Challenges for Research

CLIMATE IMPACTS ON AGRICULTURE

FAPESP
Workshop on Impacts of Global Climate Change on Agriculture and Livestock
May 27th - 2014

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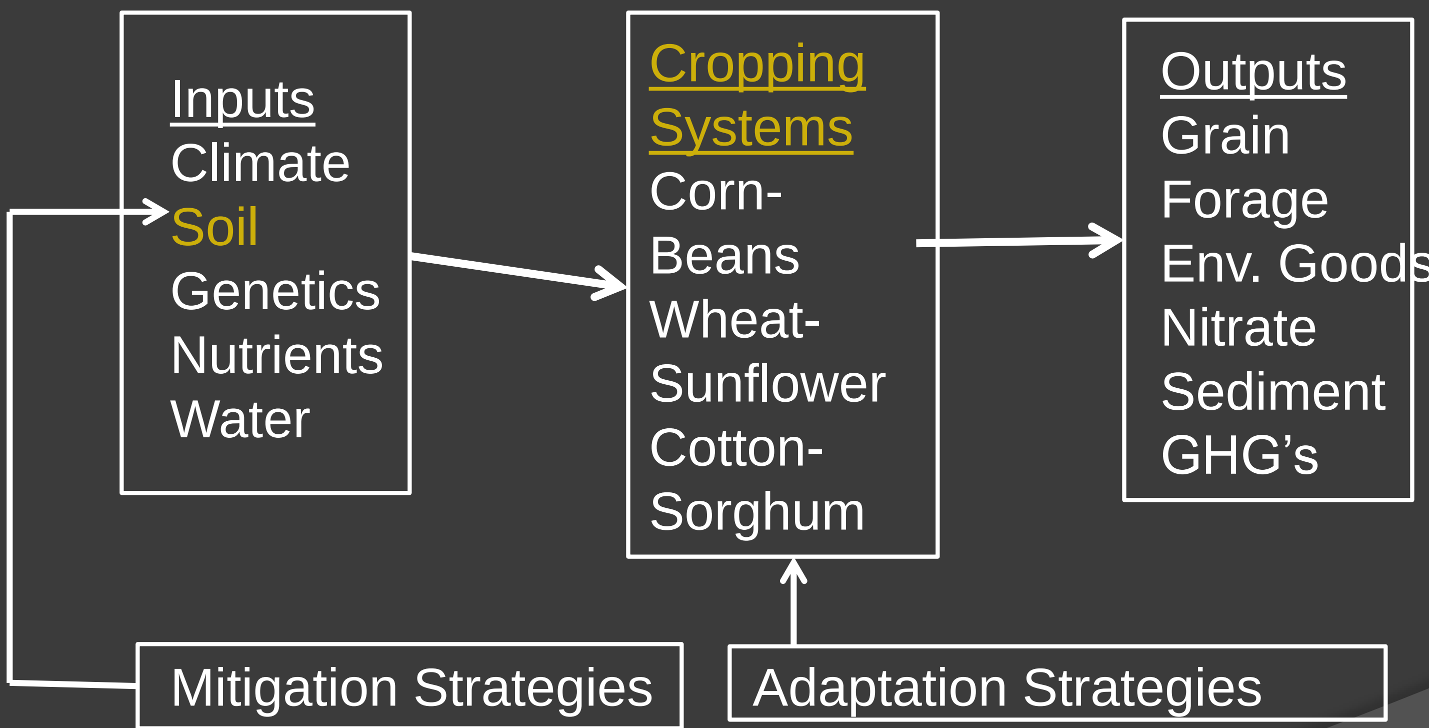
Framework For Agronomic Systems



Climate Factors

- Inputs
  - Temperature
  - Precipitation
  - Solar radiation
  - Carbon dioxide

Direct
- Growth
- Phenology
- Yield

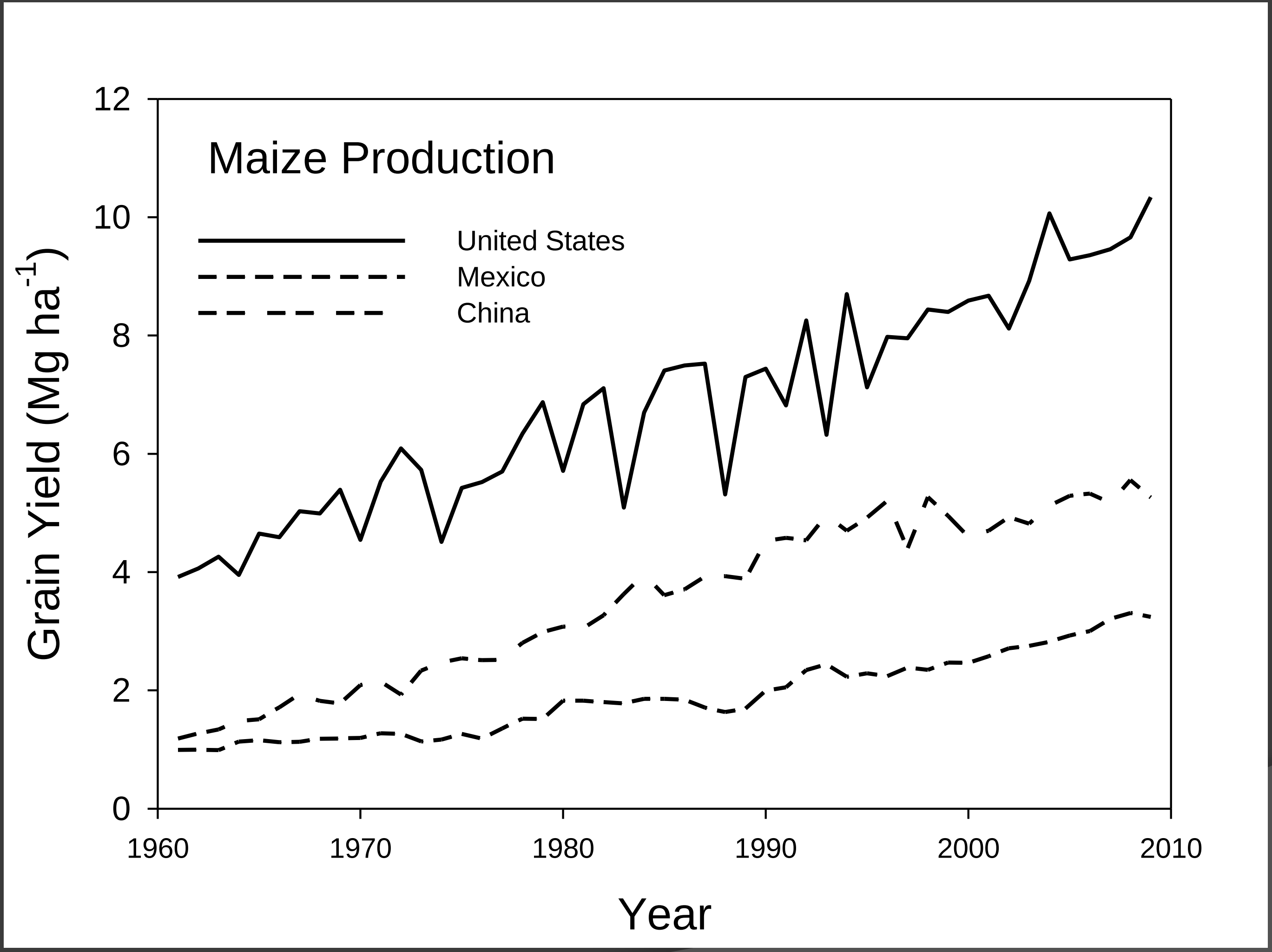
Indirect
- Insects
- Diseases
- Weeds

Soil is the underlying factor as a resource for nutrients and water

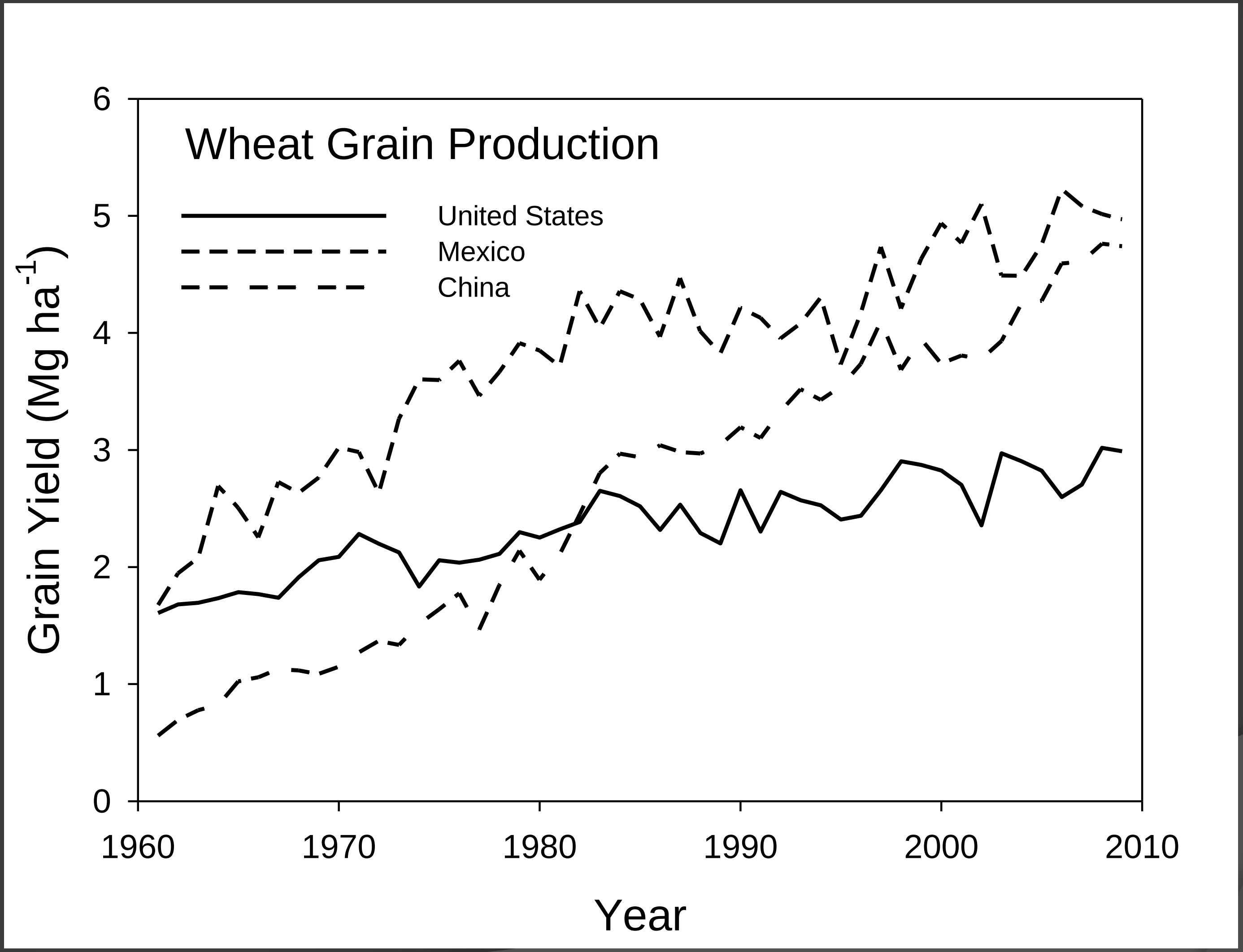
Climate vs Weather

- Climate determines where we grow a crop
- Weather determines how much we produce

Maize Yields



Wheat Yields



Projections

"Assuming no change in population growth, food consumption patterns and food waste management, the following production increases must take place by 2050:

cereals production must increase by 940 million tonnes to reach 3 billion tonnes; (45% increase)

meat production must increase by 196 million tonnes to reach 455 million tonnes; (77% increase)

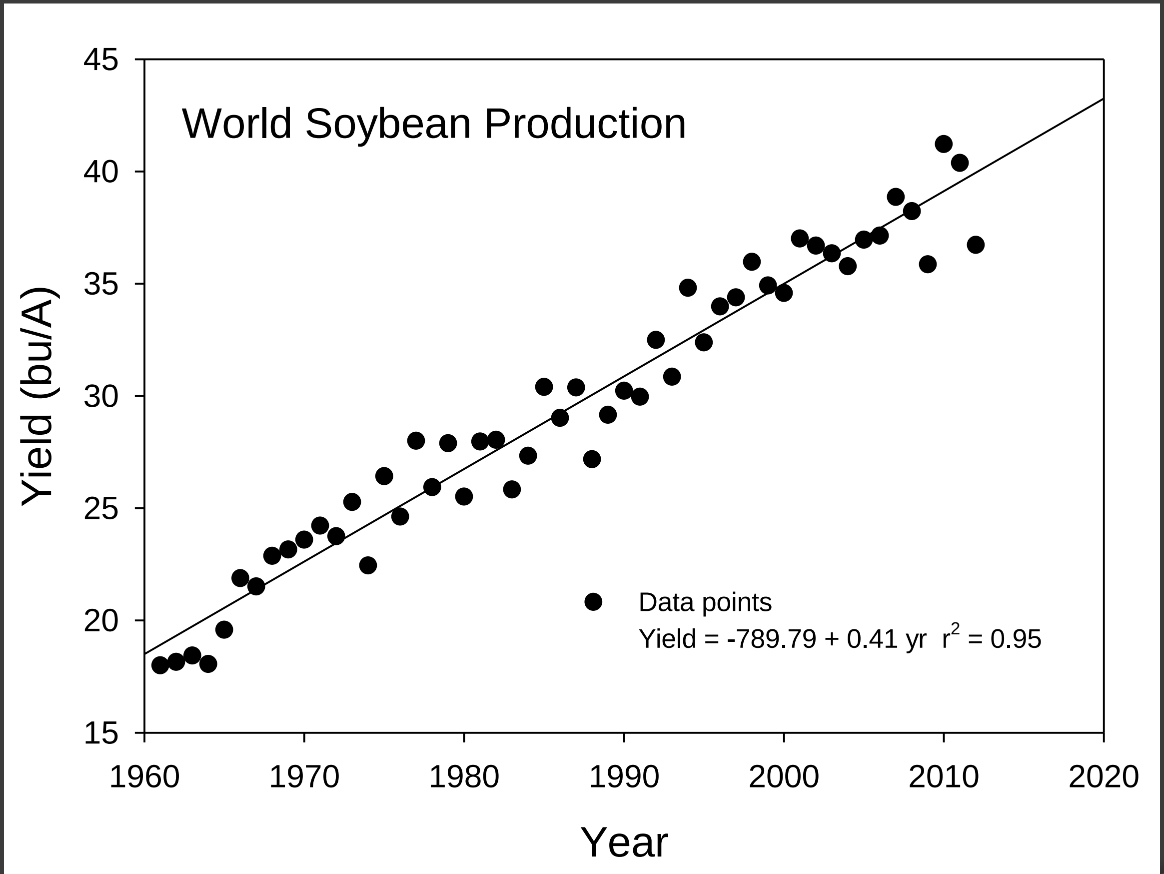
and oilcrops by must increase by 133 million tonnes to reach 282 million tonnes (89% increase) (Alexabdratos and Bruinsma, 2012).

It is also estimated that global demand for crop calories will increase by 100 percent ±11 percent and global demand for crop protein will increase by 110 percent ±7 percent from 2005 to 2050 (Tilman et al. 2011). "

Alexandratos N, Bruinsma J. 2012. World agriculture towards 2030/2050, the 2012 revision. *ESA Working Paper No. 12-03, June 2012*. Rome: Food and Agriculture Organization of the United Nations (FAO). (Available from http://www.fao.org/docrep/016/ap106e/ap106e.pdf)

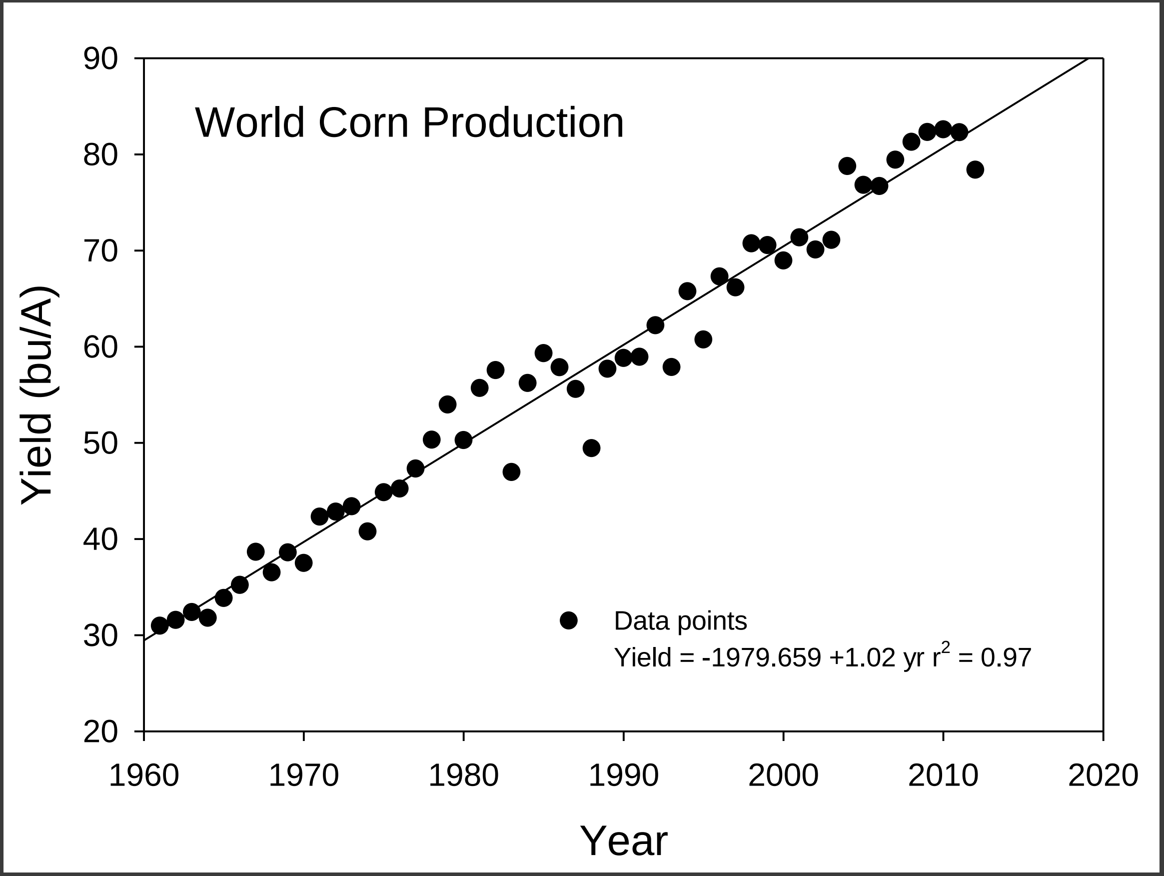
Tilman D, Balzer C, Hill J, Befort BL. 2011. Global food demand and the sustainable intensification of agriculture. *PNAS* 108(50):20260–20264. Washington DC: Proceedings of the National Academy of Sciences of the United States of America. (Available from http://www.pnas.org/content/108/50/20260)

World Soybean Production



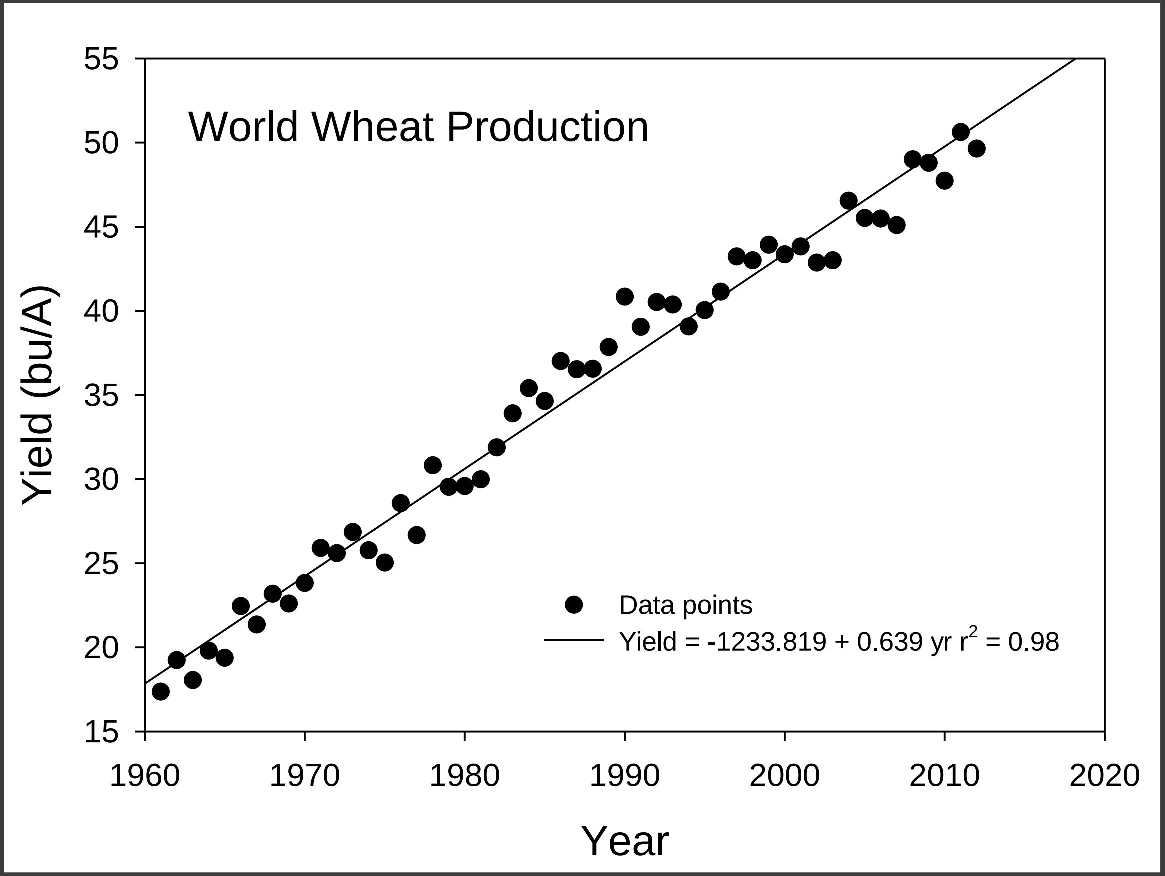
By 2050, we will have a 1066 kg/ha deficit in production compared to projected requirements

Corn Grain Production



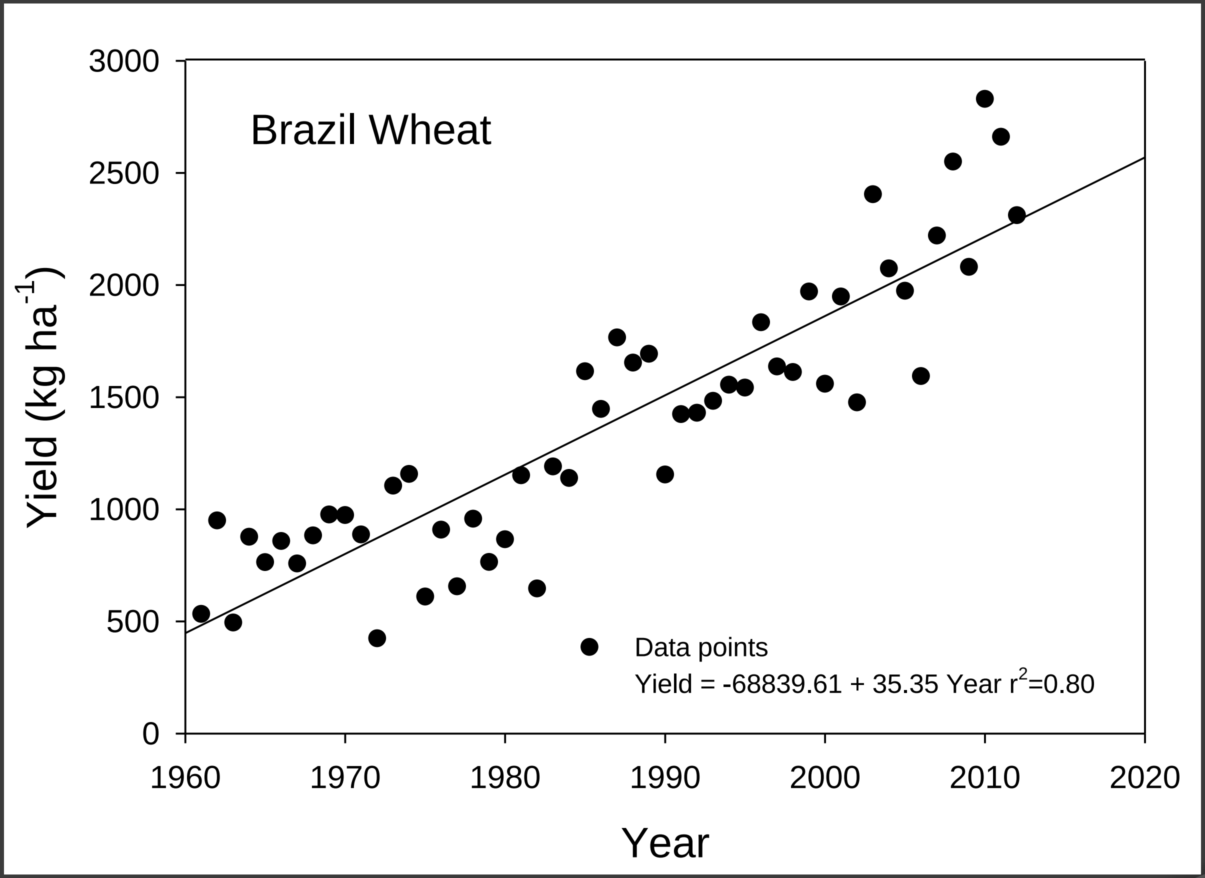
By 2050, we have a 125 kg/ha deficit on expected production compared to required production

Wheat Grain Production

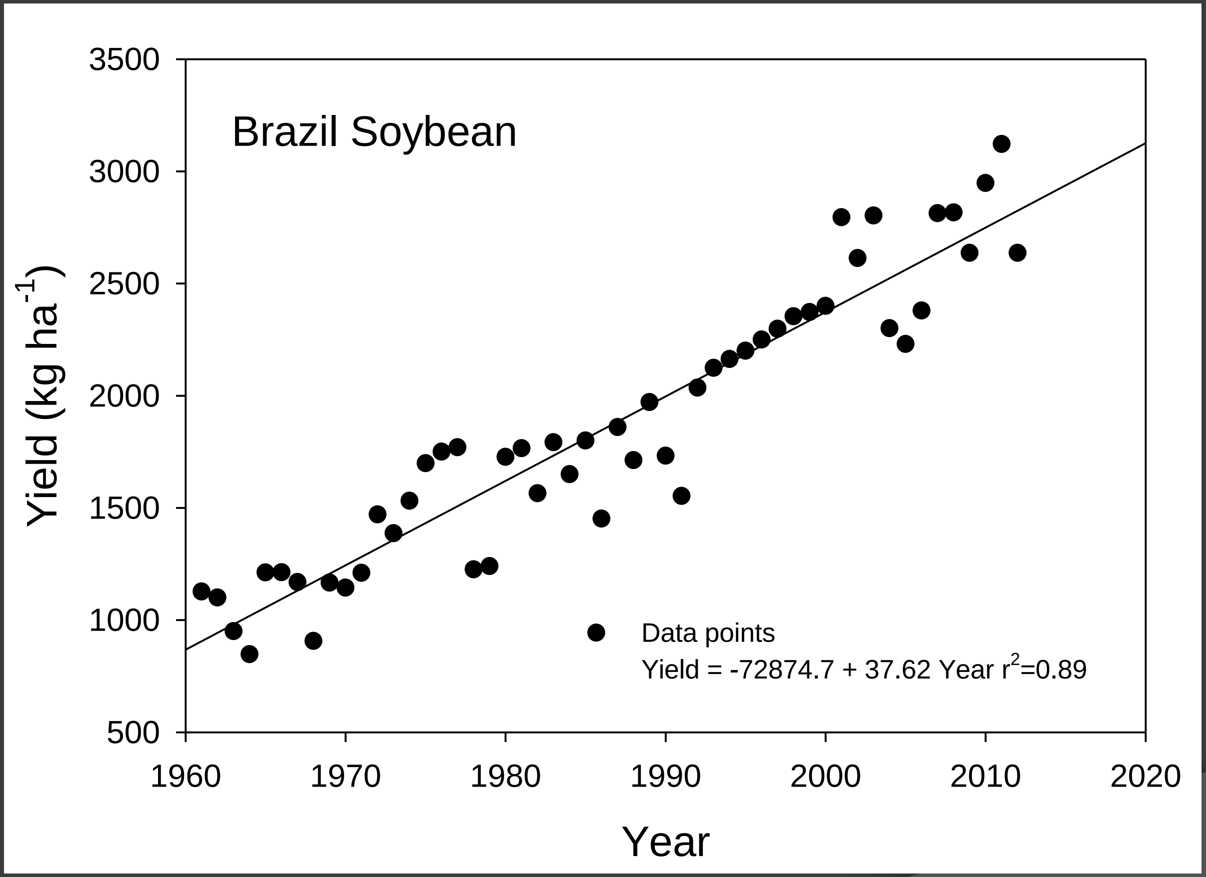


By 2050, we have a 627.2 kg/ha excess in production estimates compared to projected requirements

Brazil Wheat



Brazil Soybean



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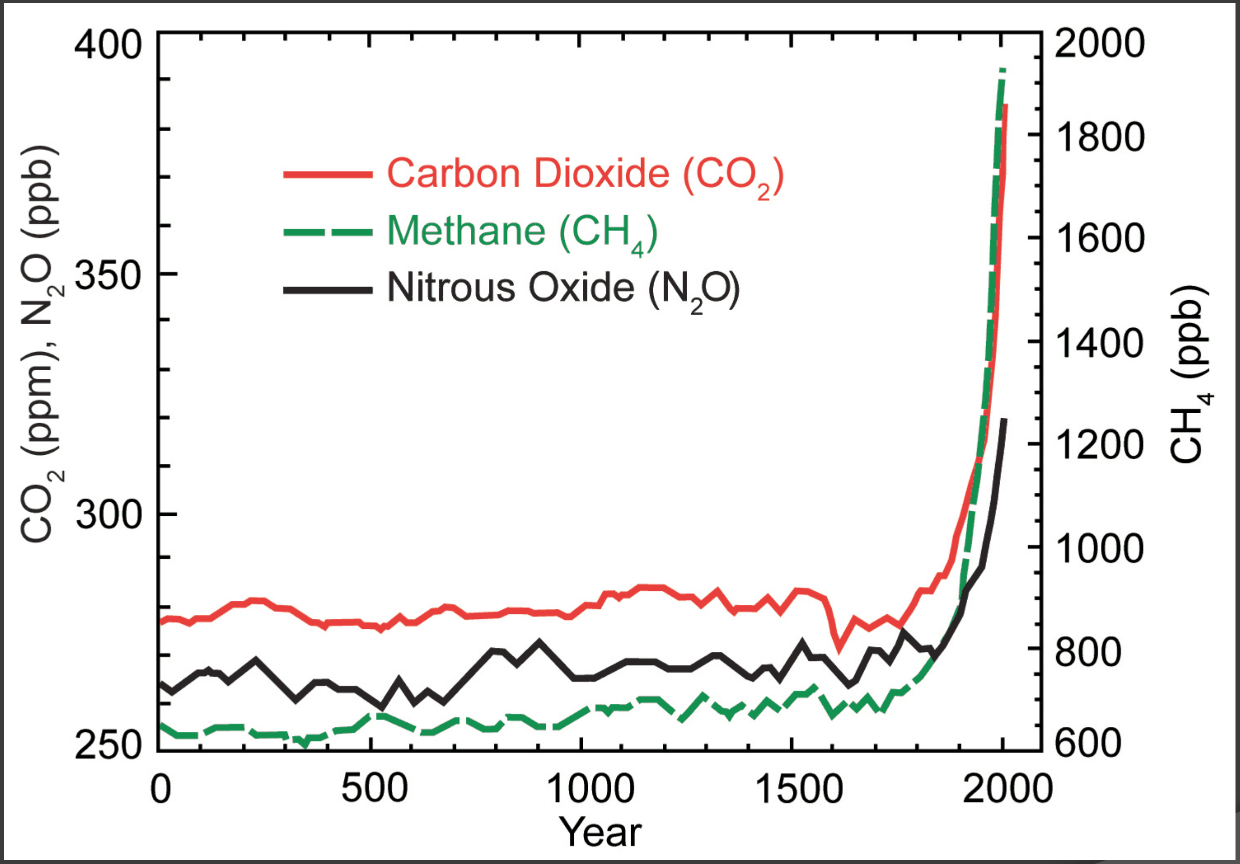
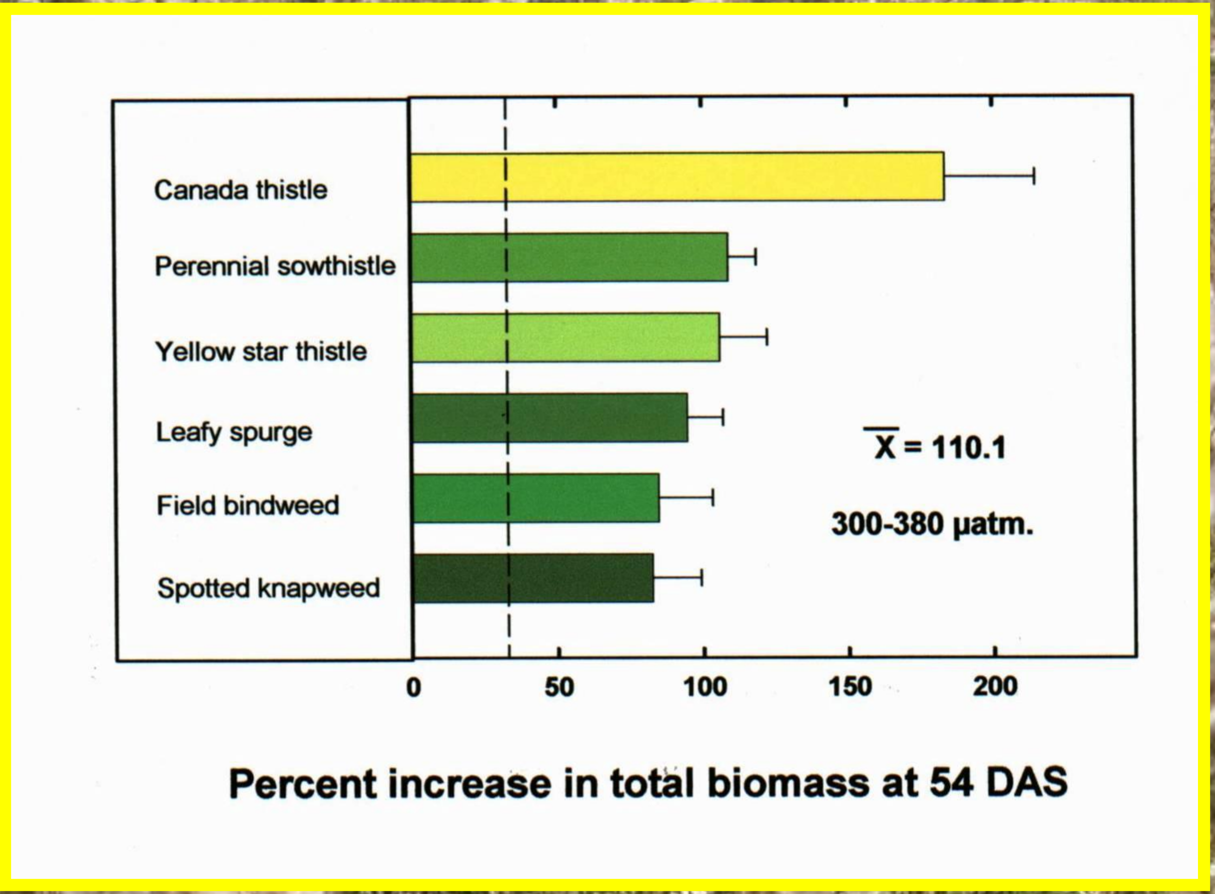
Carbon Dioxide Increases

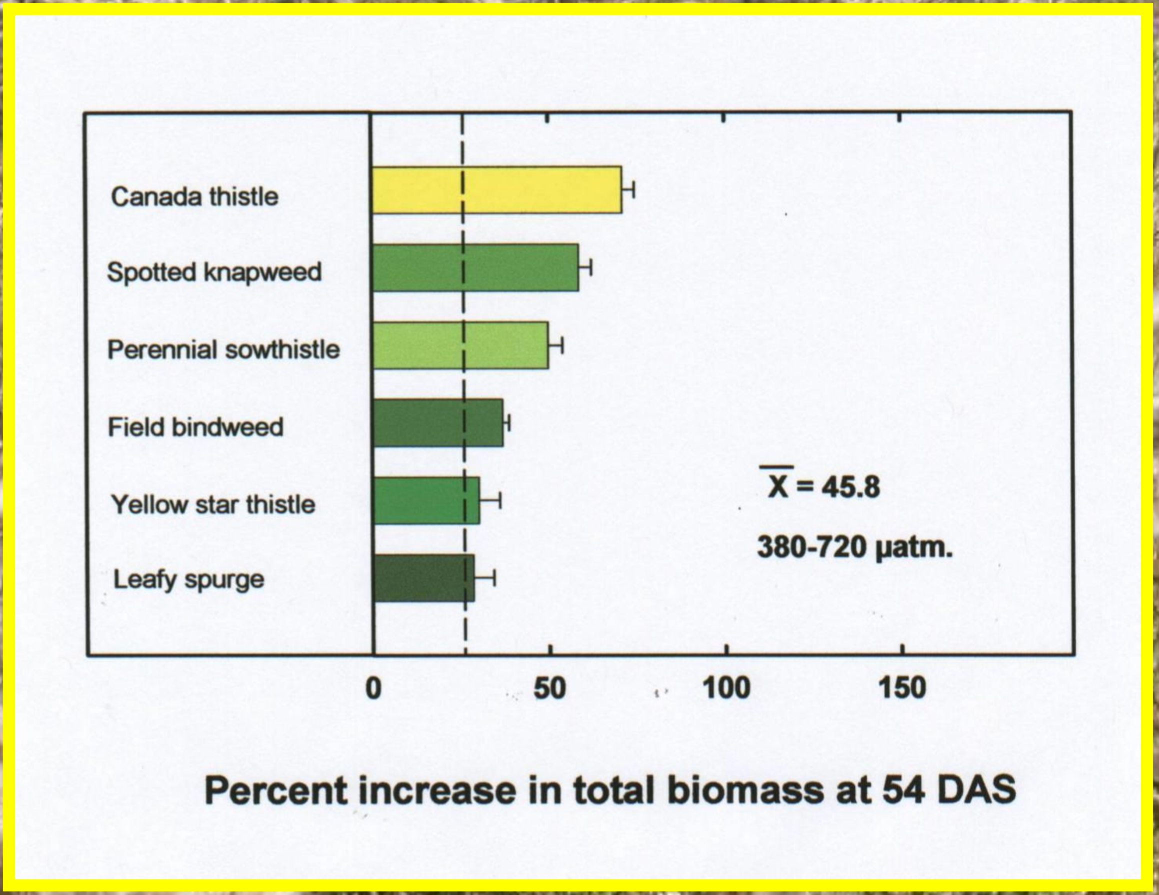


Present vs. Past



L. Ziska, USDA-ARS

Present vs. Future



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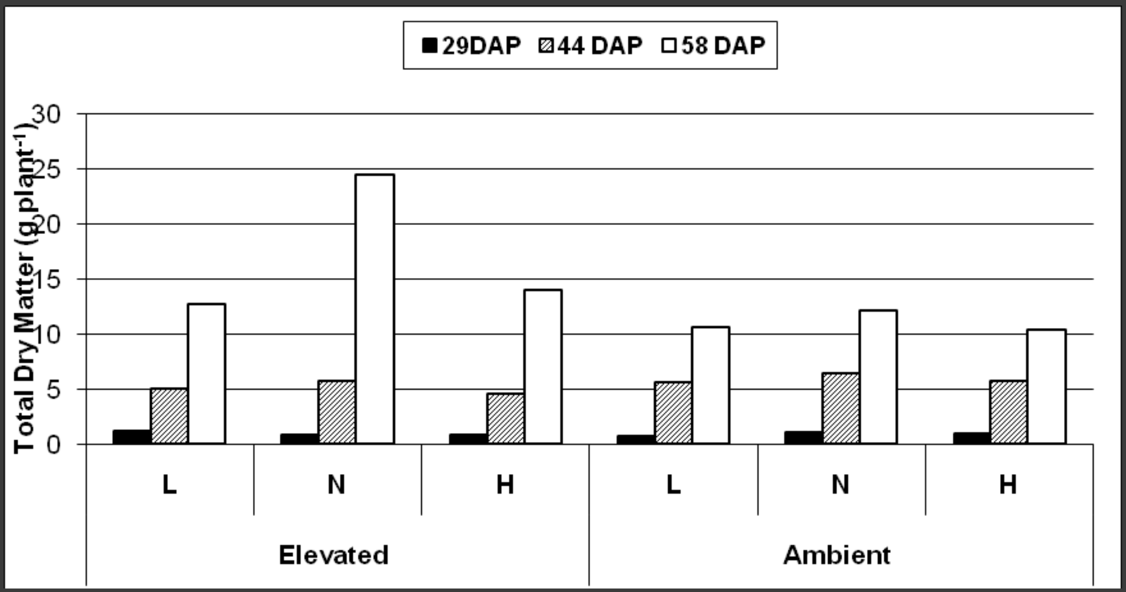
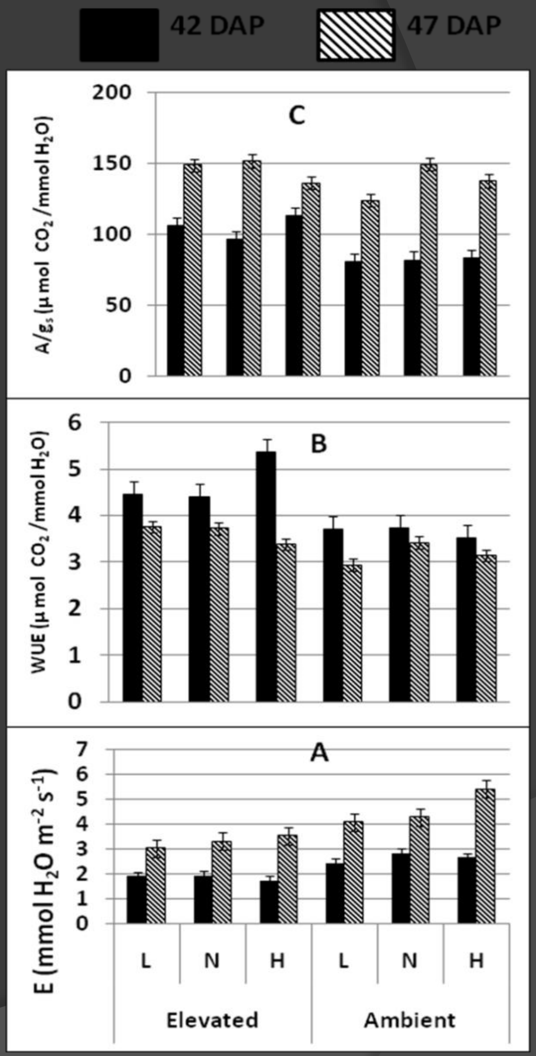
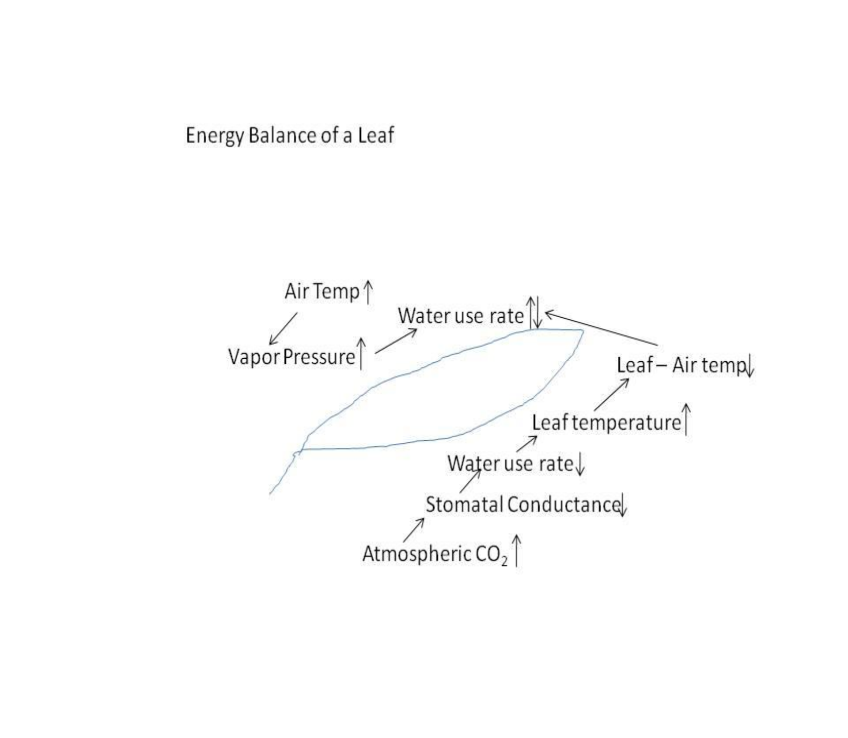
Carbon Dioxide-Water Interactions

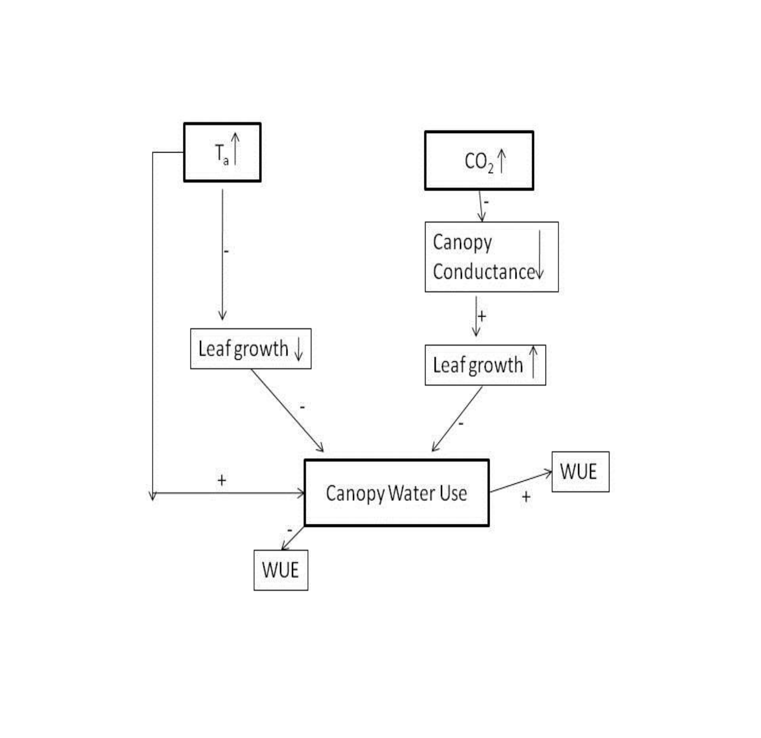




Two levels of CO_2 and three soil water levels on soybean

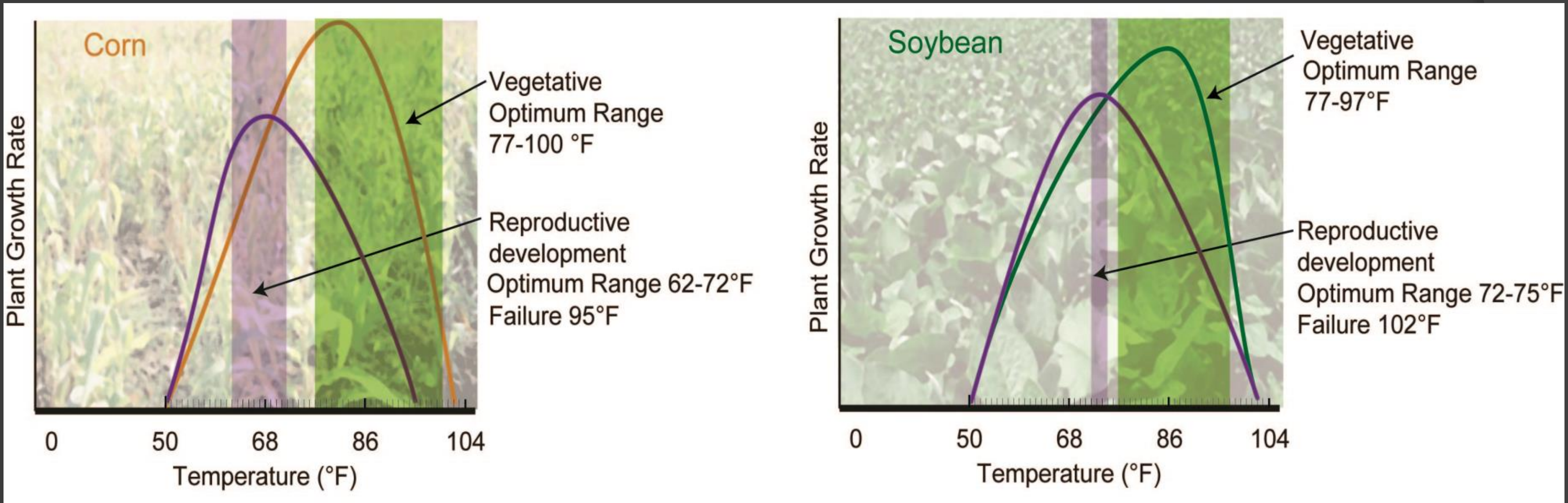
CO_2 and Temperature Interactions





CO_2 and temperature effects offset each other in a well-watered situation; however, in water limited the positive effect of CO_2 is dominant

Temperature Responses

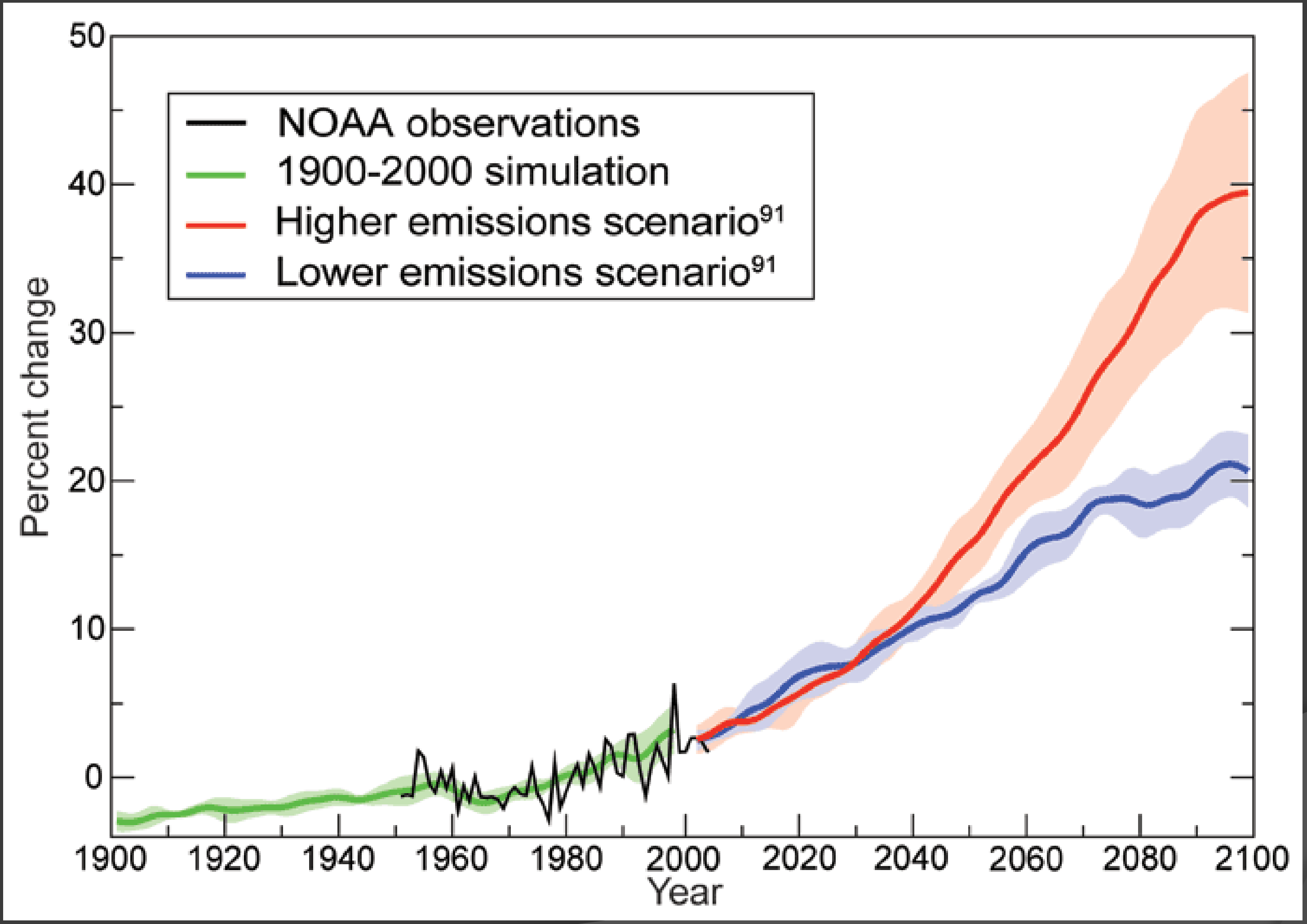


Difference in temperature response between the vegetative and reproductive stage of development for crops. The higher the temperature the faster the rate of development

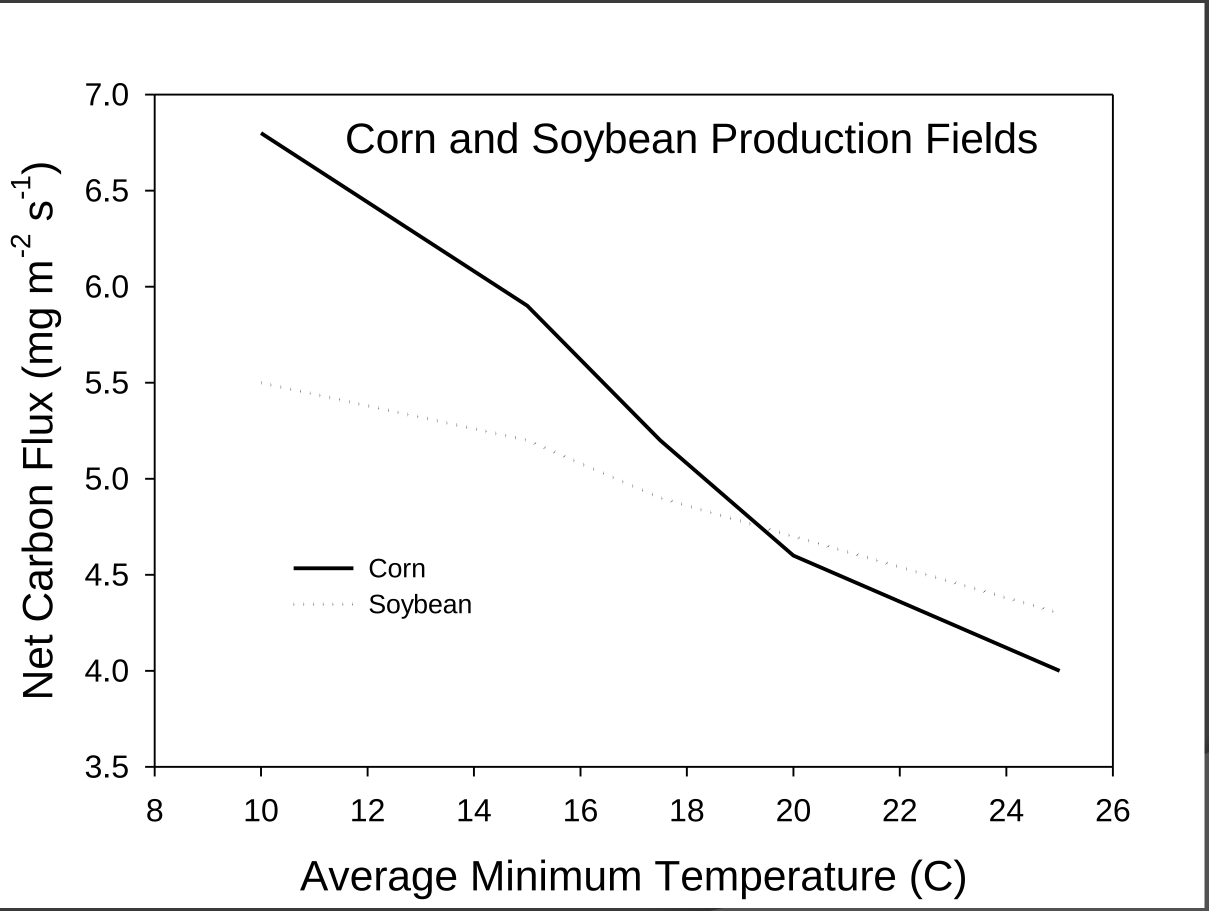
Temperature

Crop	Optimum Temp (C)		Temp Range (C)		Failure Temp (C)
	Veg	Reprod	Veg	Reprod	
Maize	34		18-32	18-22	35
Soybean	30	26	25-37	22-24	39
Wheat	26	26	20-30	15	34
Rice	36	33	33	23-26	35-36
Cotton	37	30	34	25-26	35
Tomato	22	22		22-25	30

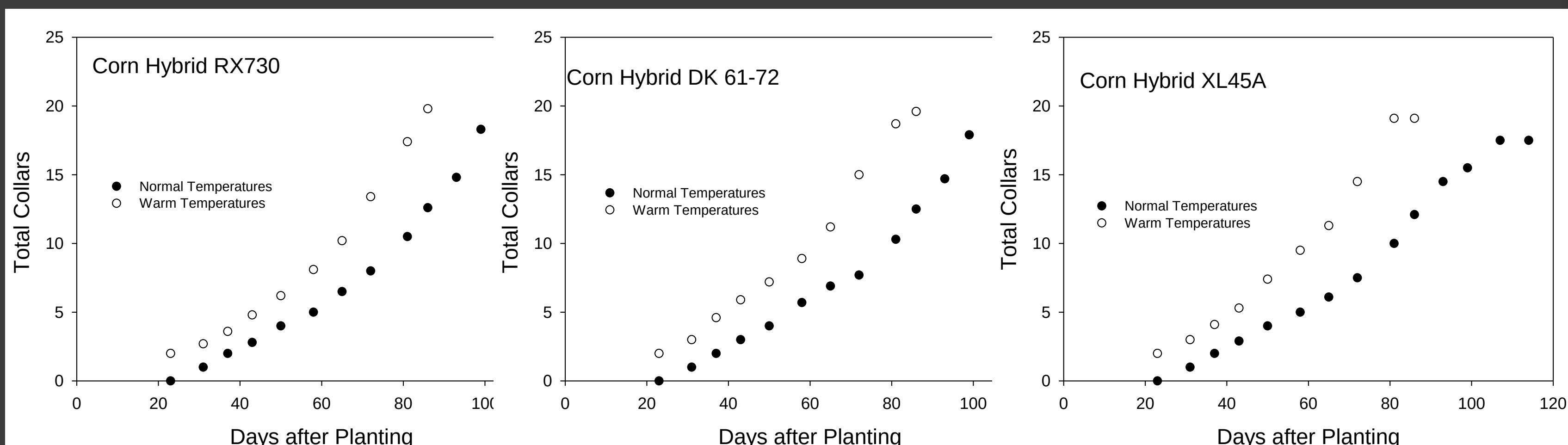
Nighttime Temperatures



Impact of Warm Nights on Corn and Soybean Productivity



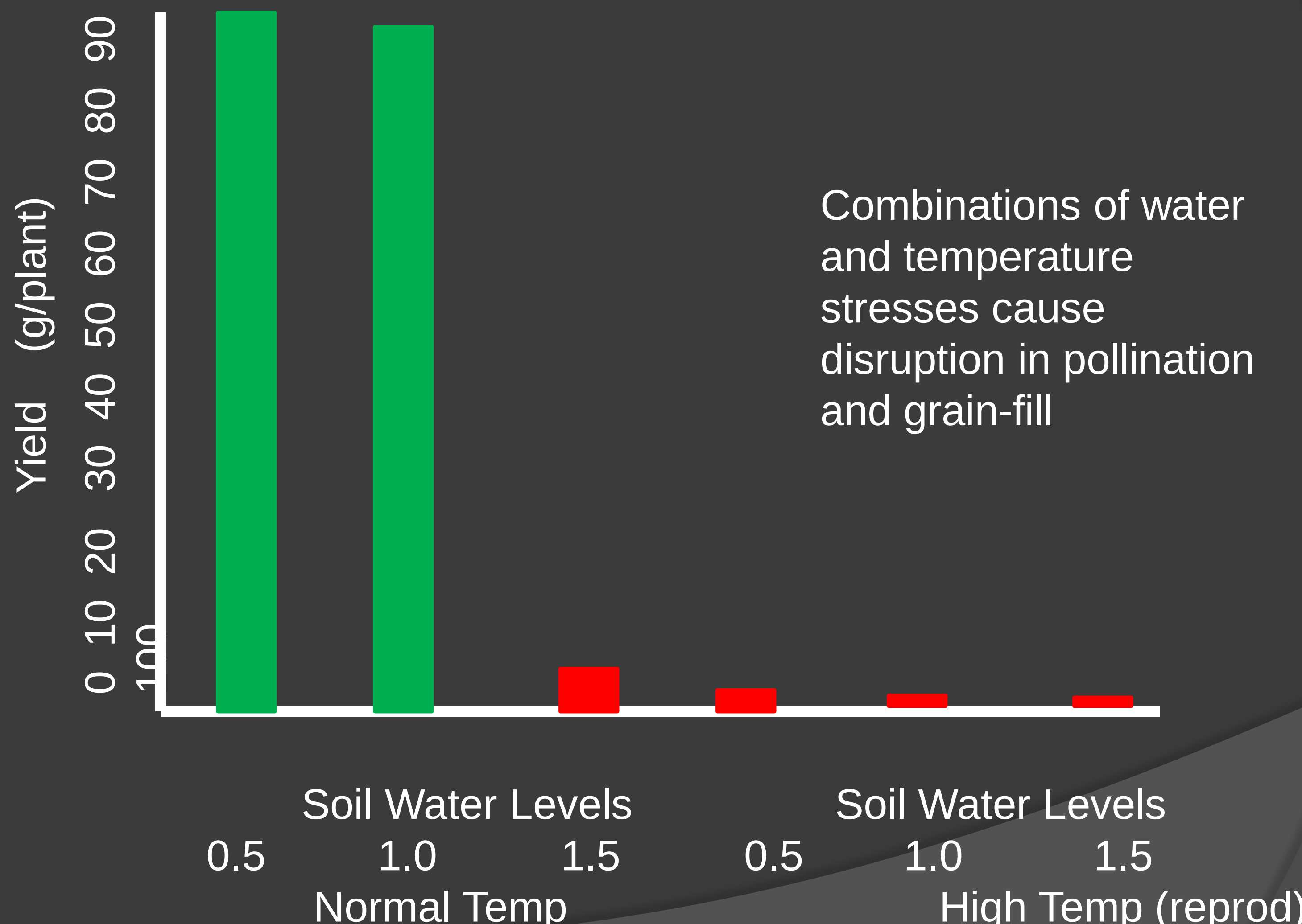
Temperature effects on Corn Phenology



1505 15805 5519 19130 4453 24774 kg ha^{-1}

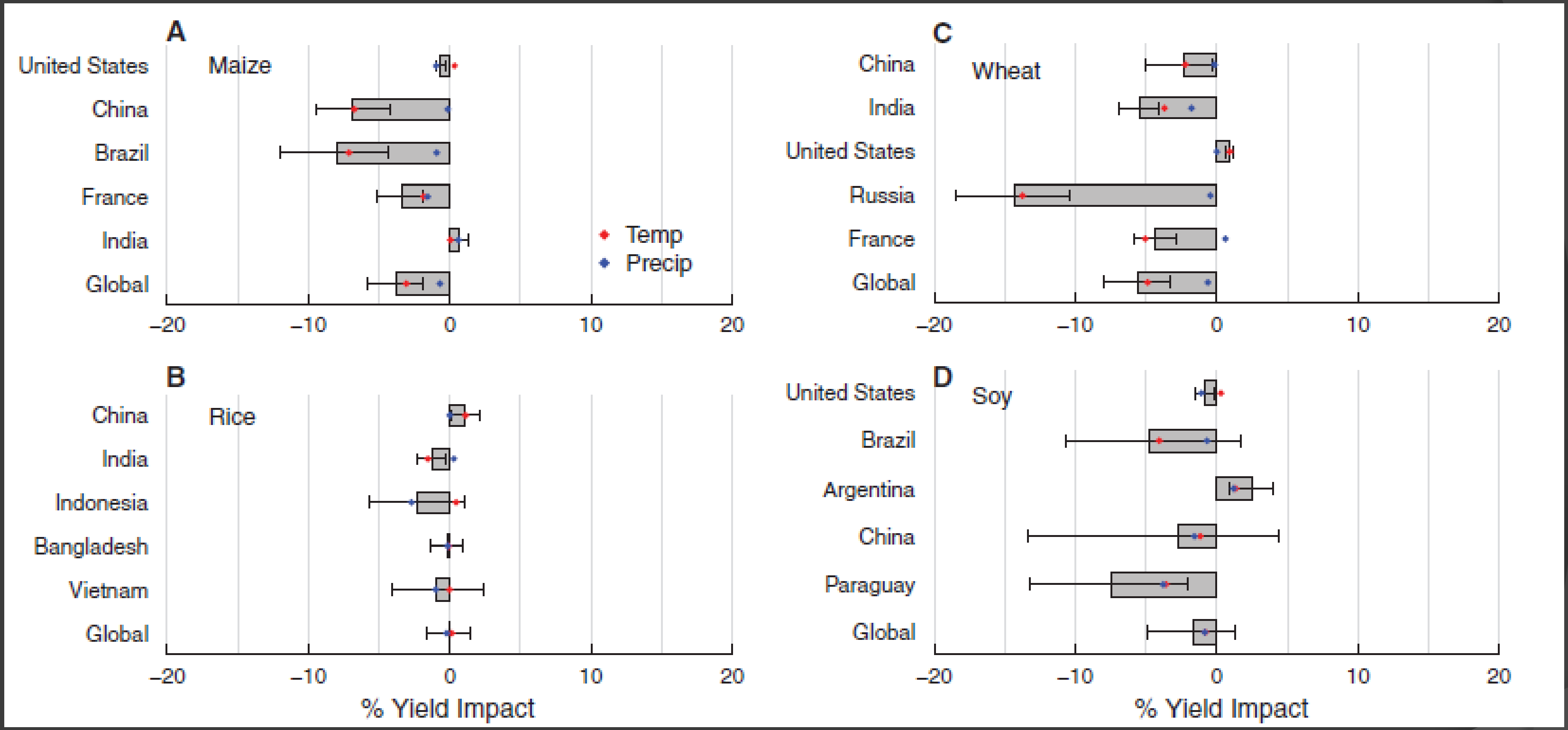
Rhizotron study with warm chamber 4C warmer than normal chamber with simulation of Ames IA temperature patterns.

Rhizotron Results



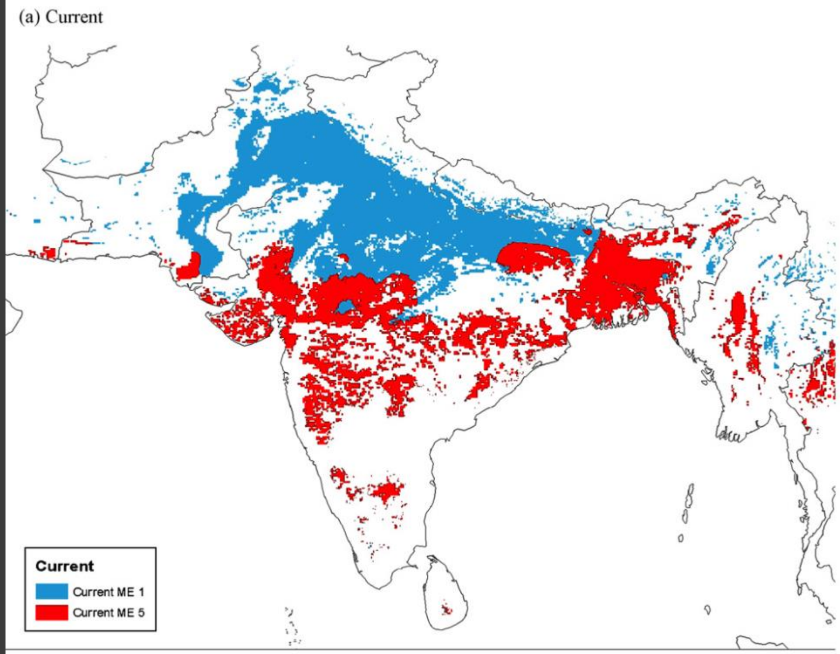
Combinations of water and temperature stresses cause disruption in pollination and grain-fill

Current Reductions in Yields

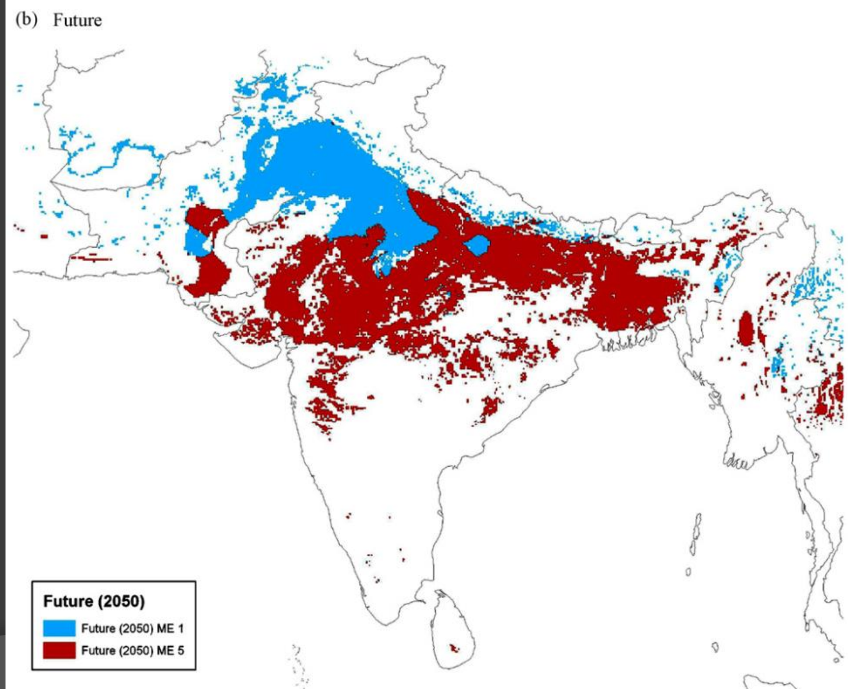


Lobell et al. 2011 Science 333:616-620

Current Mega-climate regimes



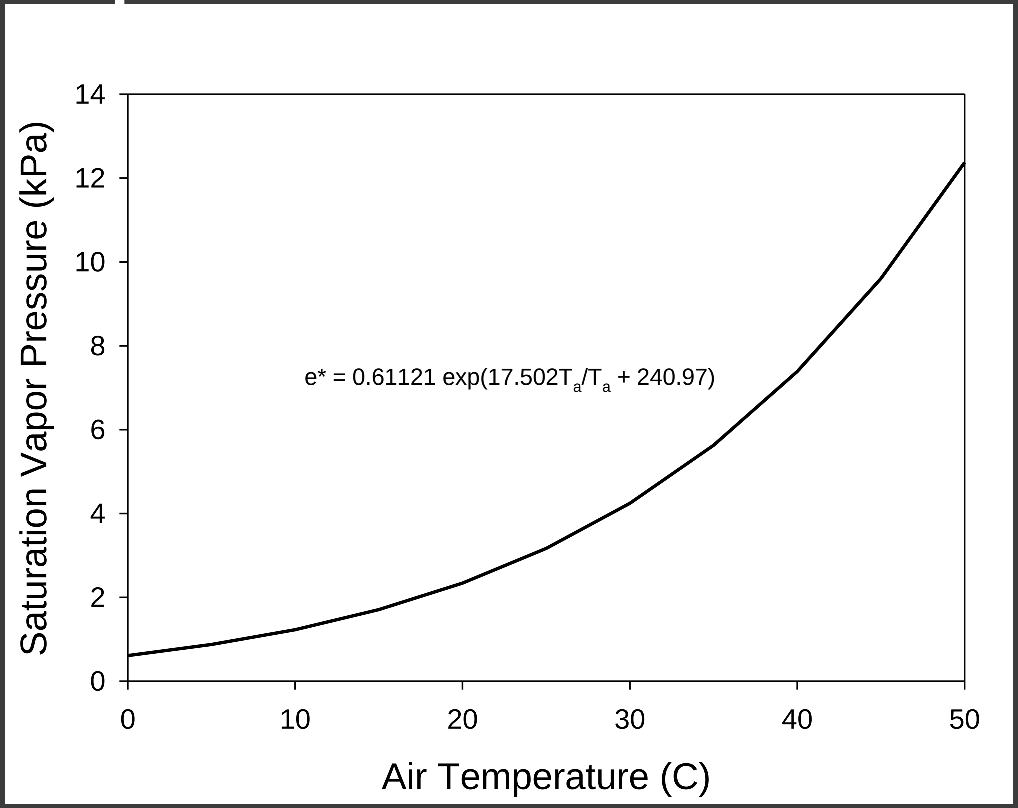
Future (2050) mega-climate regimes



Move from a favorable to unfavorable climate for wheat

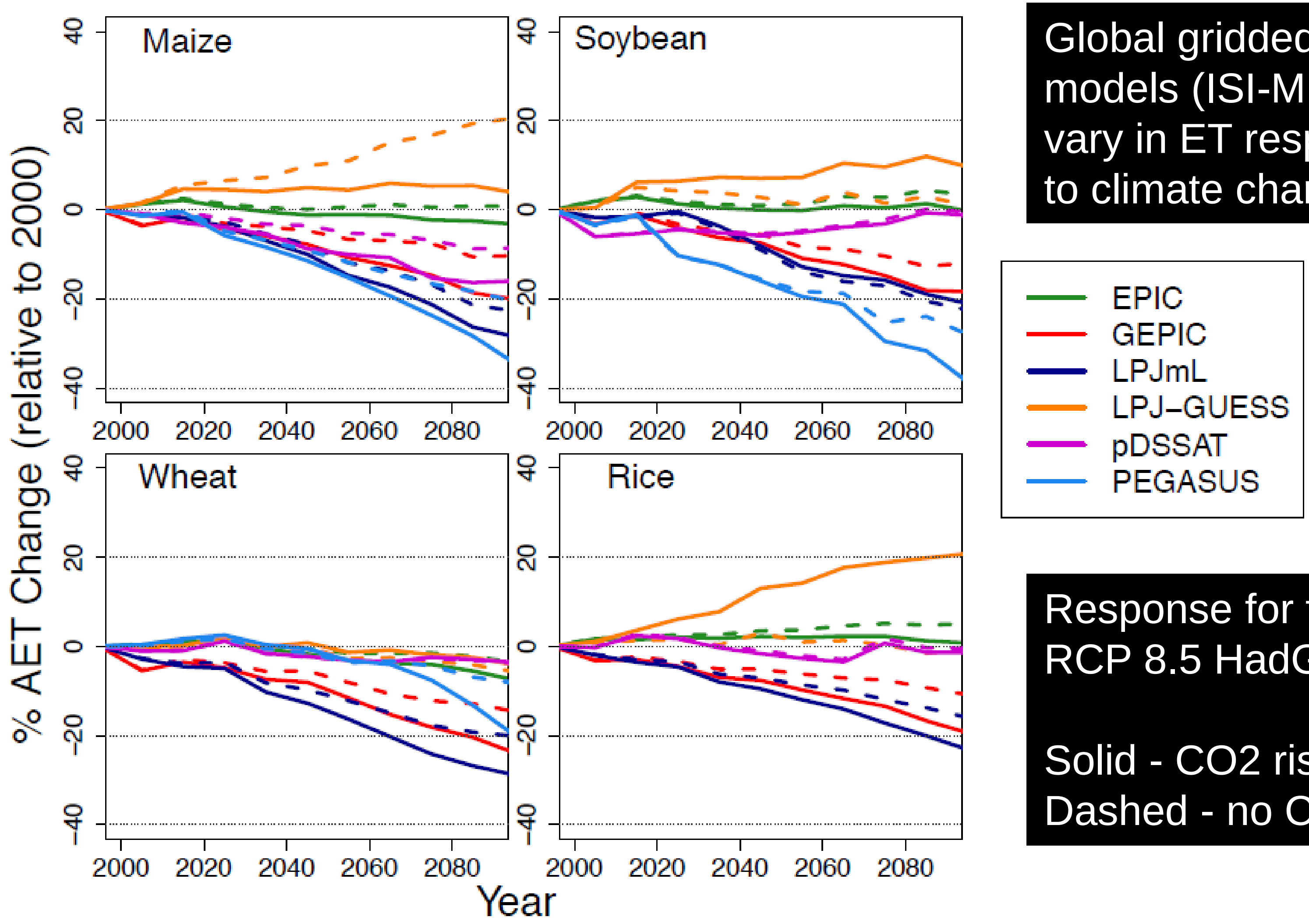
Ortiz et al. Agric Ecosys & Environ. 2008. 126:46-58

Temperature Effects on Evaporation



$$ET = \frac{\rho c_p (T_0 - T_s)}{r_a} + \frac{\rho c_p [e_s(T_0) - e_a]}{\gamma (1 + {}^{r_s}/_{r_a}) r_a}$$

Global Models Disagree on CO2 (Climate) Effect on ET

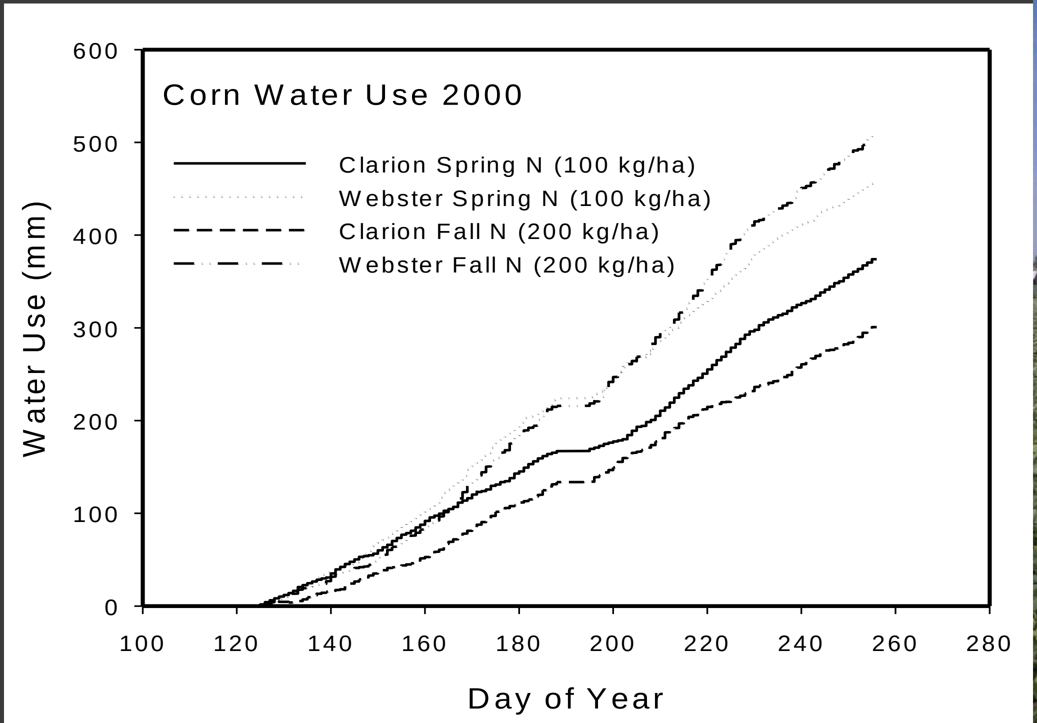


Global gridded models (ISI-MIP) vary in ET response to climate change.

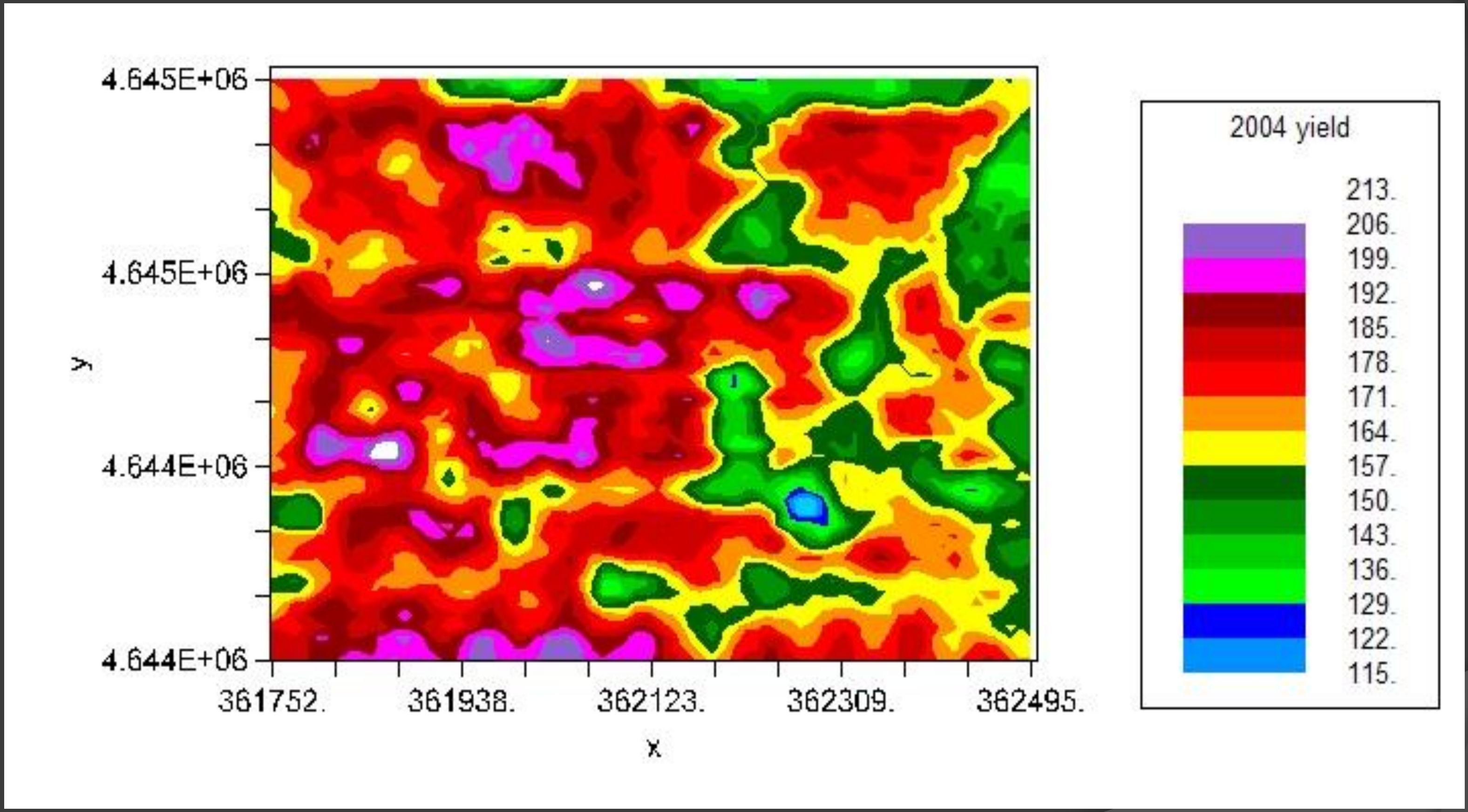
Response for future RCP 8.5 HadGEM-ES:

Solid - CO2 rising
Dashed - no CO2

Soil Water Use Rates



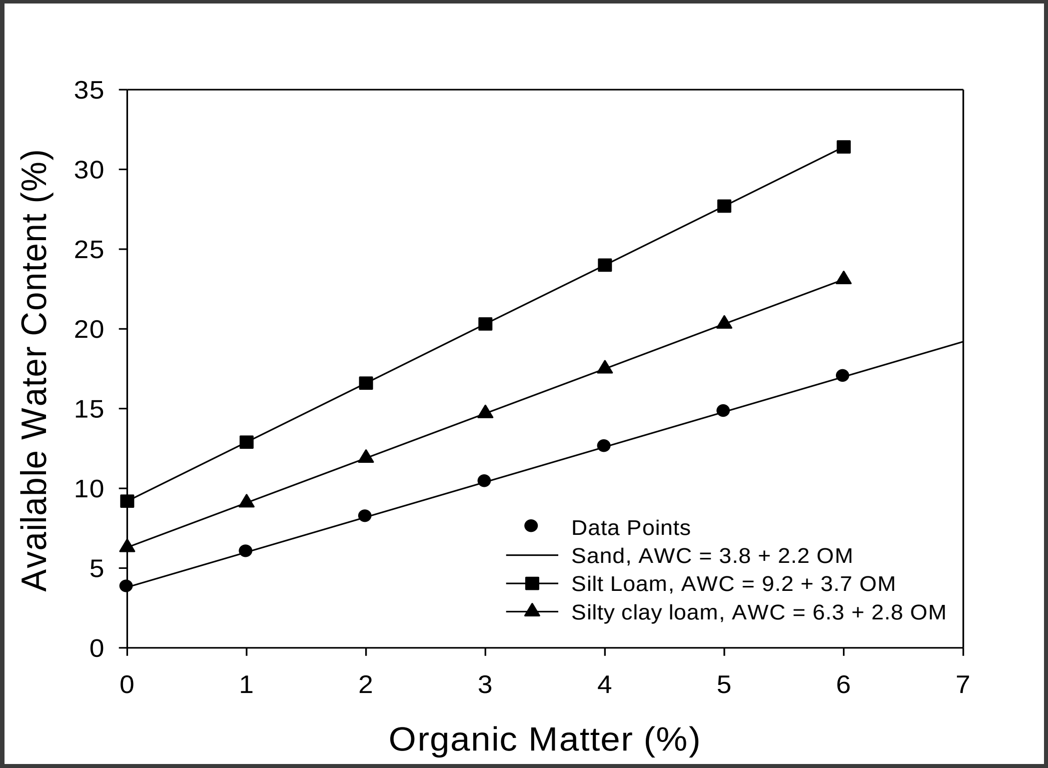
Crop Yield Variation



Precipitation

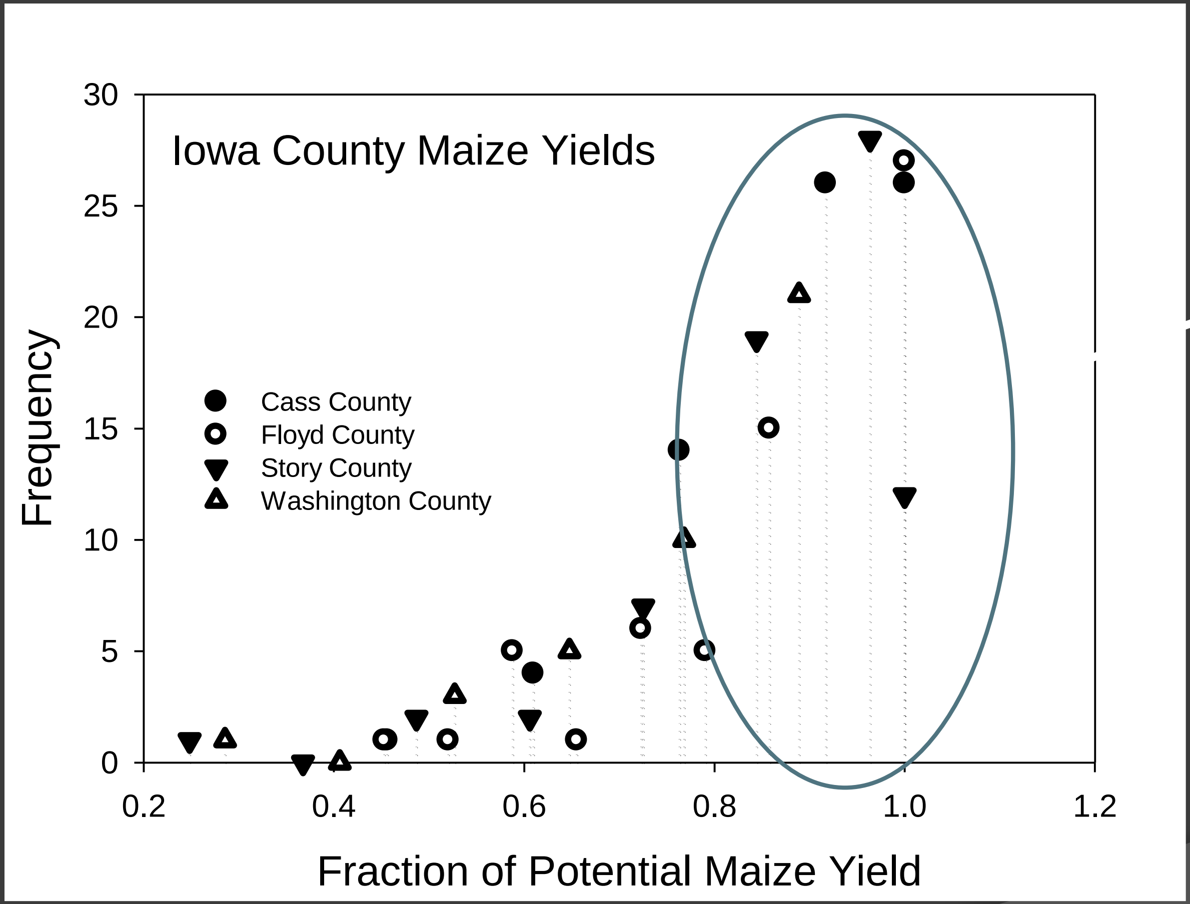
- Expect increased variation among years
- Expect increased variation within a year
- Expect increase in intensity of storms and decreased frequency of storms

Soil Water Availability



Hudson, 1994

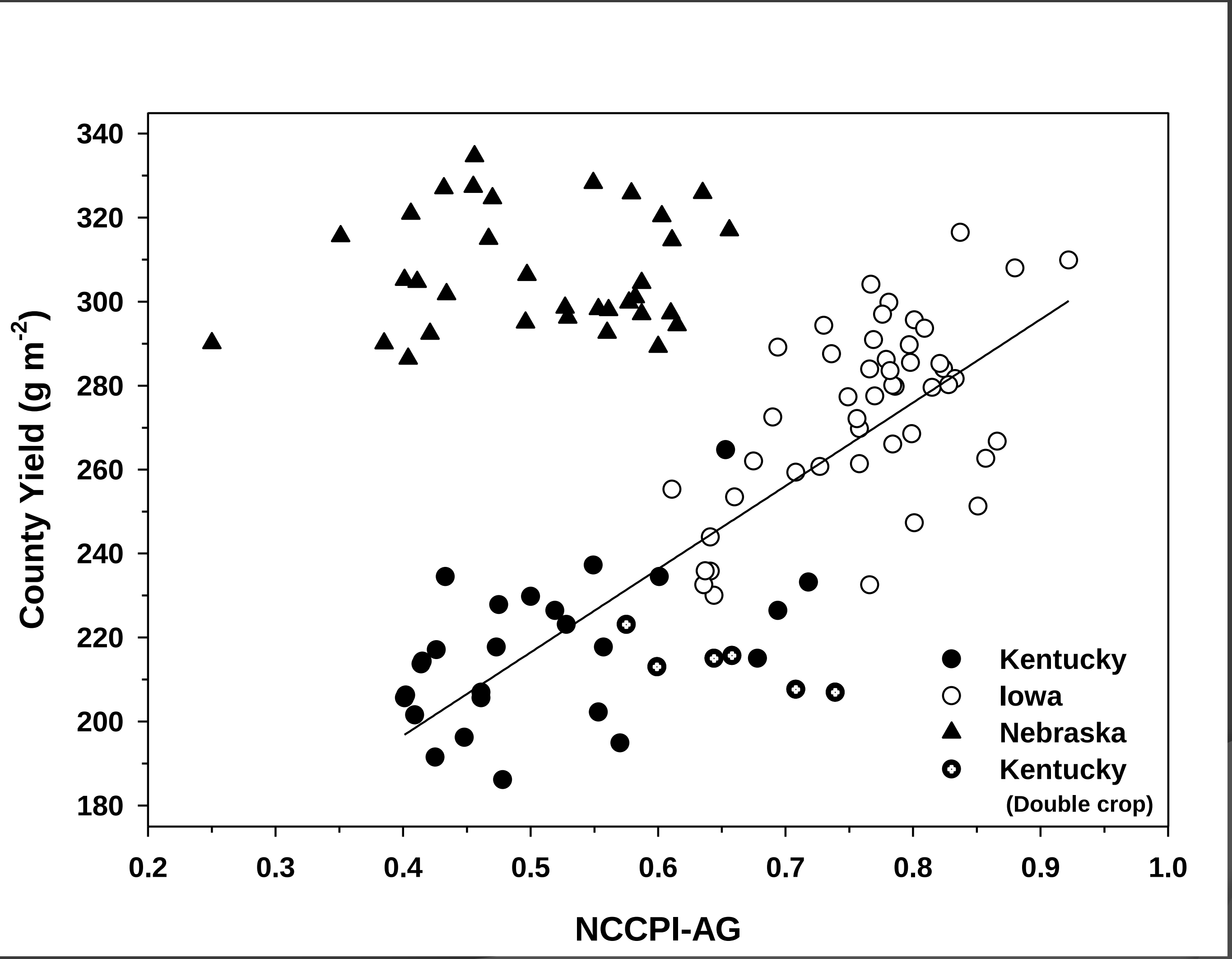
Variation in Yields



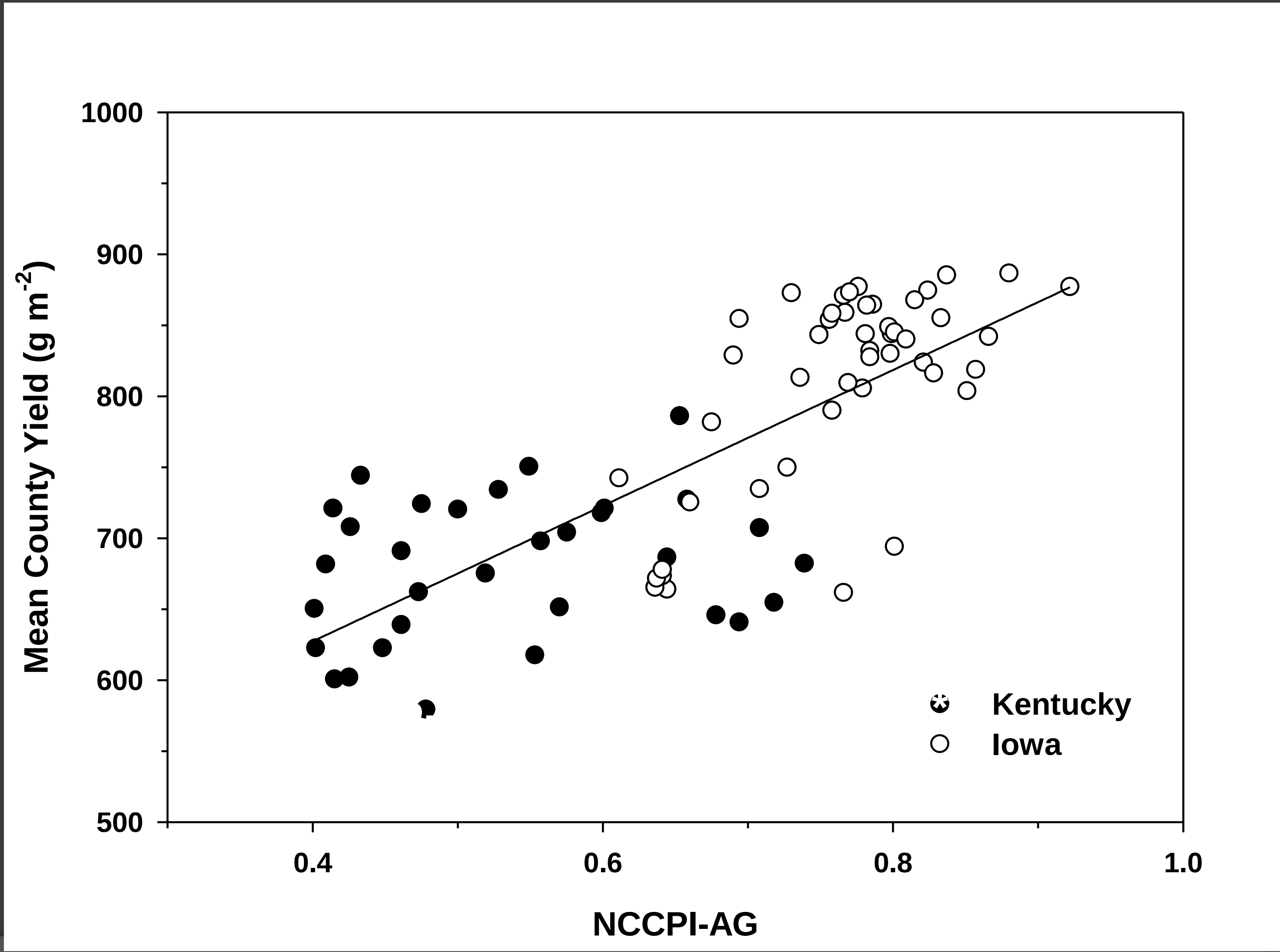
20% of the yield loss occurs 80% of the time due to water availability

The majority of the yield losses due to the weather are short-term stresses

Soybean yields across the Midwest



Maize County Yields



Implications

- Climate will definitely impact crops both directly and indirectly
- Soil management to increase water holding capacity and reduce E from ET will be a critical climate resilient factor
- Quantify the indirect effects due to insects, diseases, and weeds
- Quantify the effects of climate change on nutritional quality of grain, forage, and produce
- We need to approach climate resilience and adaptation strategies as a G x E x M problem