.8	0.2	-0.5	1.0	-0.7
MN	-0.7	0.3		-0.1		-0.7
PA	-0.7	-0.1		0.1		1.9
US	1.9	1.5	1.1	-0.6	1.0	-1.1

Regional change from Baseline Nitrogen to Water

ECH
1.4%

CNR
2.1%

CSIRO
1.5%

MIROC
5.0%

Case: No-adaptation

- Planted acreage is fixed at baseline levels in all regions to model effect of farmers not adapting to changing yields
- Not adapting to new conditions would lead to a decline in welfare nationally
- However, non-optimal acreage shifts and the resulting price situation may result in some regions being better off if all regions did not adapt

Crop price change under adaptation

Consumers benefit from adaptation in most situations

	Scenario			
	ECH	CSIRO	CNR	MIROC
Corn	-3.2%	-3.2%	-3.6%	-3.9%
Sorghum	-1.1%	-1.8%	-1.1%	-1.2%
Barley	2.1%	2.6%	-1.6%	-2.9%
Oats	-0.6%	-0.4%	-8.7%	-7.1%
Wheat	0.2%	-3.0%	-0.7%	-0.6%
Rice	0.0%	-0.3%	-0.4%	-0.3%
Soybeans	-0.6%	-0.1%	0.7%	1.9%
Cotton	-8.2%	-5.5%	-5.7%	-9.0%

Adaptation results in a lower price in this scenario for this crop compared to no-adaptation

Regional Change from Adaptation Scenario Corn (ADD NATIONAL TOTALS)

ECH
%

CNR
%

CSIRO
%

MIROC
%

Case: Pest movement

- Estimated relationships between ARMS pesticide expenditures and latitude and 2) temperatures and latitude were combined to estimate 3) expenditure and yield impacts.
- Pest prevalence shifts increase costs
  - Vary by crop, region and scenario

Scenario	Average enterprise production cost increase over baseline	Maximum
ECH	0.48%	2.47%
CSIRO	0.39%	2.05%
CNR	0.58%	2.95%
MIROC	0.86%	4.48%

Impact of pest movement

Acreage change from Baseline

		CNR	CSIRO	ECH	MIROC
Total	w/o pest impact	1.9	1.8	0.8	3.2
	with pest impact	4.0	2.7	5.0	8.8
Corn	w/o pest impact	1.5	2.5	2.7	3.7
	with pest impact	2.6	3.1	4.8	5.7
Soybeans	w/o pest impact	1.1	0.7	-2.1	-1.4
	with pest impact	0.2	-0.4	-2.3	-1.0
Wheat	w/o pest impact	-0.6	-0.1	0.5	0.4
	with pest impact	0.7	0.6	2.2	2.8
Cotton	w/o pest impact	1.0	0.6	0.1	1.1
	with pest impact	1.0	0.7	0.2	1.2
Other crops	w/o pest impact	-1.1	-2.0	-0.4	-0.7
	with pest impact	-0.4	-1.3	0.1	0.0

- More acres of most crops required to make up for yield penalty
- Total acreage reduction in milder scenarios reversed when pest impacts are considered

Regional additional pest impacts
Wheat Acres

ECH
3.1%

CNR
2.5%

CSIRO
1.4%

MIROC
4.5%

Case: Introducing Drought-Tolerant Varieties

- Additional drought tolerance in crop varieties is a good example of an adaptive genetic response to climate change with likely impact by 2030
- Yields are increased for non-irrigated crops in low precipitation regions
  - Corn: 15%
  - Wheat, Soy, Cotton: 10%
  - All others: no change

Crop price impacts of drought-tolerant varieties relative to baseline

		ECH	CSIRO	CNR	MIROC
Corn	none	-2.2%	-2.1%	3.7%	6.0%
	DT	**-2.4%**	-2.1%	**3.5%**	**5.8%**
Soybeans	none	-3.5%	0.3%	7.6%	22.1%
	DT	**-3.6%**	**0.1%**	**7.4%**	**21.8%**
Wheat	none	-1.6%	-5.9%	-0.8%	-1.0%
	DT	-1.6%	**-6.3%**	**-1.1%**	**-1.8%**
Cotton	none	-19.7%	-14.5%	-17.7%	-22.7%
	DT	-19.7%	-14.4%	-17.0%	-22.7%

Summary

- Regional effects vary over the range of weather shifts
  - CB shows smallest range of change for most outputs
  - PA, SP and DL have the greatest sensitivity
- More extreme scenarios produce larger (and more negative) changes
- Impacts are likely to be different than this analysis indicates as we do not account for:
  - The full range of adaptive activities
  - All aspects of climate change