Transitioning Cereal Systems to Adapt to Climate Change

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An 80/20 approach to climate change adaptation in cereal systems

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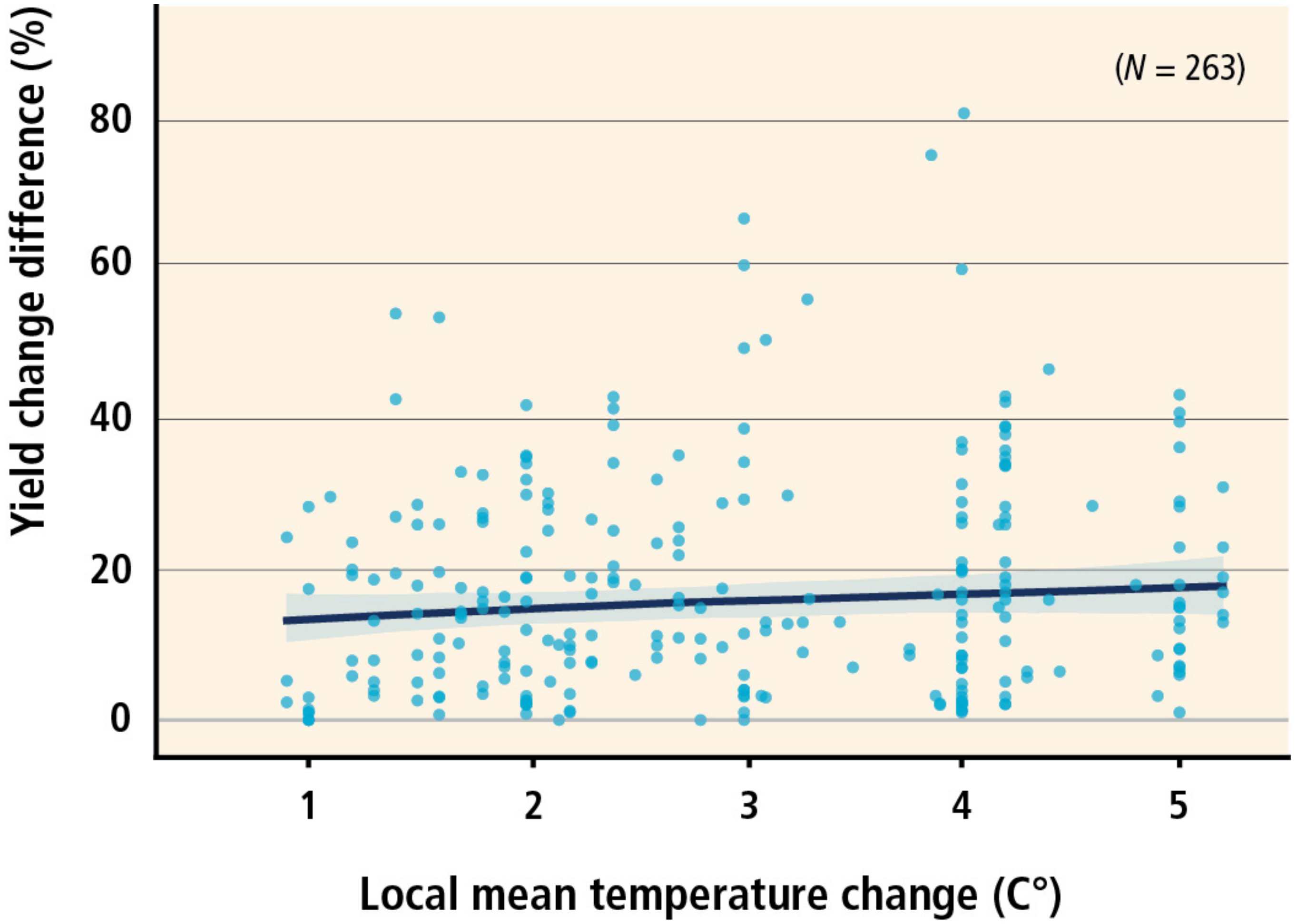
Transitioning Cereal Systems to Adapt to Climate Change, November 14, 2015

Main points

- “Adaptation” is not as easy as it sounds

IPCC: Adaptation is something that reduces negative or enhances positive impacts of climate change

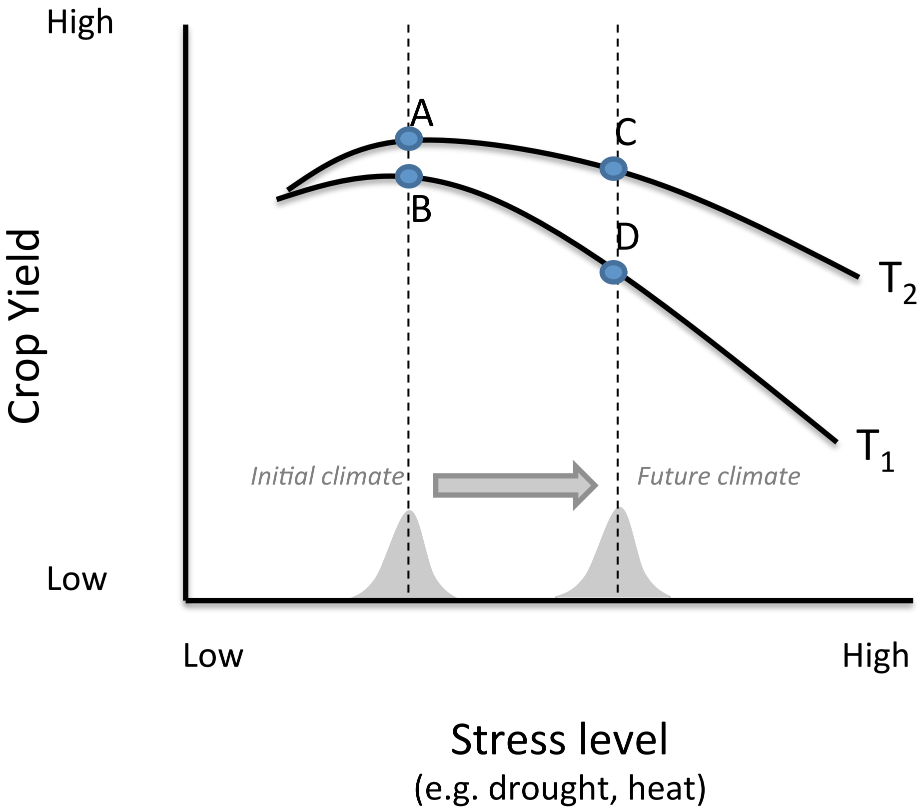
Model estimates of adaptation



IPCC WG2, 2014

The problem:

- Models are typically calculating adaptation as C - D



e.g.:
A = Stable climate, new "drought-tolerant" seed

B = Stable climate, no new technologies

C = More drought, new "drought-tolerant" seed

D = More drought, no new technologies

Lobell, 2014, *Global Food Security*

What types of adaptations are used?

Table 5 Adaptations tested in crop modelling study.

Country	Crop tested[a]	Change of planting date	Change of cultivar/ crop	Additional irrigation	Additional N fertilizer
Argentina	m	x	x[1,7]	x	
Australia	r,w	x[2]	x	x[2]	
Bangladesh	r		x		
Brazil	w,m,s	x[2]	x[1]	x,x[2,3]	x
Canada	w	x[6]		x,x[2]	
China	r	x	x,x[5,7]		
Egypt	m,w	x	x	x	
France	m,w	x,x[7]	x	x	
India	w			x	
Japan	r,w,m	x[2]		x[2]	
Mexico	m	x	x[1]	x[3]	x
Pakistan	w	x		x	
Philippines	r	x[5]	x[5]		
Thailand	r		x		
Uruguay	b	x	x	x	x,x[4]
USA	w,m,s	x	x	x	
USSR	w	x[6,7]	x		
Zimbabwe	m	x[2]		x,x[2]	x

[a] w = wheat; m = maize; r = rice; s = soybeans; b = barley

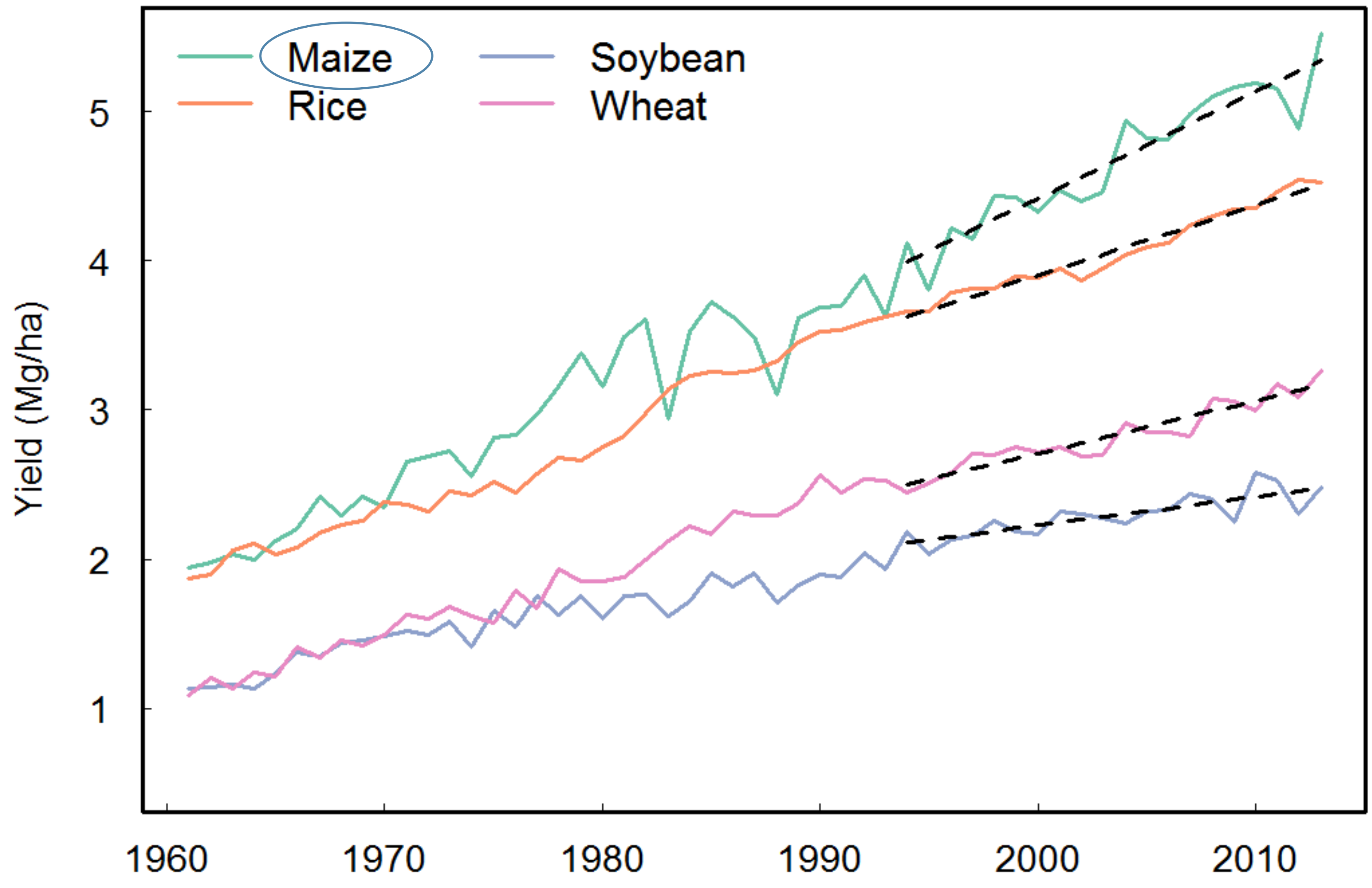
Rosenzweig and Parry 1994 *Nature*

We know that, regardless of climate change:

1) Technologies that reduce climate risks lead to greater intensification (e.g., Emerick et al. 2015). Indeed, this is the basis for a lot of current investment in Africa.

2) A lot of past yield progress has been driven by genetic and management changes that improve stress tolerance or escape.

Global average grain yields



Most of historical gains in maize from better stress tolerance

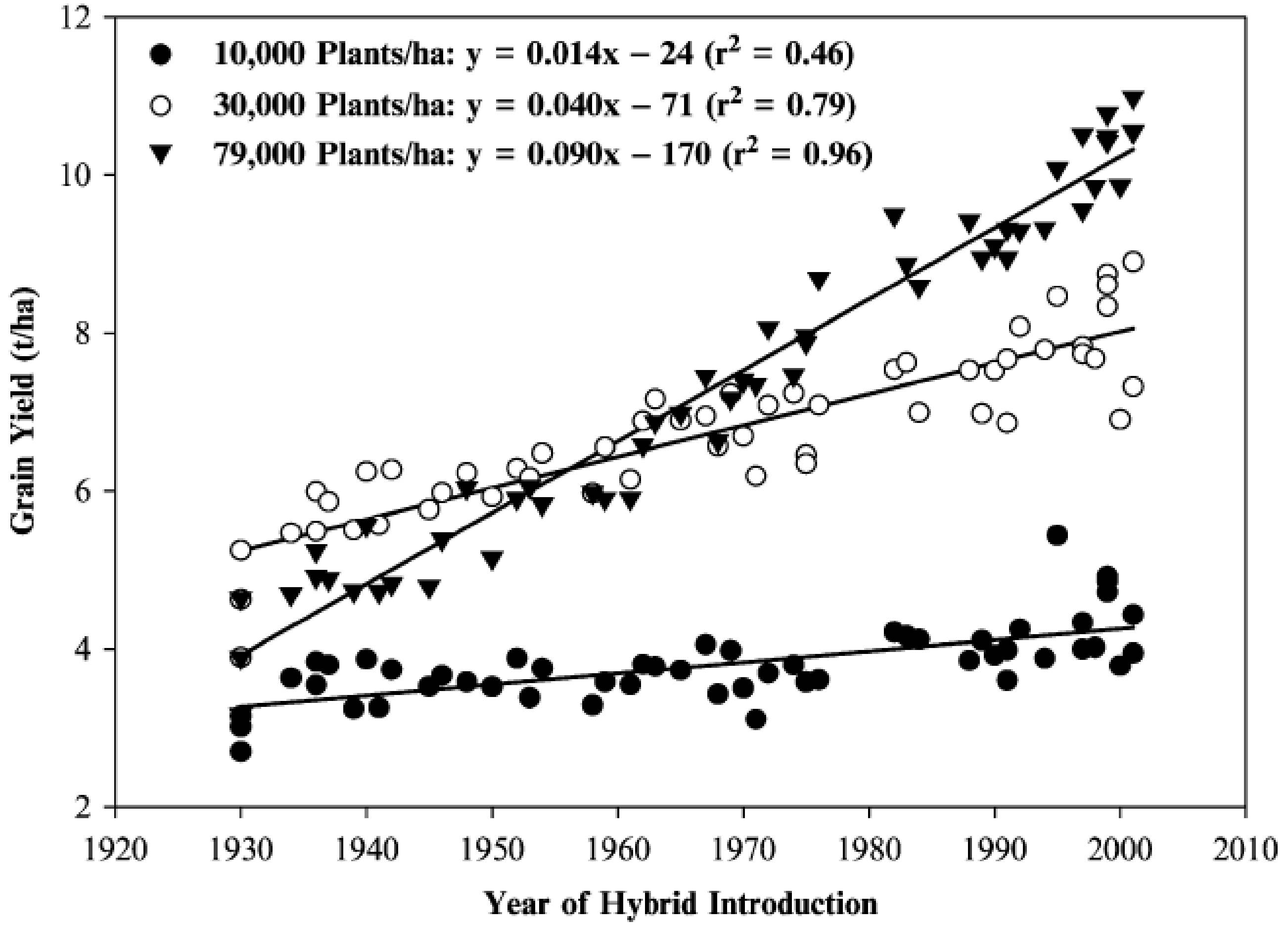
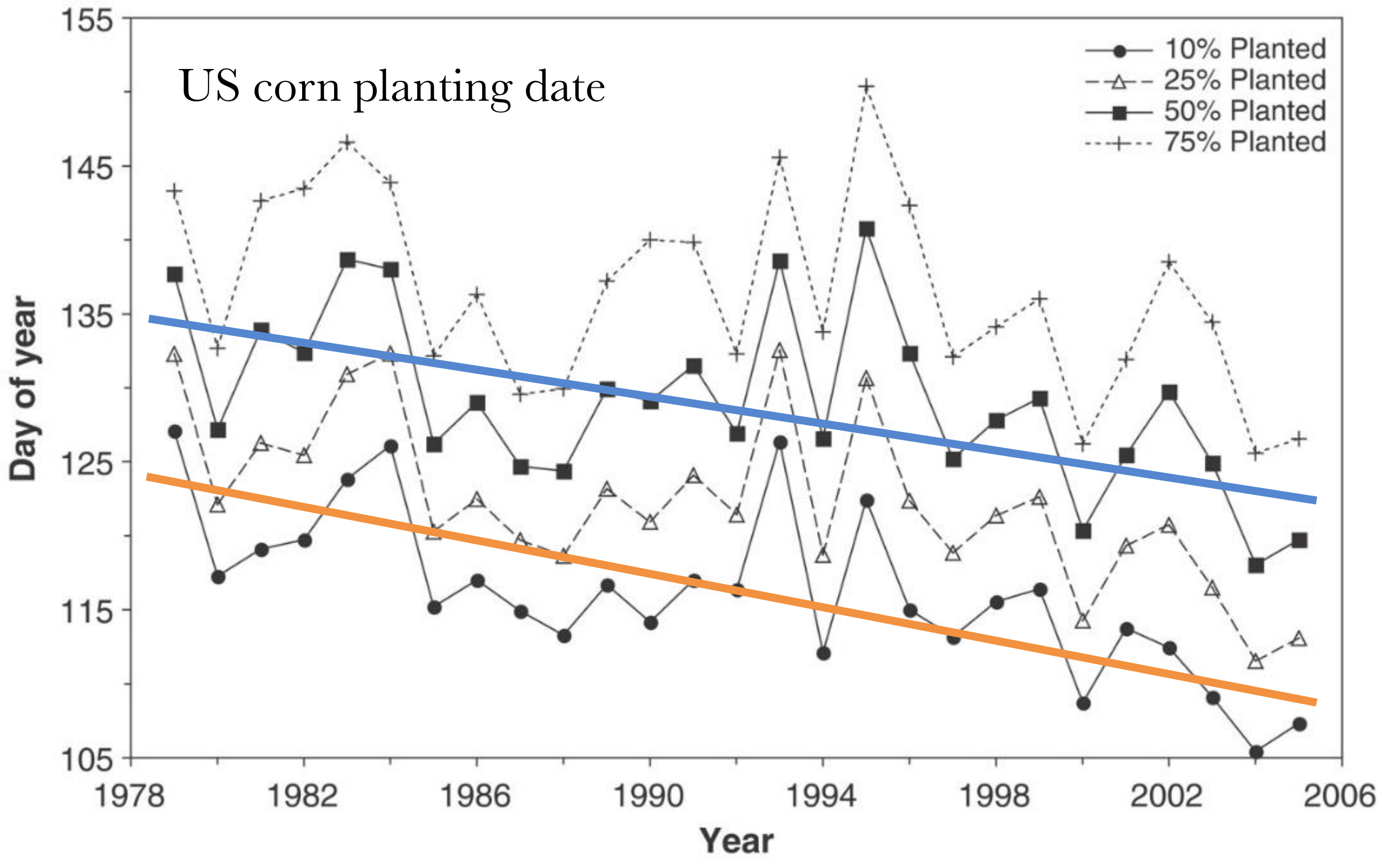


Figure 6 Grain yield per hybrid regressed on year of hybrid introduction at each of three plant densities: 10,000, 30,000, and 79,000 plants ha^{-1}. Best linear unbiased predictors (BLUPs) for hybrid grain yield based on trials grown in the years 1991–2001, three locations per year, one replication per density. From Duvick *et al.* (2004b). Copyright © 2004 by John Wiley & Sons, Inc. This material is used by permission of John Wiley & Sons, Inc.

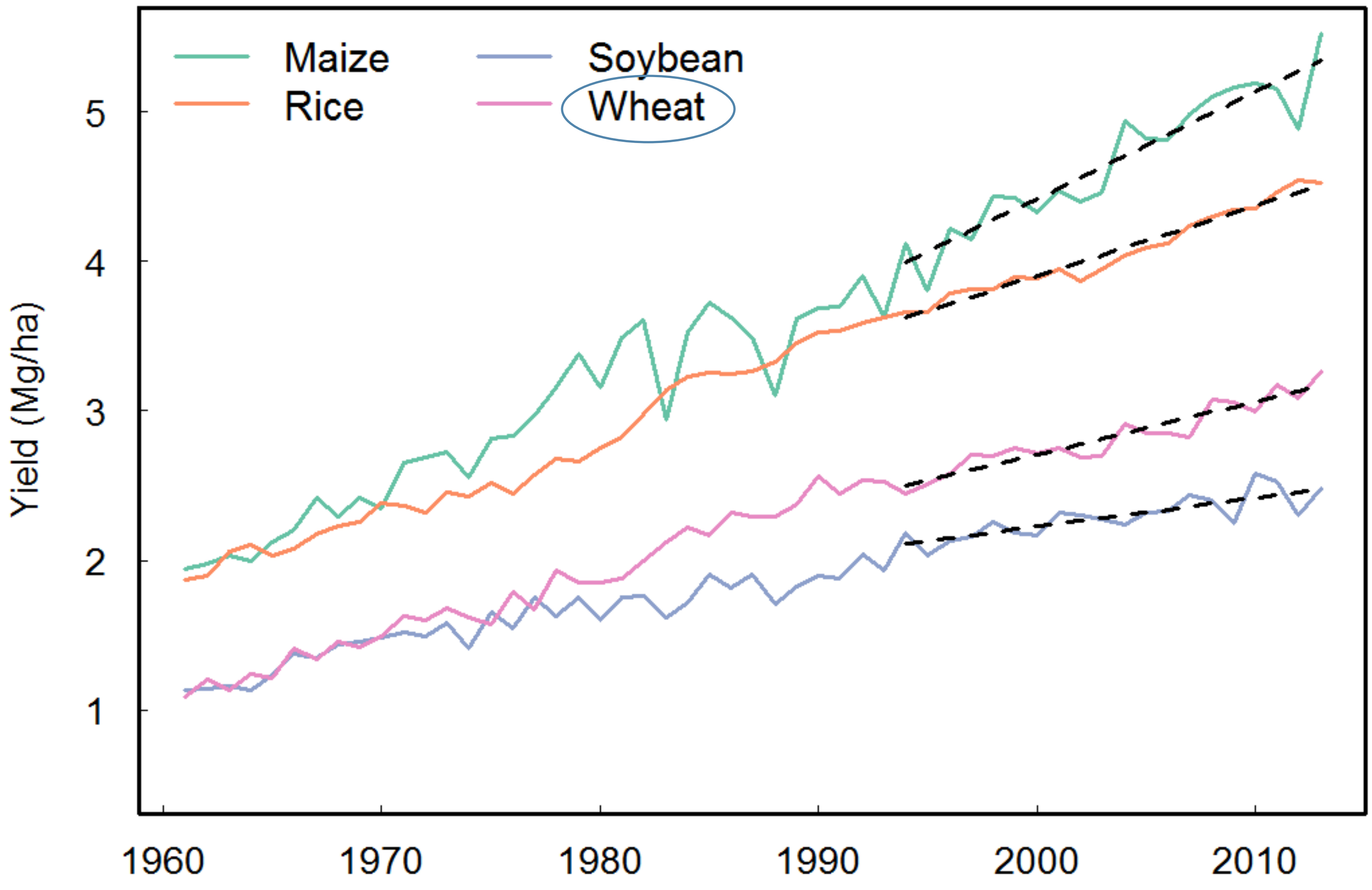
Duvick 2005

Earlier sowing and longer varieties also part of “exogenous” yield trend

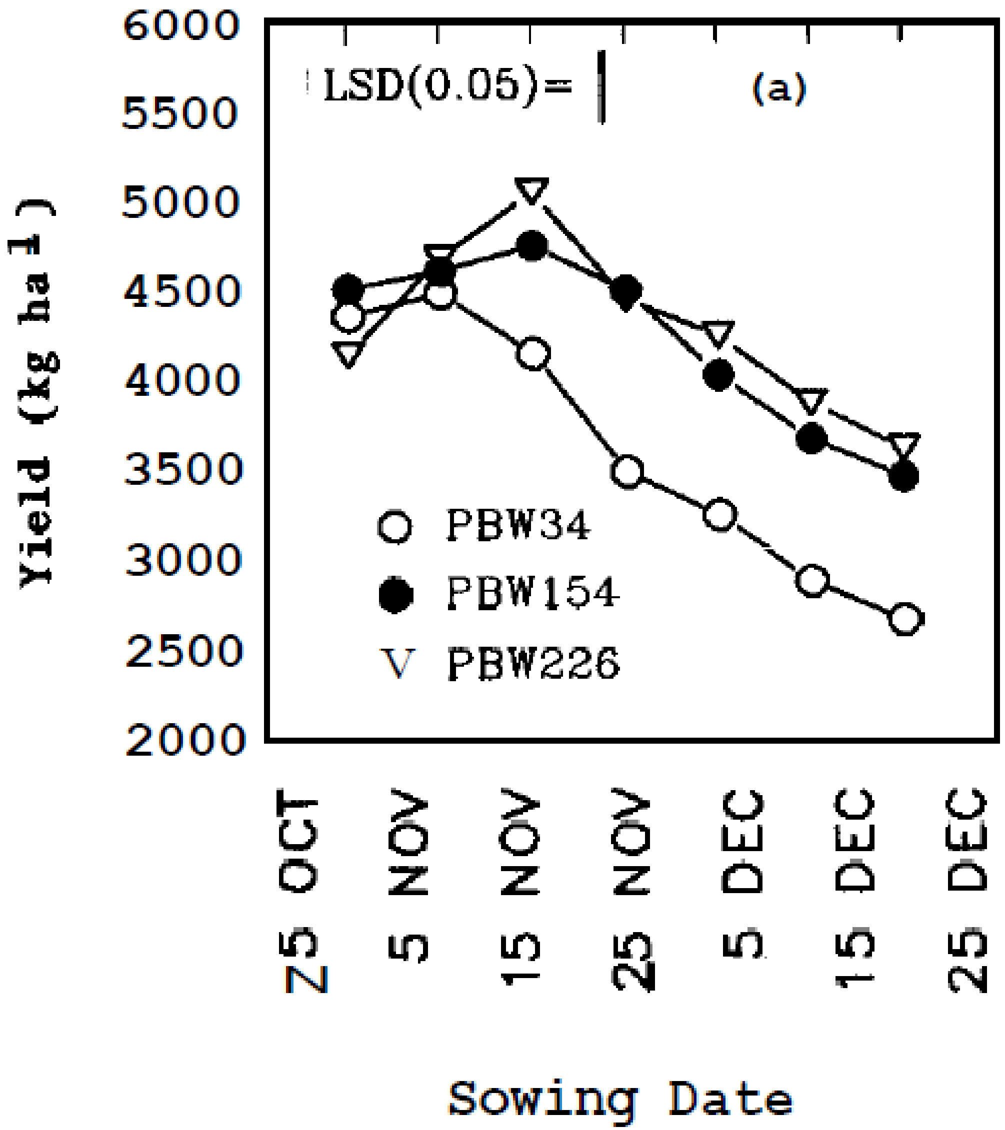


“Averaged across the 12 states, the simulated effect of trends to earlier planting and longer season cultivars accounts for 26% of the observed yield trend from 1981 to 2005”

Kucharik et al 2006, Sacks and Kucharik 2011

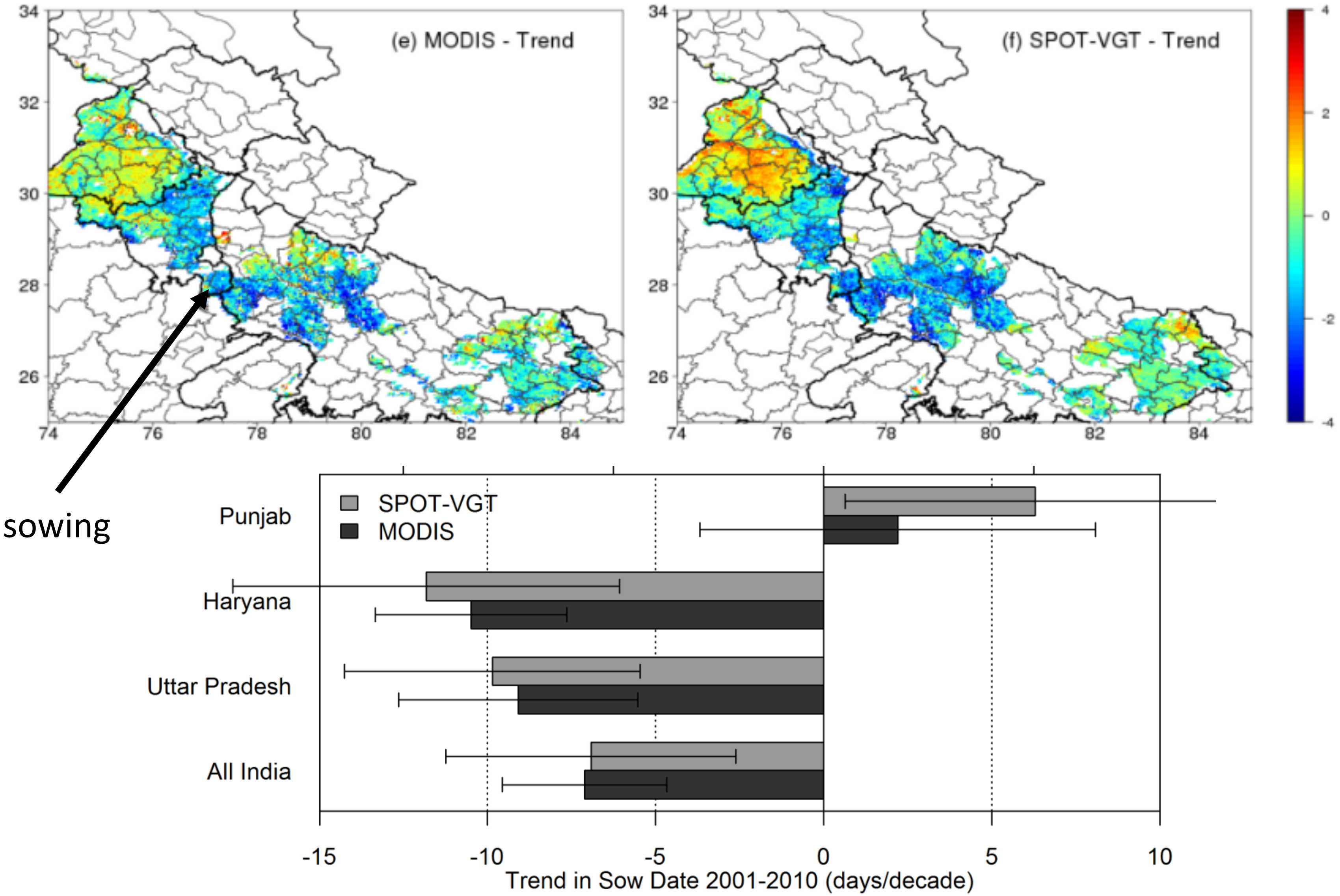

Maize
Rice
Soybean
Wheat
Yield (Mg/ha)
1
2
3
4
5
1960
1970
1980
1990
2000
2010

Heat is a well-known constraint in India



Ortiz-Monasterio et al. 1994

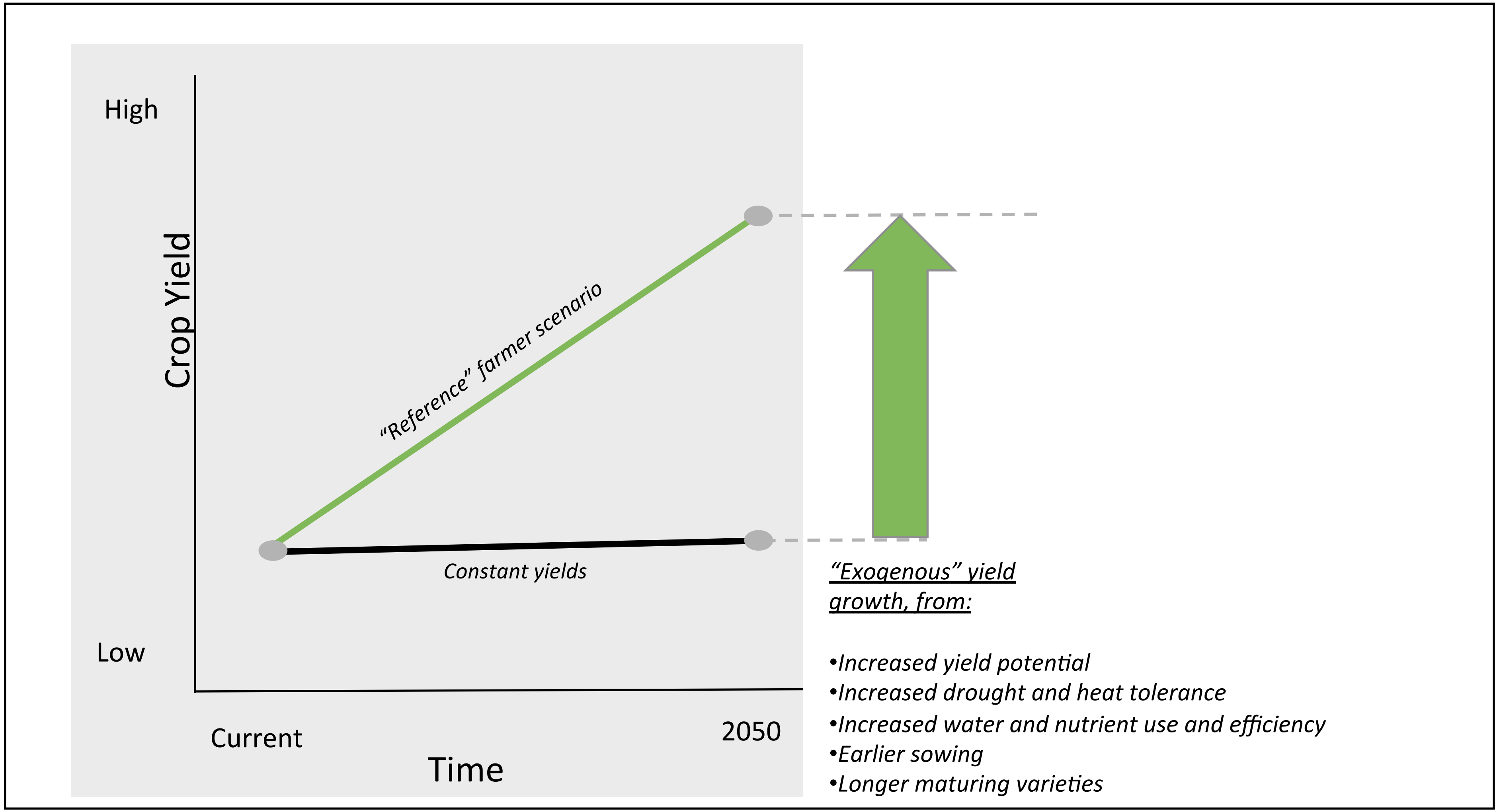
Much of recent wheat yield growth can be attributed to earlier sowing



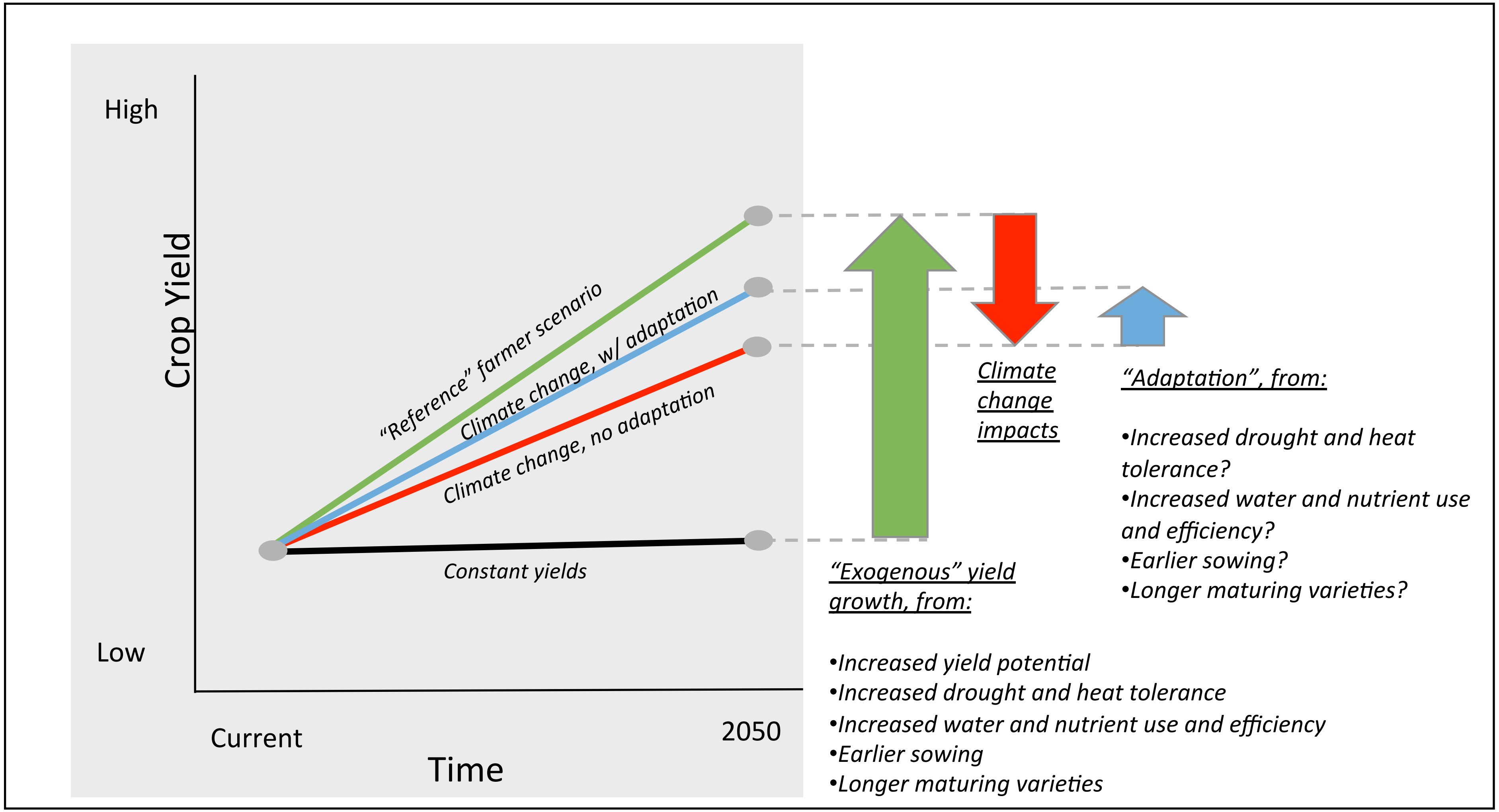
Earlier sowing

Lobell et al., 2013, *Ag Syst*

Beware of double counting



Beware of double counting



Empirical Evidence

No sign of declining sensitivity to drought in corn

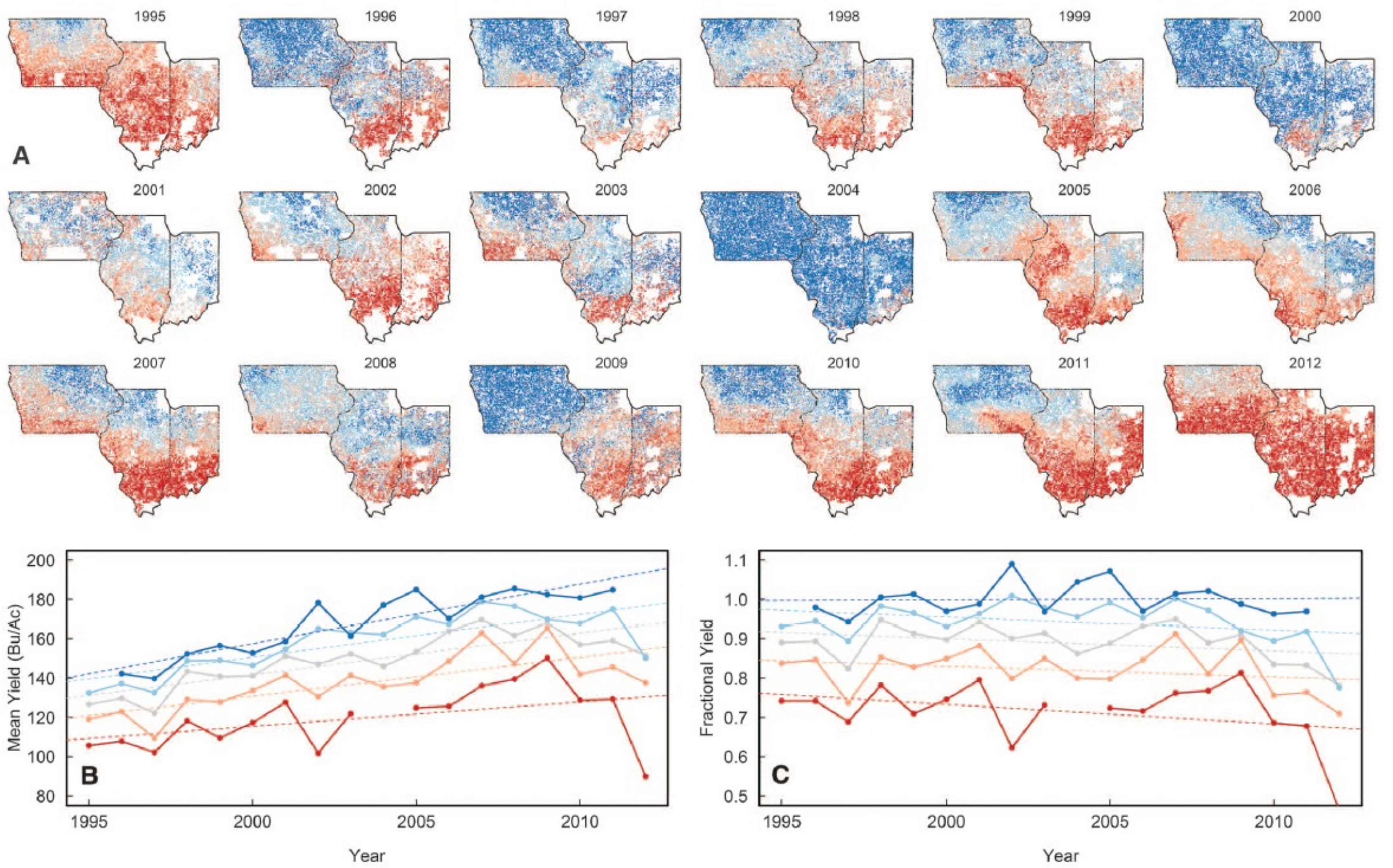
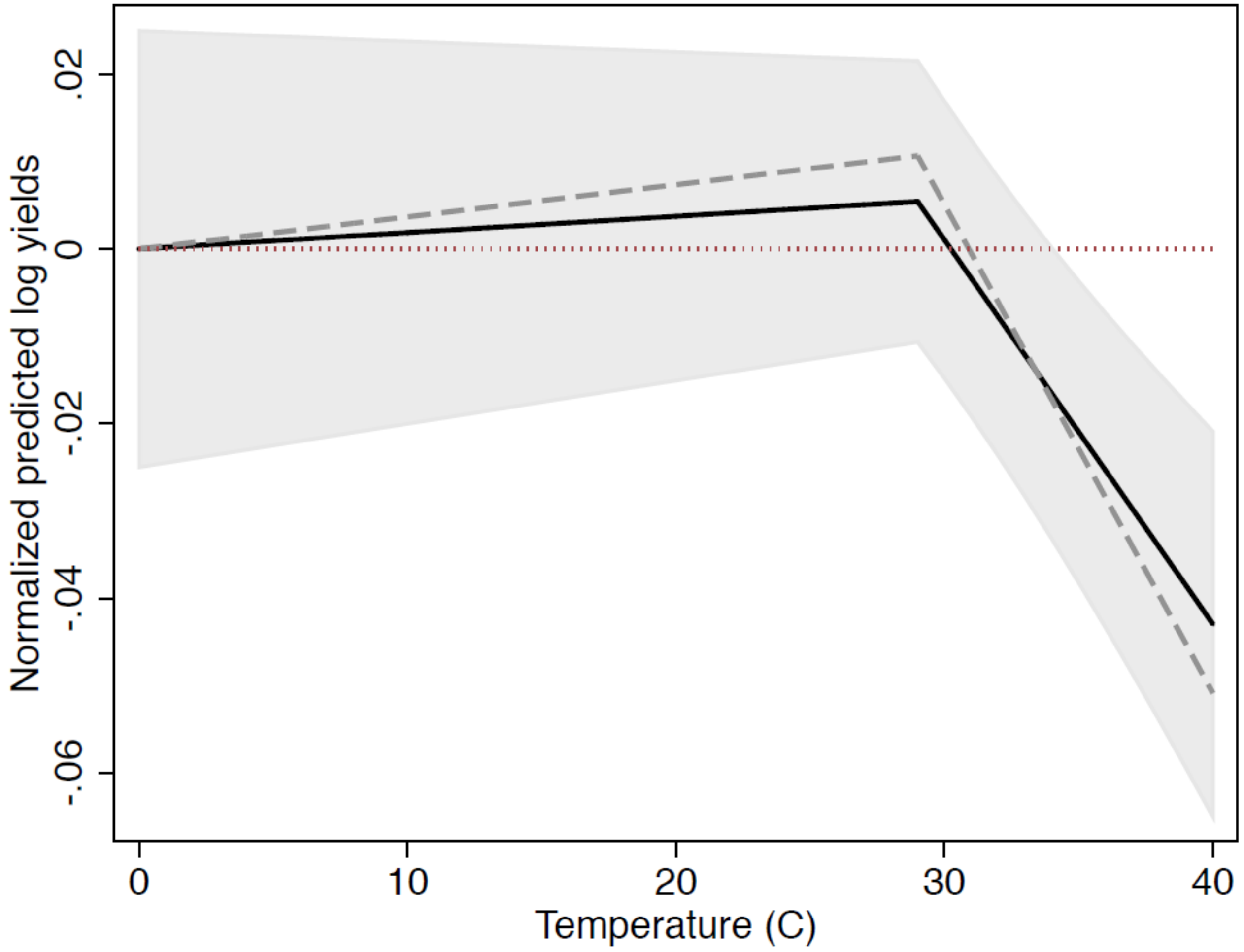


Fig. 2. Maize yields in different environments over time. (A) The yields (Bu/Ac) for each environment index quintile by year. Dashed lines

Lobell et al., 2014, *Science*

No evidence of less sensitivity on long vs. short time scales



US corn yield response inferred from:

Annual anomalies

20 year differences

Burke and Emerick, 2015

No sign of declining sensitivity to heat in wheat

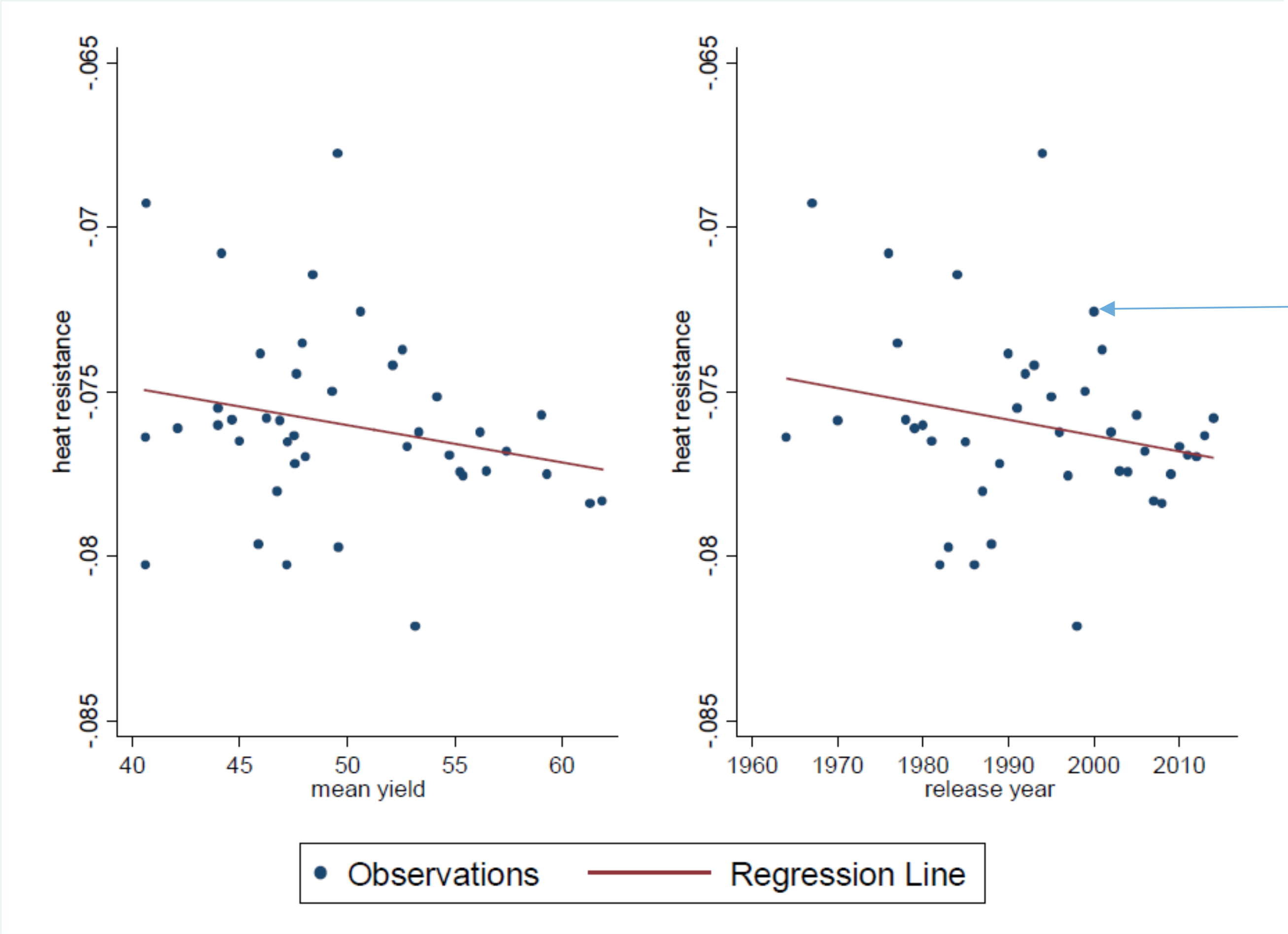


Figure S14 **The tradeoff between mean yield and heat resistance and the evolution of resistance over time.** Mean yields are predicted using the preferred model in Table S4 Column 3 with yields replacing log-yields and all weather variables held constant at their sample average.

% US wheat yield change for 1 degree day above 34 °C

Tack et al., 2015, *PNAS*

Main points

- “Adaptation” is not as easy as it sounds
- Most adaptation funding aims to support generic productivity improvements, whether or not they actually reduce climate impacts. That makes some sense, in that anything “good” will offset “bad” impacts

Is this all just semantics?

Farmers clearly need technologies and policies that reduce current climate risks. Adaptation in this broader sense isn't bad.

BUT this should not lead to:

-understating impacts of climate change

-failure to deal with novel risks

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- But, an “adaptation strategy” should balance these generic needs with a partial focus on the ***new*** needs and opportunities that arise because of climate change

An example for Australia

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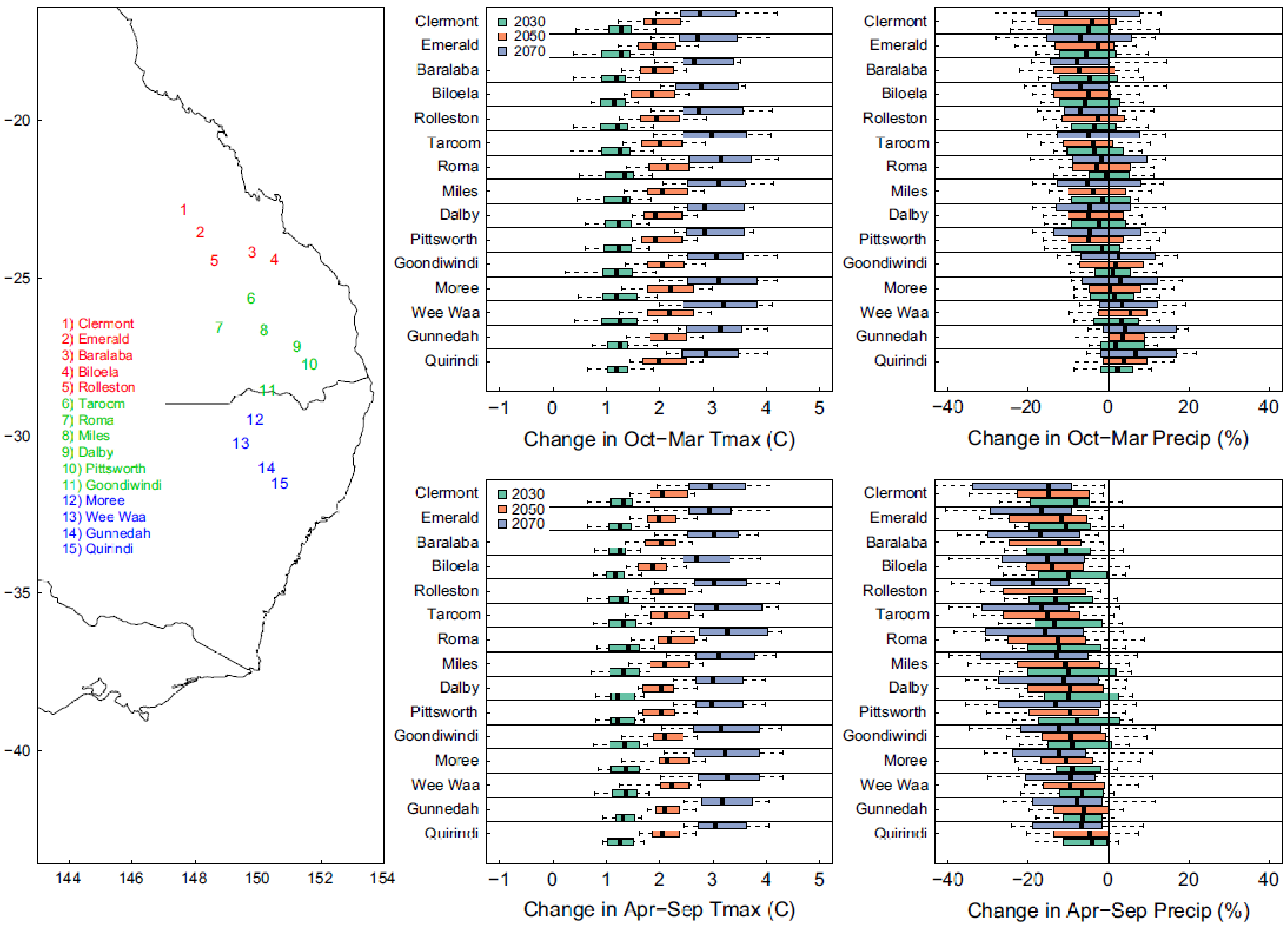
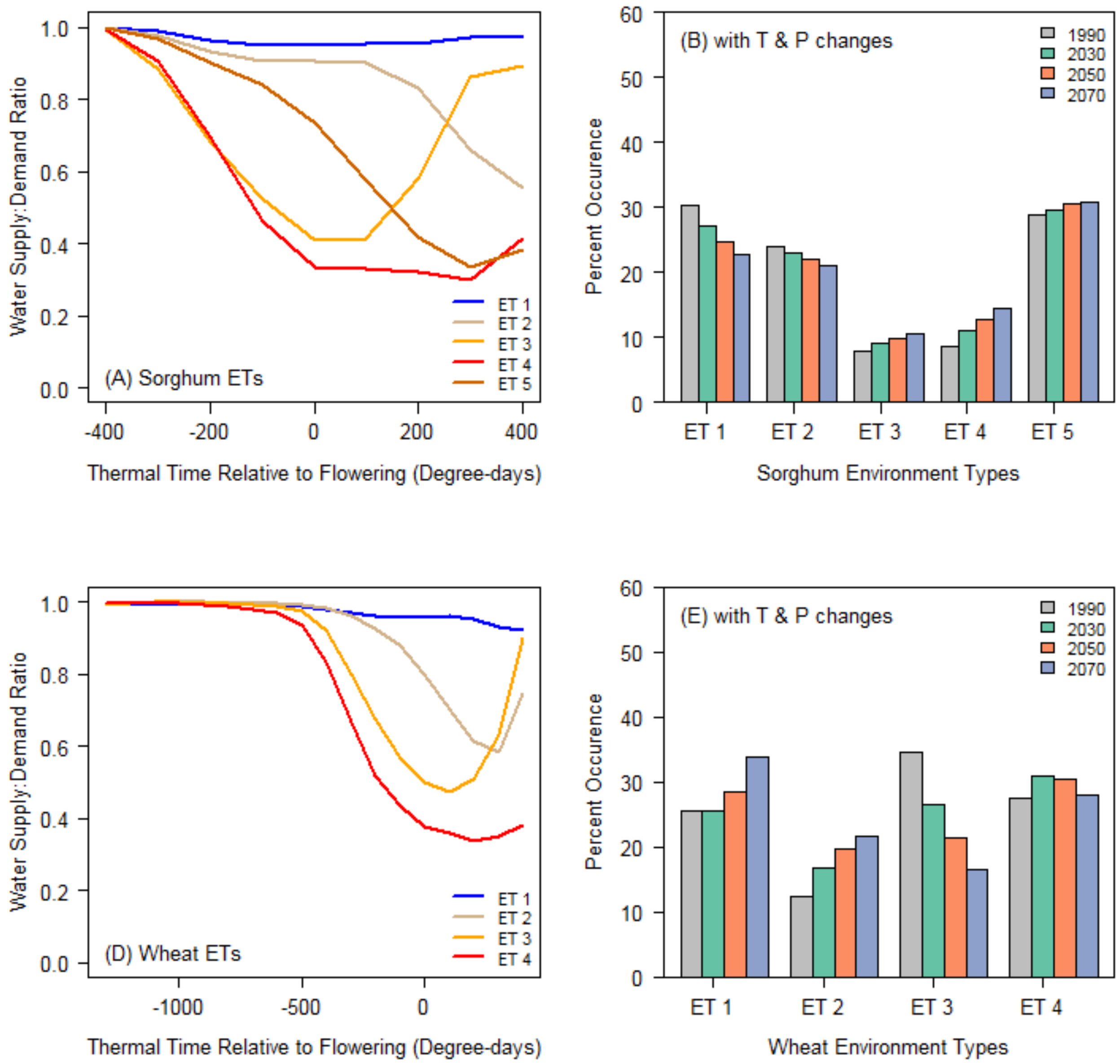


Fig. 1 The locations of the 15 simulated sites (left) and projected changes in average daily maximum temperature (T_{max}) and cumulative season precipitation (Precip) for the sorghum (top) and wheat (bottom) growing seasons in northeast Australia. Boxplots indicate the median (vertical hatch), 25–75th percentile (box), and 10–90th percentile (whiskers) among the 33 GCMs used for this study.

Lobell et al. 2015, *Global Change Biology*

Drought environment types:



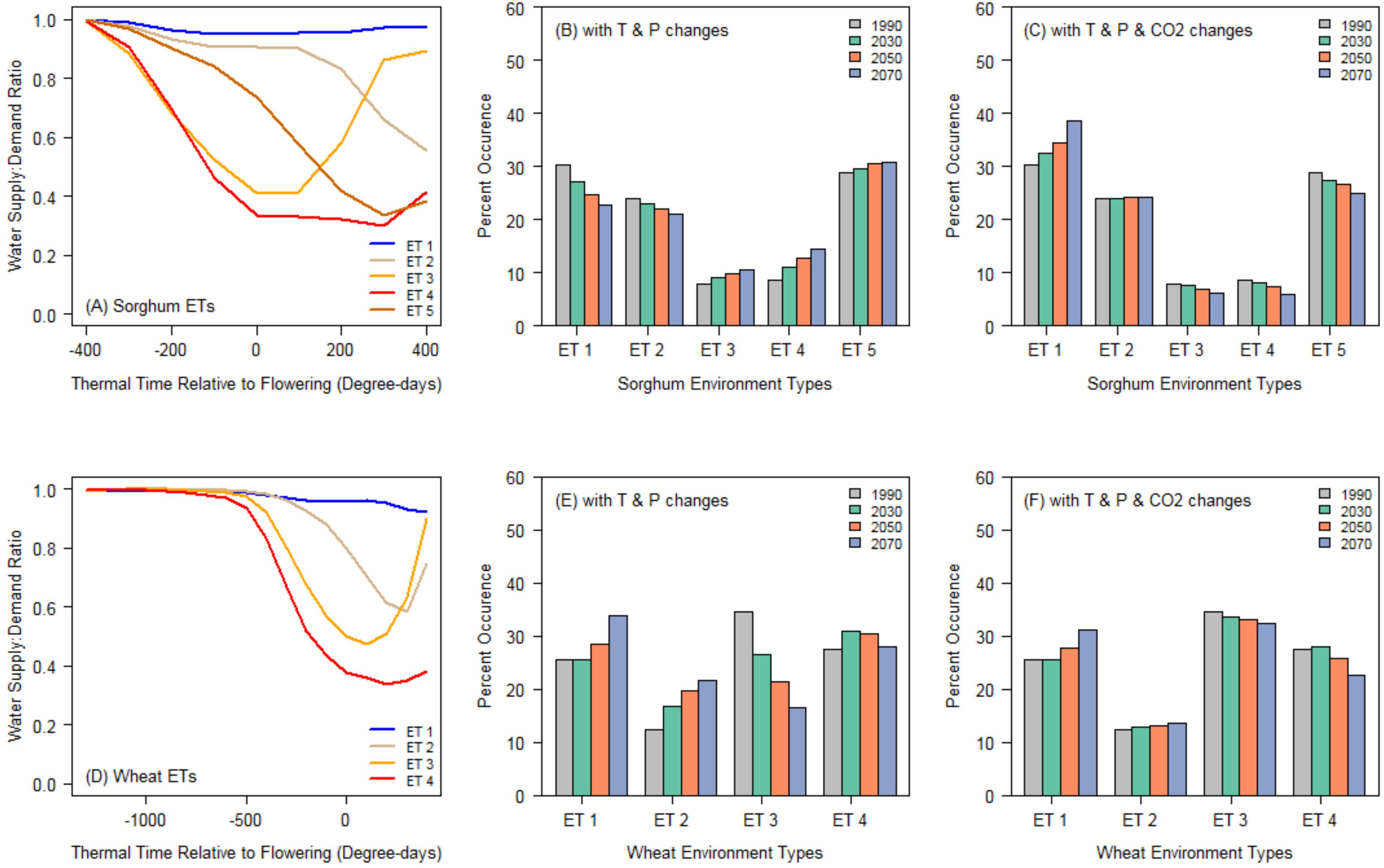
sorghum drought increase

Wheat drought decrease

Lobell et al. 2015, *Global Change Biology*

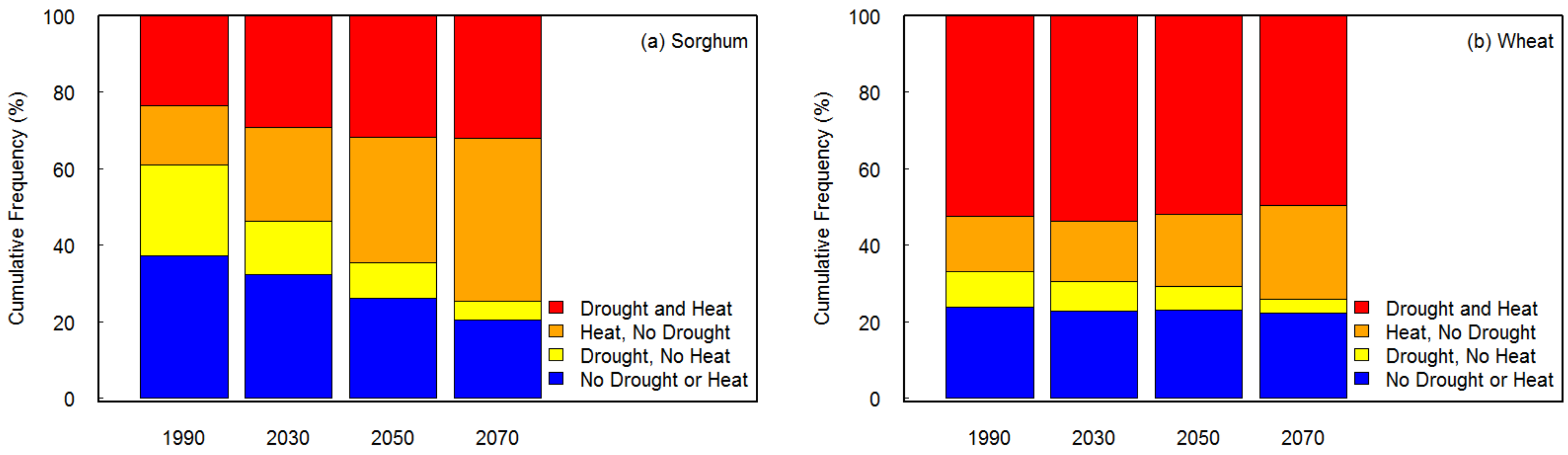
Drought environment types:

Drought decrease for both with CO_2



For both crops, it will be much less common to get drought without heat:

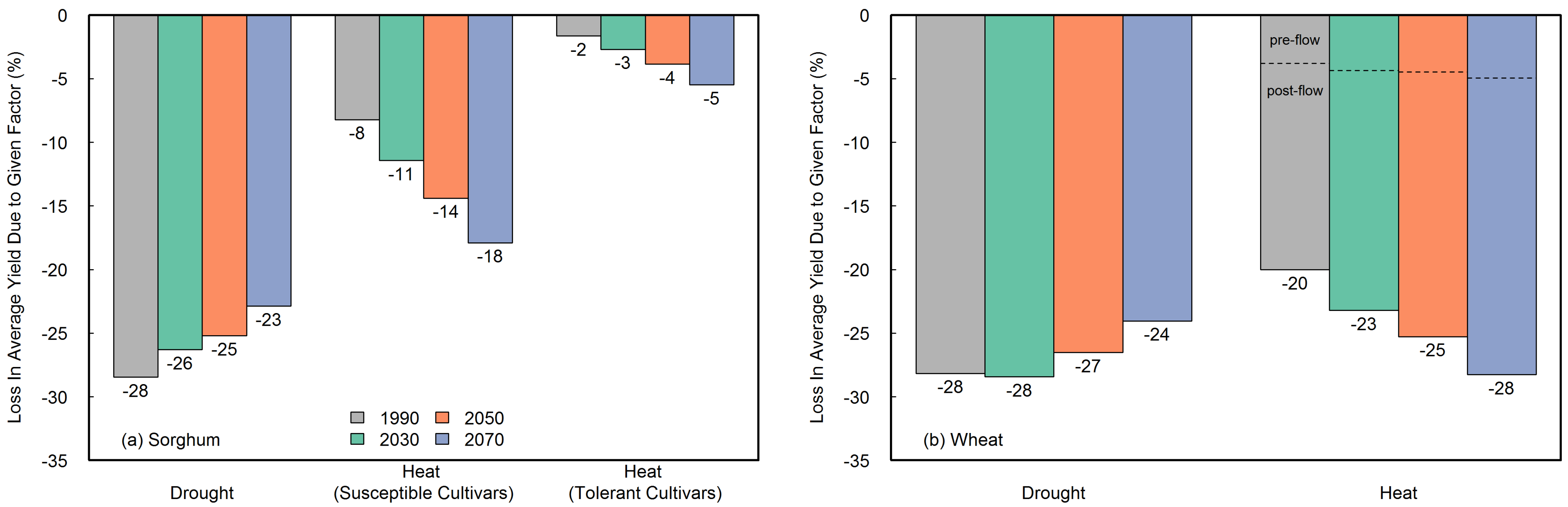
Frequency of different combinations of “drought” and “heat”



“drought” = ET 3, 4, or 5
“heat” = >10% yield loss from heat in susceptible variety

For both crops, heat becomes relatively more important

Average yield impacts associated with drought and heat



Implications

- Breeding to reduce impacts of high temperatures is increasingly important

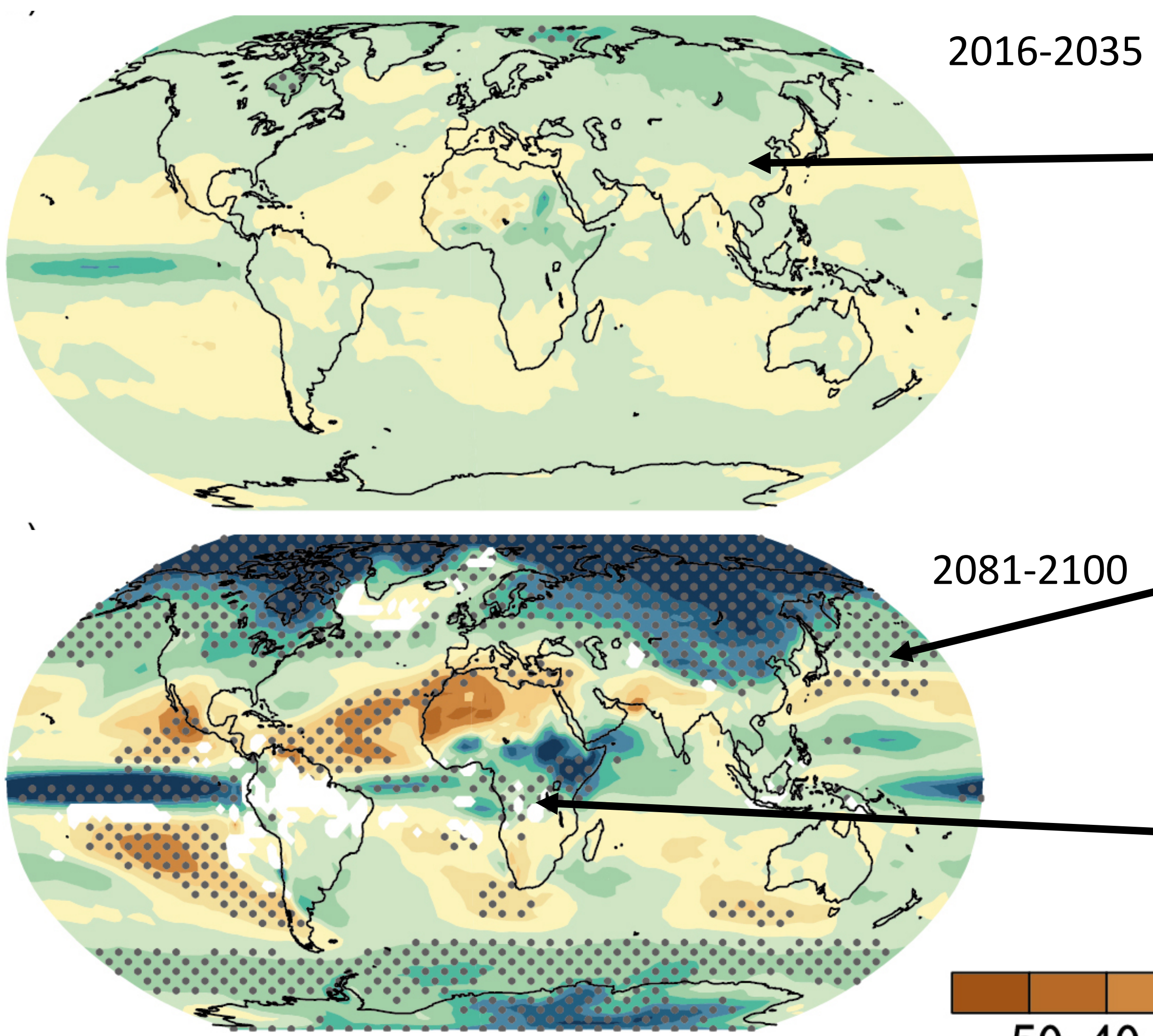
- Drought traits will remain useful, but only if they are useful during hot droughts

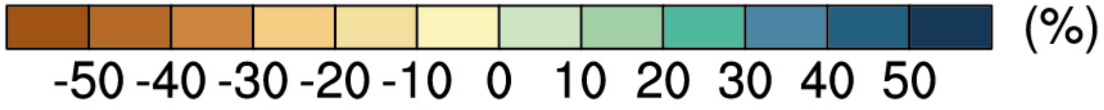
Main points

- “Adaptation” is not as easy as it sounds
- Most adaptation funding aims to support generic productivity improvements, whether or not they actually reduce climate impacts. That makes some sense, in that anything “good” will offset “bad” impacts
- But, an “adaptation strategy” should balance these generic needs with a partial focus on the ***new*** needs and opportunities that arise because of climate change
- These new needs will depend on region-specific trends in T, P, and humidity, as well as the current focus of crop research.

Rainfall is “uncertain” mostly because of natural variability

DJF Precipitation changes (RCP8.5) compared to 1986-2005



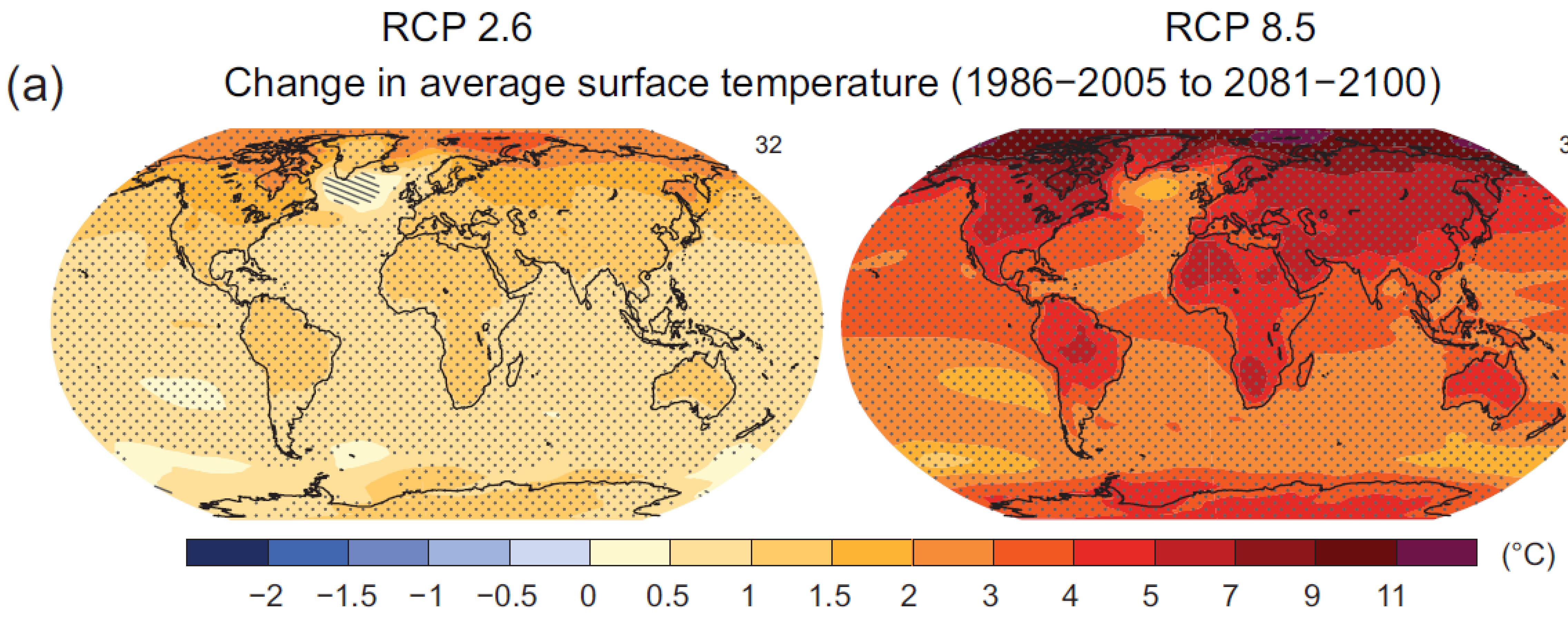


3 types of projections:

- Agreed on small effect of climate change (no marking): <50% of models show significant change relative to natural variability
- Robust large change (stipling): >50% models show significant change relative to natural variability, and 80% agree on sign of change
- Unreliable large change (white): as above but <80% agree on sign of change

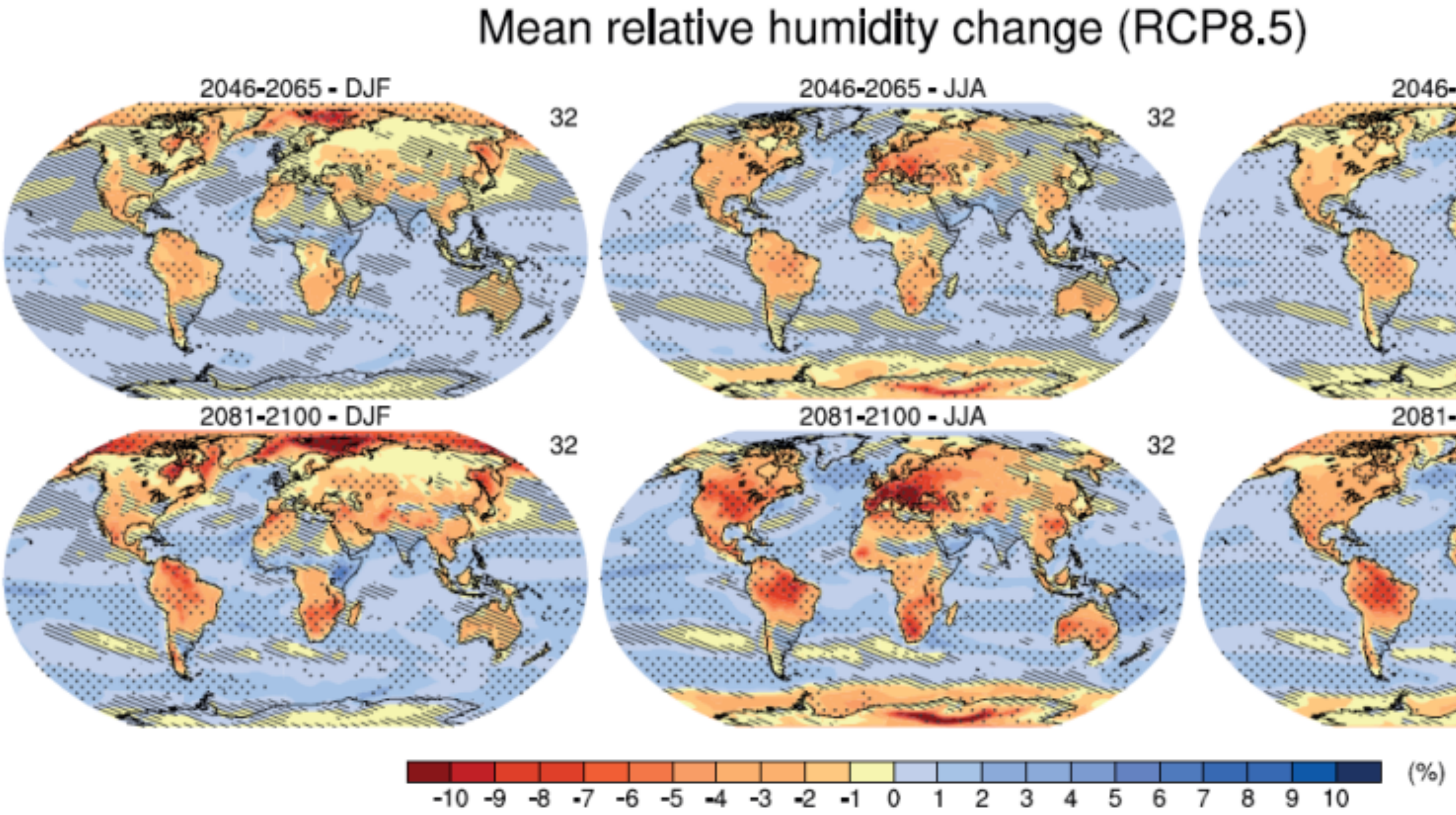
Based on IPCC (2013), WG1, CH12

Changes in other aspects of hydrology are less uncertain



IPCC (2013), WG1, SPM

Changes in other aspects of hydrology are less uncertain



IPCC (2013), WG1, CH12

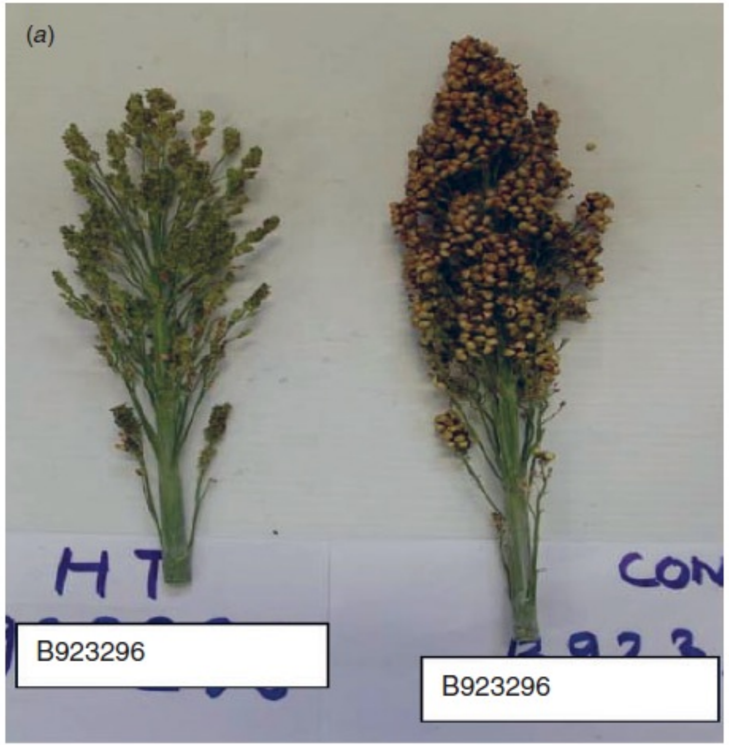
So what is an 80/20 approach?

- If we assume adaptation funds are large relative to current agricultural investment, take 80% and work on stuff that brings biggest overall benefits in current climate (i.e., “no-regrets”).
- But set aside 20% to identify and develop strategies that are truly adaptive to the new climate.
- In doing this, be careful not to overstate the adaptive benefit. Farmers are not dumb – they capitalize on new technologies even without climate change, and we shouldn’t double count this as adaptation.

Some “good bets” for true adaptation

- In temperate (richer) countries, anything that takes advantage of less cold constraints (e.g., double cropping)
- In both poor and rich countries, anything that deals with rapidly increasing risks (e.g. heat tolerance at flowering)

Sorghum heat tolerance



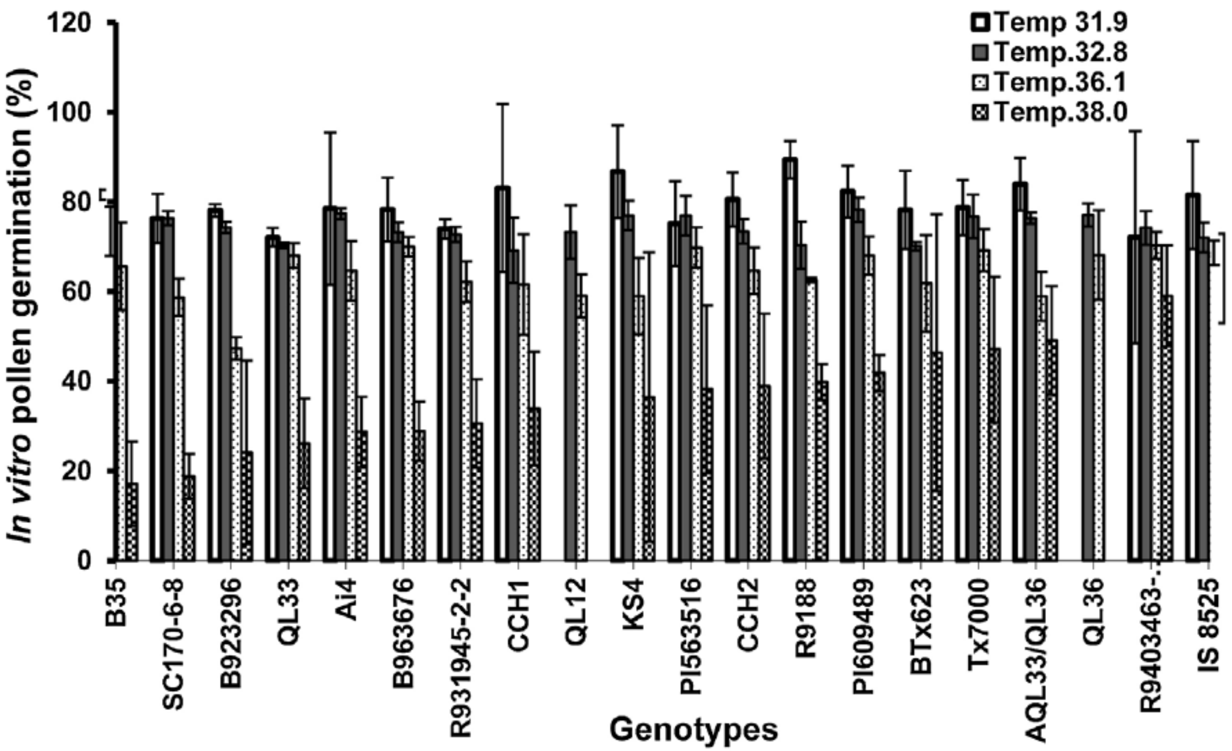
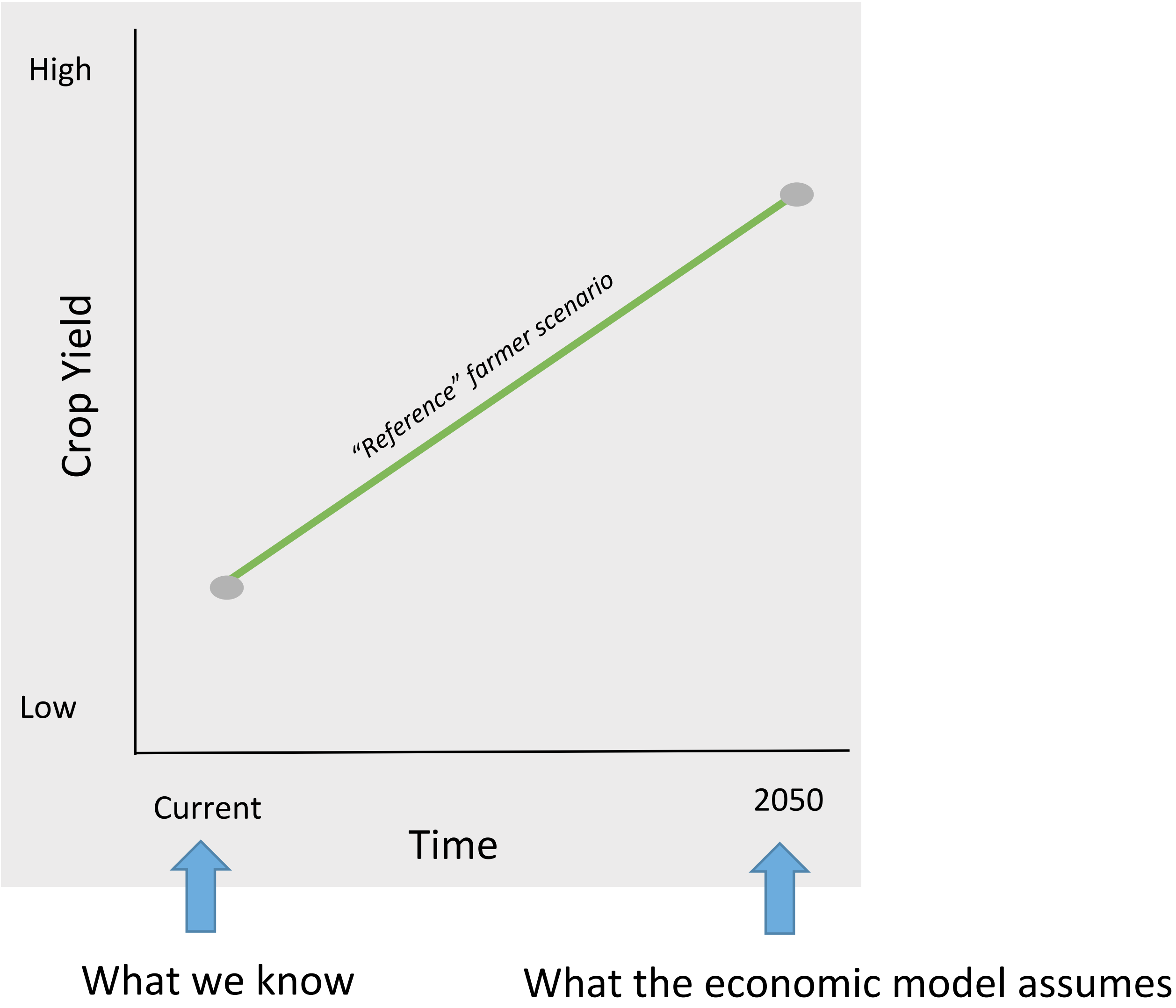


Fig. 3. *In-vitro* pollen germination (%) for various genotypes grown under four temperature regimes (31.9/21.0 °C, 32.8/21.0 °C, 36.1/21.0 °C and 38/21.0 °C) in the CEF experiment. Error bars indicate the standard error of the mean for each genotype.

sensitive ⟷ tolerant

Singh et al. 2015

Most of these are an important source of “exogenous” yield trends in supply projections



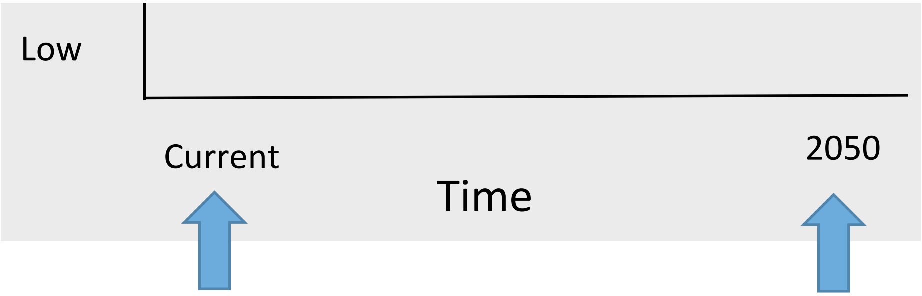
Most of these are an important source of “exogenous” yield trends in supply projections

Table S10. Exogenous yield increases between 2005 and 2050 (percentage change over the period)

Crop	Brazil	China	India	United States
Coarse grains	123	104	132	68
Oil seeds	23	50	38	43
Rice	48	43	79	44
Wheat	103	62	40	49

Source: IMPACT modeling suite (1). These projections do not include climate change effects or endogenous yield responses to changes in input or output prices.

(Rosenzweig et al. 2014, PNAS)



What we know

What the economic model assumes

What types of adaptations are used?

Table 5 Adaptations tested in crop modelling study.

Country	Crop tested[a]	Change of planting date	Change of cultivar/ crop	Additional irrigation	Additional N fertilizer
Argentina	m	x	x[1,7]	x	
Australia	r,w	x[2]	x	x[2]	
Bangladesh	r		x		
Brazil	w,m,s	x[2]	x[1]	x,x[2,3]	x
Canada	w	x[6]		x,x[2]	
China	r	x	x,x[5,7]		
Egypt	m,w	x	x	x	
France	m,w	x,x[7]	x	x	
India	w			x	
Japan	r,w,m	x[2]		x[2]	
Mexico	m	x	x[1]	x[3]	x
Pakistan	w	x		x	
Philippines	r	x[5]	x[5]		
Thailand	r		x		
Uruguay	b	x	x	x	x,x[4]
USA	w,m,s	x	x	x	
USSR	w	x[6,7]	x		
Zimbabwe	m	x[2]		x,x[2]	x

[a] w = wheat; m = maize; r = rice; s = soybeans; b = barley

Rosenzweig and Parry 1994 *Nature*

"An 80/20 approach to climate change adaptation in cereal systems"

Abstract:
Much of what is required to improve cereal systems in the face of climate change are the same things that we'd need even if the climate was not changing. These include general needs such as robust breeding and agronomy research capacity, and more specific needs such as improved drought tolerance. Thus, a large fraction (say, 80%) of "adaptation" resources aimed at improving agriculture should focus on these things, as they often represent the most cost-effective investment strategies. At the same time, climate change opens up some unique risks and opportunities -- things we could safely ignore if the climate was not changing. Effective adaptation involves not pitting old needs vs. new needs, but rather identifying the right investments to make in each category. One way to achieve this balance is to focus modeling and experimental work on identifying investments that have significantly higher or lower value in future vs. current climate. Some examples of this type of work will be presented.

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

Thank you!

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