Climate change implications for plant genetic resources conservation

Von Mark V. Cruz and David A. Dierig

USDA-ARS National Center for Genetic Resources Preservation
1111 South Mason St., Fort Collins, CO 80521-4500

United States Department Of Agriculture
Agricultural Research Service

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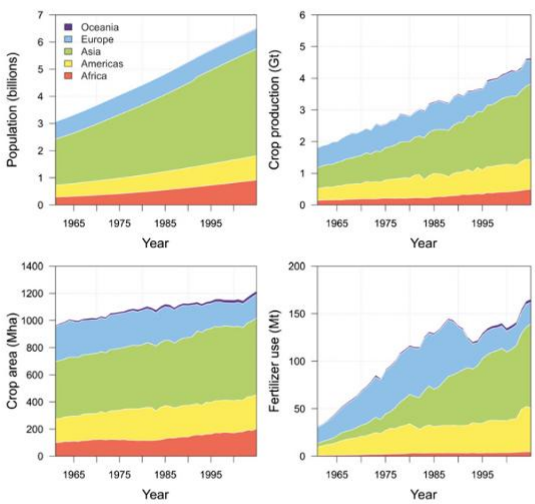
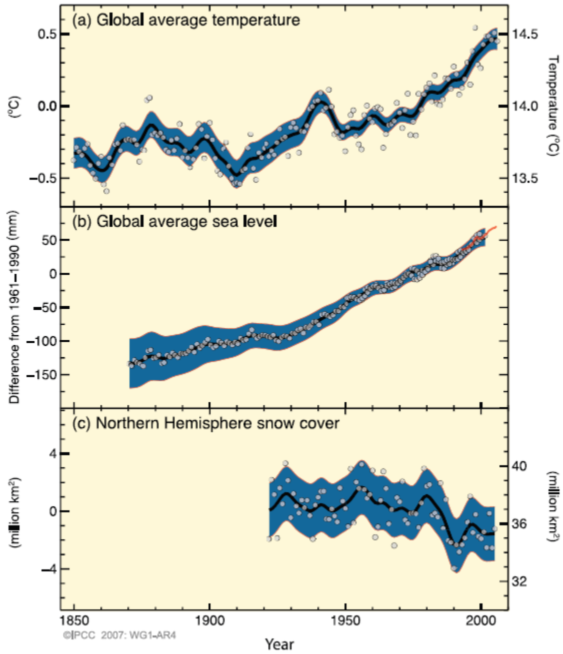
Regional trends in population, crop production, crop area and fertilizer use



Source: Burney et al. (2010)

Changes in temperature, sea level and snow cover



Source: IPCC (2007). WG1 AR4

Projections stated in IPCC WG1 AR4

- A warming of about 0.2°C per decade
- A further warming of about 0.1°C per decade
  - (Even with GH gases and aerosols at constant year 2000 levels)
- Larger climate change effects and further warming during the 21st century
  - (Given continued GH emissions at or above current rates)
- Anthropogenic warming and sea level rise would continue for centuries, even if GH gas concentrations were to be stabilized

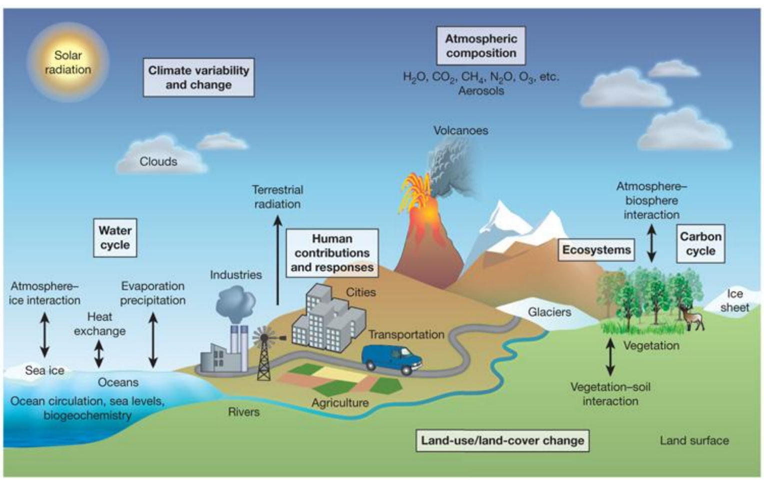
Source: IPCC (2007): Summary for Policymakers.

General conclusions in spite of projection errors

- warming due to **increased concentrations** of heat-trapping gases in atmosphere
- increase in the concentration of these gases over the last century is due to **human activities**, especially the burning of fossil fuels and deforestation.
- human-induced changes **overwhelm** natural causes in changing Earth's climate
- warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times
  - increasing rates of sea-level rise
  - alterations in the hydrologic cycle
  - rising concentrations of carbon dioxide are making the oceans more acidic

Source: Gleick et al. (2010)

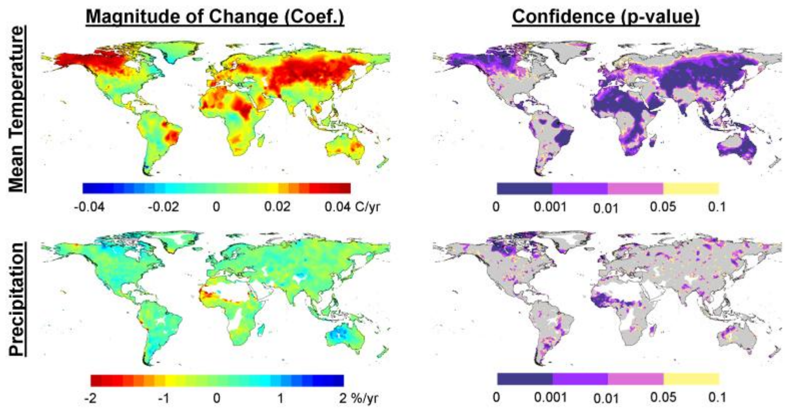
Major natural and anthropogenic processes and influences on the climate system addressed in scenarios



Source: RH Moss *et al. Nature* **463**, 747-756 (2010) doi:10.1038/nature08823

nature

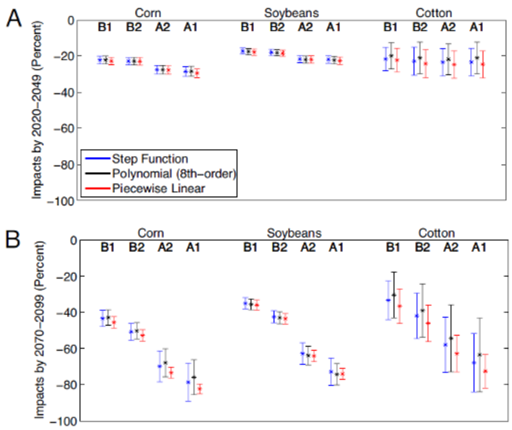
Temperature and precipitation change (1951 to 2002)



Source: Girvetz et al. (2009)

Hotspots for Recent Historical Climate Change Are in Central Asia, North Africa, and North America

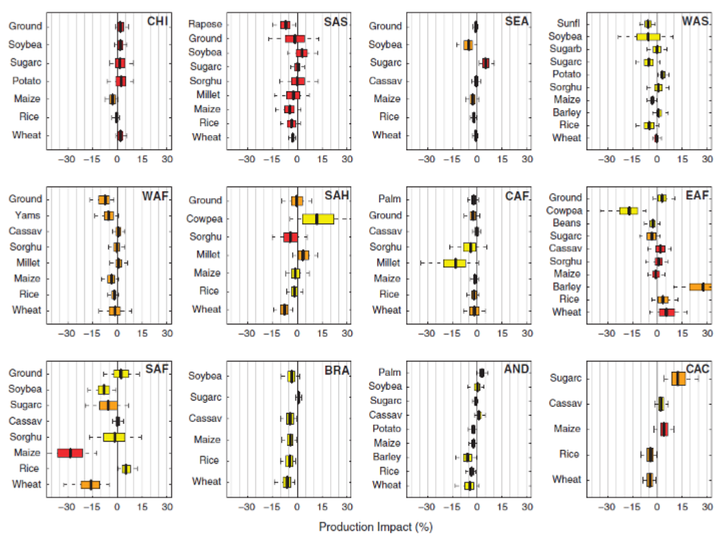
Predicted climate change impacts on crop yields



- Yields may decrease by about 30% before end of the century under the slowest warming scenario
- Yields may decrease by 63–82% under most rapid warming scenario

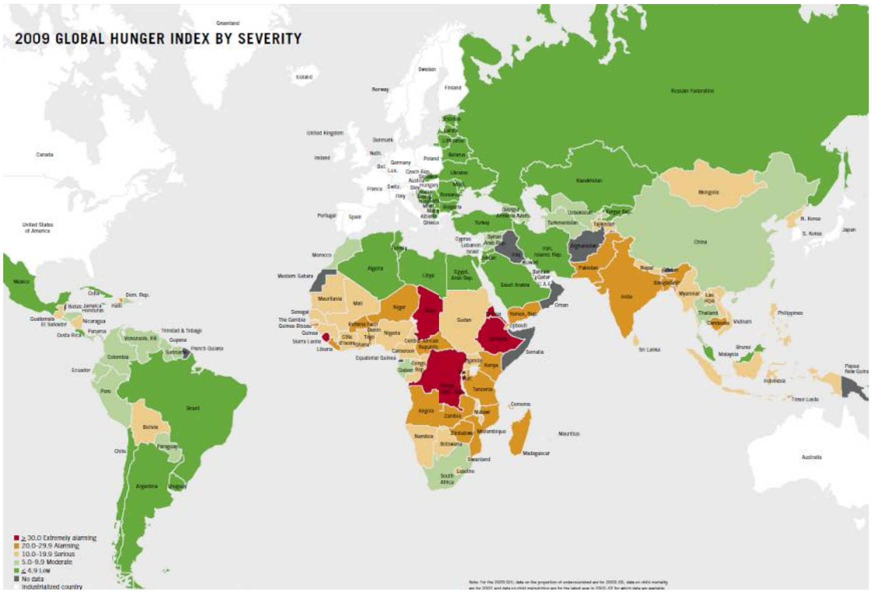
Data: Burney et al. (2010)
Graph: Tollefson (2010)

Projections of production impacts in 2030 from climate change



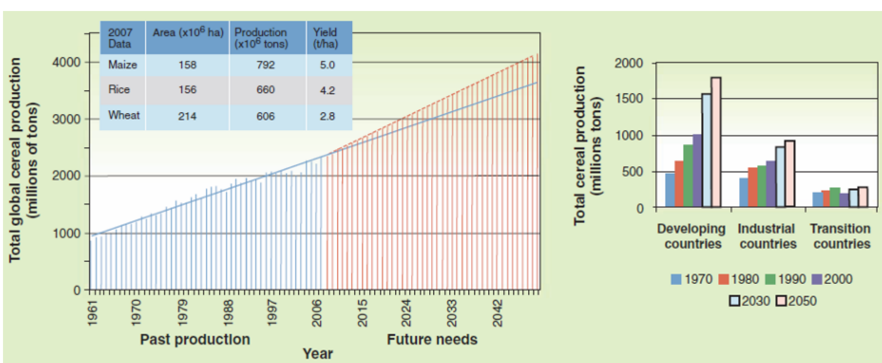
Regions with large food-insecure human populations will likely suffer negative impacts on important crops

Source: Lobell et al. (2008)



Source: IFPRI (2009)

Cereal production targets (to 2050)

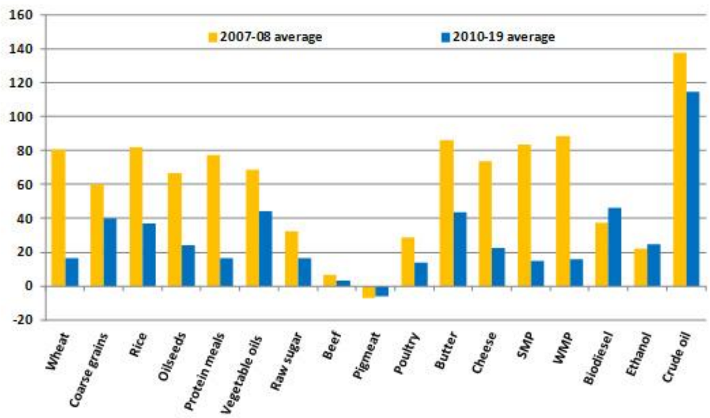


2007 Data	Area ($x10^6$ ha)	Production ($x10^6$ tons)	Yield (t/ha)
Maize	158	792	5.0
Rice	156	660	4.2
Wheat	214	606	2.8

- production will need to rise to over 4000 million metric tons by 2050.
- rate of yield increase must increase from 32 million metric tons per year to 44 million metric tons per year to meet this demand, an increase of 37%.

Source: Tester and Langridge (2010)

Average commodity prices to rise in 2010-19



- Average wheat and coarse grain prices are projected to be nearly 15-40% higher in real terms relative to 1997-2006, while for vegetable oils real prices are expected to be more than 40% higher

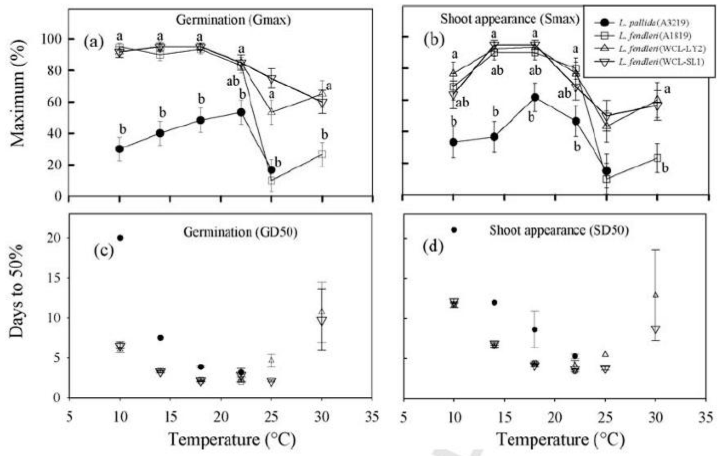
Source: OECD-FAO Agricultural Outlook 2010-2019

Other possible effects on crop production

- **Negative**
  - Production areas
    - Expected reduction in land suitable for growing many types of crops in different parts of the world

Source: Newton et al. (2010); Silva et al. (2010)

Effect of temperature on *Lesquerella* germination and shoot appearance



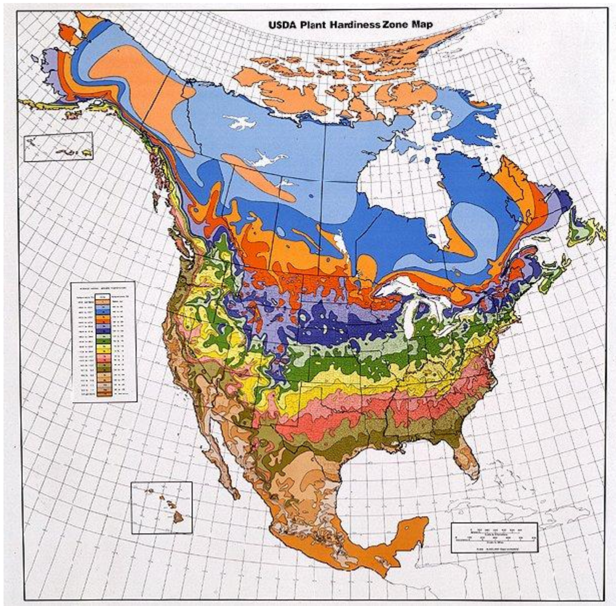
- Gmax and Smax declined sharply at 22C
- Plants takes longer to reach GD50, or may not even reach GD50 at higher temperatures

Source: Adam et al. (2007)

Other possible effects on crop production

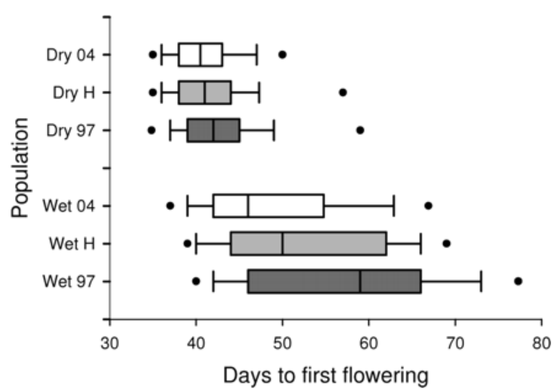
- **Negative**
  - Production areas
    - Expected reduction in land suitable for growing many types of crops in different parts of the world
- **Positive**
  - Possible extension of growing season in northern latitudes
  - Earlier sowing dates, more crop species may become suitable
  - Nitrogen fixation in legumes may increase

Source: Newton et al. (2010); Silva et al. (2010)



The 2003 US National Arboretum "Web Version" of the USDA Plant Hardiness Zone Map

Effect of drought on Brassica flowering time



"…abbreviated growing seasons caused by drought led to the evolution of earlier onset of flowering. Descendants **bloomed earlier** than ancestors, advancing first flowering by 1.9 days in one study population and 8.6 days in another."

Source: Franks et al. (2007)

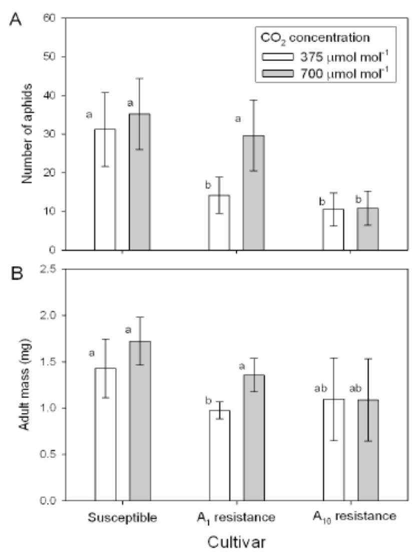
Other possible effects on crop production

- **Negative**
  - Production areas
    - Expected reduction in land suitable for growing many types of crops in different parts of the world
- **Positive**
  - Possible extension of growing season in northern latitudes
  - Earlier sowing dates, more crop species may become suitable
  - Nitrogen fixation in legumes may increase
- **Variable**
  - Disease complexes
    - Might reduce the incidence of diseases related to moist conditions
    - Might enhance quick development of pathogen variants
    - Might also depend on impact on life cycle of disease vectors

Source: Newton et al. (2010); Silva et al. (2010)

Resistance of raspberry on aphids at ambient and elevated CO_2 conditions

- Under elevated CO2, the number of aphids in resistant cultivar (A_1) became equivalent to a susceptible cultivar
- Cultivar with A_{10} resistance with intact resistance at ambient and elevated CO2



Source: Martin and Johnson (2010)

Crop Biodiversity

Benefits of agricultural biodiversity

- Private benefits to farmers
- Local or regional benefits to farmers and consumers
- Global benefits to future farmers, plant breeders and consumers

Source: Brussaard et al. (2010)

Narrow genetic base - consequences

Increased vulnerability to pests and diseases

1845 and 1846 Potato late blight disease

- 50% loss in Ireland potato plantations
- Result = Irish potato famine

1869 Coffee rust

- Wiped out plantations in Ceylon
- Ceylon switched to growing tea

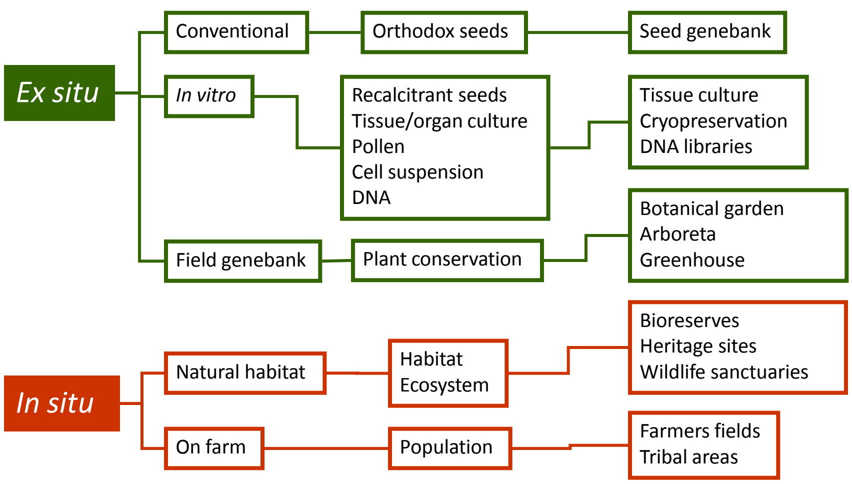
1970 U.S. corn leaf blight epidemic

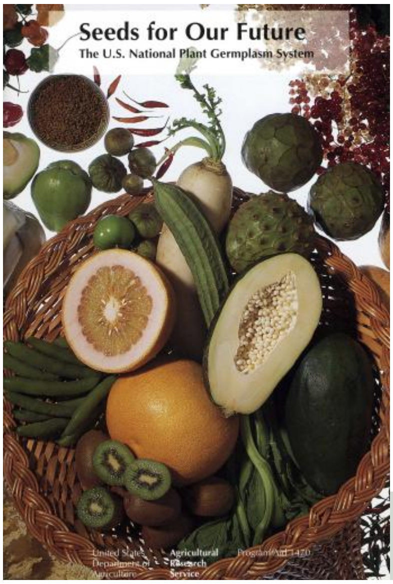
- Affected corn fields in US midwest
- 50% loss in US midwest corn fields

From: Damania (2008)

Types of Genebanks

Conservation Strategies





The US National Plant Germplasm System

The NPGS aids scientists and the need for genetic diversity by:

- acquiring crop germplasm
- preserving crop germplasm
- evaluating crop germplasm
- documenting crop germplasm
- distributing crop germplasm

Scientists must have access to genetic diversity to help bring forth new varieties that can resist pests, diseases, and environmental stresses.

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NCGRP

Preserving our Future

National Center for Genetic Resources Preservation

Mission: Acquire, evaluate, preserve and provide a national collection of genetic resources to secure the biological diversity that underpins a sustainable US agricultural economy through diligent stewardship, research and communication

History

- 1958 – built as National Seed Storage Laboratory (NSSL)
- 1977 – pioneered freezer storage (-16C) in storage of plant germplasm
- 1992 – NSSL building was expanded and storage capacity increased 10x
- 1999 – animal genebank started, name changed to the NCGRP, mission now covers preserving germplasm of all life forms important to US agriculture

Office of Research Leader	David Dierig
Plant Germplasm Preservation Research	Christina Walters Gayle Volk Christopher Richards
Plant Genetic Preservation Program	David Ellis Maria Jenderek
Animal Genetic Preservation Program	Harvey Blackburn Phil Purdy

Strategies and Technologies for PGR preservation

Biochemistry

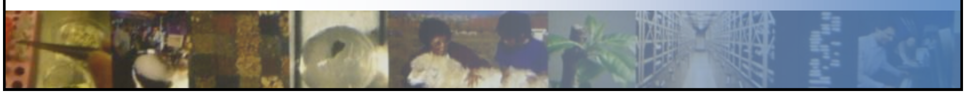
Molecular Biology

Seed Biophysics

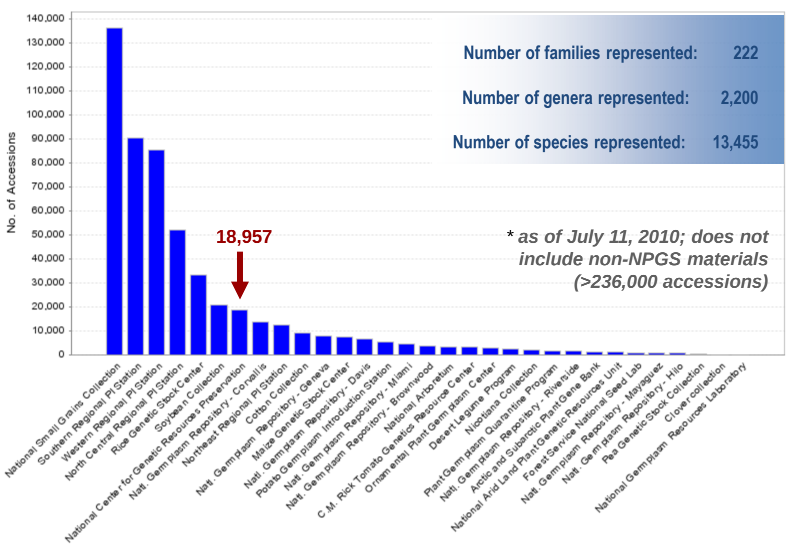
Seed Quality

Tissue culture

Cryobiology



Number of accessions held by NPGS sites = 536,523*



Number of families represented:	222
Number of genera represented:	2,200
Number of species represented:	13,455

** as of July 11, 2010; does not include non-NPGS materials (>236,000 accessions)*

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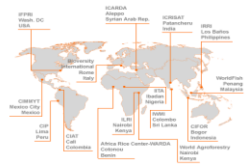
CGIAR genebanks



• CIAT (Colombia)	Cassava, common bean, forages
• CIMMYT (Mexico)	Wheat, maize
• CIP (Peru)	Potato, sweet potato
• ICARDA (Syria)	Cereals, forages, chickpea, lentil, faba bean
• ICRAF (Kenya)	Agroforestry trees
• ICRISAT (India)	Sorghum, pearl millet, pigeon pea, groundnut
• IITA (Nigeria)	Bambara groundnut, cassava, cowpea, yam
• ILRI (Kenya)	Forages
• Bioversity (Italy)	Musa
• IRRI (Philippines)	Rice
• WARDA (Cote d Ivore)	Rice

666,080 accessions = 10% of world total *(Koo et al., 2003)*

696,554 accessions *(includes AVRDC; SINGER database, accessed 7-14-2010)*

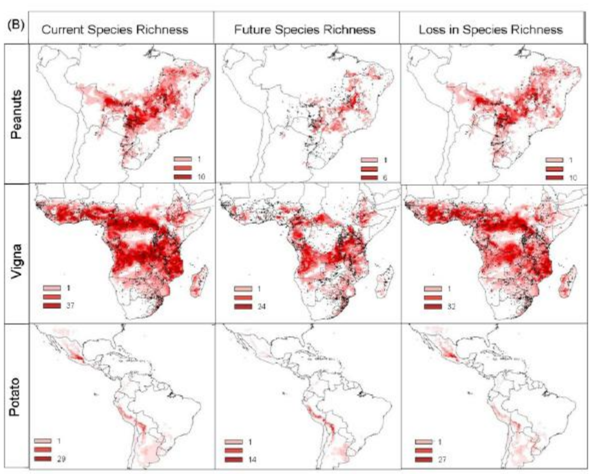
Most vulnerable collections

- ***Ex situ*** **-> Field genebanks**
  - Tissue culture back-up ? Cryostorage?
  - BUT… tissue culture or cryo may not work for all species
- ***In situ*** **-> Natural habitat & on-farm**
  - Effects on crop wild relatives?
    - 16-22% of wild species might go extinct (Jarvis et al. 2008)
    - Only 2-18% of crop wild relatives are represented in *ex situ* collections (Khoury et al., 2010)

Considerations

- Some species can adapt to projected future environments, some cannot
  - Phenotypic plasticity
- Monitoring changes in biodiversity is desirable

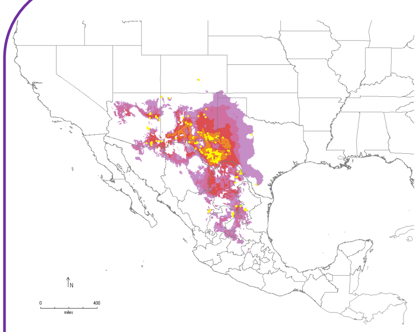
Species richness of crop wild relatives under different climatic scenarios



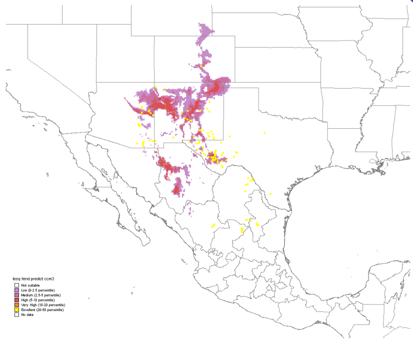
Source: Jarvis et al., 2008

- Significant change in pattern of species richness
- Habitat fragmentation – 19% loss under no migration scenario

Predicted distributions of *Lesquerella fendleri*



Current climate



Increased CO_2 scenario of future climate

Possible constriction in suitable habitats under increased CO_2 conditions

Collecting *Lesquerella fendleri*

Germplasm Enhancement of Maize

A collaborative effort of public and private sector researchers to broaden and enhance the maize germplasm base. More than 60 collaborators.

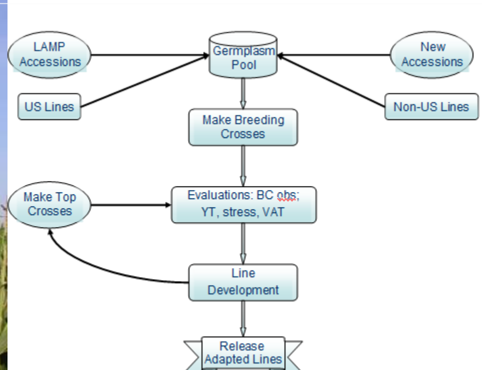
Key traits of interest:

- Abiotic stress tolerance
- Reduced level of mycotoxins
- Disease resistance
- Insect resistance
- Value added grain and silage traits

USDA ARS United States Department Of Agriculture Agricultural Research Service — NCRPIS — Iowa State

Germplasm Enhancement of Maize

New Races for Allelic Diversity



Source: Blanco (2008)

Germplasm Enhancement of Maize

GEM Germplasm Releases

Year	# Lines Released	Germplasm Attributes
2001	1	Resistance to 1st brood ECB (non-DIMBOA)
2002	2	Yield, resistance to anthracnose and GLS
2003	82	Yield, earlier flowering, GLS, Fusarium Resistance, VAT, Temperate adaptation
2004	26	Temperate adaptation, yield, VAT, Stress tolerance, CEW, grain mold resistance, earlier flowering, superior nutritional quality
2005	29	Temperate adaptation, yield, VAT, High protein, earlier flowering
2006	26	Yield, VAT, earlier flowering
2007	21	Protein, oil, high starch for ethanol, 50% exotics; disease resistance, Amylose maize VII line (GEMS-0067)
2008	13	Temperate adaptation, yield, VAT, waxy lines
2009	12	Oil, leaf blight resistance

Source: http://www.public.iastate.edu/~usda-gem

Priority actions

- Further collecting, regeneration, safety duplication, and *in situ* conservation
  - Safeguard against habitat destruction, deforestation, urbanization, climate change, grazing, expansion of modern agriculture, abandonment of traditional agriculture
- Research on collections – testing effects of different climatic environments
  - Will help in understanding physiological basis of adaptation (e.g. seed dormancy, flowering time, etc.)
  - Important role of regional genebanks and active germplasm sites
  - Screening variation for drought, heat and frost stresses

Increased collaboration

- **Collaboration**
  - Ease in future collecting and characterization
    - Standardization of descriptors
    - Development of new ones
    - Development of data management systems
  - Helps conservation of cross-border weedy and wild species
- IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
  - Similar to IPCC

Recommendations

- **Research**
  - Develop knowledge base on species
  - Ecological research to sample unexplored areas
  - New technologies for long-term conservation
  - Development of new crops
    - *Lesquerella* example
  - Breeding technologies for locally important crops. Crops generally are well adapted to local conditions, form the basis of local food
- **Continued capacity building and IEC in genomics and plant genetic resources**
  - Include policymakers, philanthropic institutions in stakeholder lists
  - Outreach, formal trainings (e.g. MSc PGR in UPLB, other SEAsia countries)
  - Crop info clearinghouses (e.g. SGRP's Crop Genebank Knowledge Base)

Outreach in genomics and plant genetic resources

Plant Genome Outreach to Native Americans

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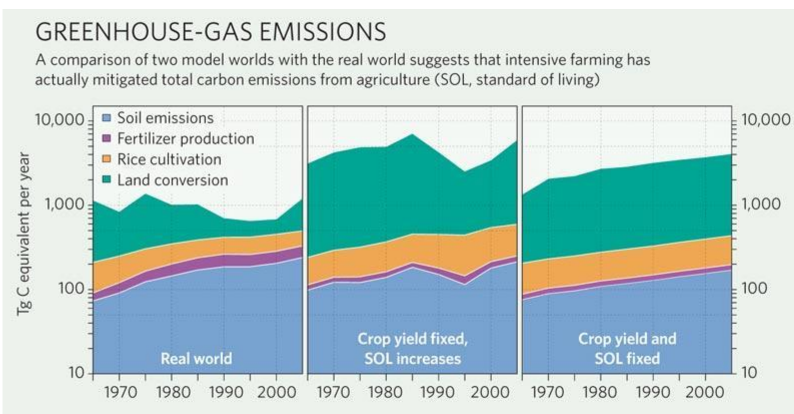
Green Revolution may have eased climate change



Data: Burney et al. (2010)
Graph: Tollefson (2010)

Additional information about germplasm collections, conservation activities, protocols and technologies at:

http://www.ars-grin.gov/ncgrp/index.htm

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