Transitioning Cereal Systems to Adapt to Climate Change

November 13-14, 2015

Funded through Award #2011-68002-30191 from USDA National Institute of Food and Agriculture

What we know about public and private adaptation strategies

Bruce McCarl
Regents Professor
Texas A&M University

What we know about public and private adaptation strategies

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Adaptation

Effects

Plan of talk

Will Cover

- Why might arid cereal systems be vulnerable?
- What about adaptation?
    - ➢ The adaptation imperative
    - ➢ What we have seen happen so far
    - ➢ What are adaption roles and issues

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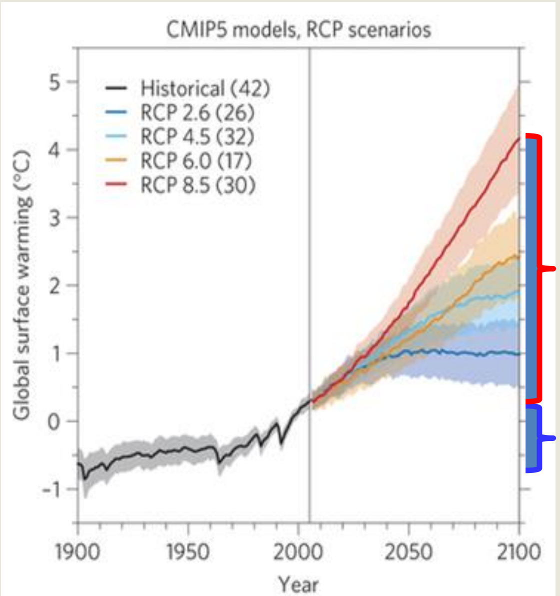
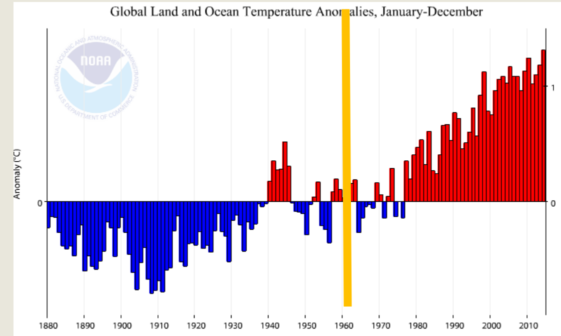
Why Vulnerable -Temperature and Extremes



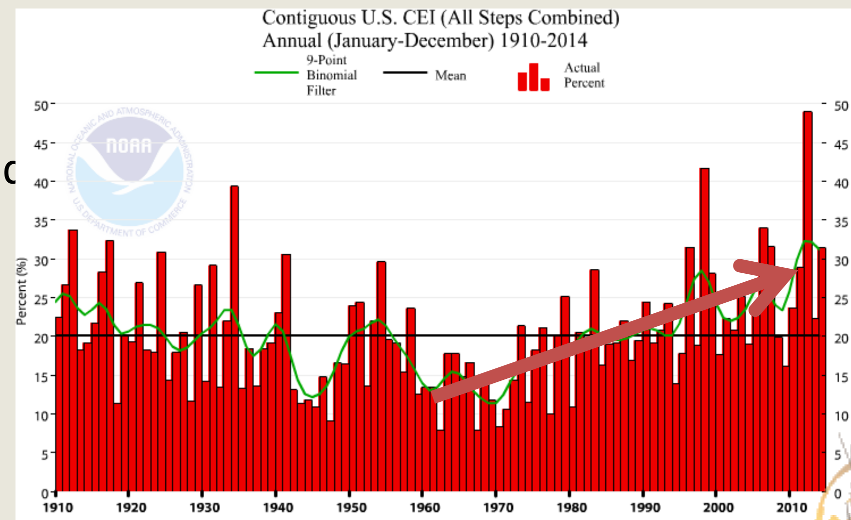
What could happen

What we have seen so far



We see an increase in events and variability since about 1970 when warming began

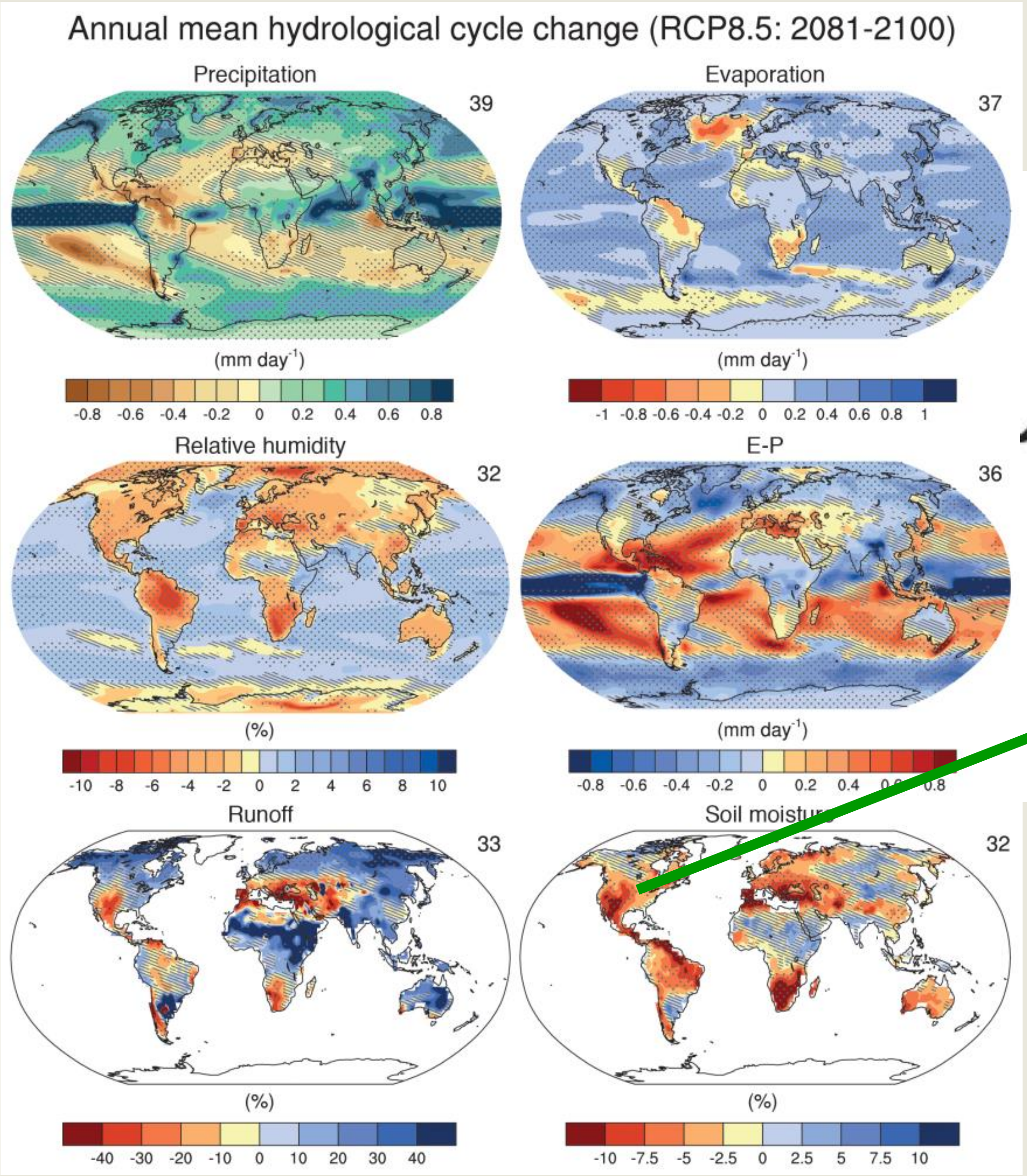
From IPCC and NOAA climate extremes index
http://www.ncdc.noaa.gov/extremes/cei/introc

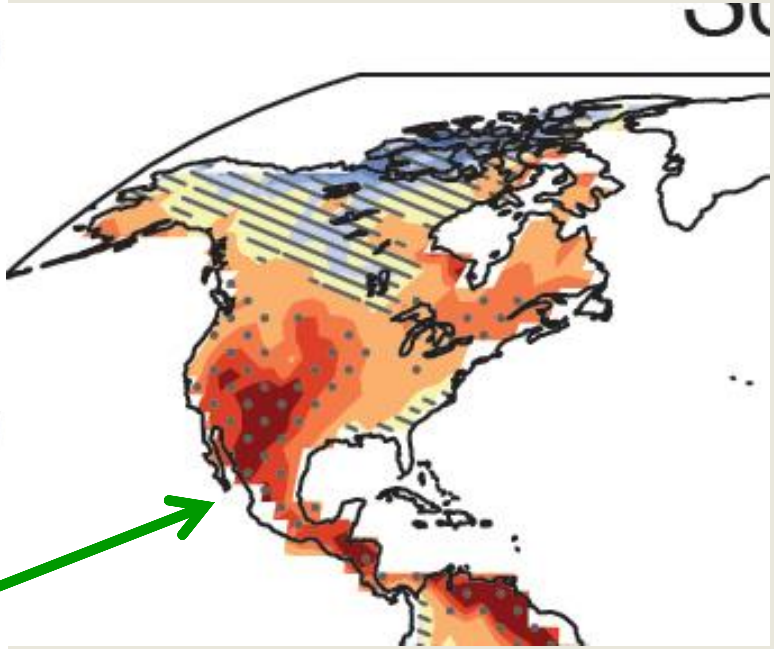


average of percentage of conterminous U.S. area:

- with maximum temperatures much below or above normal
- with minimum temperatures much above or below normal.
- under severe drought
- with severe moisture surplus
- with a much greater than normal precipitation from extremes
- with a much greater than normal number of days with precipitation
- with much greater than normal days without precipitation.

Why Vulnerable - Soil moisture

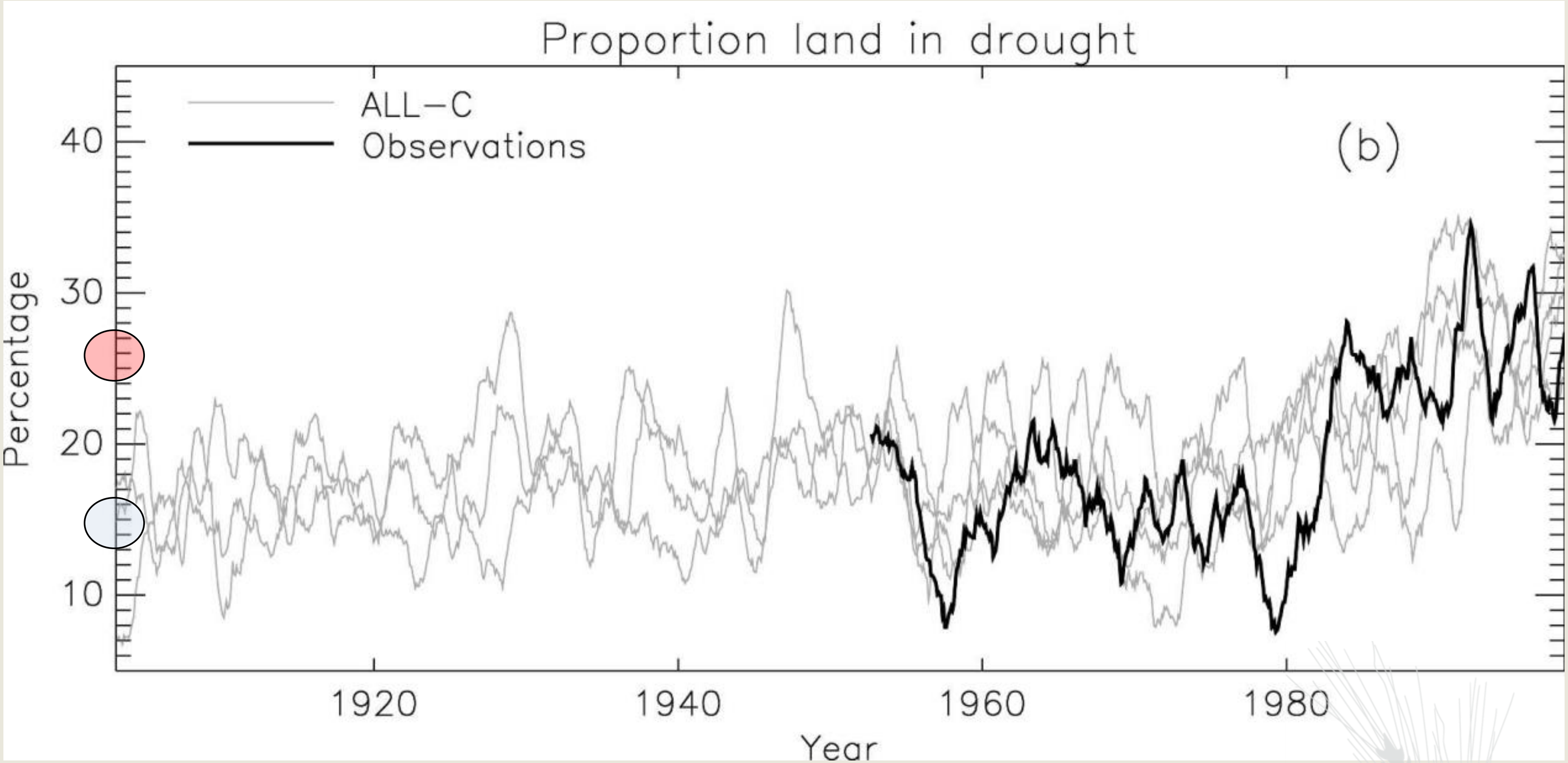




Soil Moisture

Source IPCC 2013, WGI
http://www.ipcc.ch/report/ar5/wg1/

Why Vulnerable - -- Drought

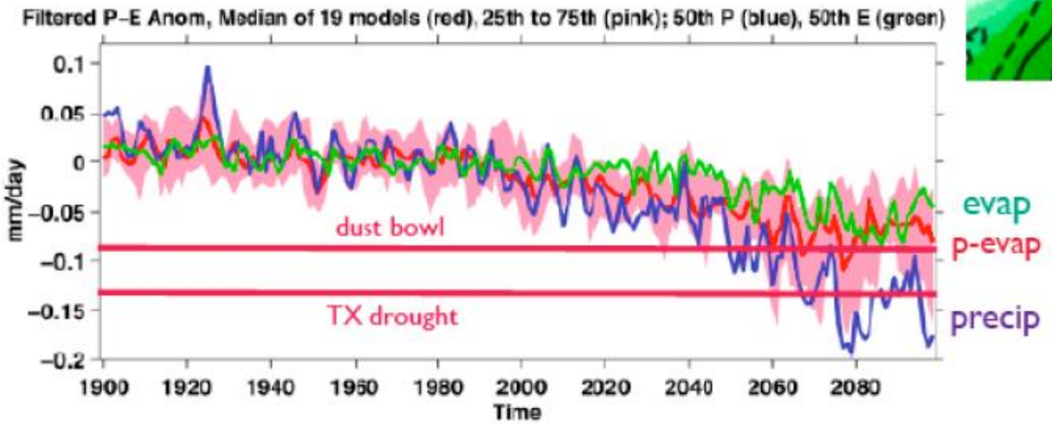


Doubled frequency

ELEANOR J. BURKE, SIMON J. BROWN, AND NIKOLAOS CHRISTIDIS , Modeling the Recent Evolution of Global Drought and Projections for the Twenty-First Century with the Hadley Centre Climate Model

Why Vulnerable - Southwest US water

Climate Model Results: Future SW Moisture



Region Included

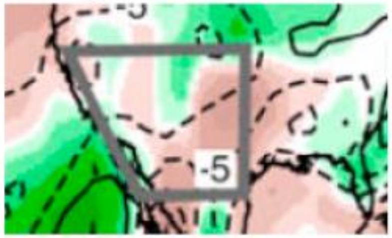


Fig. 1. Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125°W to 95°W and 25°N to 40°N, land areas only), averaged over ensemble members for each of the 19 models. The historical period used known and estimated climate forcings, and the projections used the SResA1B emissions scenario. The median (red line) and 25th and 75th percentiles (pink shading) of the *P* – *E* distribution among the 19 models are shown, as are the ensemble medians of *P* (blue line) and *E* (green line) for the period common to all models (1900–2098). Anomalies (Anom) for each model are relative to that model's climatology from 1950–2000. Results have been 6-year low-pass Butterworth-filtered to emphasize low-frequency variability that is of most consequence for water resources. The model ensemble mean *P* – *E* in this region is around 0.3 mm/day.

SEAGER et al., *Science*, 2007

BOTTOM LINE: MUCH LESS WATER IN THE SOUTHWEST

What have we seen in Agriculture

Observations - Ag sensitivity - IPCC

Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (*high confidence*).

Studies showing positive impacts relate mainly to high-latitude regions

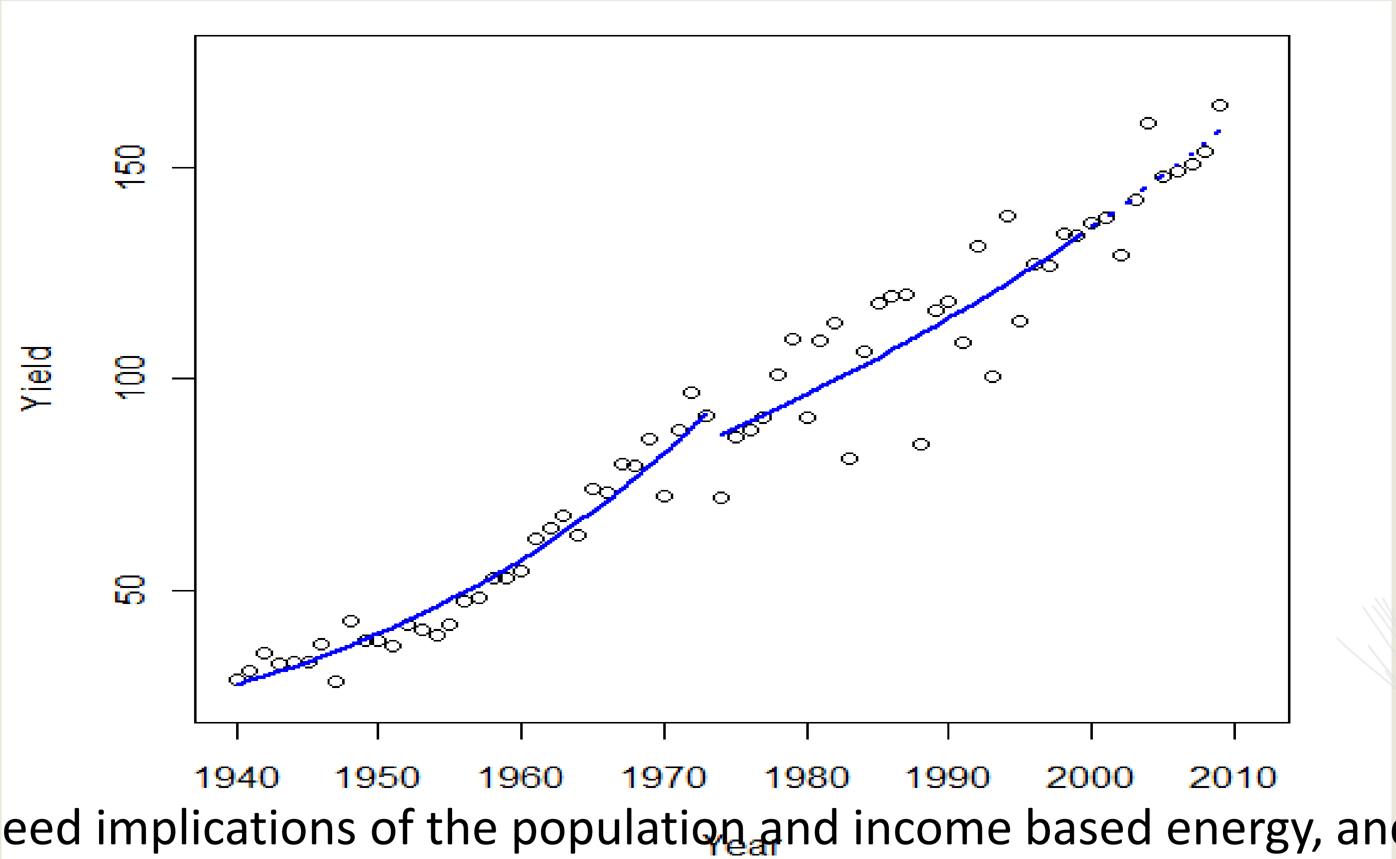
Climate change has negatively affected wheat and maize yields for many regions and in the global aggregate (*medium confidence*).

Periods of rapid food and cereal price increases following climate extremes indicate sensitivity to climate extremes (*medium confidence).*

Source ipcc wg ii 2014, spm

Observations - Technology

People are observing that yield growth is falling off
Corn illustrates 2.7% before 1973, 1.7% since



Soil need implications of the population and income based energy, and food demand growth coupled with technological progress.

THREE ESSAYS ON AGRICULTURAL AND FORESTRY OFFSETS IN CLIMATE CHANGE MITIGATION A Dissertation by SIYI FENG PhD thesis, TAMU May 2012

Observations –
Ag sensitivity – research returns

Scenario A1B	Return of Public Research Capital *with* Climate change 2020	2050	2100	Percent increase / reduction under climate change 2020	2050	2100
Northeast	0.112	0.113	0.106	1.89	2.35	-3.32
Southeast	0.111	0.110	0.107	0.65	-0.35	-3.07
Central	0.108	0.114	0.108	-1.75	3.78	-1.41
North Plains	0.121	0.118	0.110	9.59	6.91	-0.02
South Plains	0.085	0.100	0.098	-22.32	-8.94	-11.20
Mountains	0.122	0.112	0.111	10.69	1.35	0.92
Pacific	0.125	0.109	0.110	13.70	-0.67	0.04
National	**0.112**	**0.111**	**0.107**	**1.37**	**0.93**	**-2.58**

Scenario A2	2020	2050	2100	2020	2050	2100
Northeast	0.118	0.106	0.106	6.88	-3.74	-3.81
Southeast	0.106	0.108	0.106	-3.41	-2.25	-3.30
Central	0.106	0.111	0.107	-3.36	0.71	-2.95
North Plains	0.108	0.112	0.109	-1.61	1.60	-0.84
South Plains	0.069	0.093	0.097	-37.32	-15.42	-12.16
Mountains	0.109	0.111	0.114	-1.23	0.79	3.24
Pacific	0.121	0.108	0.108	10.00	-1.42	-2.20
National	**0.106**	**0.107**	**0.107**	**-3.44**	**-2.69**	**-2.95**

Some gains many losses under SRES scenarios.
Southwest loses

Villavicencio, X., B.A. McCarl, X.M. Wu, and W.E. Huffman, "Climate Change Influences on Agricultural Research Productivity", Climatic Change, Volume 119, Issue 3-4, pp 815-824, 2013.

Observations - Ag sensitivity - Pests

Pest incidence and costs are expected to rise

Impacts of rainfall on total pesticide usage cost for corn, cotton, soybeans and wheat are positive. mixed effect of temperature.

% Change in Average Pesticide Cost for a % Change in Climate

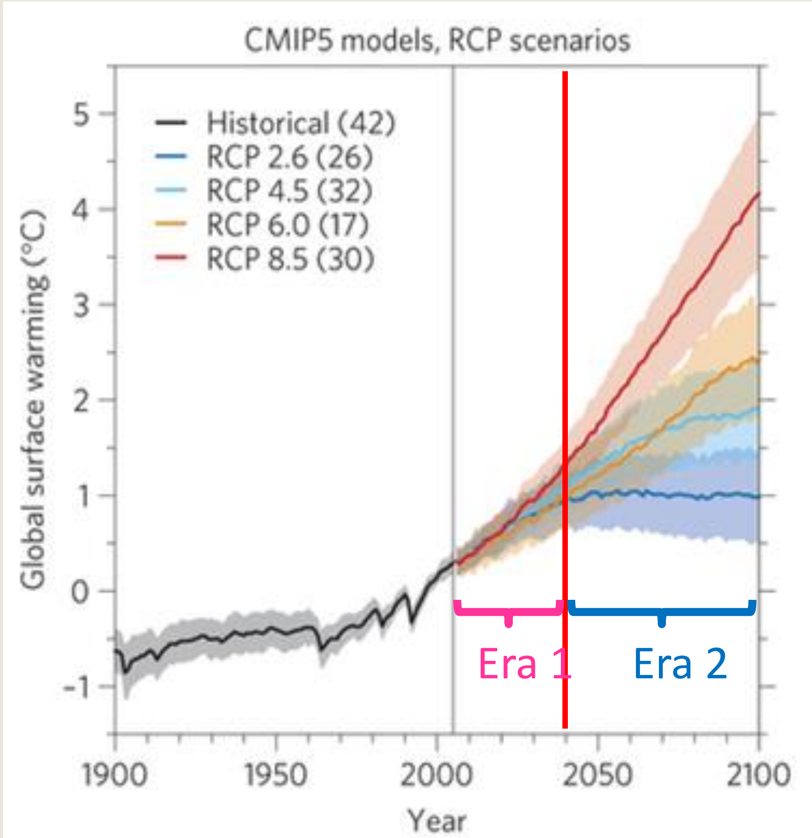
	Precipitation	Temperature
CORN	**2.83**	**0.45**
COTTON	**0.02**	**0.54**
POTATOES	**2.58**	**0.61**
SOYBEANS	**0.18**	**0.26**
WHEAT	**0.68**	**-0.73**

Hotter and wetter mostly cost increasing

Chen, C.C., and B.A. McCarl, "Pesticide Usage as Influenced by Climate: A Statistical Investigation", Climatic Change, 50, 475-487, 2001.

Adaptation and its inevitability

Adaptation – Inevitability



4°

2°

Inevitable amount

What we have
Seen so far

Era 1 – In this time period (now until 2040-2050) there is not much contribution from limiting emissions with an inevitable amount of climate change. Needs adaptation plus mitigation

Era 2 – In this time period (2050-2100) mitigation has effects and the climate is warming the question is how much

McCarl, B.A., "Elaborations on Climate Adaptation in U.S. Agriculture", Choices, 2nd Quarter

Observed Adaptations

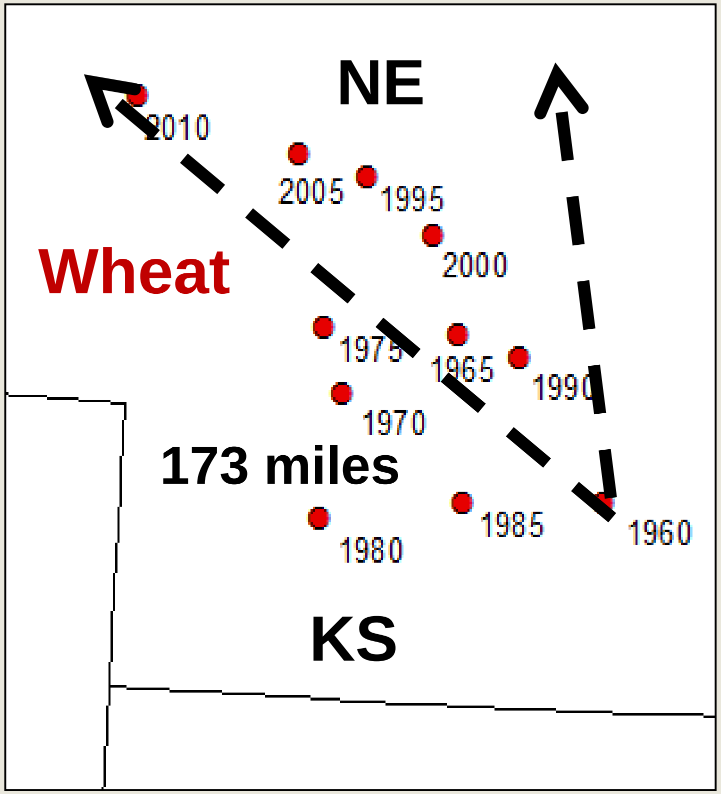
Observations - Natural Adaptation

We also have seen

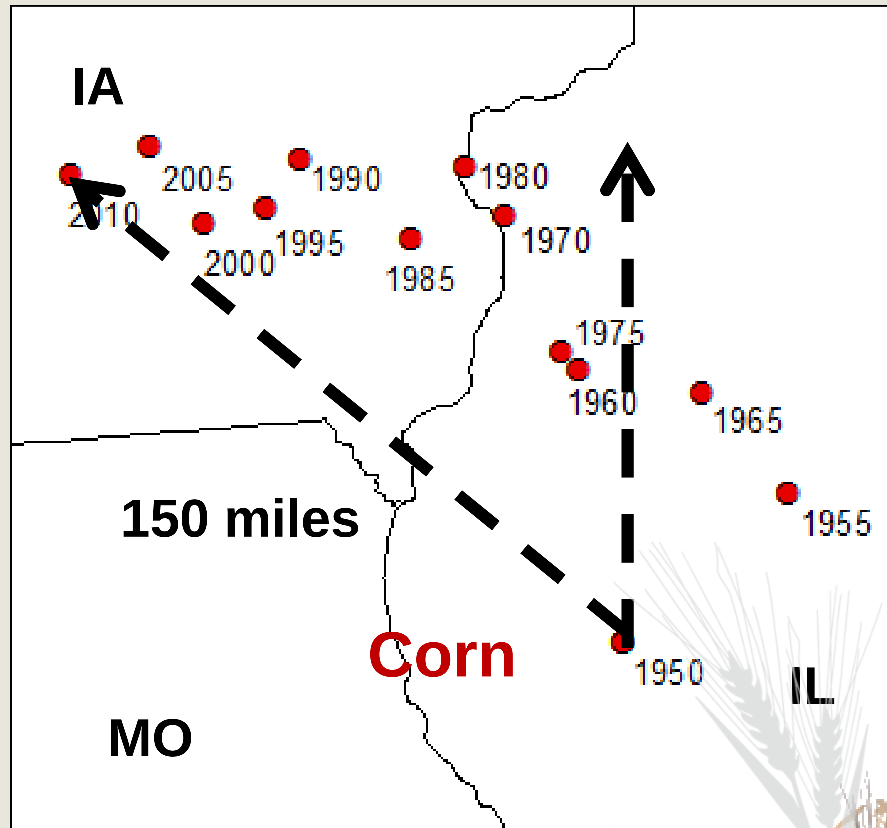
- Melting glaciers
- More pests
- Sea level rise
- Coastal retreat

Pictures over time of glacial water supply source, for Boulder CO

Observations - Autonomous Adaptation

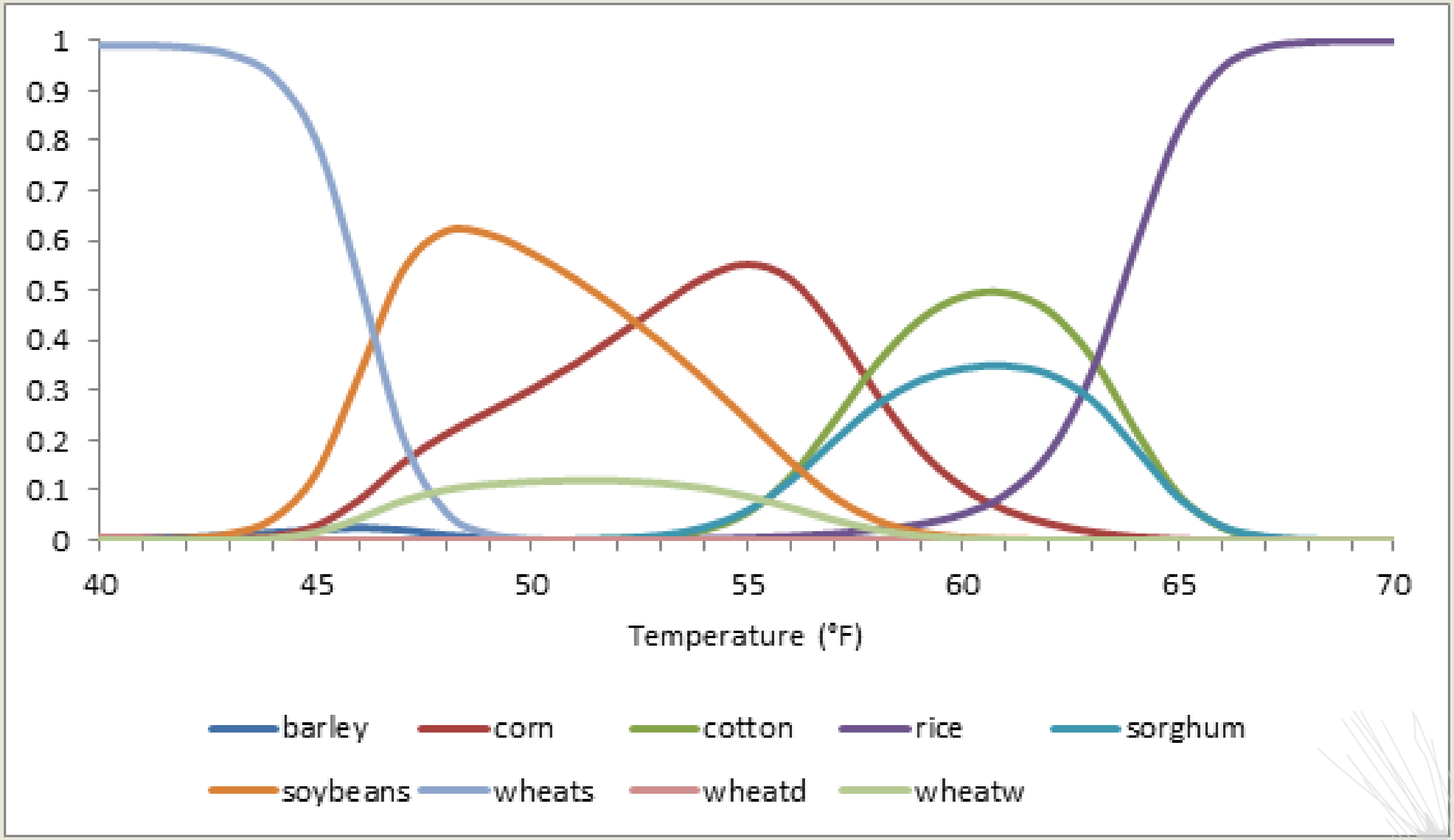


Production Weighted Centroid 1950-2010



Attavanich, W., B.A. McCarl, Z. Ahmedov, S.W. Fuller, and D.V. Vedenov, "Climate Change and Infrastructure: Effects of Climate Change on U.S. Grain Transport", Nature Climate Change, on line at doi:10. 1038/nclimate1892, VOL 3 JULY 2013, 638-643, 2013.

Observations - Autonomous Crop Choice

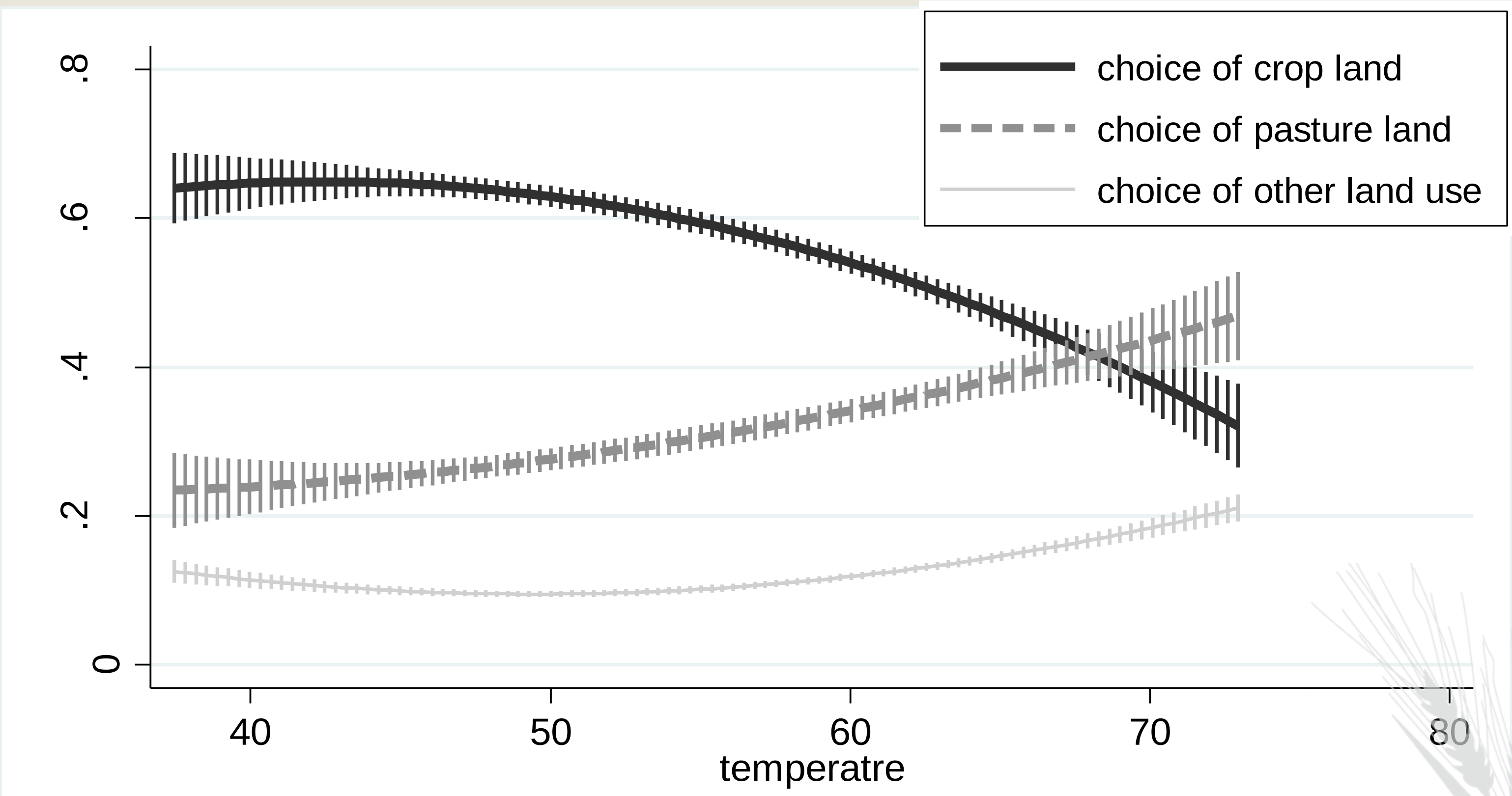


Crop mix shift as climate warms - wheat at low end rice at upper. Neglects grasslands

Park, J.Y., B.A. McCarl, and X.M. Wu, "The Effects of Climate on Crop Mix and Climate Change Adaptation", 2013.

Observations - Autonomous Land Use

- Farm gate adaptations include changes in irrigation, crop mix, land use and to a lesser extent irrigation methods.



Crop land moves to pasture

Mu, J.E., B.A. McCarl, and A.M. Wein, "Adaptation to climate change: changes in farmland use and stocking rate in the U. S", Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.

Observations - Autonomous Stocking Rates

Table 5 Changes of Land Use Allocation and Cattle Stocking Rate

	Base	2010-2039	2040-2069	2070-2099
		HadCM3-B1 emission scenario		
Crop	0.60	-0.22	-0.28	-0.33
Pasture	0.29	0.28	0.35	0.41
Other land use	0.11	-0.06	-0.07	-0.08
Cattle stocking rate*(animal/acre)	0.25	-35.48	-41.86	-48.87
		HadCM3-A1B emission scenario		
Crop	0.60	-0.31	-0.38	-0.43
Pasture	0.29	0.39	0.46	0.52
Other land use	0.11	-0.07	-0.09	0.09
Cattle stocking rate*(animal/acre)	0.25	-49.89	-58.01	-66.34
		HadCM3-A2 emission scenario		
Crop	0.60	-0.28	-0.35	-0.44
Pasture	0.29	0.35	0.43	0.53
Other land use	0.11	-0.07	-0.08	0.09
Cattle stocking rate *(animal/acre)	0.25	-47.72	-54.63	-70.27

Stocking rates decrease

Mu, J.E., B.A. McCarl, and A.M. Wein, "Adaptation to climate change: changes in farmland use and stocking rate in the U. S", Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.

Types of Adaptation
And
Failitating Adaptation

Adaptation challenge

Throughout history, people and societies have **adapted** to and coped with climate, climate variability, and extremes, with varying degrees of success particularly in agriculture.

But the pace of adaptation may be unprecedented. We may be on the treadmill requiring almost constant adaptive actions.

Adaptation is **place- and context-specific**, with no single approach for reducing risks appropriate across all settings.

Adaptation can be "natural" or "autonomous" or "planned."

Natural adaptations are actions in ecosystem stimulated by species reacting to climate

Autonomous adaptations are actions taken voluntarily by decision-makers (such as farmers or city leaders)

Planned adaptations are interventions by governments to address needs unlikely to be met by autonomous actions (**Public goods**)

A public good is an item where individuals cannot be effectively excluded from use and where use by one individual does not reduce availability to others like a sea wall or a new cropping practice

Public goods include cropping practices , flood control systems, lighthouses, and street lighting.

Public goods problems are often closely related to the "free-rider" problem, in which people not paying for the good may continue to access it. Thus, the good may be under-produced, overused or degraded. Many adaptation actions fall here

Adaptation can be "natural" or "autonomous" or "planned."

Public sector may play important roles in all cases.

- Support autonomous adaptation providing information, shaping market conditions , developing technologies

- Act directly by developing strategies, providing resources, and carrying out projects (infrastructure development).

- Influence natural adaptation by managing the unmanaged

Government scientists and policy makers are in the public sector group and would address public goods

Adaptation – Ag Means to adapt

Investment to facilitate adaptation

- Research
- Extension
- Capital investment

Ag Adaptation

- Irrigation
- Drought resistant varieties
- Tolerant breeds and varieties
- Crop and livestock mix
- Crop to pasture
- Abandonment

McCarl, B.A., Adaptation Options for Agriculture, Forestry and Fisheries, A Report to the UNFCCC Secretariat Financial and Technical Support Division, 2007. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf

Adaptation and the treadmill

Climate change and its continual progression raises a new demand on agriculture research and extension

Traditionally in agriculture we did research on yield improvement and some maintenance for say pest resistance

We could count on weather being stationary but now this is likely not so.

So we must devote resources to technological adaptation in maintaining productivity at a spot

Adaptation Limits

A few words from the IPCC (WGII 2014)

Adaptive capacity is uneven across and within societies
There are substantial limits and barriers to adaptation.

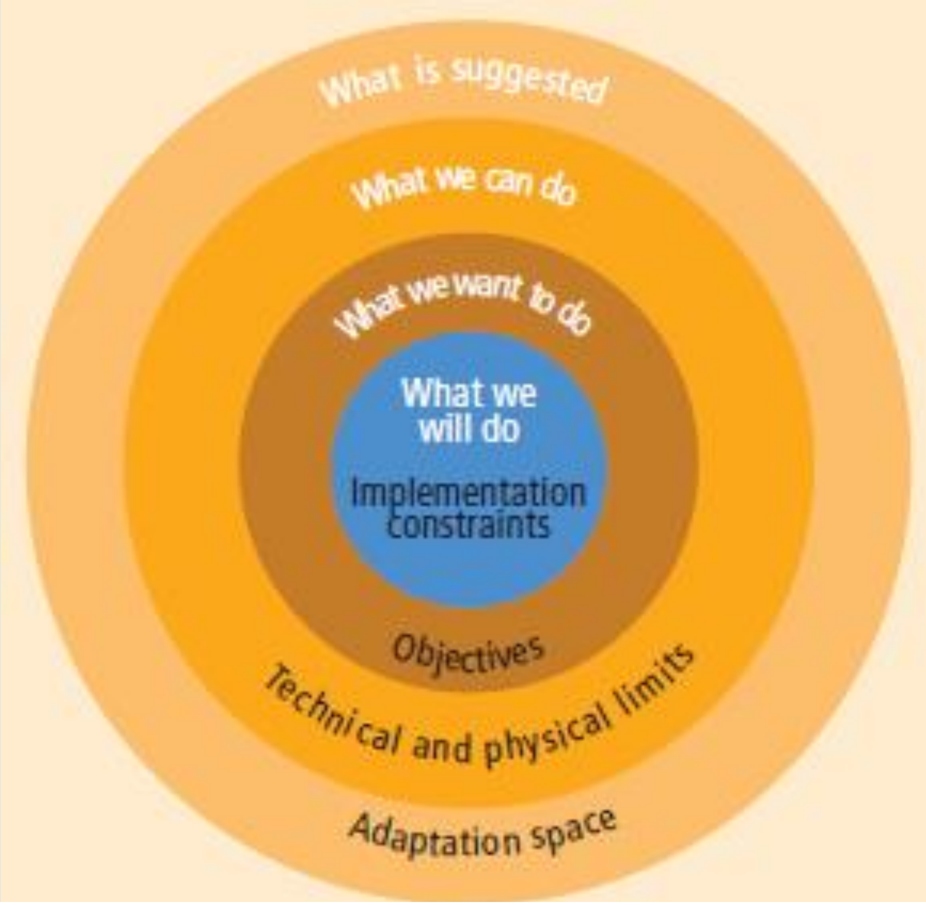


Figure 17-1 | The narrowing of adaptation from the space of all possible adaptations to what will be done. Forces causing the narrowing are listed in black.

Burden of Adaptation

Investment is the cost of adaptation.

Adaptation Occurs in Three Quarters

1. Research
2. Extension
3. Capital investment

Climate change adaptation could mean an investment of $5 - $13 billion per year globally

McCarl, B.A., Adaptation Options for Agriculture, Forestry and Fisheries, A Report to the UNFCCC Secretariat Financial and Technical Support Division, 2007. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf

Who will pay for Adaptation

Some people will just adjust, but we may need improved varieties, practices, as well as additional facilities for irrigation, land development and infrastructure relocation.

Where does the money come from

suffers from public good underinvestment

plus money needed in other areas

Difficulties in project evaluation

Additionality

Uncertainty

Permanence

Maladaptation and leakage

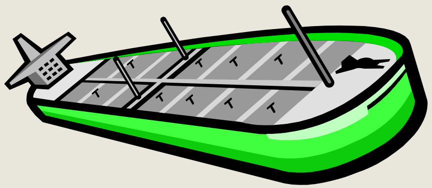
Concluding Remarks About Adaptation

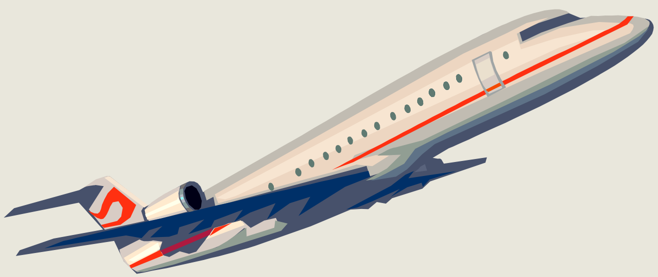
- **Agriculture will have to adapt at unprecedented rates**
  - 1º C by 2040
  - 2-4º C by 2100
- **Requires public and private roles**
  - Public fosters those that create public goods
  - Private role to offer traditional investment
  - Many possible strategies
  - Adaptation will require large investments
- **Adaptation may dominate over mitigation for some time**
  - Adaptation is happening now
  - Adaptation has its limits

The onset and exact effects of climate change are uncertain

Energy

Climate Change Adaptation





Climate Change Mitigation

Climate Change Effects

We will be squeezed

Thank you!

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

University of Idaho

Washington State University

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Oregon State University OSU

CHS

Pacific Northwest Farmers Cooperative

Monsanto