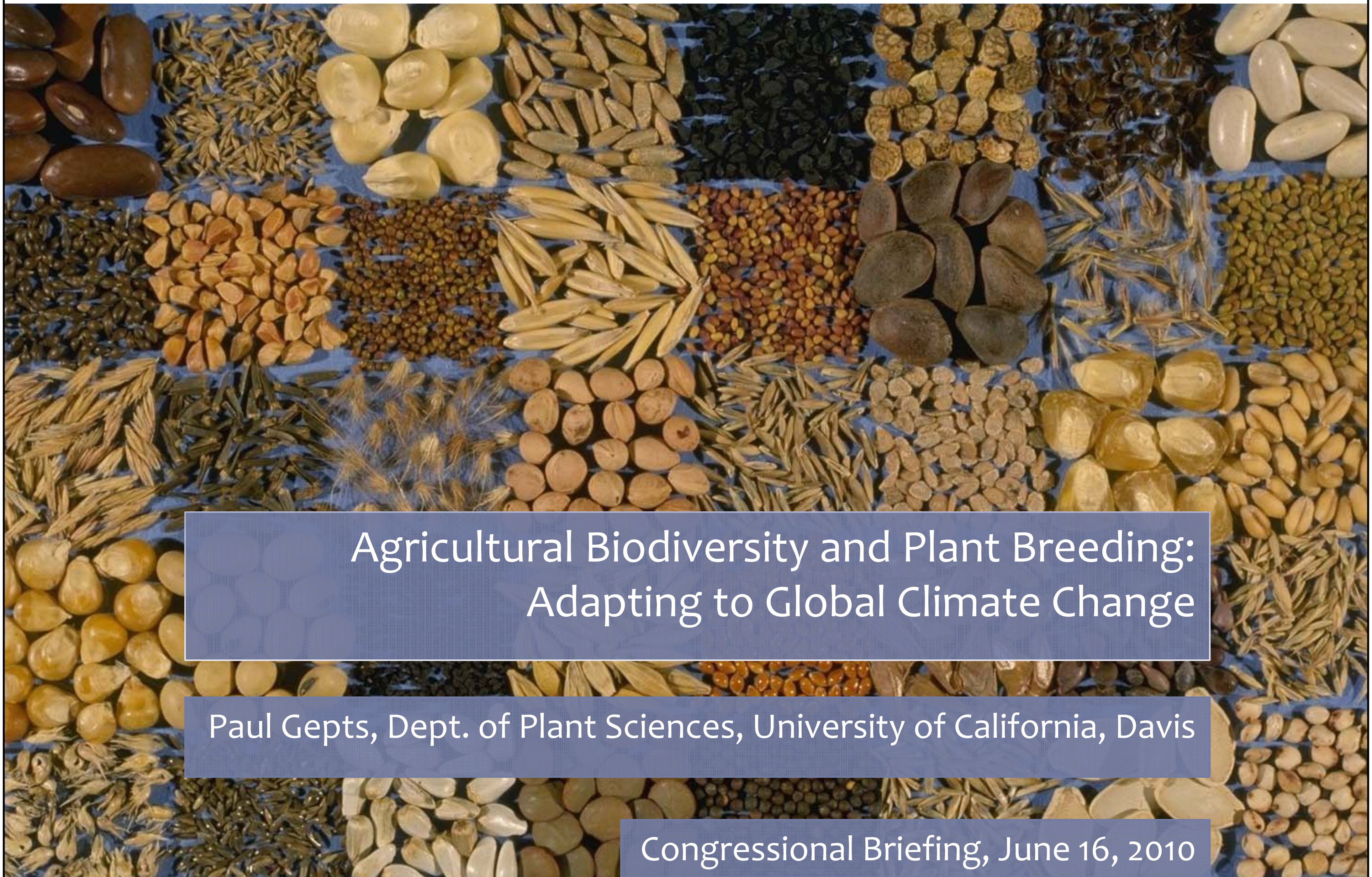


Agricultural Biodiversity and Plant Breeding: Adapting to Global Climate Change

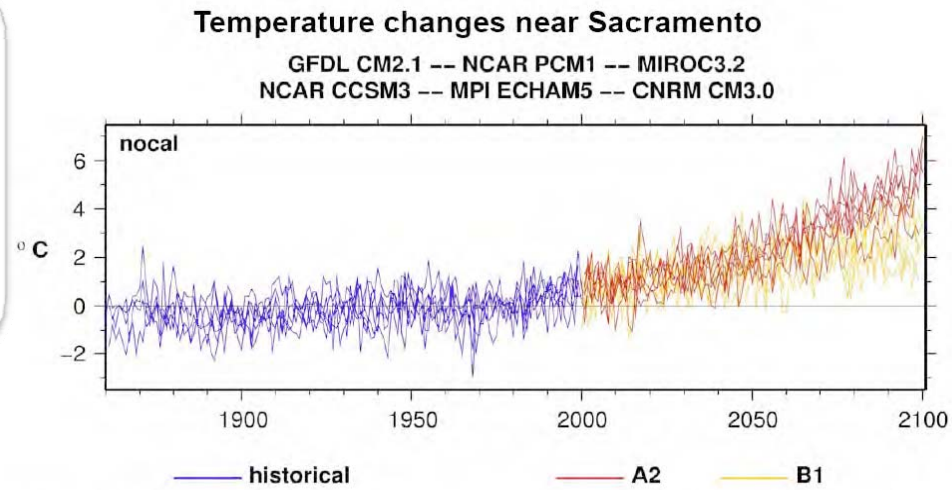
Paul Gepts, Dept. of Plant Sciences, University of California, Davis

Congressional Briefing, June 16, 2010

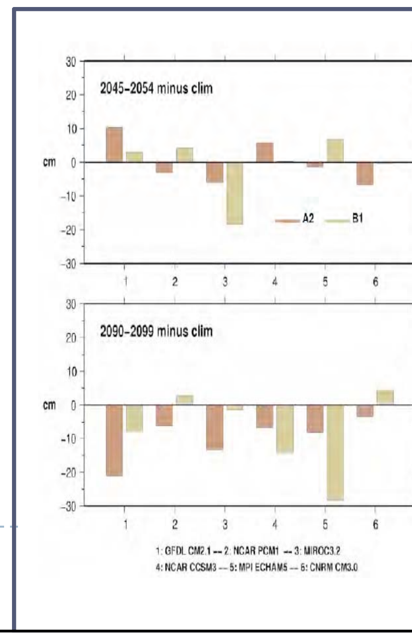
Photo: USDA-NPGS

What to Expect in Terms of Climate?

- Two main **greenhouse-gas emission** scenarios:
  - A2: continued high emissions
  - B1: reduction in emission
- **Time frame:** 50, 100 years
- **Examples:** from CA Central Valley



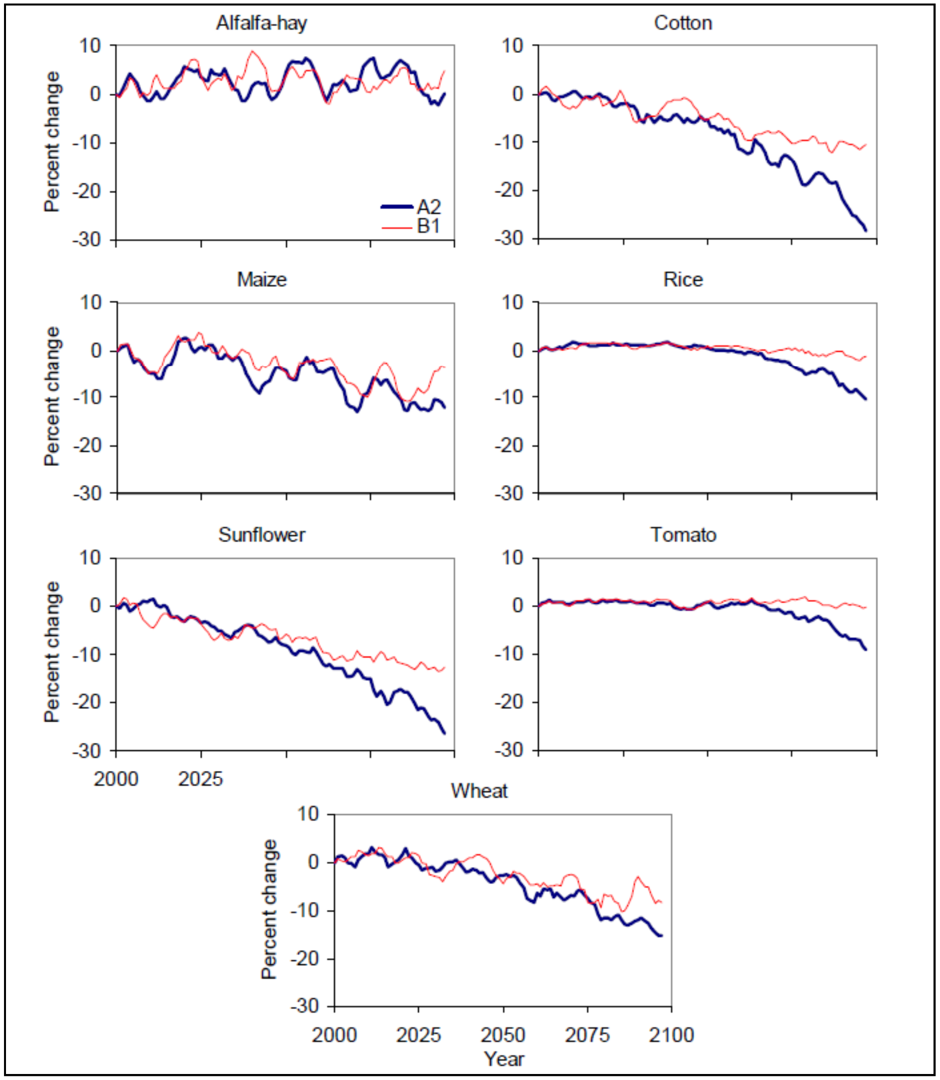
- Higher temperatures:
  - high: +4-6°C (+7-11°F);
  - low: +2-3°C (+4-5°F)
- Precipitation:
  - 50 years: reduction to increase
  - 100 years: marked reduction;
- **Increased unpredictability**



Rainfall

Jackson et al. 2009

Annual crops: Yield predictions over the next century



For most crops:
- ➢ reduction in yield
- ➢ sharper reduction for high emission scenario

Prior experience:
- ➢ 50% of yield increases in 20th century result from genetic improvement by plant breeding
- ➢ Other 50%: cultivation practices

Lee et al. 2009

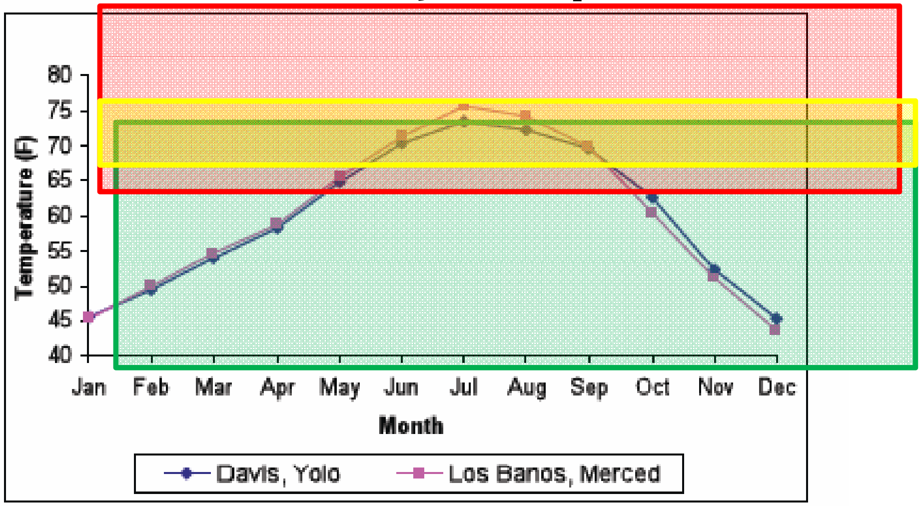
How to Address Global Climate Change?
Targets for Agricultural Biodiversity & Plant Breeding

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

- Photos: Seed Savers Exchange

Strategy # 1: Switch Crops or Crop Mixtures

Mean monthly temperature



Optimum temperatures

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

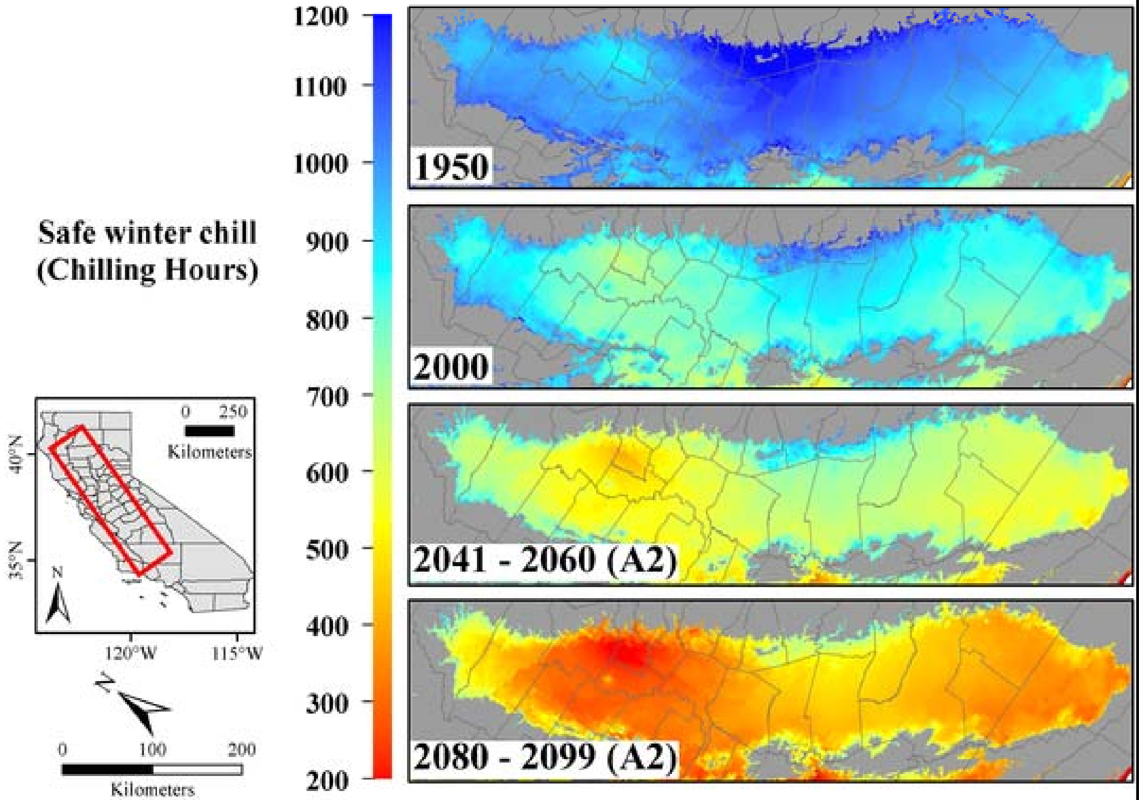
- **Reproductive development** is particularly vulnerable:
  - Pollen viability and production: maize: <77°F; rice:<95°F
  - Kernel development: maize: <86°F
  - Fruit trees: chilling requirement

Jackson et al. 2009

Strategy #2: Let Crops Track Climate Change:

Continuous Field Testing of Existing Variability for Adaptation Traits

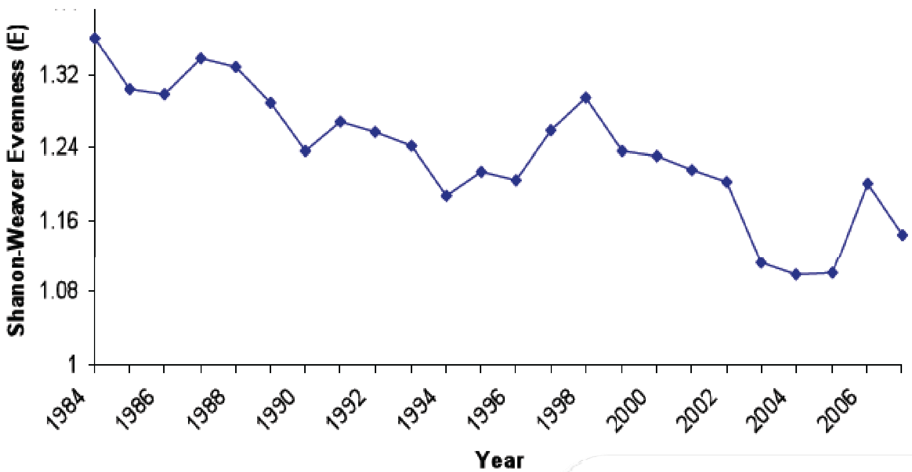
- Fruit and nut trees:
  - need chilling period in winter for yield in following summer
- Test existing and introduced biodiversity for low-chill requirement of fruit and nut trees:
  - Existing varieties
  - Heirloom varieties
  - Center of origin in Central Asia
  - Transgenic diversity



- Luedeling et al. 2009

Strategy #3: Reverse Loss of Diversity among Crops

Evenness of crop diversity



- ➢ More crop choices means more robust agricultural systems:
  - More opportunities for farmers
  - Especially when faced with increasingly unpredictable climate
- Similar to well-balanced financial portfolio

Jackson et al. 2009

Strategy #4: Breeding Can Provide Drought-Tolerant Varieties

Grain Yield in Corn Field trials/Zimbabwe

Yield (g/m²)	Parental Lines		Offspring	
Environment	**Drought-tolerant**	**Local variety**	**Mean**	**Max**
Water-stressed	117	80	104	254
Well-watered	323	155	200	461

Similar Results with Other Crops

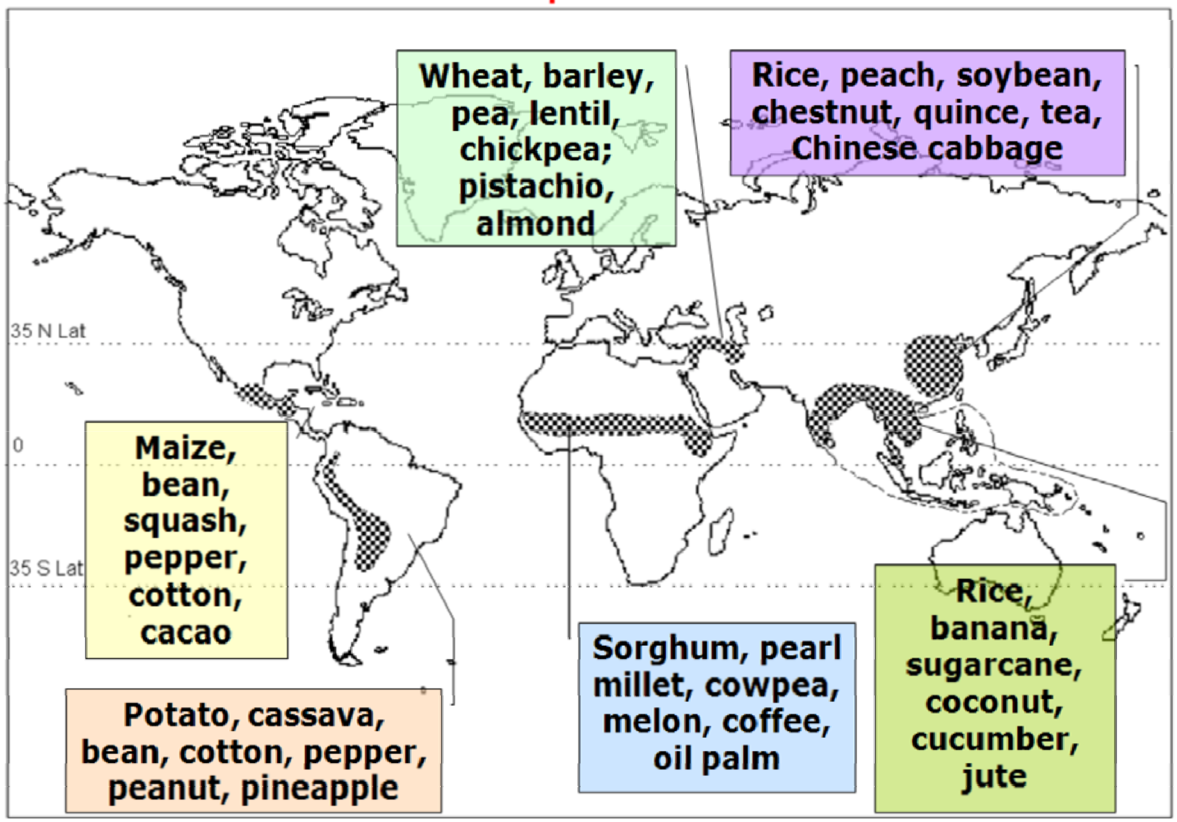
Lessons:

- Natural crop biodiversity for drought tolerance
- Selection systems exist to identify drought tolerance
- Part of the offspring above the best parent
- Selection under stress can also lead to improved performance under non-stress

Messmer et al. 2009

Where Do We Find Crop Biodiversity?

Centers of Domestication of Crop Plants



Gepts 2004

- **Sources of biodiversity:**
  - On-site: biodiversity hotspots for crops
  - Off-site: gene banks: e.g., USDA, CGIAR, national gene banks, Svalbard “doomsday vault”, NGOs, farmers’ seedbanks

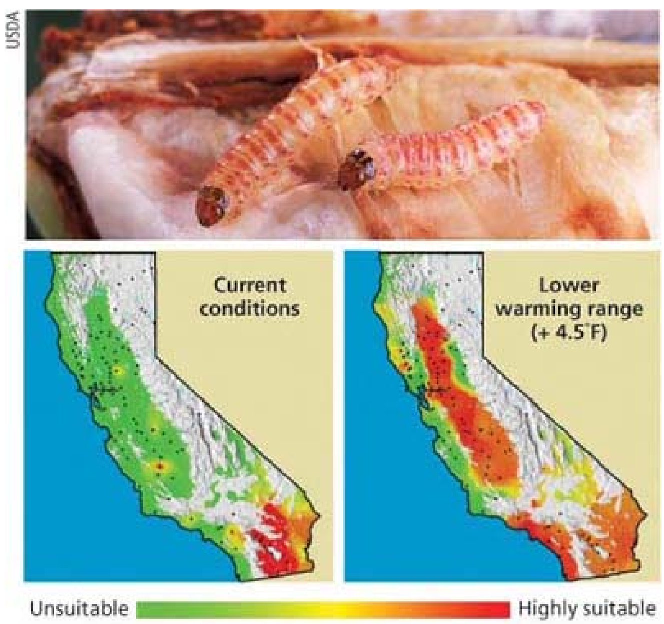
Strategy #5: Address Biological Interactions, like New Pests and Reduction in Pollinator Frequency

Example 1: Pink bollworm/ cotton

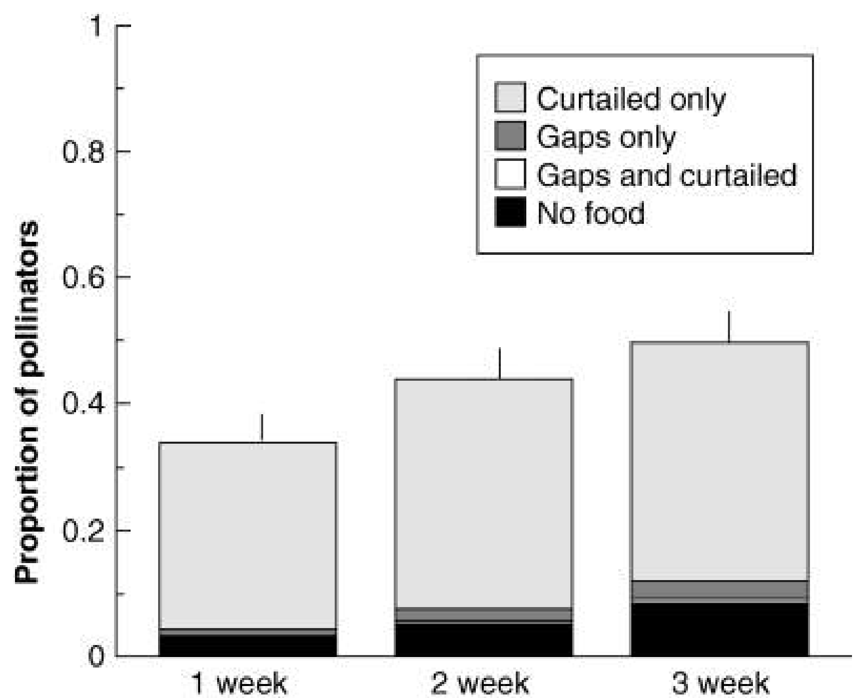
- Expansion of distribution

Example 2: Pollinator species:

- 17-50% threatened by shifts in flowering time & floral resources



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)

(Memmott et al. 2007)

Discussion

- Plant breeding and agricultural biodiversity can address climate change for B1 ⇒ Adaptation of agriculture to A2 would be very difficult
- Five strategies:
  - **1 & 2**: Diversity among crops: substitution and addition ⇒ Testing for alternative crops Transition strategies; support to farmers for transition
  - **3**: Ongoing selection to track climate change
  - **4**: Breeding for drought & heat tolerance ⇒ Conservation of genetic diversity, locally and in gene banks, e.g., USDA, CGIAR, local seed banks
  - **5**: Breeding for resistance to diseases and pests ⇒ Long-term support for plant breeding and breeding research