What can Agricultural Biodiversity and Plant Breeding do to address Climate Change?

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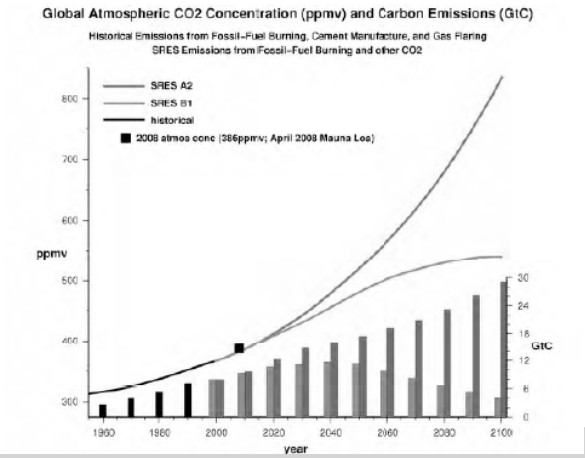
Outline

- What can we expect in terms of climate change?
- Crop target traits?
- What can crop biodiversity and plant breeding do for you? Change in crop adaptation
  - Prior to plant breeding?
  - During 20th century
  - Future changes?
- Conclusion

Climate change scenarios



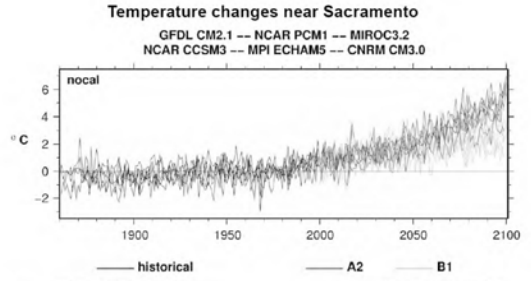
But: The estimated emissions growth for 2000–2007 was above even the most fossil fuel intensive scenario of the Intergovernmental Panel on Climate Change (SRES-IPCC)

Climate models (from IPCC/SRES): Yolo County

	Medium-high emissions	Lower emissions
Scenario	A2	B1
2050 CO_2 level	~ 550 ppm	~ 500 ppm
2100 CO_2 level	850 ppm	550 ppm
2050 temperature	+1.3 – 2°C (2.3 – 3.6 °F)	+1.3 – 1.6ºC (+2.3 - 2.9ºF)
2100 temperature	+3.8 -5.8ºC (+6.8 -10.4ºF)	+2.3 - 3.3ºC (+4.1 - 5.9ºF)
2050 precipitation	-51 mm to - 70 mm (-2.0 in to -2.8 in)	-37 mm to +6 mm (-1.5 in to +0.2 in)
2100 precipitation	-91 mm to -157 mm (-3.6 in to -6.2 in)	-117 mm to +38 mm (-4.6 in to +1.5 in)

Cayan et al. 2009; Jackson et al. 2009

What to Expect?

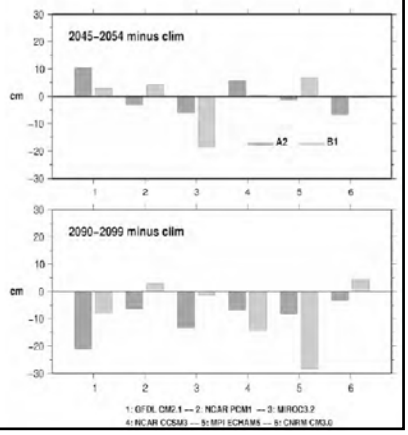


Temperature

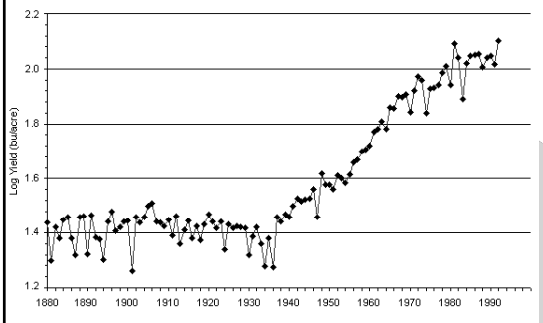
- Higher temperatures:
  - high: +4-6°C; low: +2-3°C
- Precipitation:
  - high: marked reduction; low: reduction to increase
- Increased unpredictability

(Jackson et al. 2009)

Rainfall



Corn yield trends, 20th century



- Steep increase in yield after 1930
- Causes: 50/50
  - Genetic: hybrid cultivars
  - Cultivation practices
- Increased instability in last 20-30 years: climate change?

Lesson: Plant breeding responsible for ~ 50% of production increases

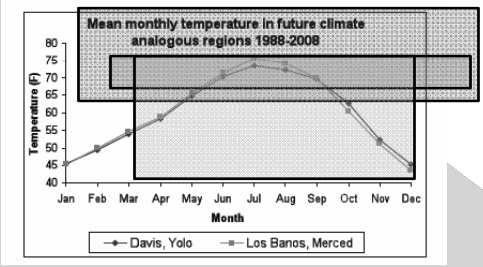
(Ruttan 1999)

CA Agriculture

- CA: among top 5 producer in the US for many commodities: from artichokes to rice to walnuts
- Challenge & Opportunity: wide diversity of crops

Agricultural Statistical Overview 2007

Some numbers…



Hot-season: melon, sweet potato: 64-95°F

Warm-season: tomato, cucumber, peppers, sweet corn: 68-77°F

Cool-season: Lettuce, broccoli, spinach: 41-77°F; legume cover crops

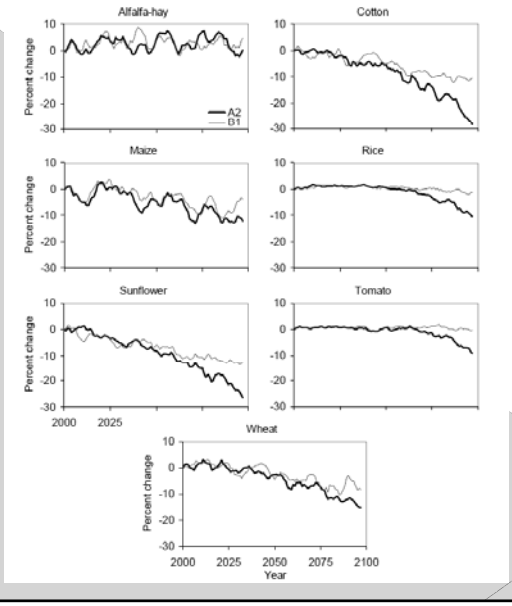
Lesson: Switch crops or crop mixtures

Reproductive development is particularly vulnerable:

- Pollen viability and production: maize: <77°F; rice: <95°F
- Kernel development: maize: <86°F
- Fruit trees: chilling requirement

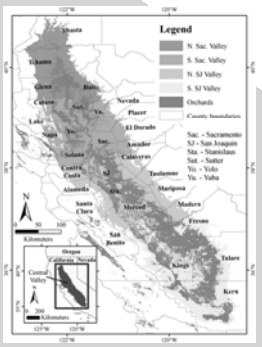
(Jackson et al. 2009)

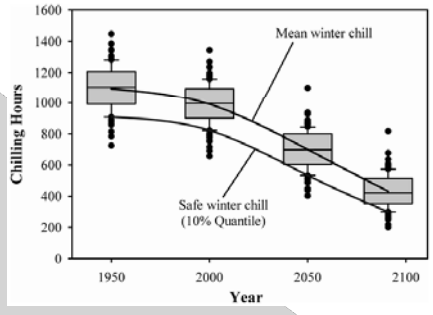
Annual Crops: Yield

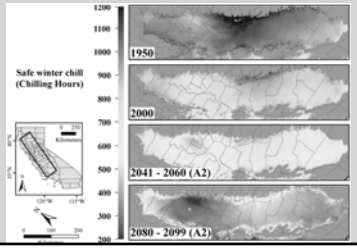


Lee et al. 2009

Perennial Crops: Chilling







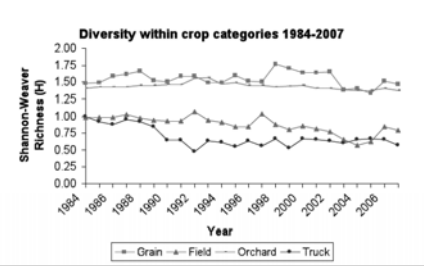
Lesson: Existing variability for adaptation traits; use it!

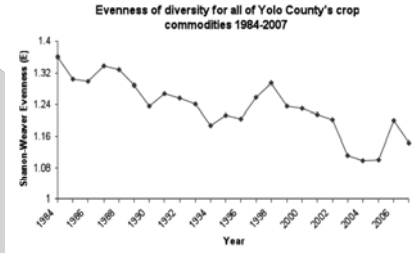
Luedeling et al. 2009

Targets for agricultural biodiversity & plant breeding

- Crop adaptation:
  - Traits: temperature, drought
  - Phenology: developmental times
  - Cycle length: extended growing season
- Pest and disease resistance
  - Changed distribution
- Pollinators
  - Changed distribution
- Crop diversification

Crop diversity



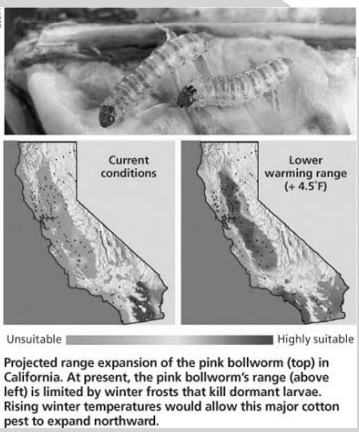


Lesson: Reverse loss of crop diversity

Jackson et al. 2009

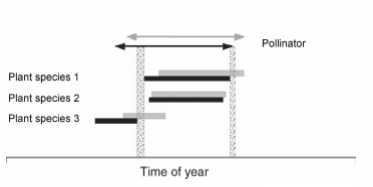
Pests & Diseases/Pollinators

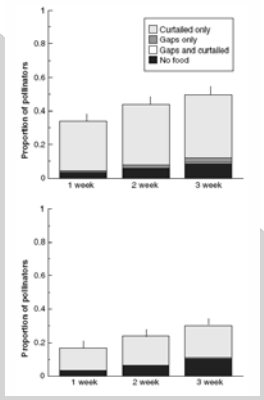
Example:
Pink bollworm/cotton



Projected range expansion of the pink bollworm (top) in California. At present, the pink bollworm's range (above left) is limited by winter frosts that kill dormant larvae. Rising winter temperatures would allow this major cotton pest to expand northward.

(Allen-Diaz 2009)



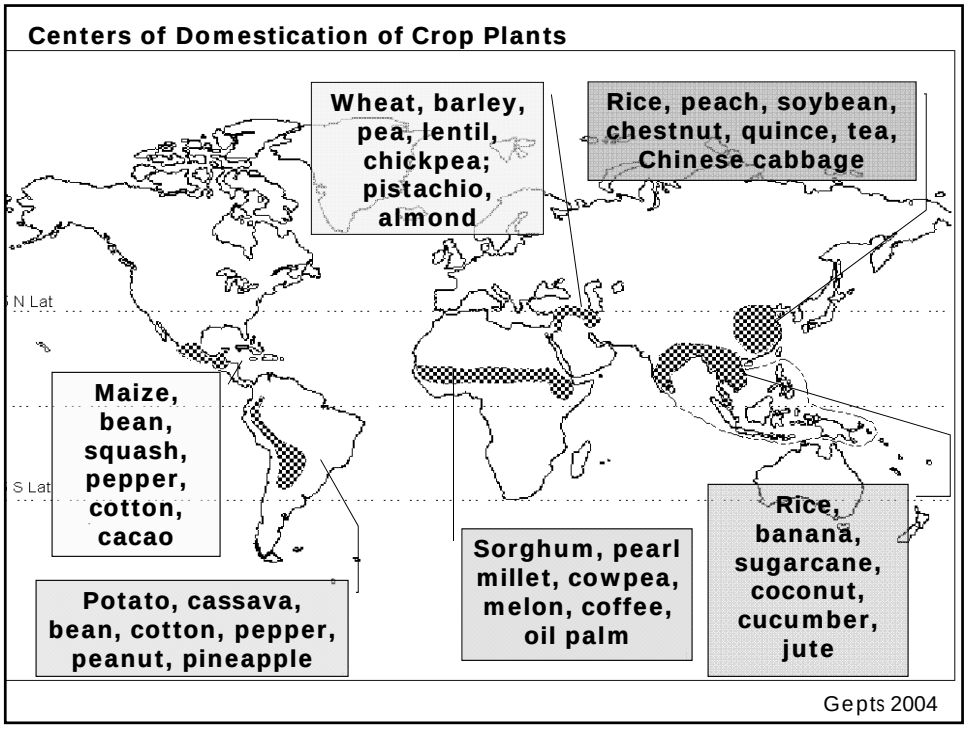


- 17-50% of pollinator species threatened:
  - Phenological shifts → reduction of floral resources

(Memmott et al. 2007)

How to evaluate potential of plant breeding?

- Past history
  - Most crops originated in the tropics/subtropics
  - Dissemination outside center of origin
- Current results
  - Screens of genetic diversity
  - Breeding for adaptation



Example of Genetic Diversity for Drought Tolerance

Grain Yield in Corn Field trials/Zimbabwe

Yield (g/m^2)	Parental Lines		Progeny		
Environment	CML444	SC-Malawi	Mean	Min	Max
Water-stressed	117	80	104	36	254
Well-watered	323	155	200	69	461

Lessons:
- Natural crop biodiversity for drought tolerance
- Variation is heritable
- Transgressive segregation

Messmer et al. 2009

Another example:
Grain Yield in Common Bean Field Trials/Colombia

	Drought treatment	% of control	Unstressed treatment	% of control
Average of 10 best progeny lines	2073	135	3458	114
Control	1531		3029	

Lessons:
- Natural crop biodiversity for drought tolerance
- Selection under stress also leads to improved performance under non-stress

Beebe et al. 2008

Conclusions

- Plant breeding can address climate change
  - Natural genetic diversity within crops
  - Can be transferred into cultivars
- Caveats:
  - Needs to be an ongoing activity
  - B1 scenario for sure; A2: ?