Food and Climate Variability: Past, Present, and Future

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- USDA-SARE (enc07-095, 2007-47001-03883).

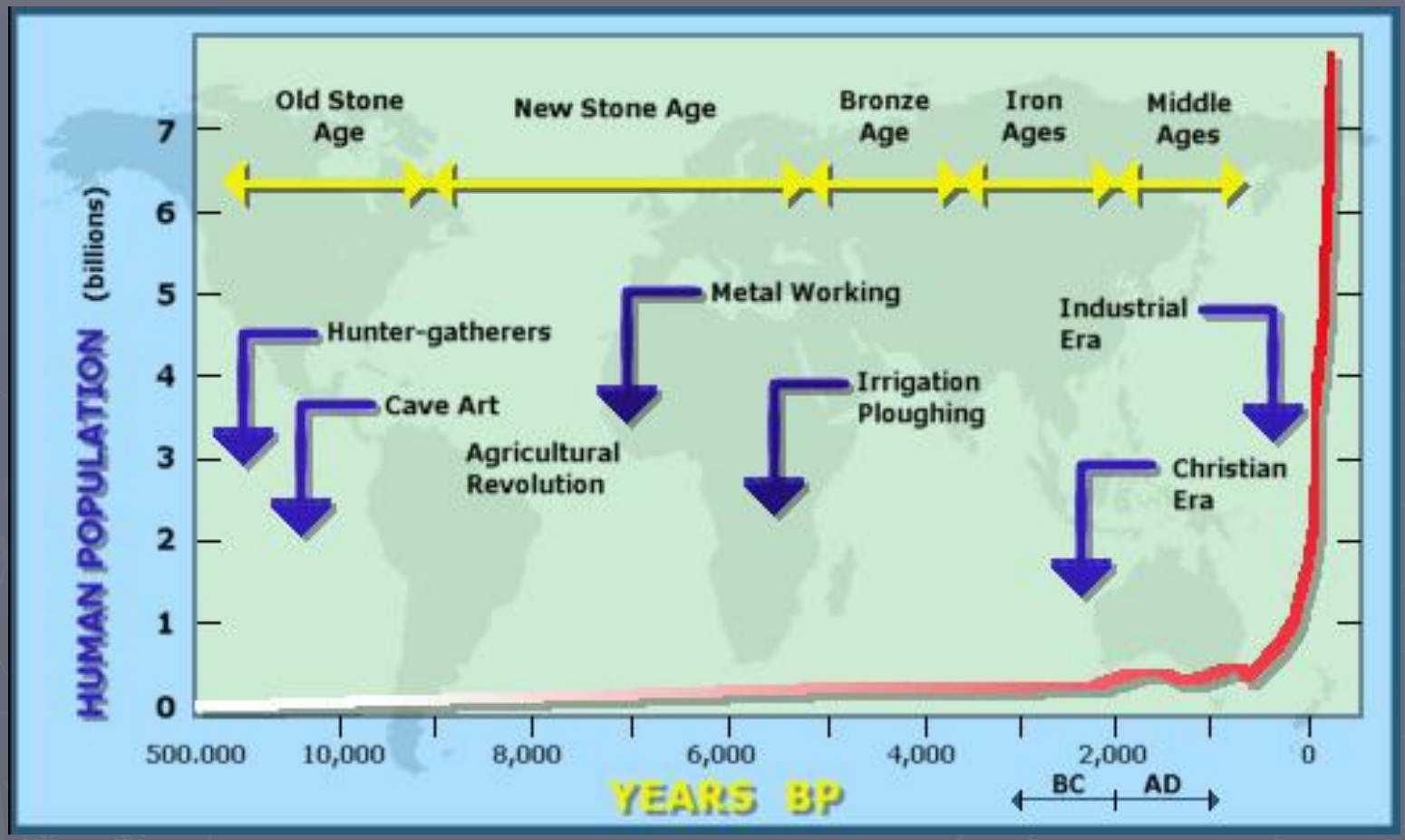
Topics

- Present
  - Limiting factors
  - Genetic diversity
  - Sustainability
- Past
  - Collapse
  - Incas
- Future
  - Geospatial technologies
  - Linking information, basic, and applied sciences

Present: Meeting goals production goals

- People
- Energy
- Decreased land availability
- Reduced amount of resources
- Reduced oil
- Genetic diversity

Population growth

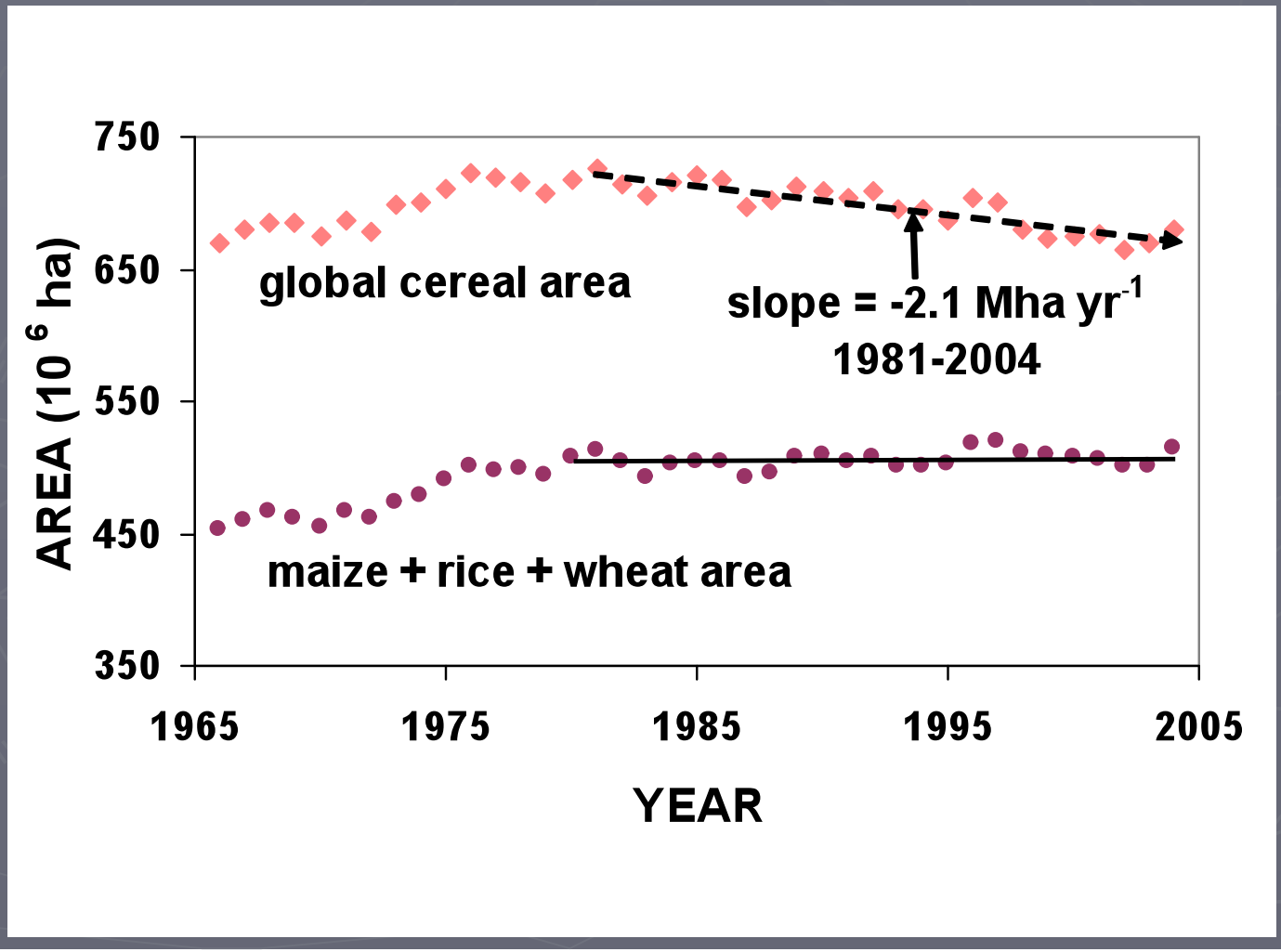


http://www.globalchange.umich.edu/globalchange2/current/lectures/human_pop/human_pop.html

Food sustainability

- Many people believe that to meet an increasing world population, food production must increase.
- The questions is how will this be accomplished in a variable climate when many of the dedicated resources for food production are decreasing?

Available Resources: Trends in Global Area Planted to Cereals is decreasing, 1966-2004 (from Cassman, 2007)

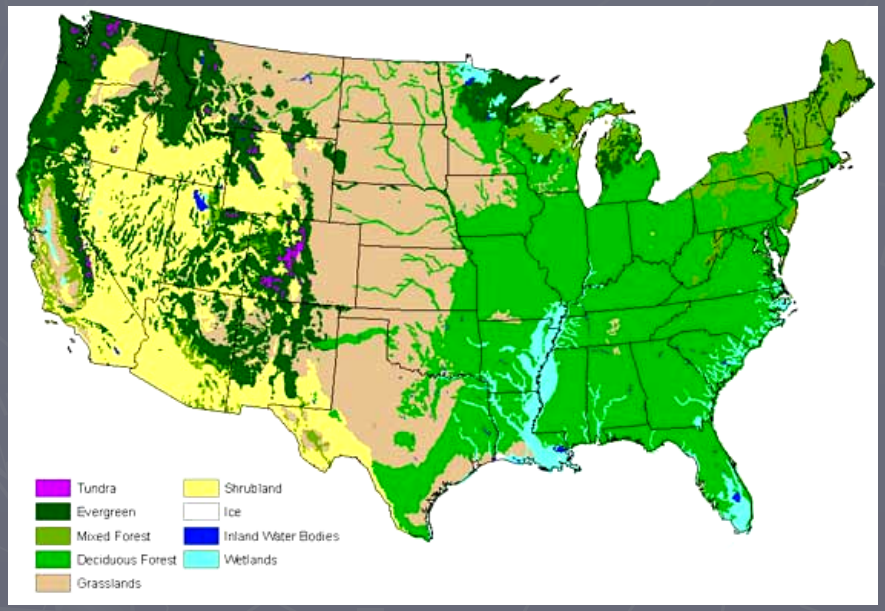


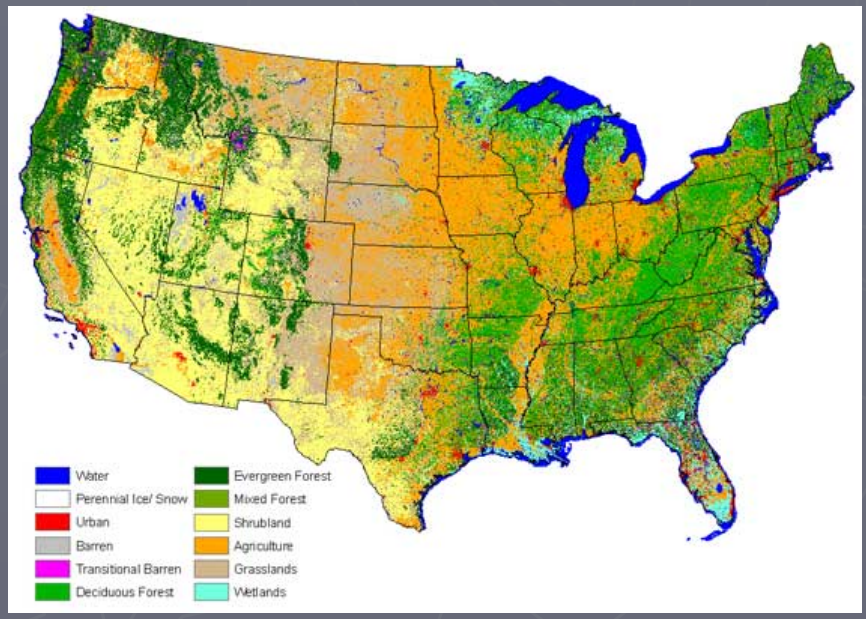
What we know: Protecting our agricultural base

- For each person added, 1 acre of space is lost to urbanization
- 1994 arable l.8 acres per person
- 2050 estimated that only 0.6 acres of arable farmland per person.

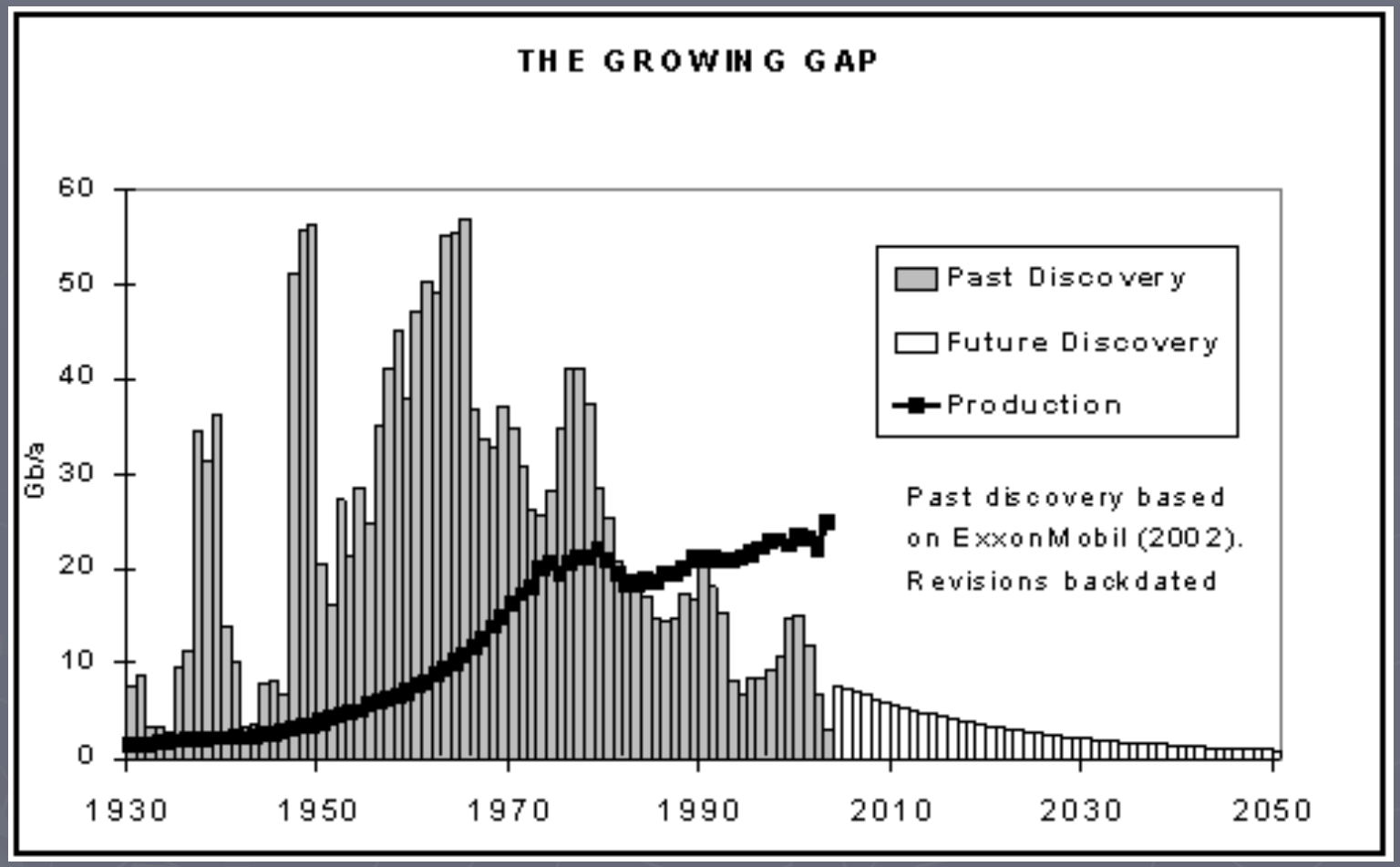
Land cover changes

Bring more land into production



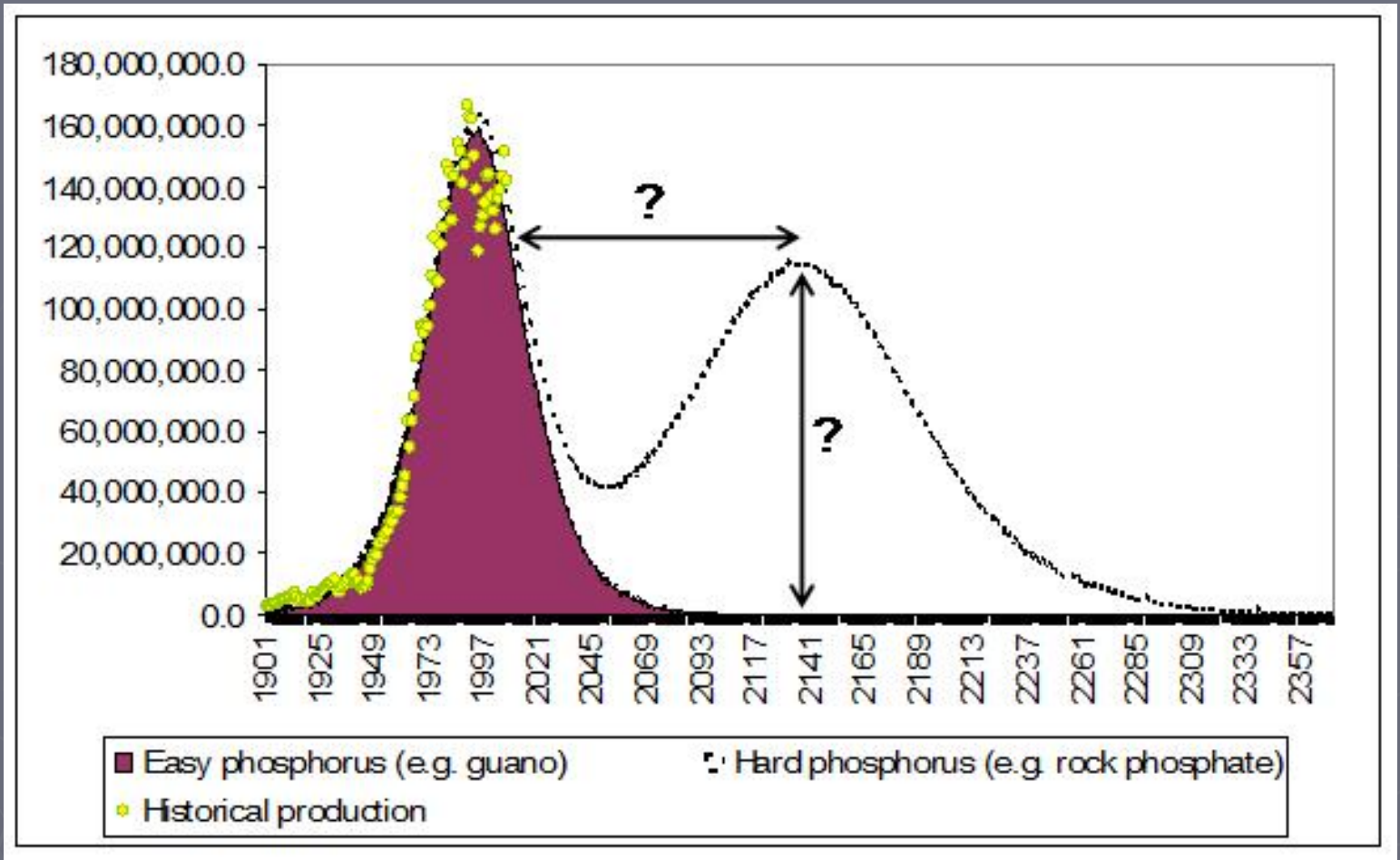


Source:http://www.mhhe.com/earthsci/geology/mcconnell/demo/hpaq.htm



Oil consumption exceeds new find

http://www.inforse.org/europe/dieret/Oil%20peak/oil%20peak.html

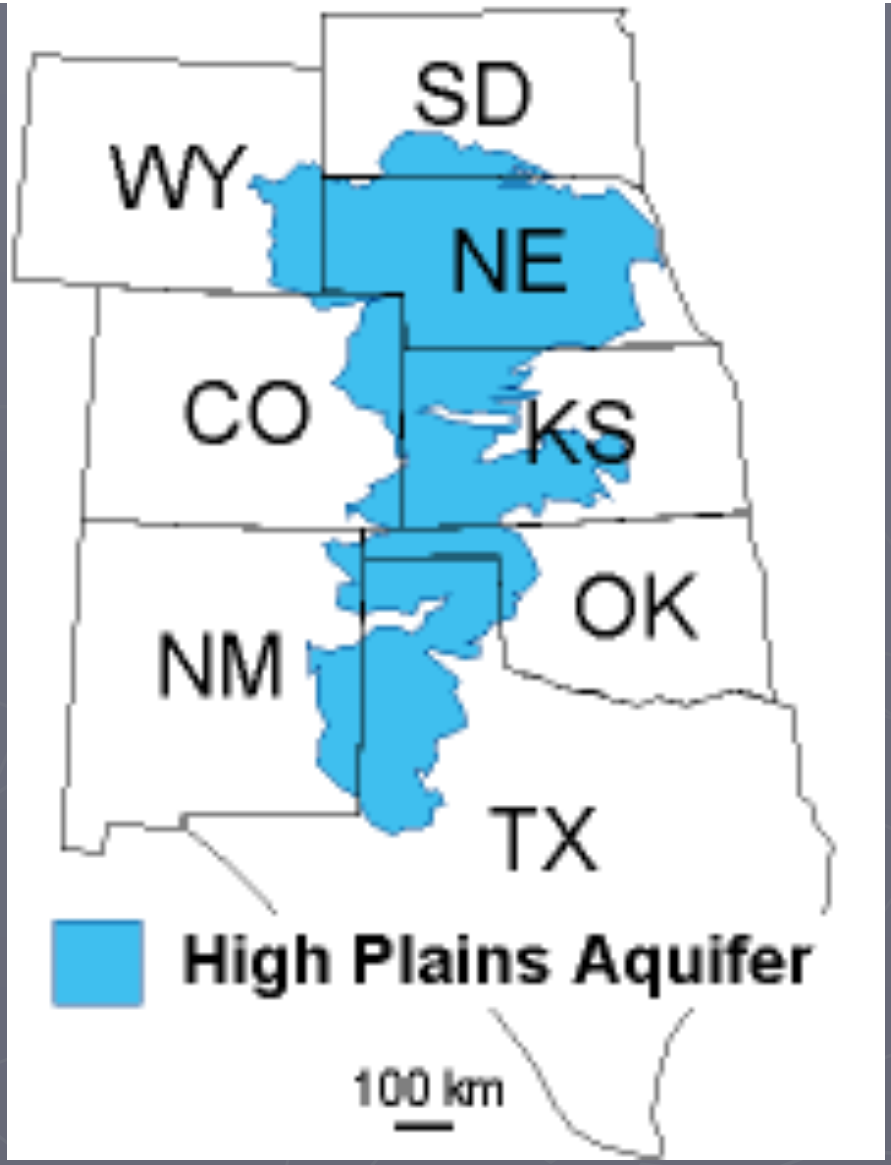


Peak P may already have occurred

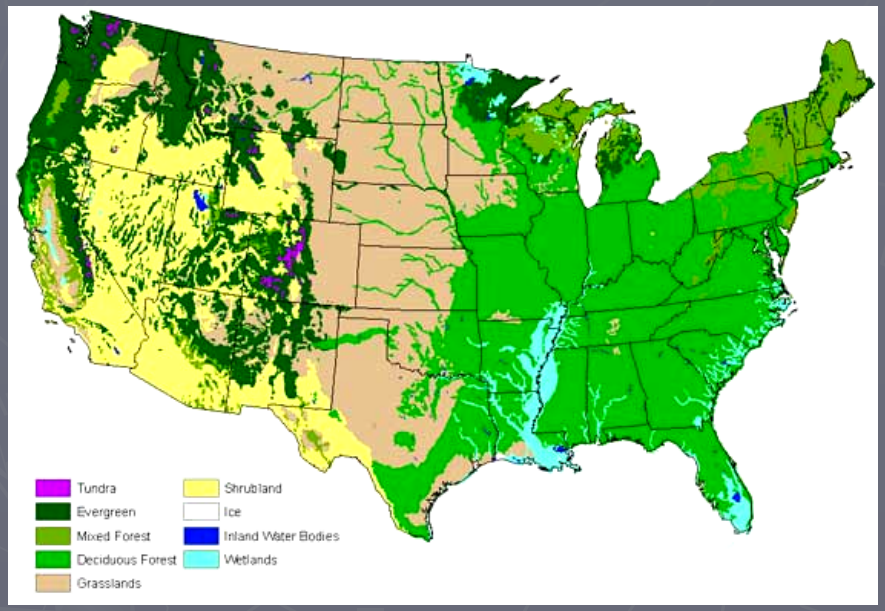
During the past several years P fertilizer has increased
From around $500/ton to over $1,000/ton

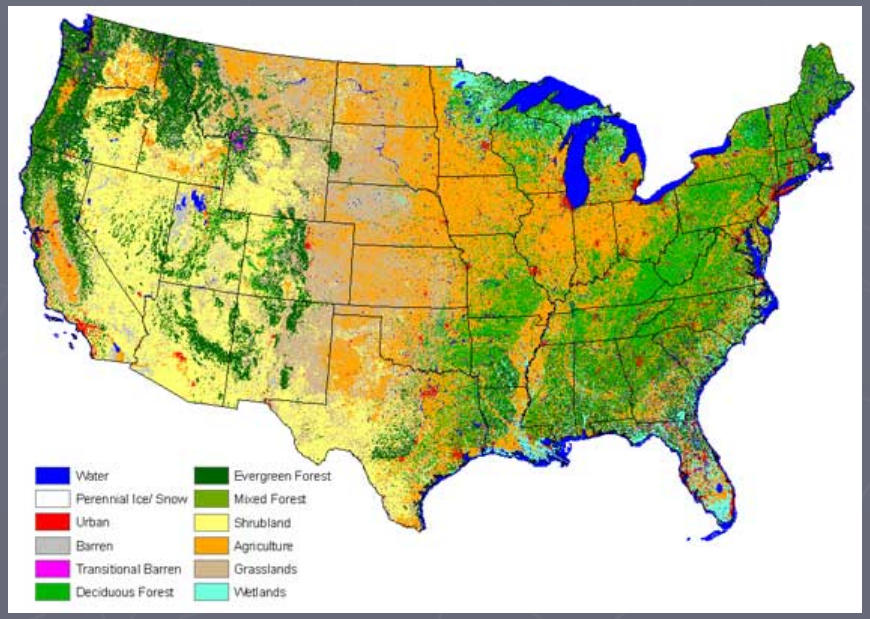
Water:

The high plains aquifer
Has provided the water
Needed to convert
Grasslands into crop
lands



Water and crop lands





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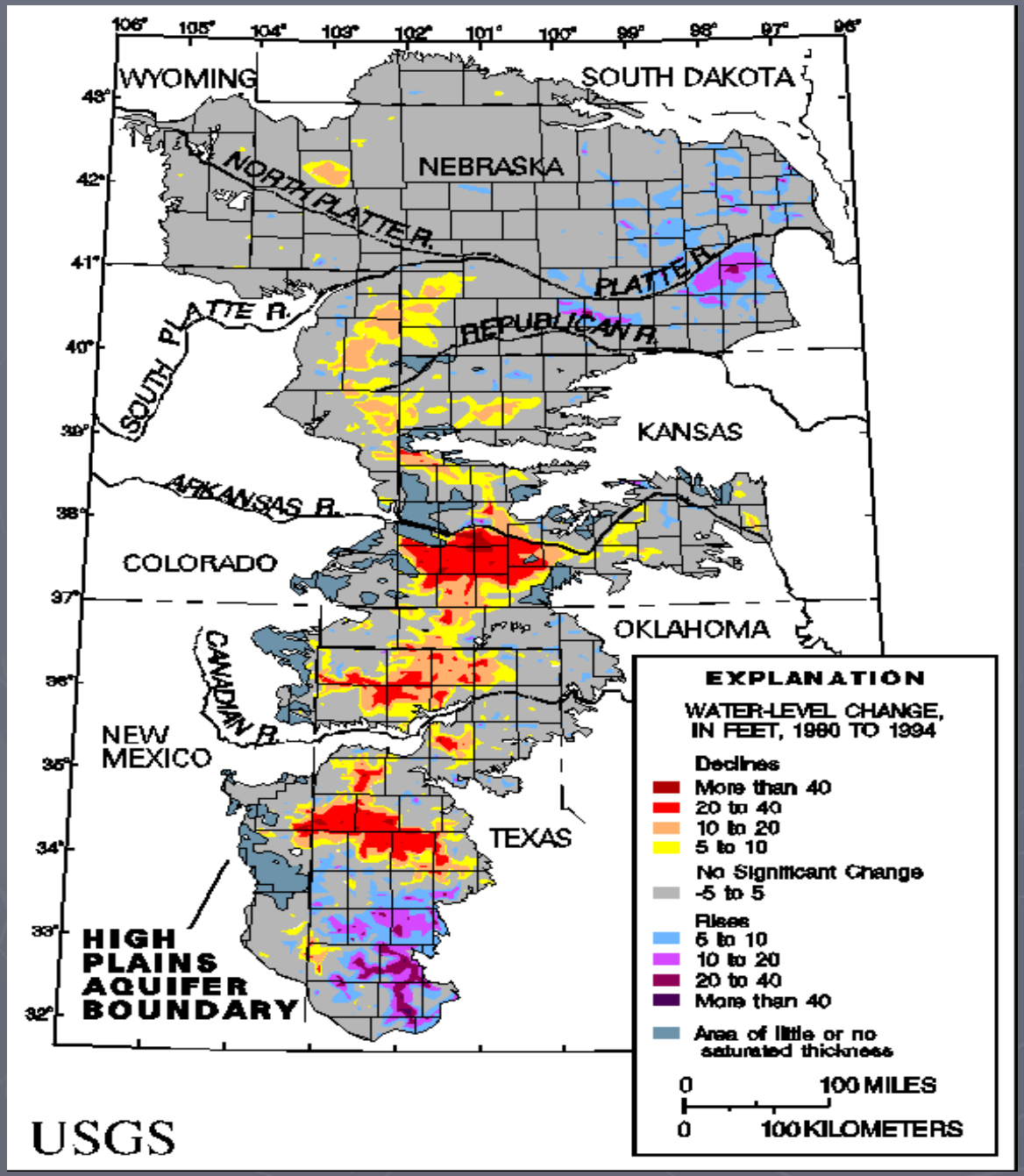


Present: decreases in the amount of available water across the Great Plains.

Soil resource: Maintaining soil productivity

Increasing short term productivity can come at a cost of mining the soil nutrients,

Adopting non-sustainable practices can reduce productivity and increase erosion.

Maintaining soil quality

- Returning enough carbon to increase or maintain soil organic carbon levels.
- Decreasing SOC levels contains risks.

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex795

Black Sunday April 14, 1935. The dust storm that turned day into night. Many believed the world was coming to an end.

Genetic resources

- Has the green revolution resulted in the development of very high yielding cultivars that are planted in near monocultures across landscapes?
- Monocultures reduce genetic diversity in the landscape;
- Does this provide a risk?

Case History: The Irish Potato Famine

In the 1840s,

almost half of the population in Ireland depended on potatoes to survive.

Sources: Encyclopedia Britannica, 2002; Pictorial Times, 1846

The Irish Potato Famine--*continued*

In order to feed its people, Ireland relied primarily upon two high-yielding potato varieties.

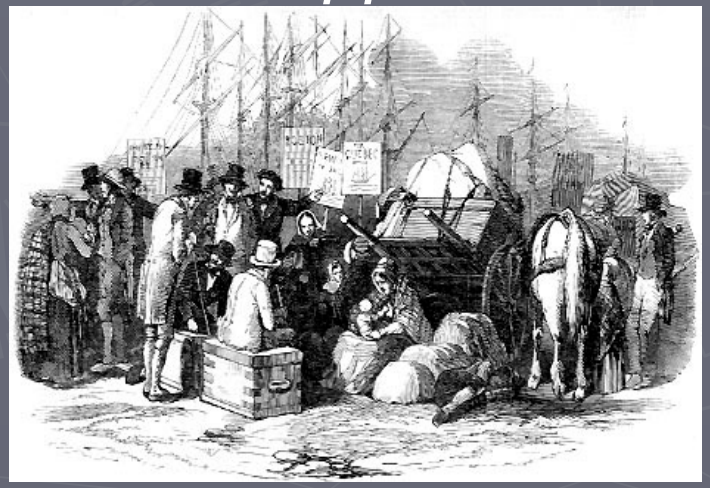
When the potato disease struck, it resulted in a massive crop failure that lasted five years, 1845-1850.

Sources: Encyclopedia Britannica, 2002; Illustrated London News, 1849

Over a 15 year period in Ireland . . .

- A loss of 1 million lives due to starvation and disease.
- A loss of 1.5 million due to emigration.

Ireland's 1845 population of 8 million dropped to 5.5 million by 1860.



Sources: Plant Diseases: Their Biology and Social Impact; Encyclopedia Britannica, 2002; Illustrated London News, 1847; 1851

Need a more recent case study?

1970

Southern Corn Leaf Blight Epidemic

In 1970, 80% of all hybrid field corn (Texas male sterile) grown in the U.S. was susceptible to Southern Corn Leaf Blight.

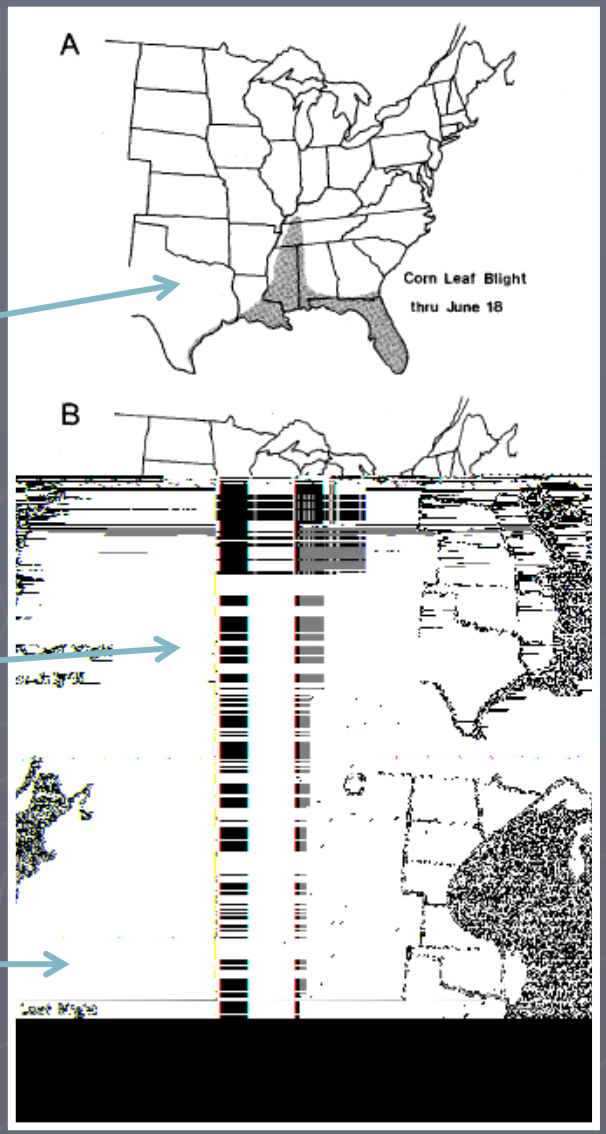
Progress of Southern Corn Leaf Blight Epidemic in North America (1970)

The path:

June 18

July 15

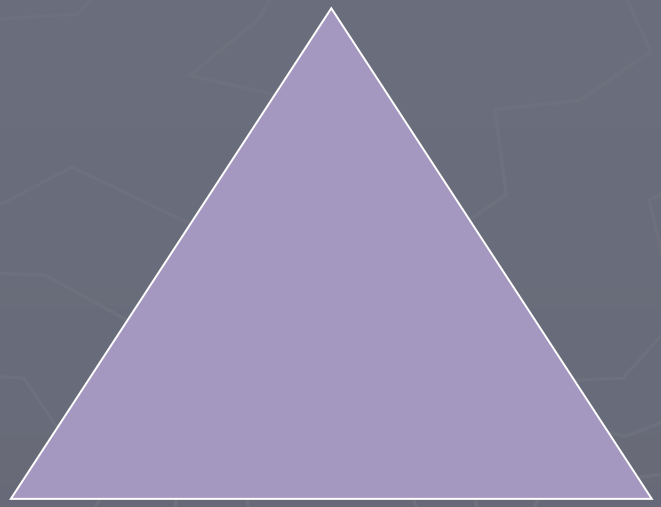
September 1



Source: Plant Diseases: Their Biology and Social Impact

Why did it happen?

Uniform susceptibility
in the host plants



The
introduction
of a pathogen

An environment
conducive to
disease

Where are we today?

How does climate variability influence our risk

Genetic resources in landscapes today

- In California in 2009, 3 red wheat varieties accounted for 51% of the planted acres (http://agric.ucdavis.edu/crops/cereals/CWC_Wheat_Var_Survey_2009.pdf)
- In North Dakota, two varieties accounted for 41% of the spring wheat planted (http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Crop_Varieties/pub/whtvr09.pdf)

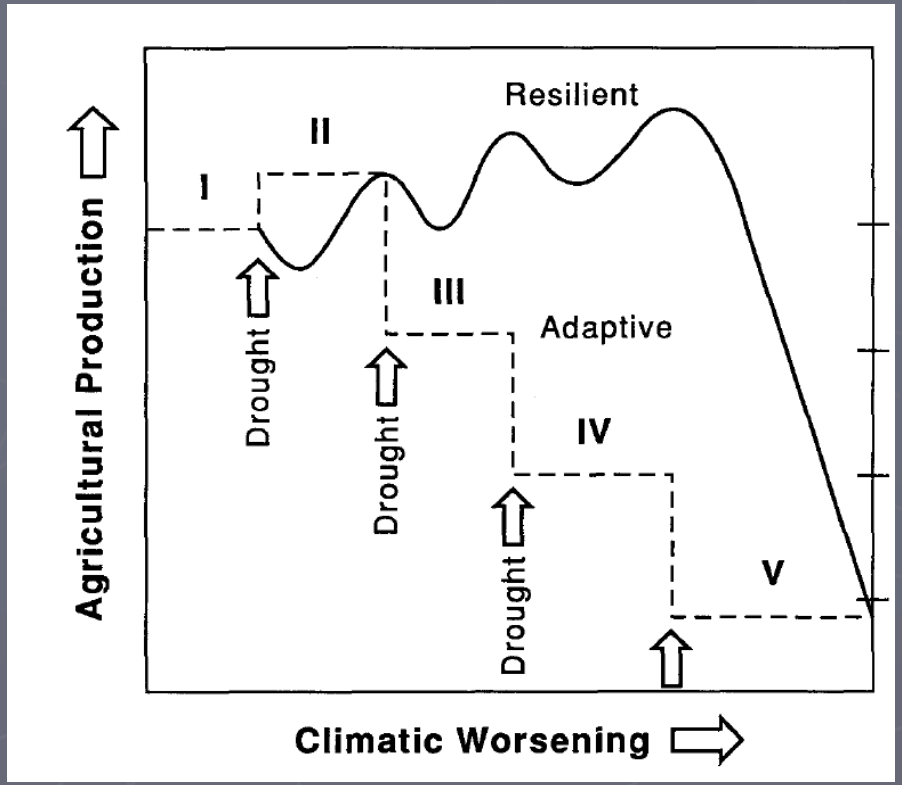
Summary Present

Are we in a cycle that is not very resilient?

Jared Diamond

Collapse: How societies choose to fail or succeed.

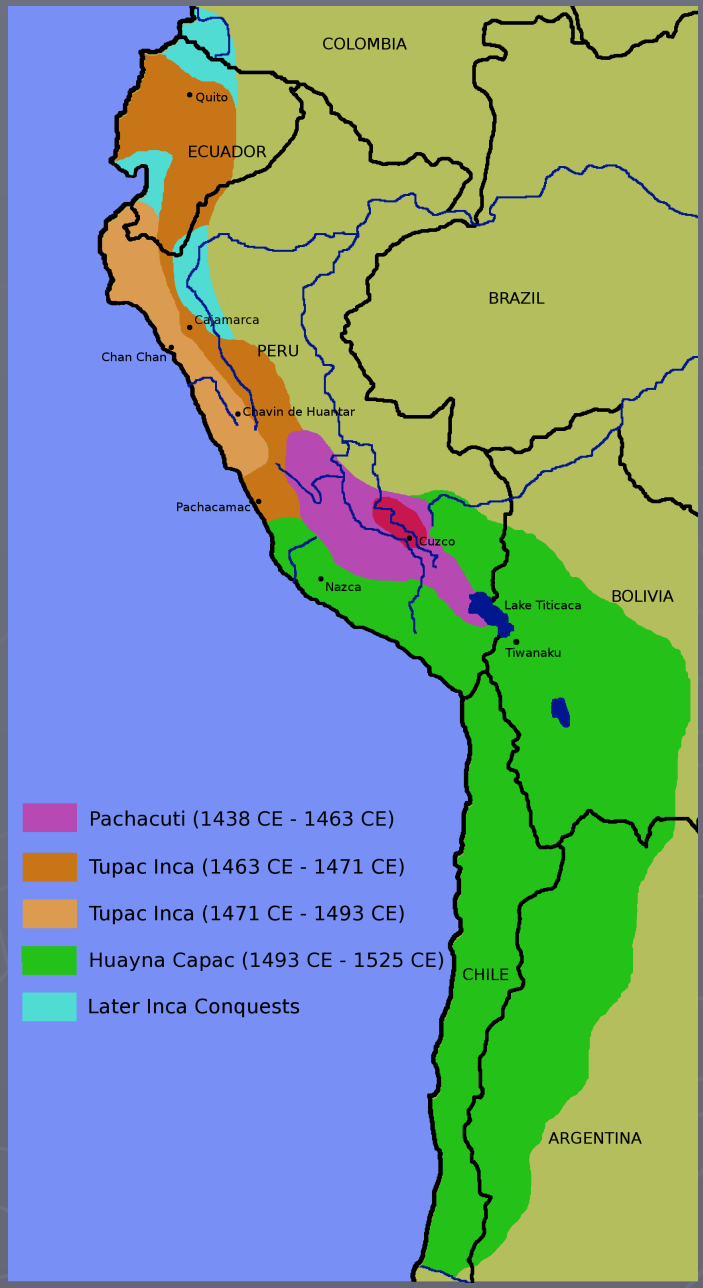
1. Habit and resource management.
2. Over use
3. Population pressure



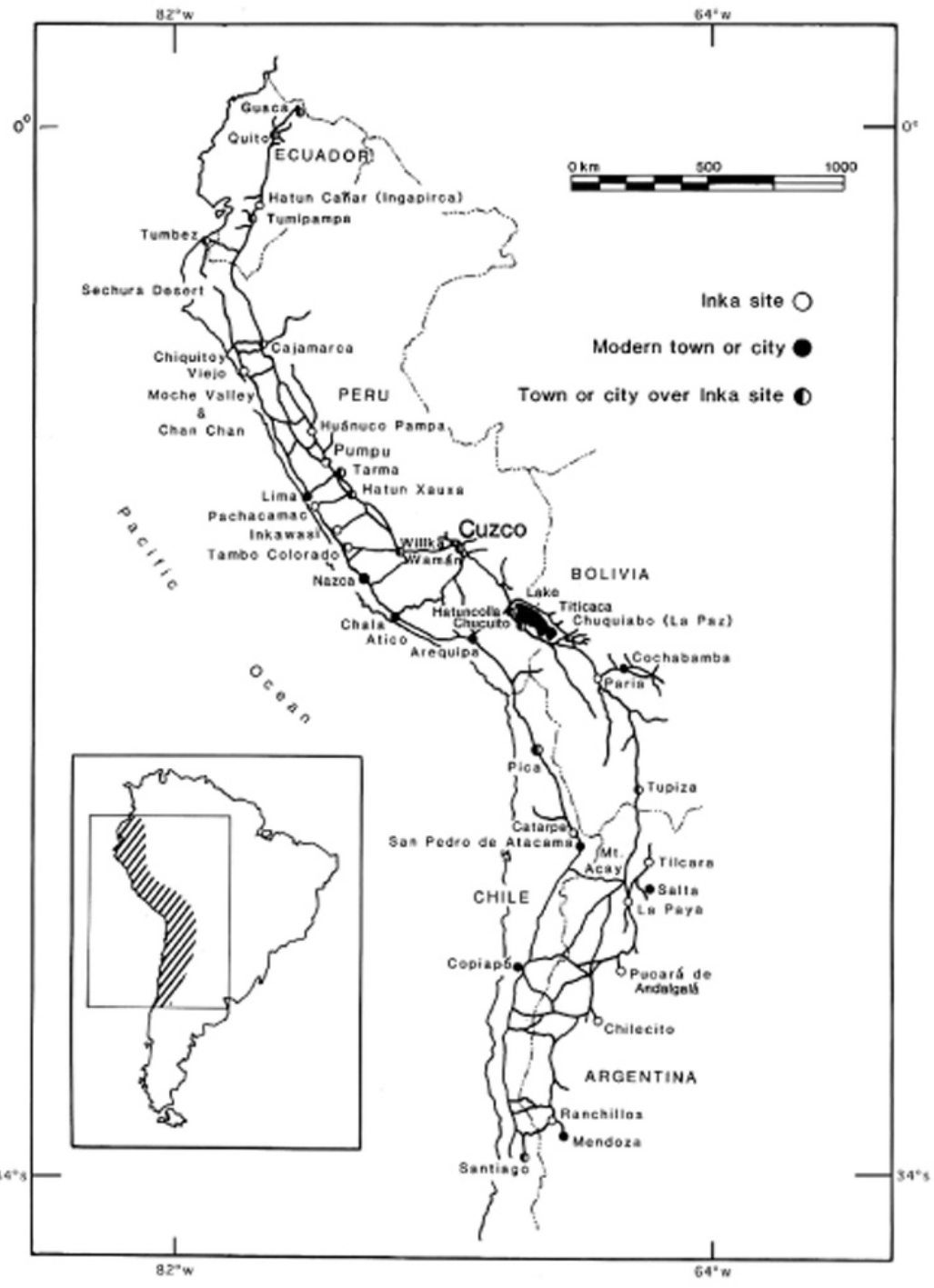
Past

Case study: Incas of South America

Investments in agricultural Research, Genetic diversity Creating micro climates.



A view of Machu Picchu, "the Lost City of the Incas


82°w
64°w
0°
0°
34°s
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0km
500
1000
Inka site
Modern town or city
Town or city over Inka site
Gusca
Quito
ECUADOR
Hatun Cañar (Ingapirca)
Tumipampa
Tumbez
Sechura Desert
Cajamarca
Chiquitoy Viejo
Moche Valley & Chan Chan
PERU
Huánuco Pampa
Pumpu
Tarma
Hatun Xauxa
Lima
Pachacamac
Inkawasi
Tambo Colorado
Cuzco
Willka Wamán
Nazca
Pacific
Ocean
Chala
Atico
Arequipa
Lake Titicaca
Hatuncolla
Chucuito
Chuquiabo (La Paz)
BOLIVIA
Cochabamba
Paria
Pica
Tupiza
Catarpe
San Pedro de Atacama
Mt Acay
Tilcara
Salta
La Paya
CHILE
Copiapó
Pucará de Andalgalá
Chilecito
ARGENTINA
Ranchillos
Mendoza
Santiago


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Innovations

- They could store between three to seven years of foods at their state warehouse.
- They prepared their foods for storage
  - Foods were freeze-dried by setting them out in dry days and cold nights
- They invested in agricultural research.
  - Technologies and varieties

Moray: The Inca Agricultural Center?

Microclimates and genetic diversity

- The Andean peoples domesticated over 70 different plants;
- They utilized and created microclimates for growing food;
- They protected themselves from environmental stress by planting many varieties of the same crop.

Creating microclimates: Terraces

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Vertical economy

- In the highlands they might grow corn, beans, garden vegetables,
- whereas in the bottom lands they might cultivate a root crop called manioc.
- Within a zone a might plant many different varieties of a specific crop
- Protected them against unpredictable temperatures and rainfall.

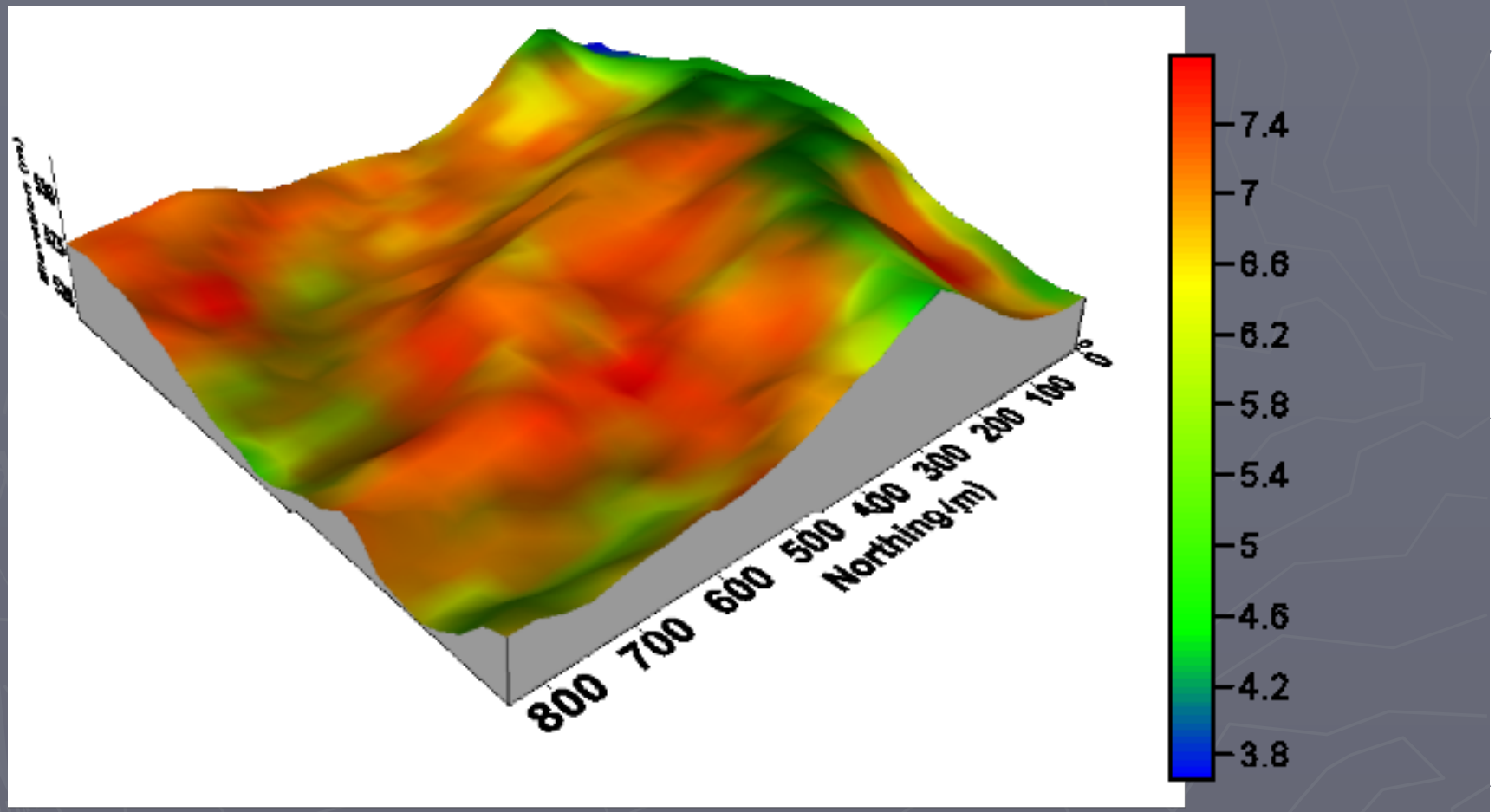
Future: New technologies

- Computer and equipment miniaturization
  - Information technologies
- Integration of applied and basic sciences
  - Gene discovery and new better adapted cultivars
  - Better understanding of biological systems
- Must make the integration of the technologies easy.

Solution: Better Utilize Information Technologies.

- Computer and equipment miniaturization
- Information technologies

Information management

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Information management

- Can improve out ability to
- Apply the correct management
- At the appropriate time
- To clearly identified problems

Integrating basic and applied sciences

Yield response to population

Plants/ha	Water regime	Yield (kg/ha)
74,500	Mod	12,330
74,500	High	12,770
149,000	Mod	13,200
149,000	High	13,470

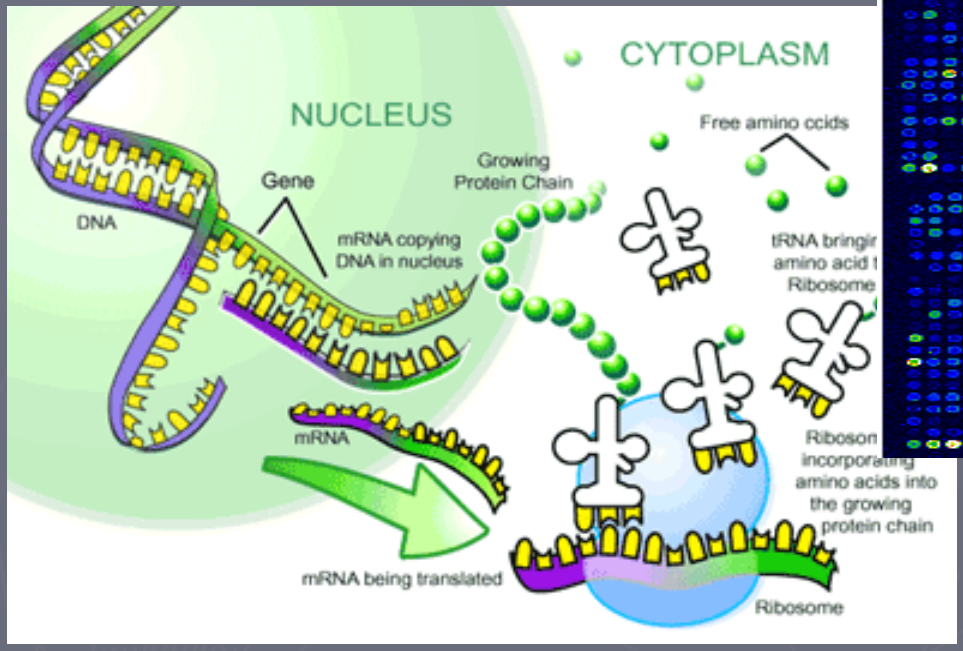
Approximately a 15 bu/a yield increase
With an increase seed cost of about $100/acre
To break even need a corn price of $6.70 or more

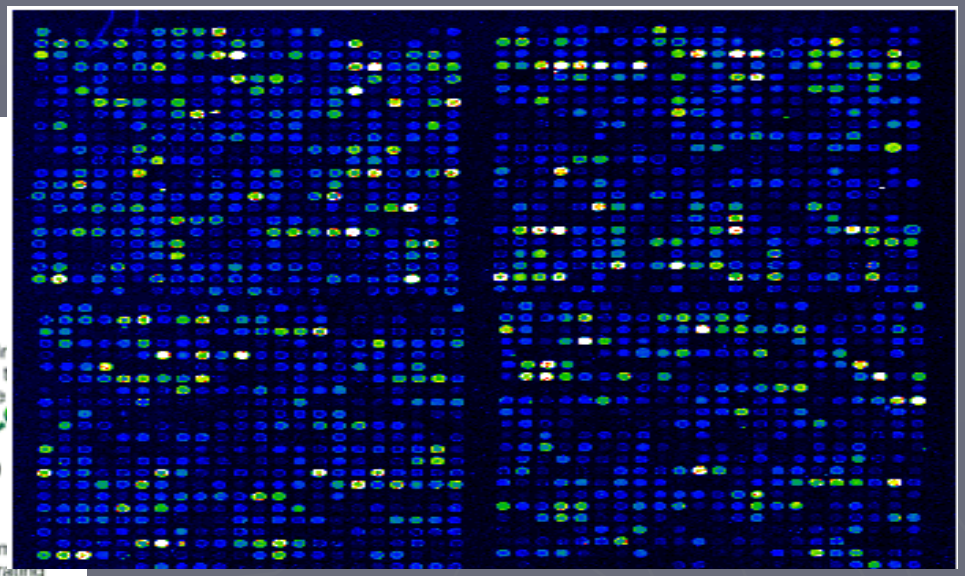
Question

- If the yield per acre remains relatively flat with increasing population, what is responsible for the decrease in the yield per plant?
- Does corn respond to adjacent corn plants the same way it responds to weeds?
- How does population rate experiments relate to weed free periods?

New tools

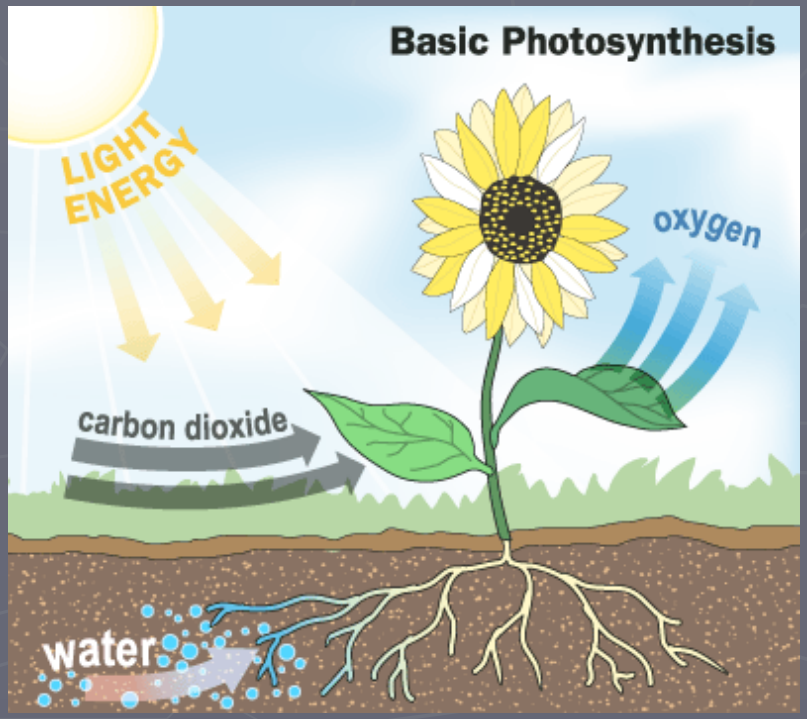
- Isotope mass spectrometer –
  - Isotopic discrimination due to C, N, and) O isotopes provides information about the system.
  - This information can be used to quantify many yield limiting factors.
  - This is an other day
- Gene mapping
  - Use of plant genomics to examine crop/ weed competition

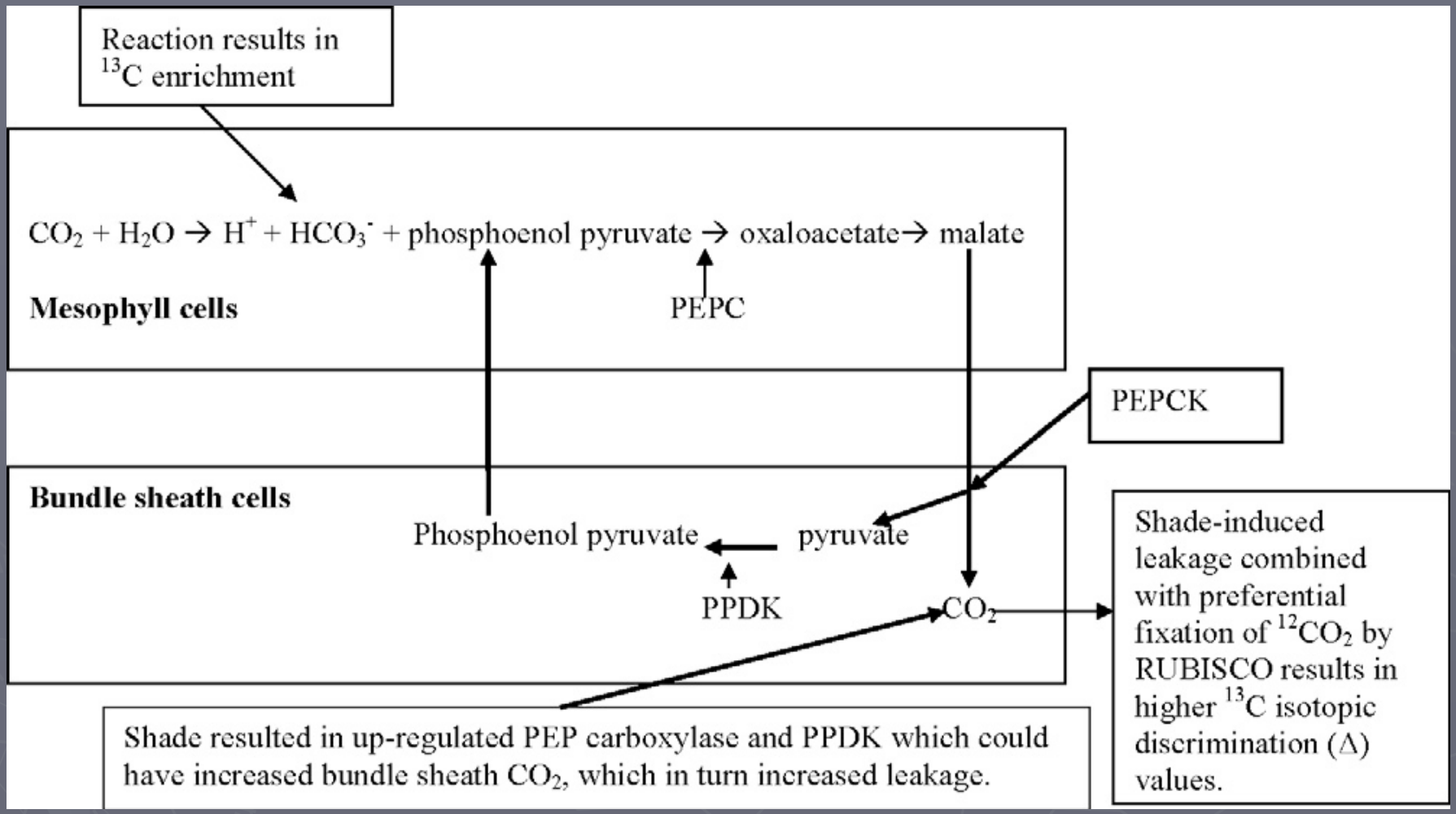




1. Extract RNA from control and treated plants
2. Attach a green die to treated and red die to control
3. Mix the treated and untreated Labeled cDNA together and expose to a slide where it is attached to individual cells
4. Blue-(red and green) similar concentration.
   red means treated is up-regulated
   green means control is up-regulated

Was competition for N, water, and light availability responsible for the results lower per plant yields?





2X treatment: Down regulation of PEPC, PEPCK, and PPDK

Net result of higher plant population

- Plants grew smaller because photosynthesis was down regulated.
- Per plant yield reductions in 2X population could not be attributed to competition for water, nutrients, or light.
- Velvet leaf had the exact opposite results

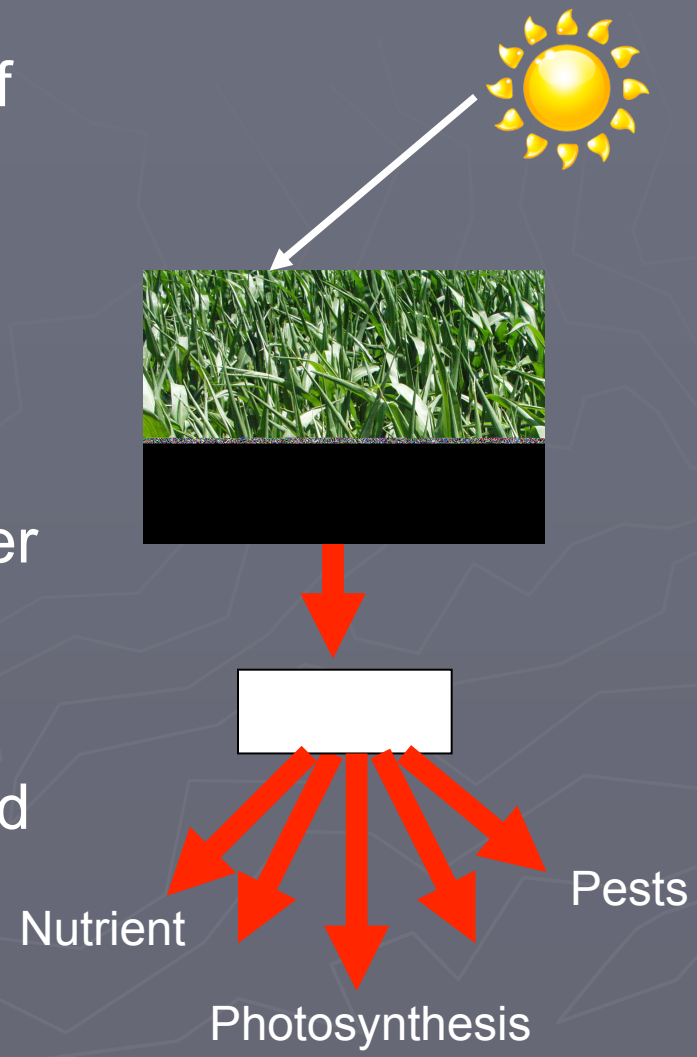
Findings

- In response to increasing population level, corn down regulated its photosynthetic capacity.

- ,

Using Molecular Tools to Assess Water Stress in Corn

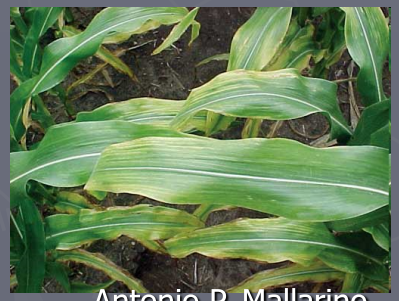
- Water stress impacted the activity of over 800 genes
- Water stress caused a cascade of events.
- Some plant responses were up-regulated, but only at the cost of other traits.
- In general, the plants ability to withstand and recover from pests and utilize nutrients were decreased.



Cold Tolerance

Salt Tolerance

Drying Tolerance



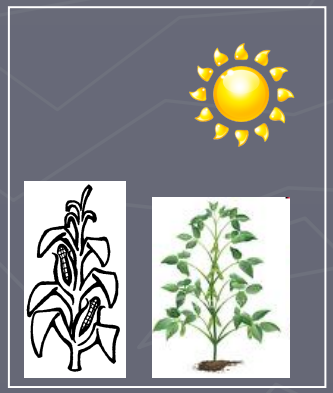
Antonio P. Mallarino

Nutrient Uptake

Recovery from Wounding

Pest Resistance

Fungal Disease Resistance



Photosynthetic Capacity

How can we use this Information?

- Decreased Nutrient Uptake
  - Modify fertilizer recommendations
- Decreased Fungal Resistance
  - Monitor potential problems and use control options when needed
- Decreased Pest Resistance
  - Monitor pest levels carefully, and consider lowering threshold levels.

Summary

- We have looked at the present, past, and potential future tools that can be used to improve crop production efficiency.
- Many people believe that we are approaching a perfect storm.
- There are many discoveries that still need to be made.
- Agricultural research is needed to help the world achieve food security and resource sustainability.