Linkage to Nutrient Management

THE G X E X M FRAMEWORK

CONTACT INFORMATION

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United States Department of Agriculture
Agricultural Research Service

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- Estimated total food production demand (www.csiro.au/Portals/Multimedia/On-the-record/Sustainable-Agriculture-Feeding-the-World.aspx)
  - 1500 – 2010: 677 x 10^{18} calories
  - 2010 – 2060: 730 x 10^{18} calories
- Science-based solutions to the dilemma
  - Put more land into agricultural production
  - Get higher yield per unit land area
    Sustainable *intensification* (FAO.org)
  - Use fewer animals
  - Waste less

We cannot achieve this by next Tuesday.

Photo credits:
http://www.prwatch.org/spin/2008/06/7424/more-you-bargained-your-chicken
http://www.dreamstime.com/royalty-free-stock-image-corn-waste-image8500156
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CLIMATE SMART AGRICULTURE
INTEGRATE ADAPTATION WITH MITIGATION

- Building soil organic matter, such as by minimum/conservation tillage; Note: Soil OM is third largest carbon pool on earth;
- Integrated nutrient management practices, such as green manures, planting of legumes, livestock manure.
- Increase water and nitrate use efficiency, irrigation, water harvesting;
- Improve livestock management practices, grassland management, land restoration, and apply agro forestry.

BETTER SOIL AND WATER MANAGEMENT PRACTICES ARE KEY

CHALLENGE: INCREASE YIELDS *SUSTAINABLY*

- Satisfy **human needs*** for food, feed, and fiber, & contribute to biofuel
- Enhance **environmental quality** & the resources base
- Sustain **economic viability** of agriculture
- Enhance the **quality of life** for farmers, farm workers, & society as a whole

** Quantity & Quality*

NAS, 2010

G x E x M: Departure From Classic *G x E* Interaction

- ***<u>G</u>enetics x <u>E</u>nvironment x <u>Management</u>***

  - ***Genetics:*** *Variety, breed, or animal haplotype*

    "Potential"
  - *Environment: Stress effects on agriculture*

    "What cannot be controlled"
  - ***Management:*** *Production practices*

    "What can be controlled"

PRODUCERS VIEW AN ALTERNATIVE TO SCIENCE REDUCTIONIST APPROACH

- Highlight the effects of *climate variability on the environment factor*
- Highlight opportunities for *management to optimize performance of genetic resources under varying environmental conditions*
- *Enhances problem solving*
  - *Which is limiting factor: G? E? M?*
  - *What can we do about it?*

G X E: PHENOTYPIC DATA

- Link animal/crop/variety development & choice with
  - *Current* environment
  - *Projected <u>changes</u>* of environment
  - Means & *<u>extremes</u>* of environment
  - Abiotic & biotic stresses

Sustainability:
- Yield/Production
- Economics
- Environment
- Quality of life

G X M : WHAT GENOTYPES RESPOND WELL TO MANAGEMENT PRACTICES?

- Link crop/variety development & choice with
  - **Soil management practices**
  - **Water management**
  - **Pest & pathogen management**
  - **Timing of planting**
  - **Cover crops & crop rotations**
  - **Erosion & conservation management**
  - **Nutrient management**

Sustainability:
- Yield/Production
- Economics
- Environment
- Quality of life

E X M: HOW DO WE SEPARATE MANAGEMENT EFFECTS FROM ENVIRONMENT?

- Link choice of management & environment
  - Reduced emissions, runoff
  - Efficient input application
    - Method
    - Temporal & spatial decisions
    - Production system/Housing

Sustainability:
- Yield/Production
- Economics
- Environment
- Quality of life

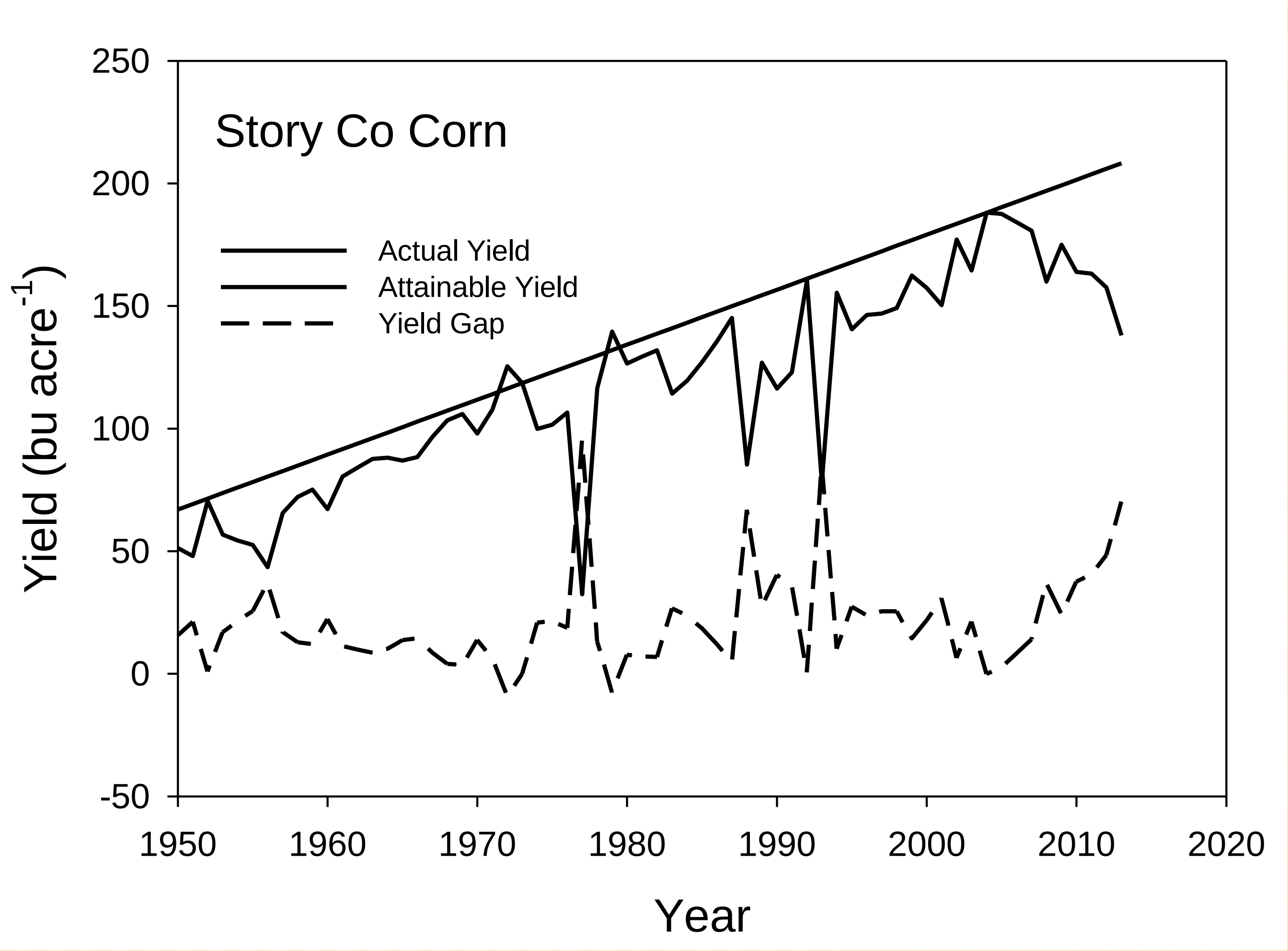
GOAL

GOAL

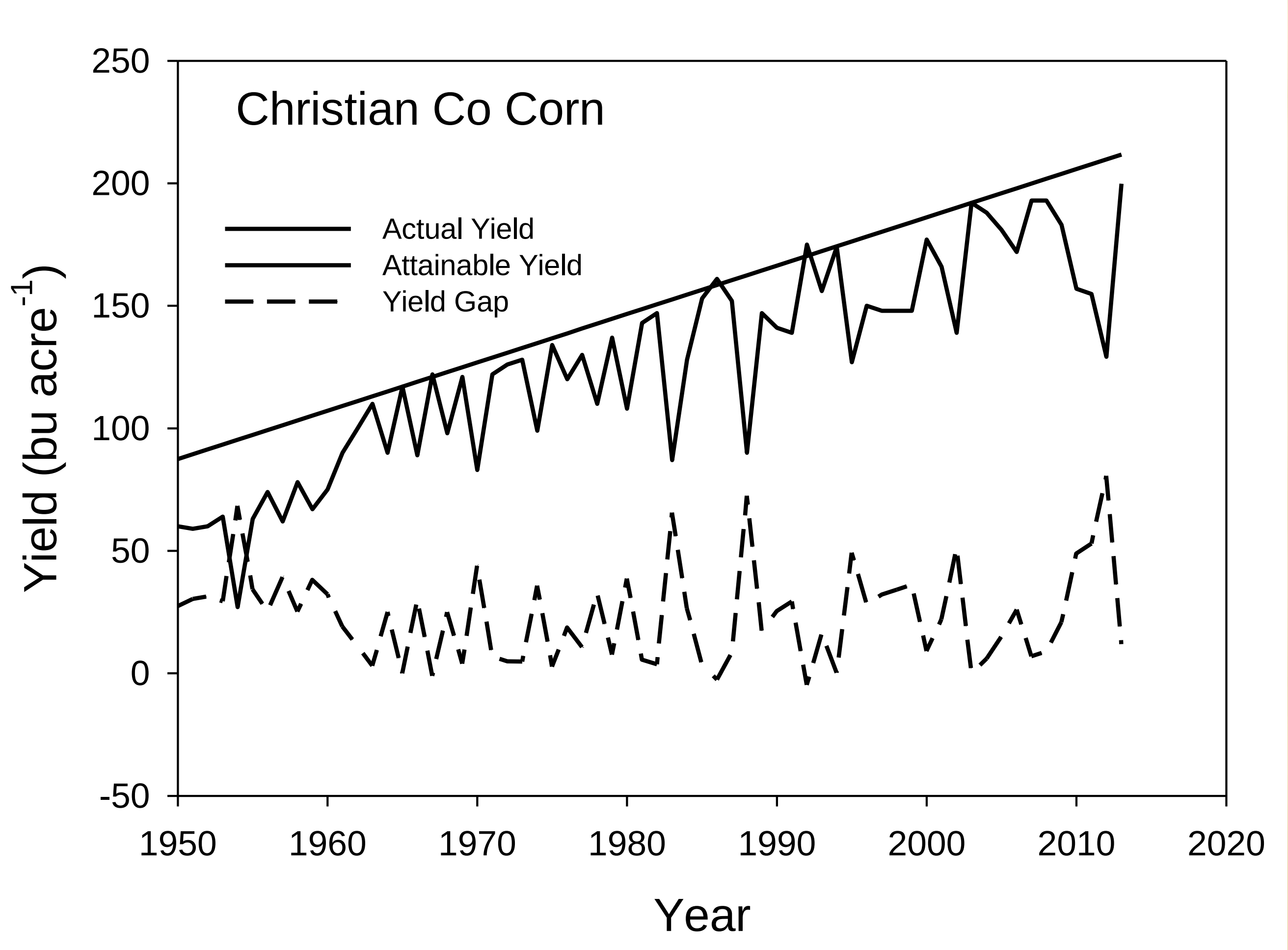
YIELD

- **Potential Yield**
  - Genetic potential under optimum conditions
  - *Genetics specific*
- **Attainable Yield**
  - Germplasm performance under optimum weather & management inputs at a specific location
  - *Location specific*
- **Farmer Yield**
  - Germplasm performance resulting from producer management decisions using specific germplasm at a specific location
  - *Producer specific*
- **Yield Gap**
  - *Differences* between potential, attainable & farmer yields

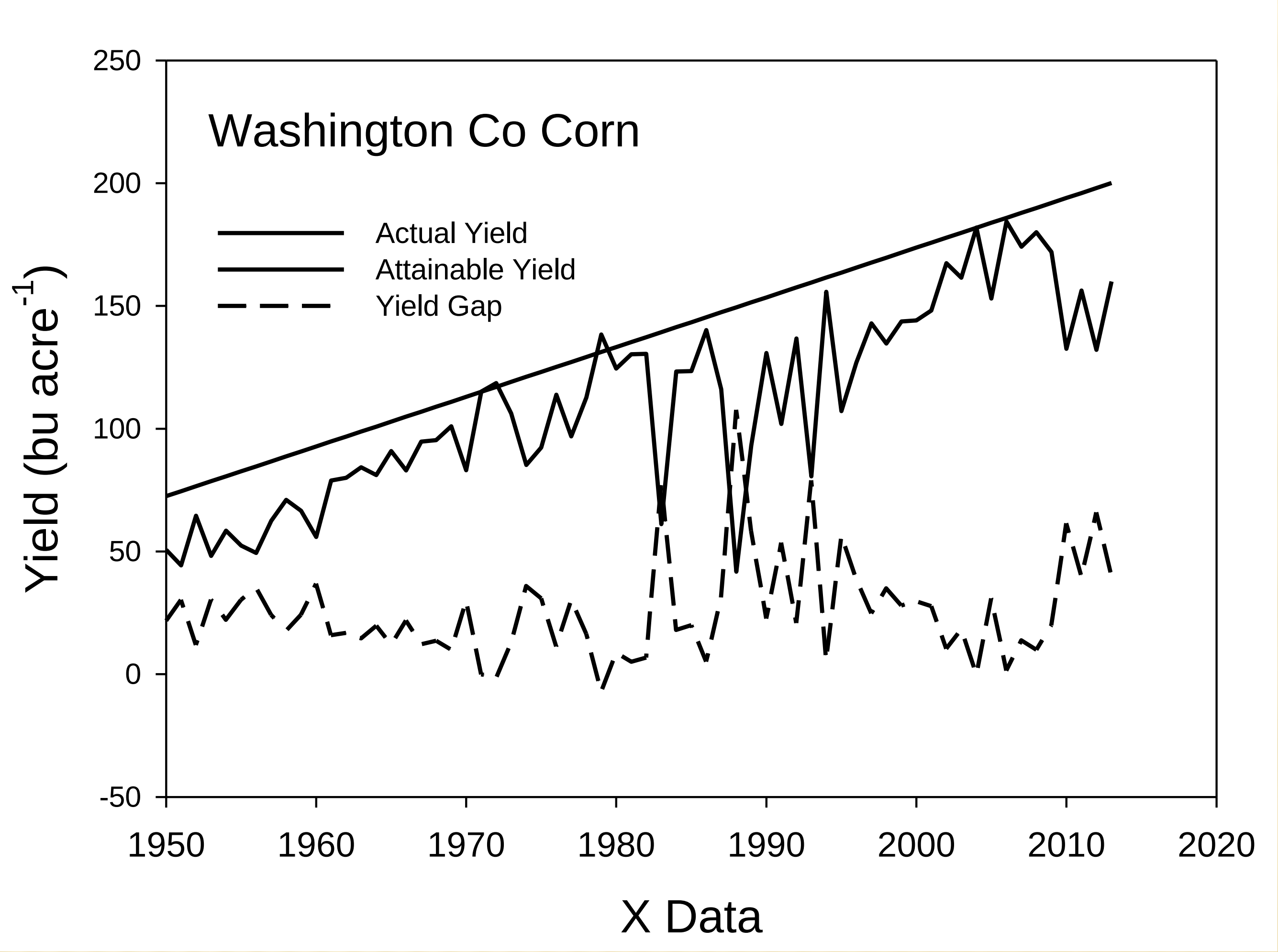
STORY COUNTY IOWA CORN



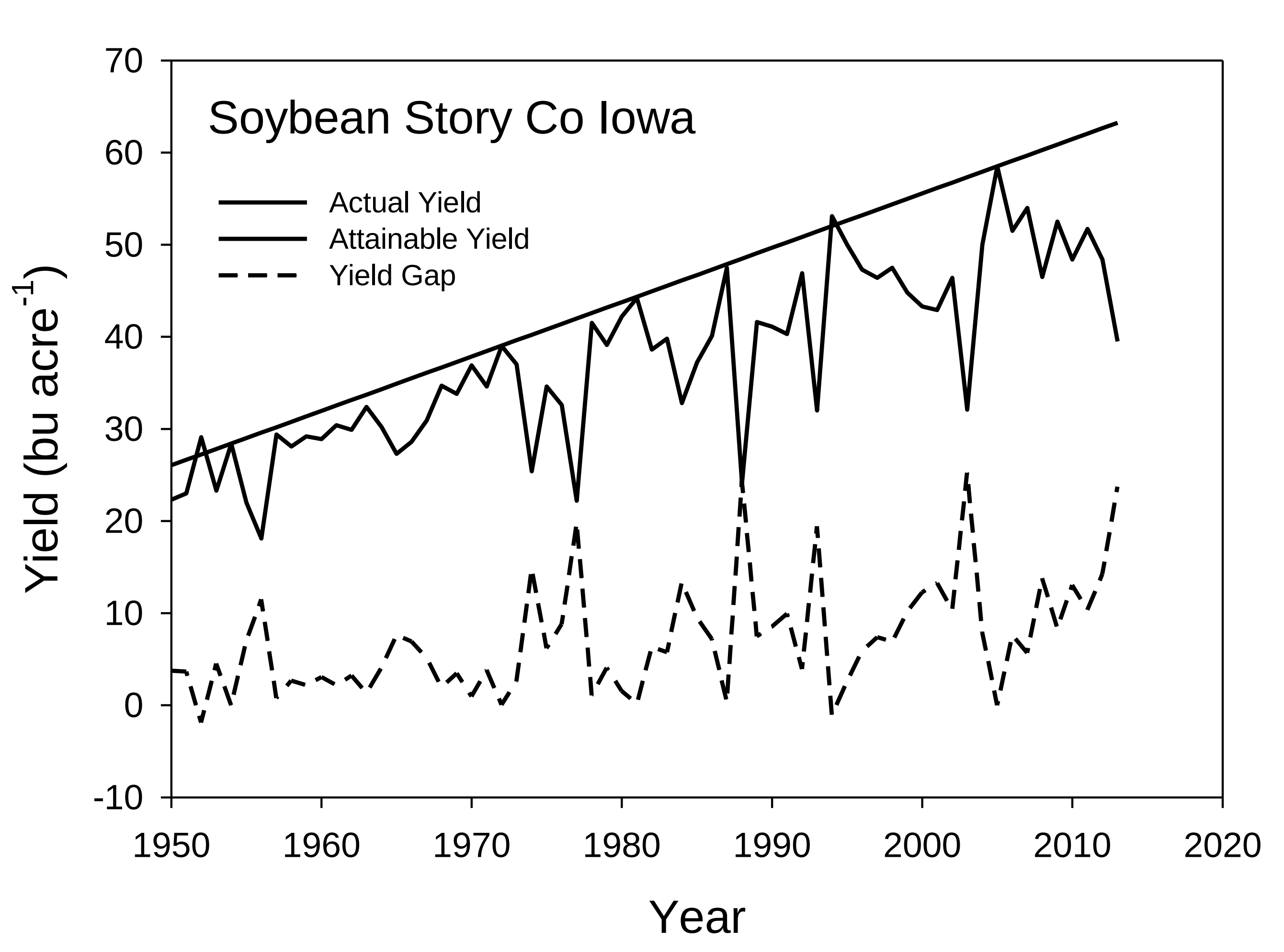
CHRISTIAN COUNTY ILLINOIS CORN



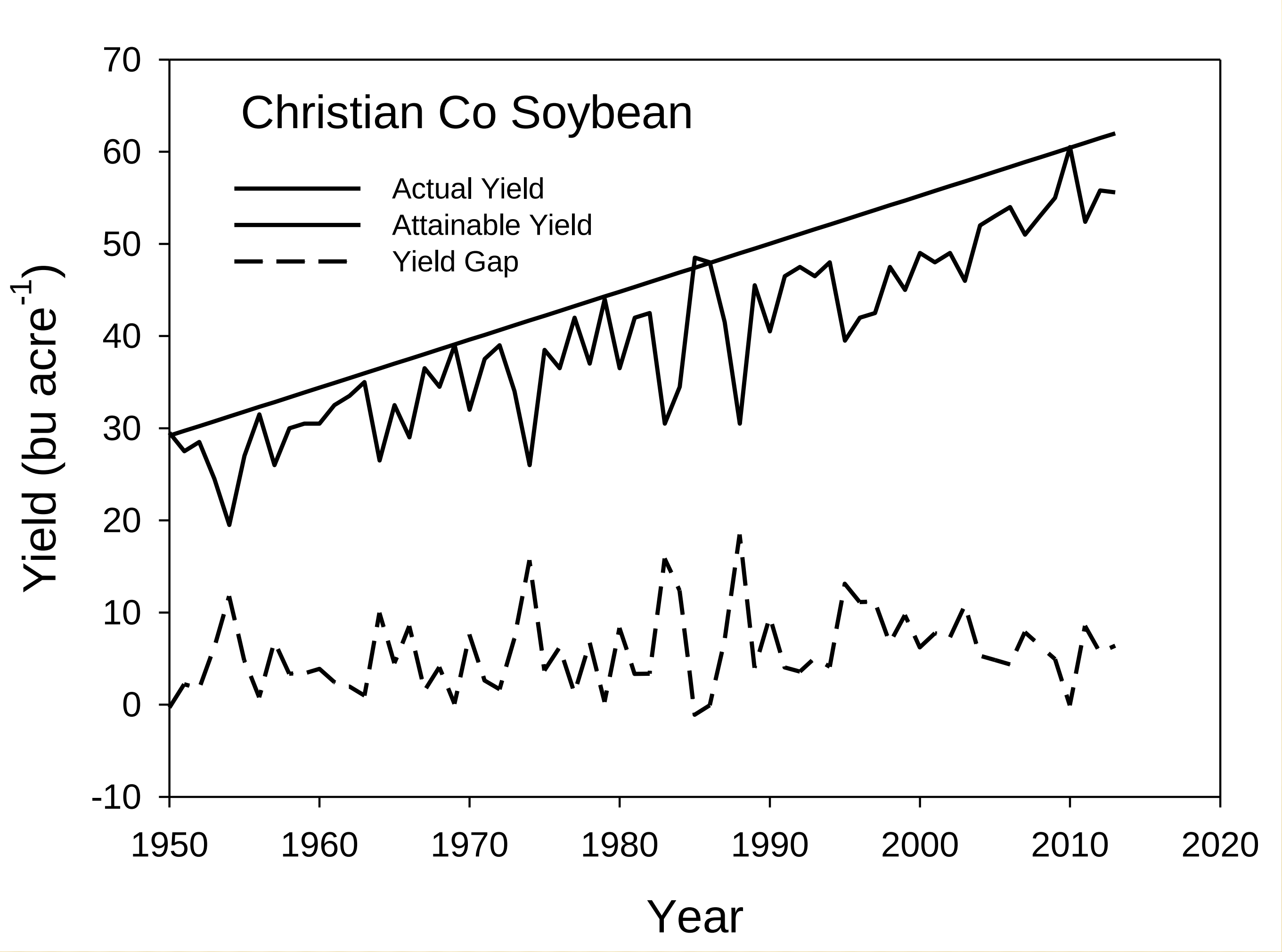
WASHINGTON COUNTY IOWA CORN



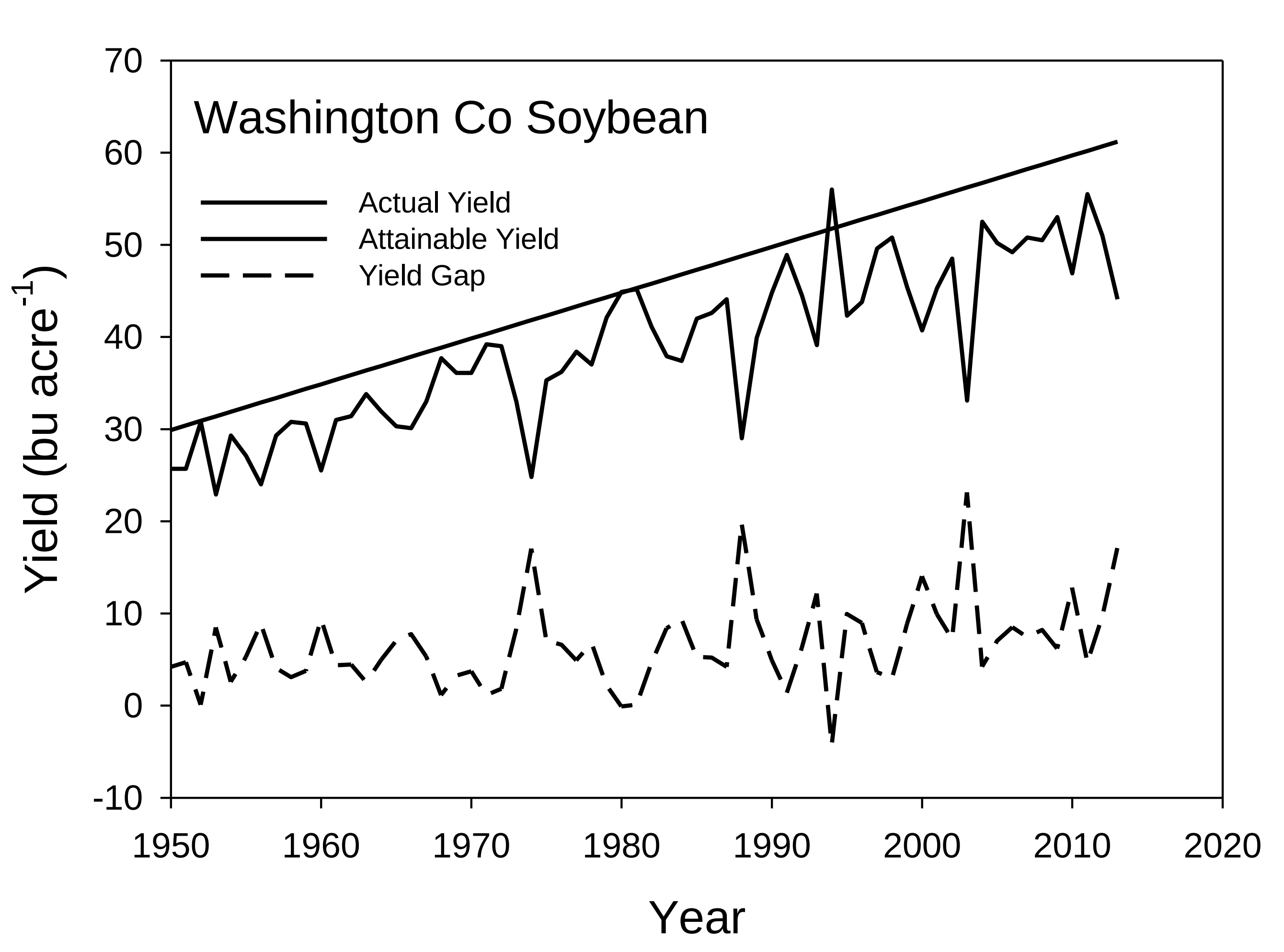
STORY COUNTY IOWA SOYBEAN



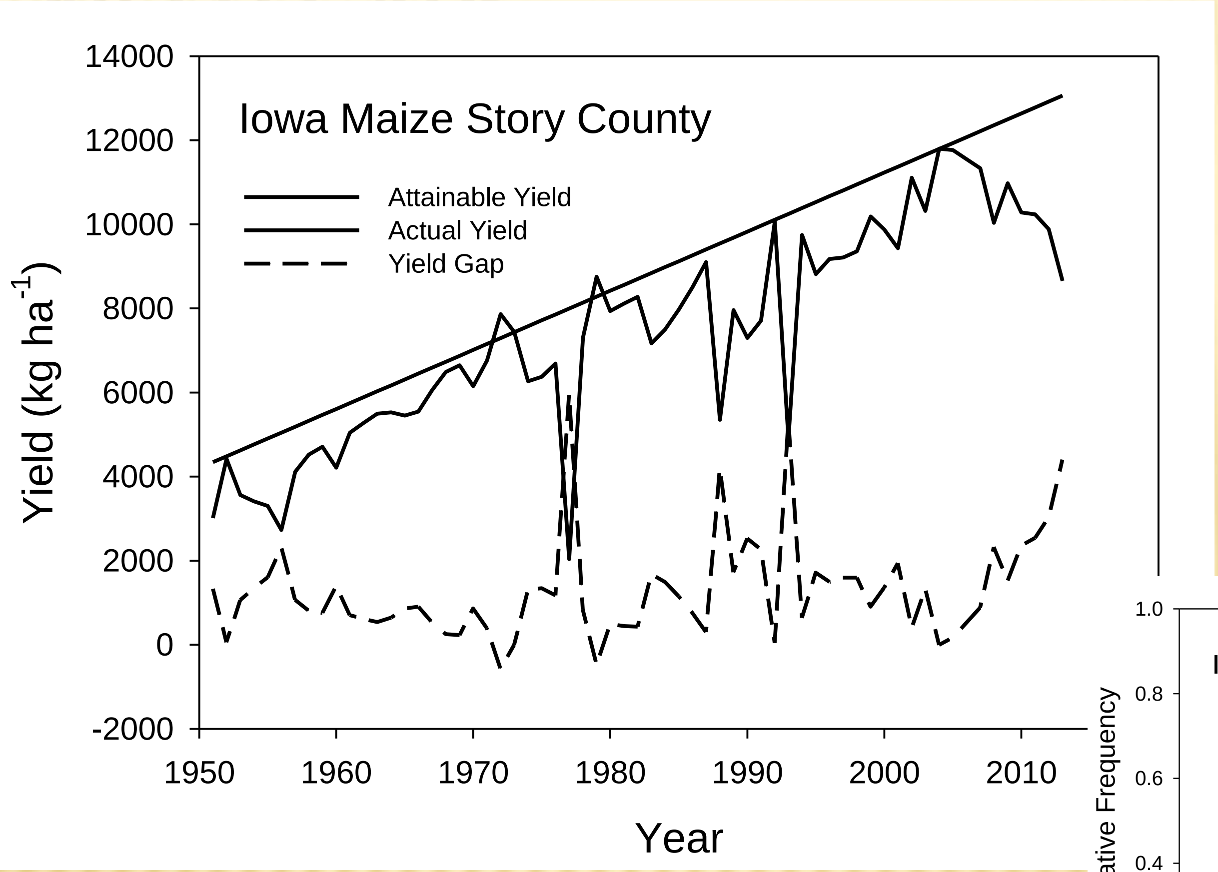
CHRISTIAN COUNTY ILLINOIS SOYBEAN



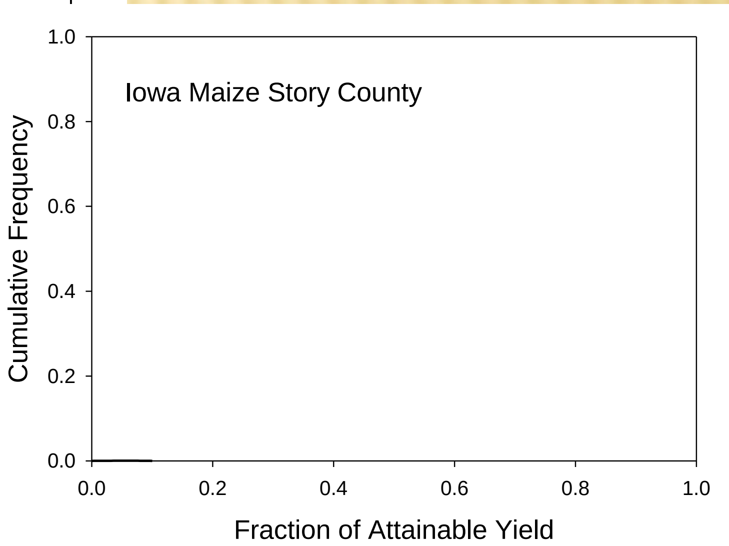
WASHINGTON COUNTY IOWA SOYBEAN



YIELD GAPS



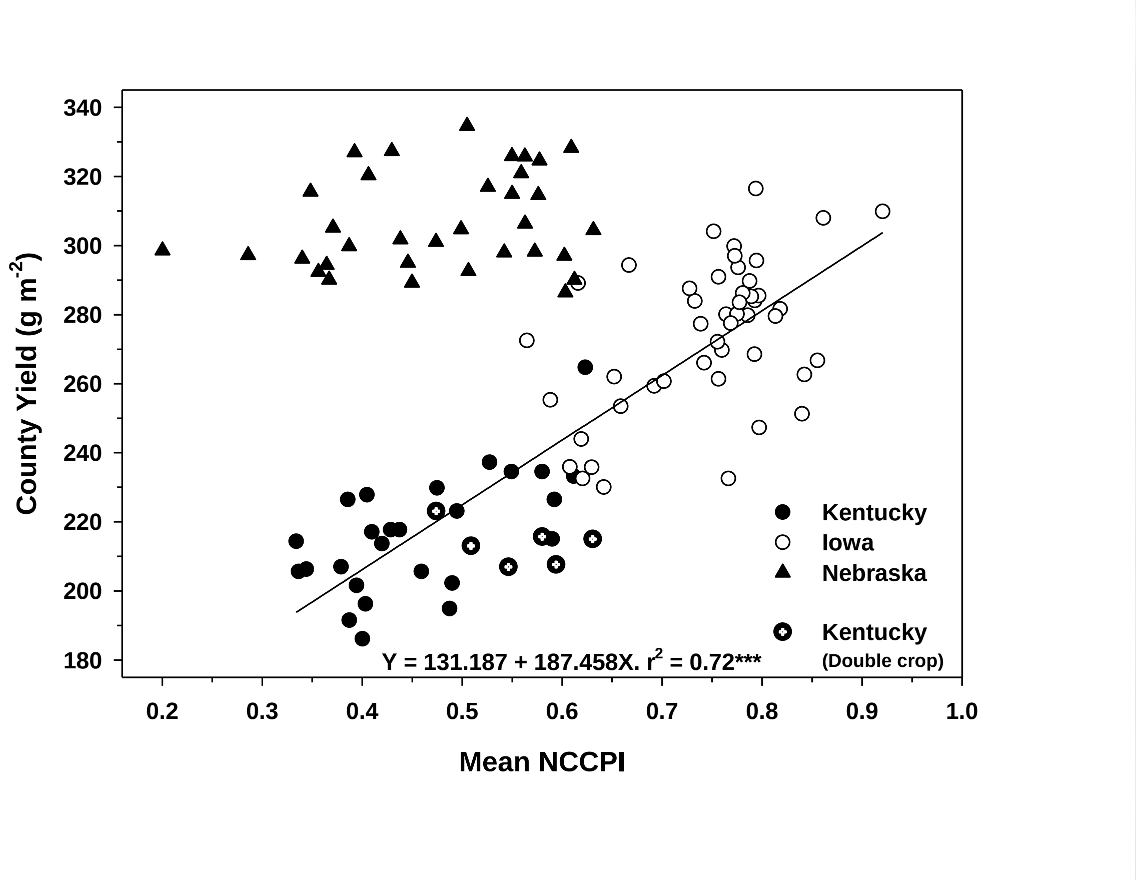
Iowa Maize Story County
Attainable Yield
Actual Yield
Yield Gap
Yield (kg ha-1)
14000
12000
10000
8000
6000
4000
2000
0
-2000
1950
1960
1970
1980
1990
2000
2010
Year



Iowa Maize Story County
Cumulative Frequency
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of Attainable Yield

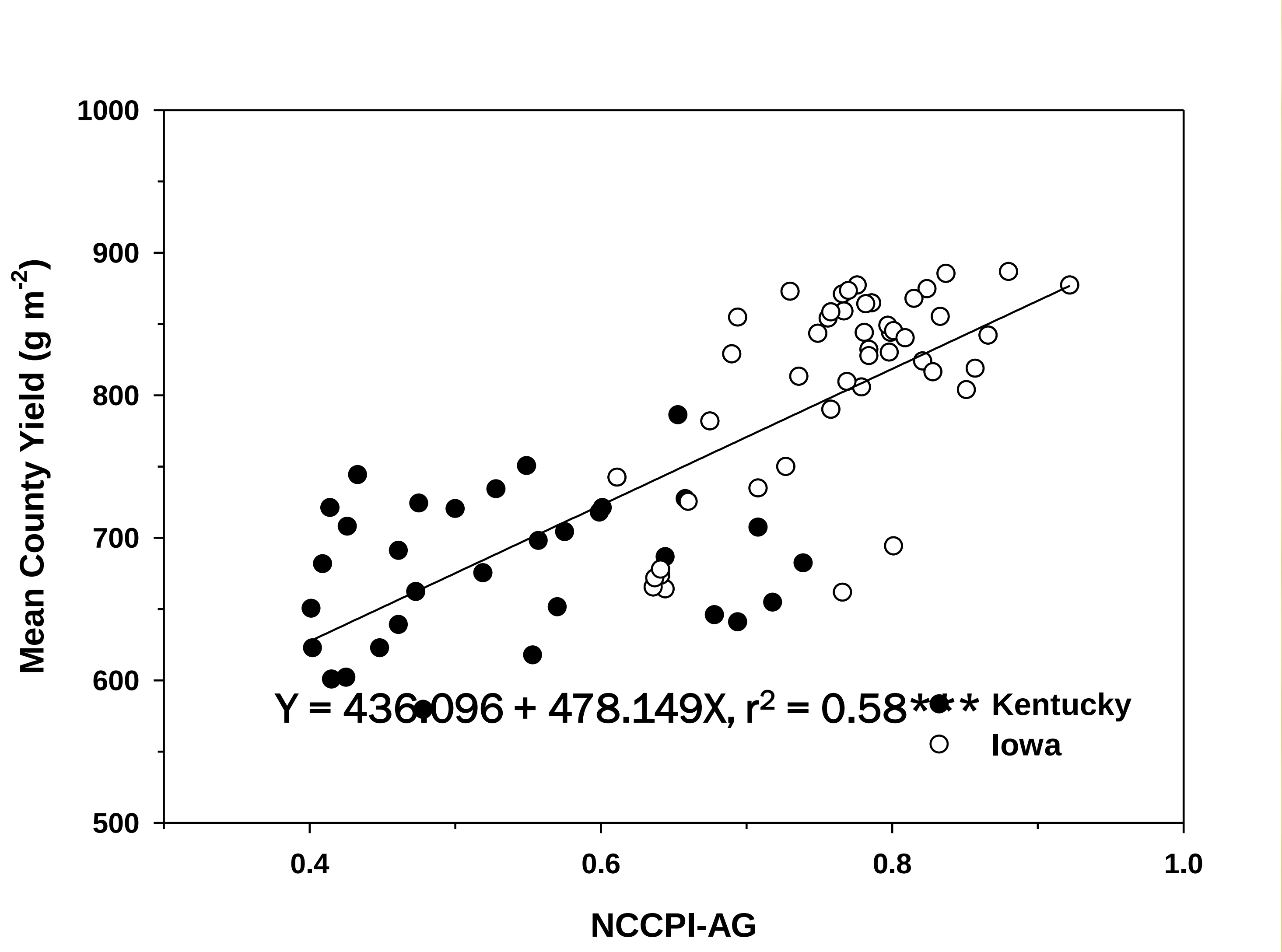
GOOD SOILS = GOOD YIELDS

Soybean yields across Iowa, Kentucky, and Nebraska

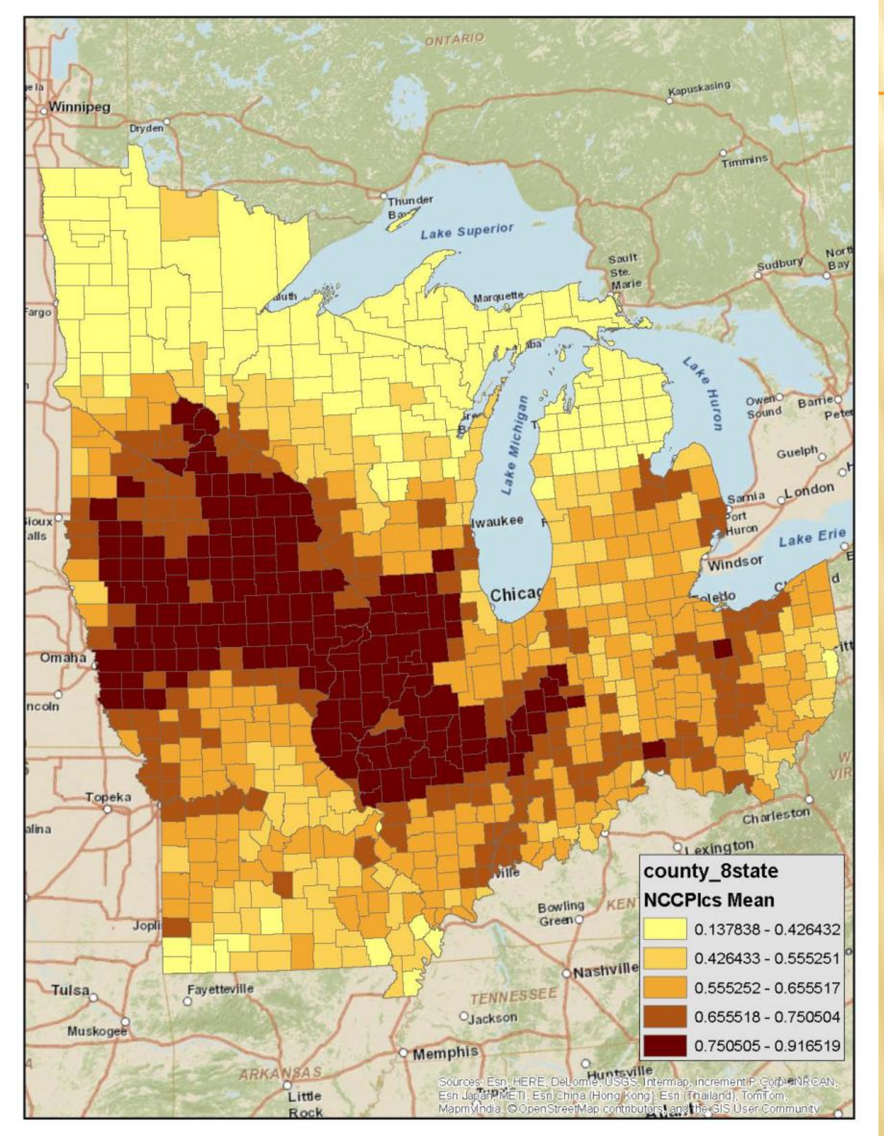


Climate resilience is derived from good soils in rainfed agricultural systems

MAIZE COUNTY YIELDS



VARIATION IN NCCPI ACROSS THE MIDWEST

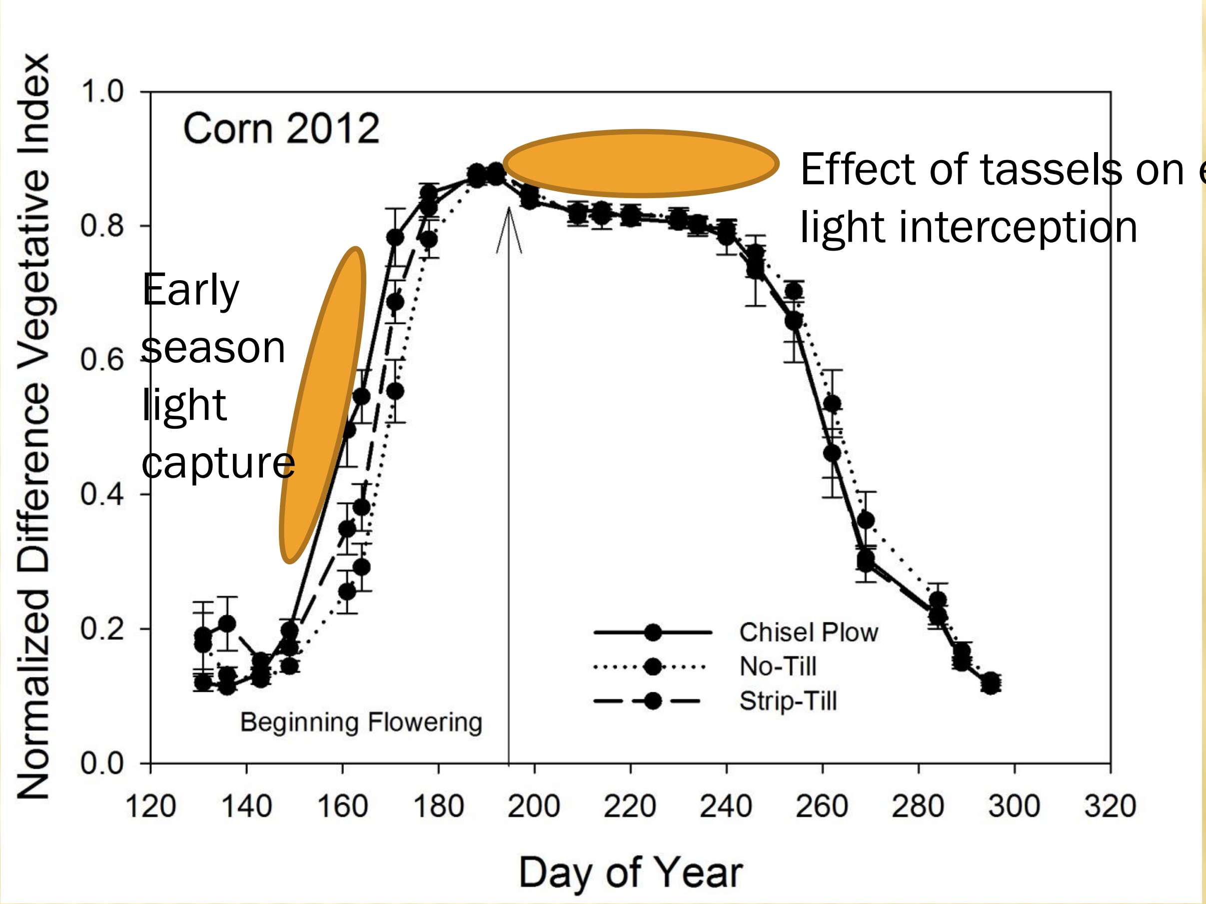


YIELD COMPONENTS

- Corn Yield = plants per area x ears per plant x kernels per ear x weight per kernel
- Soybean Yield = plants per area x pods per plant x seed per pod x weight per seed

- Each of these yield components is affected during the growing season.

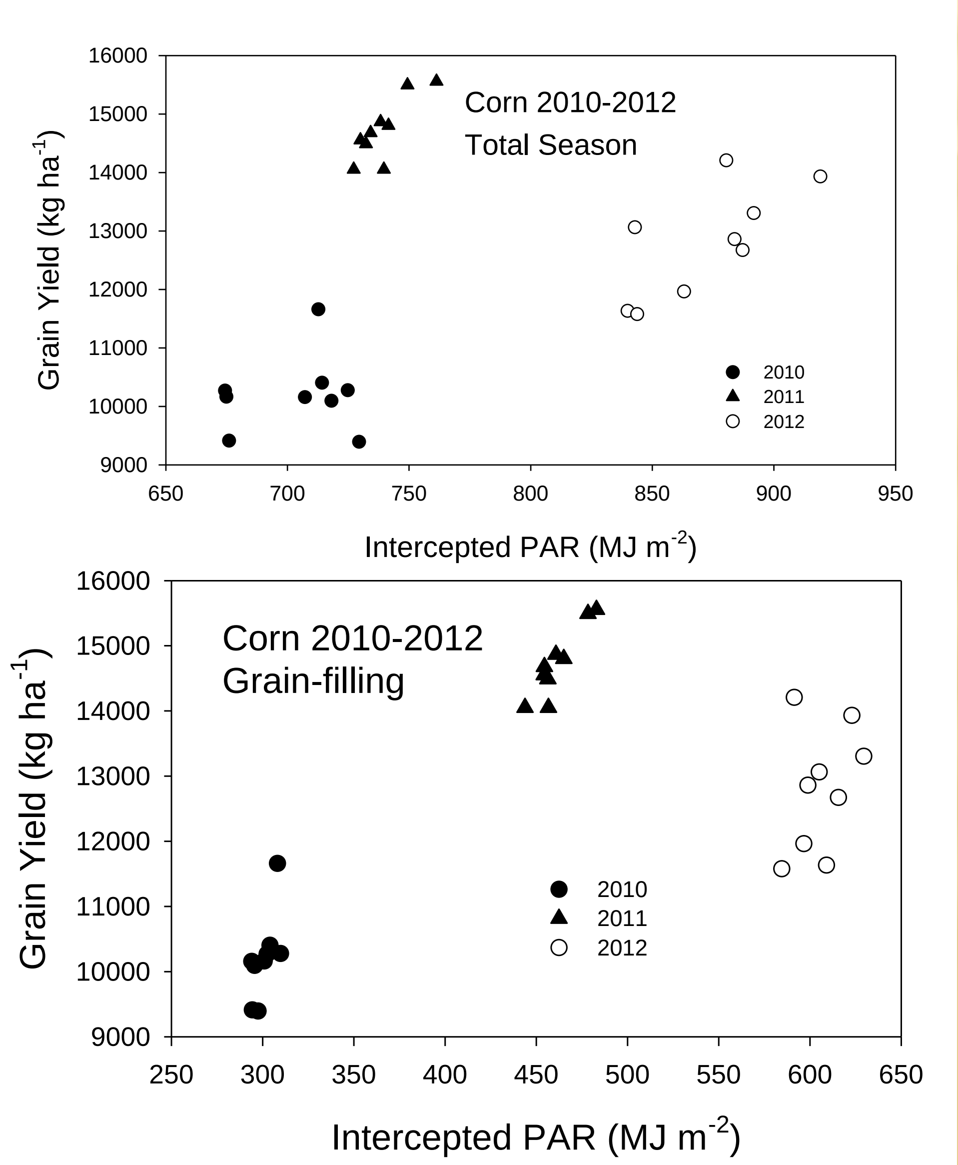
GROWTH PATTERNS



Early season light capture

Effect of tassels on efficiency of light interception

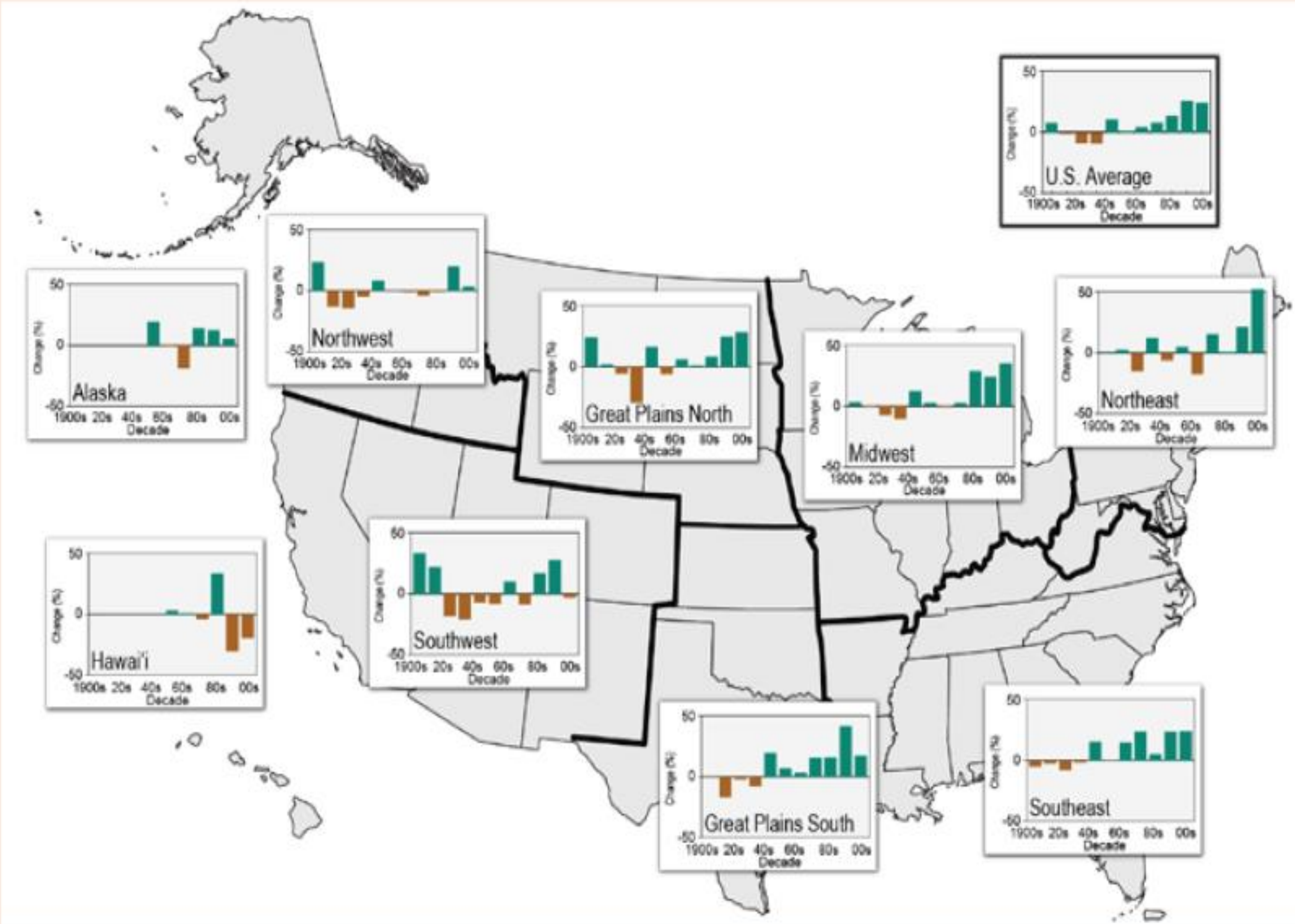
RADIATION USE EFFICIENCY

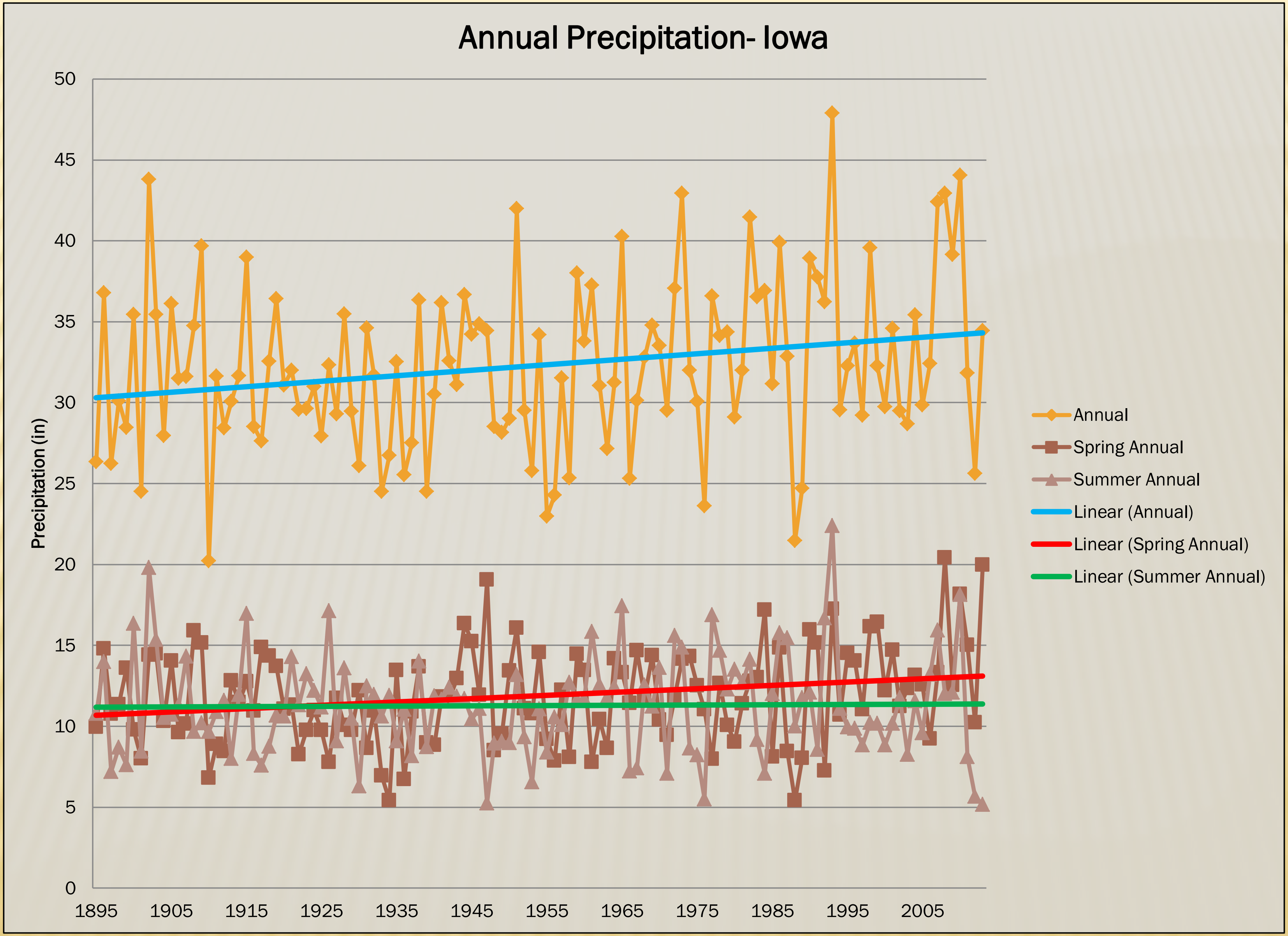


MAJOR LIMITATIONS TO YIELD

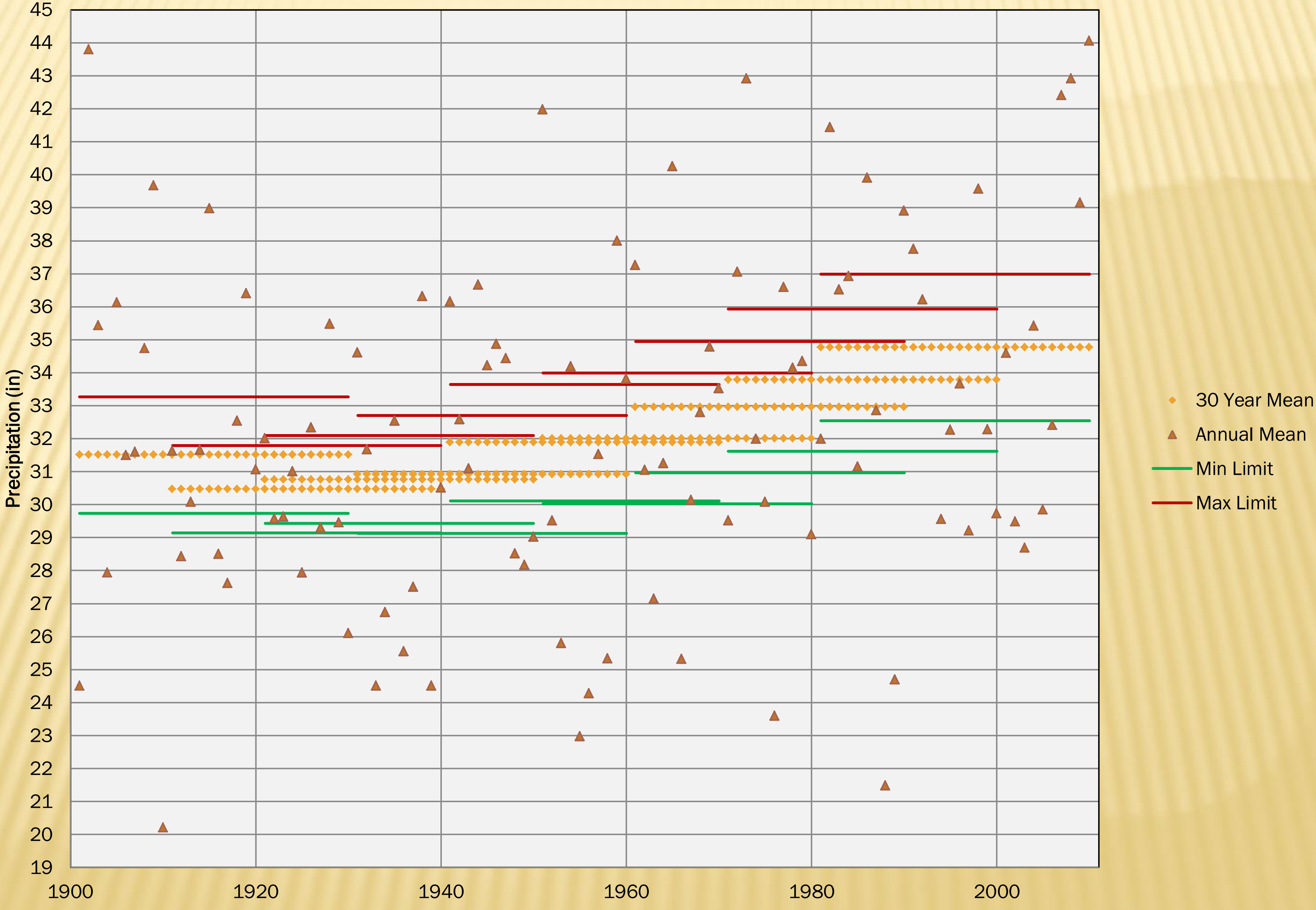
- Water
- Nutrients
- Temperature
- Solar radiation
- Pests
  - Weeds
  - Insects
  - Diseases

Observed Change in Very Heavy Precipitation

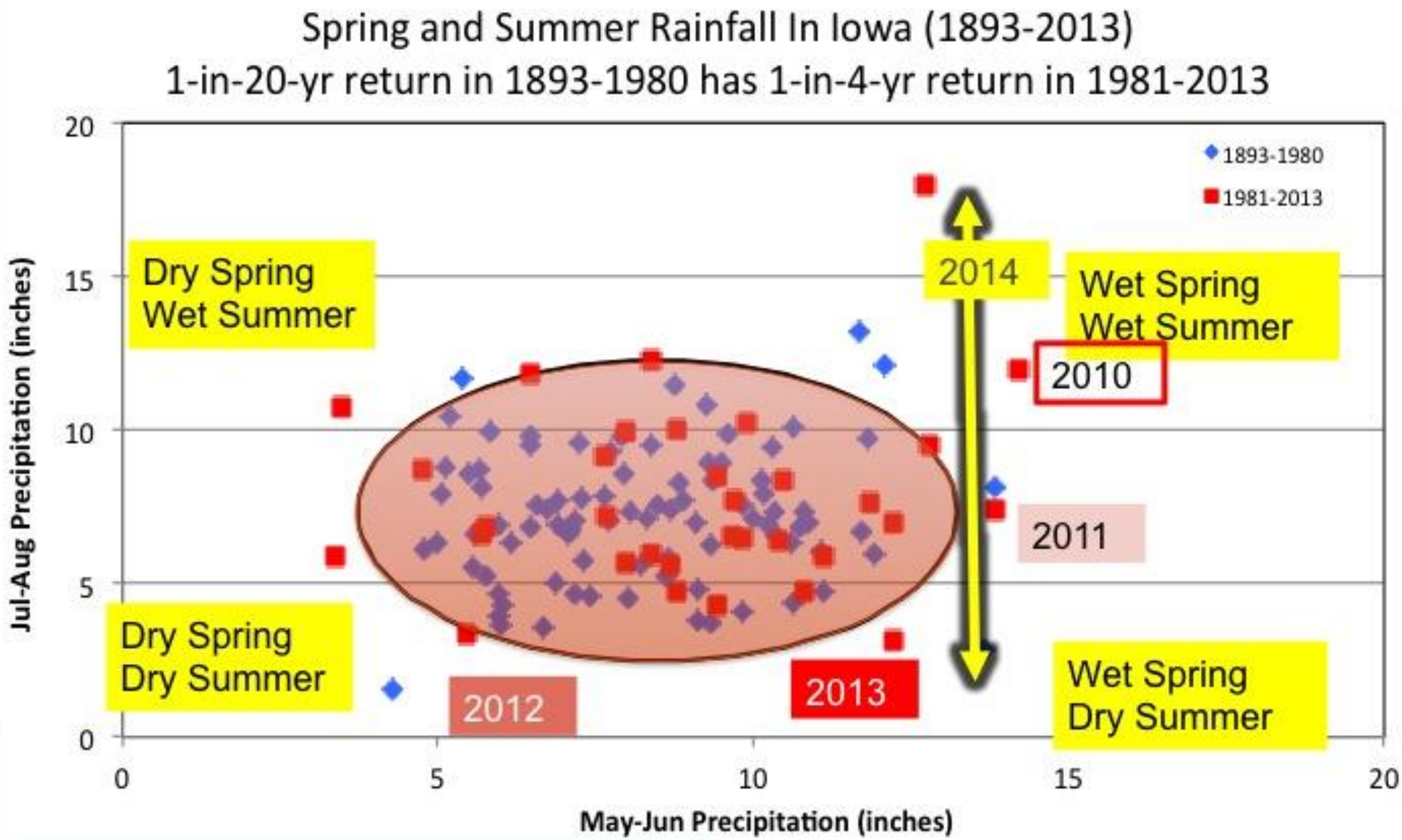



Annual Precipitation- Iowa
Precipitation (in)
50
45
40
35
30
25
20
15
10
5
0
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
Annual
Spring Annual
Summer Annual
Linear (Annual)
Linear (Spring Annual)
Linear (Summer Annual)

Iowa Precipitation: 1901-2010



Weather Trend: Unusual combinations of spring and summer rainfall are occurring more often



Data Source: State of Iowa Climatologist

EROSION: HOW MUCH IS TOLERABLE

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THE WIND BLOWS TOO

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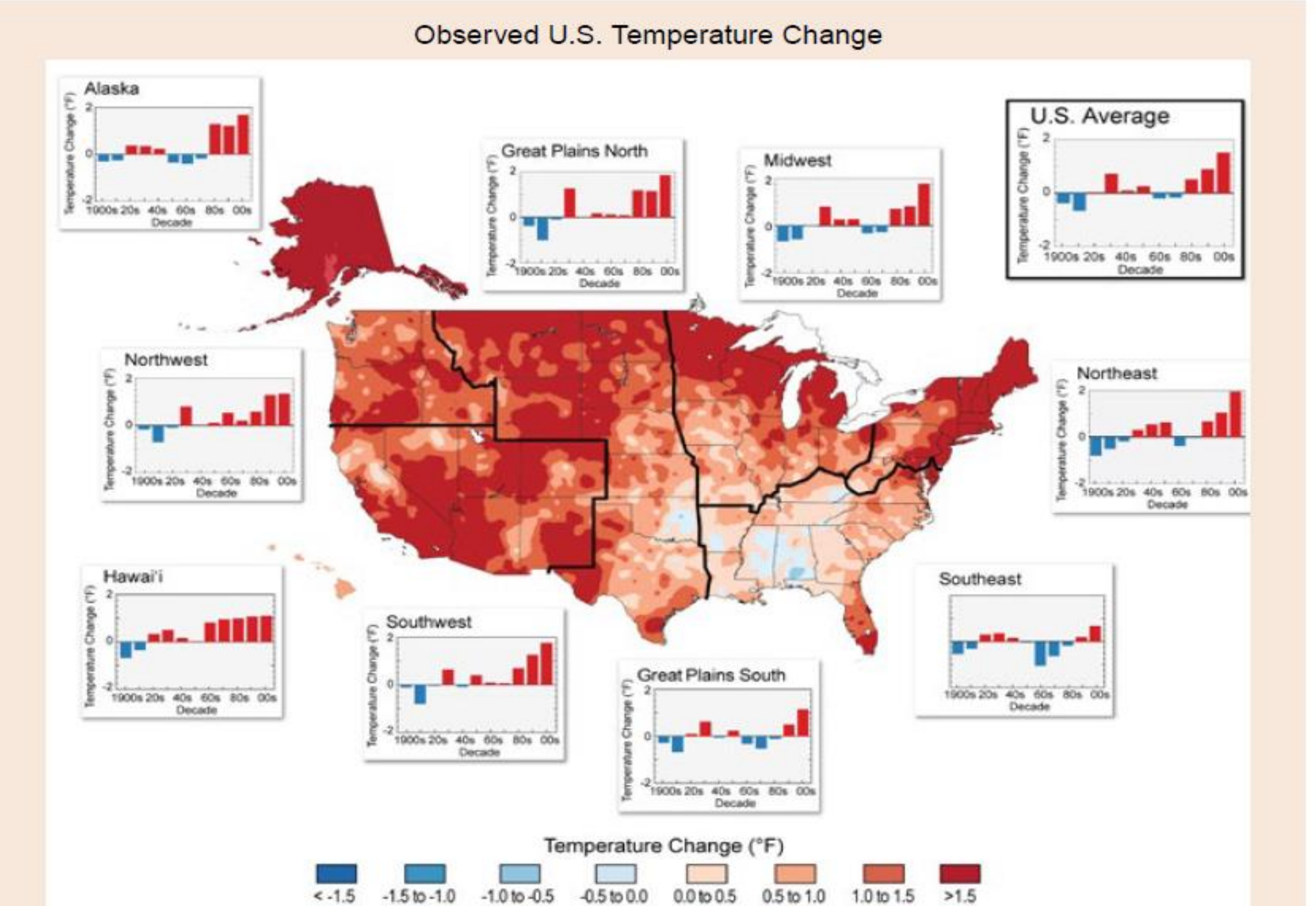
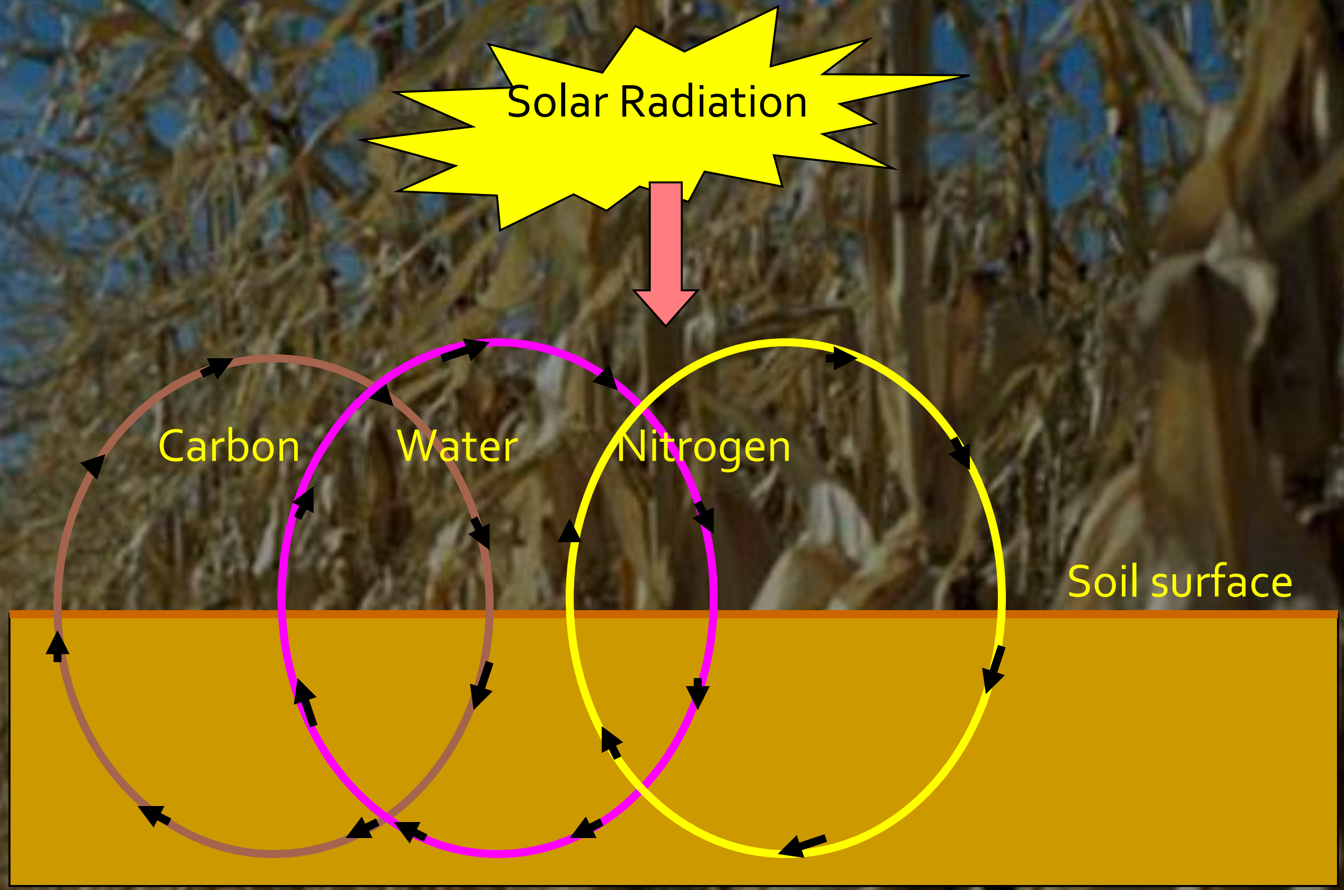

Observed U.S. Temperature Change
Alaska
Great Plains North
Midwest
U.S. Average
Northwest
Northeast
Hawai'i
Southwest
Great Plains South
Southeast
Temperature Change (°F)
Decade
1900s 20s 40s 60s 80s 00s
Temperature Change (°F)
< -1.5
-1.5 to -1.0
-1.0 to -0.5
-0.5 to 0.0
0.0 to 0.5
0.5 to 1.0
1.0 to 1.5
>1.5

INTEGRATING NUTRIENTS INTO G X E X M

- Ensuring nutrients are available throughout the growing season
- Linkage between soil health and nutrient cycling
- Linkage between water and nutrients



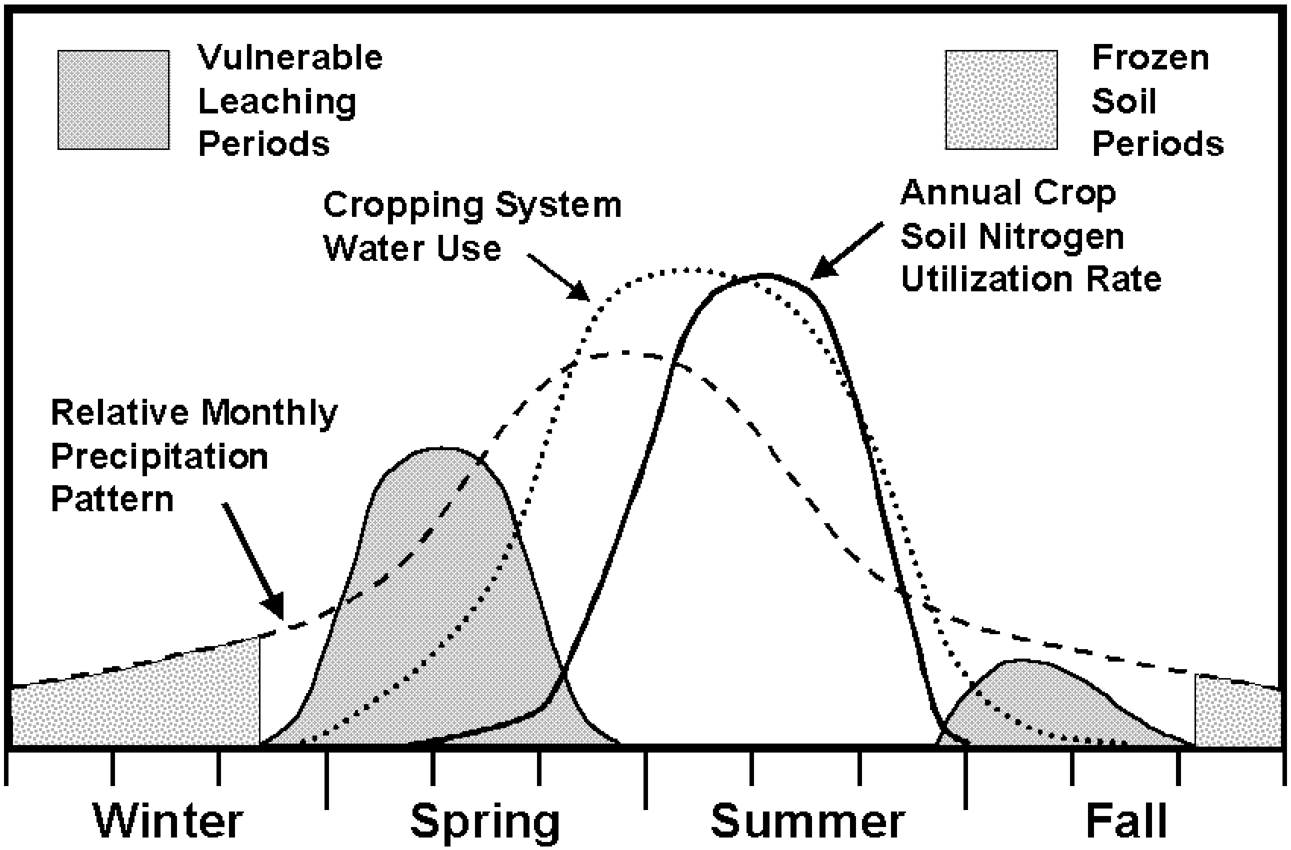
Key Processes

Photosynthesis
Respiration
Org Matter decomp
Plant decomposition

Precipitation
Evaporation
Infiltration
Runoff
Percolation

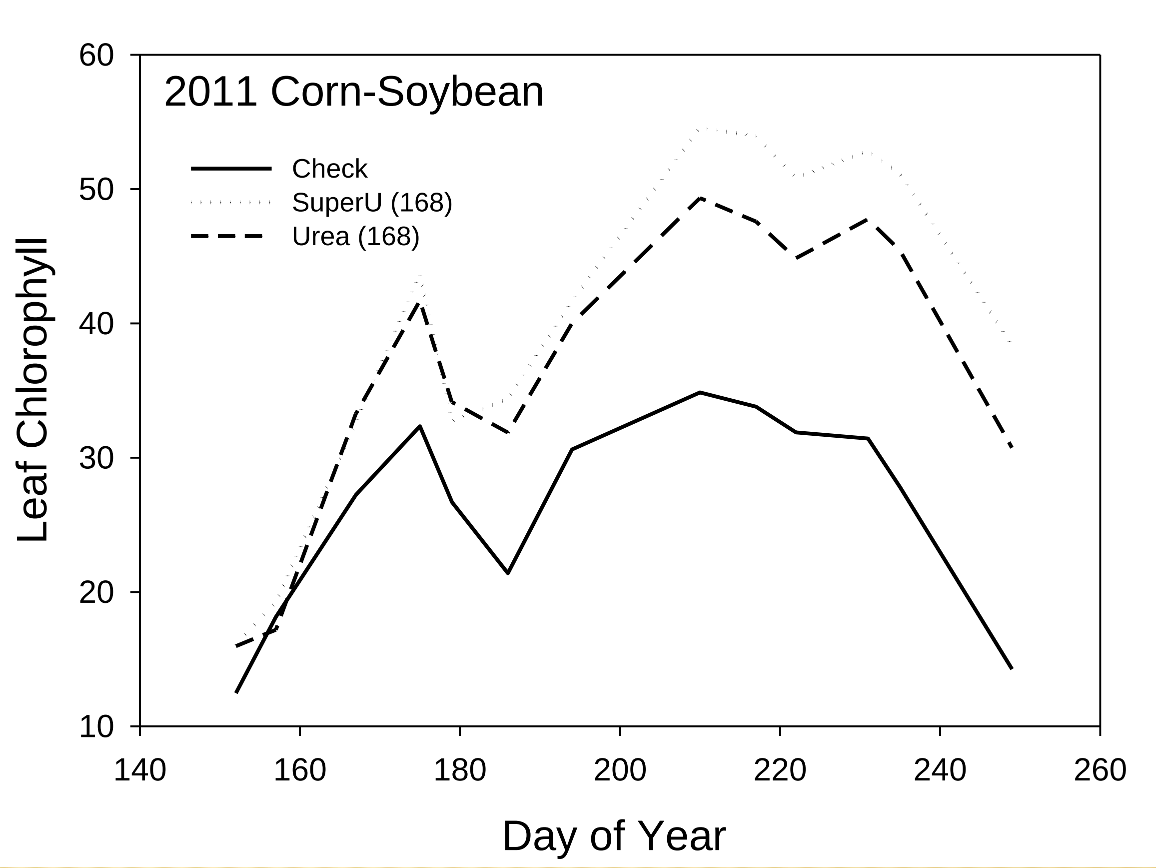
N Fixation
Mineralization
Denitrification
Plant decomposition

Cycles interact over time and space with different rates

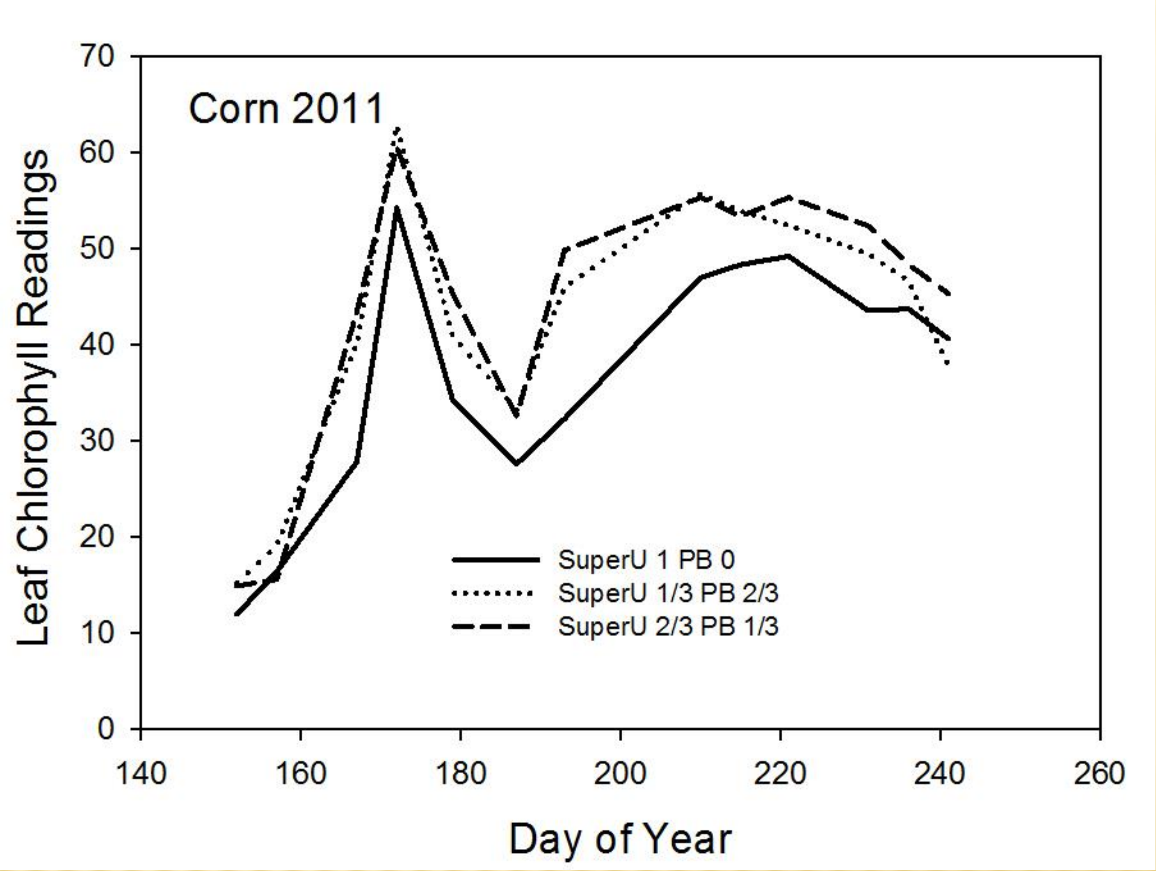


General seasonal patterns for precipitation, nitrogen uptake rate by a corn crop, cropping system water use and periods potentially favorable for nitrate leaching from Midwestern corn production.

LEAF CHLOROPHYLL CHANGES

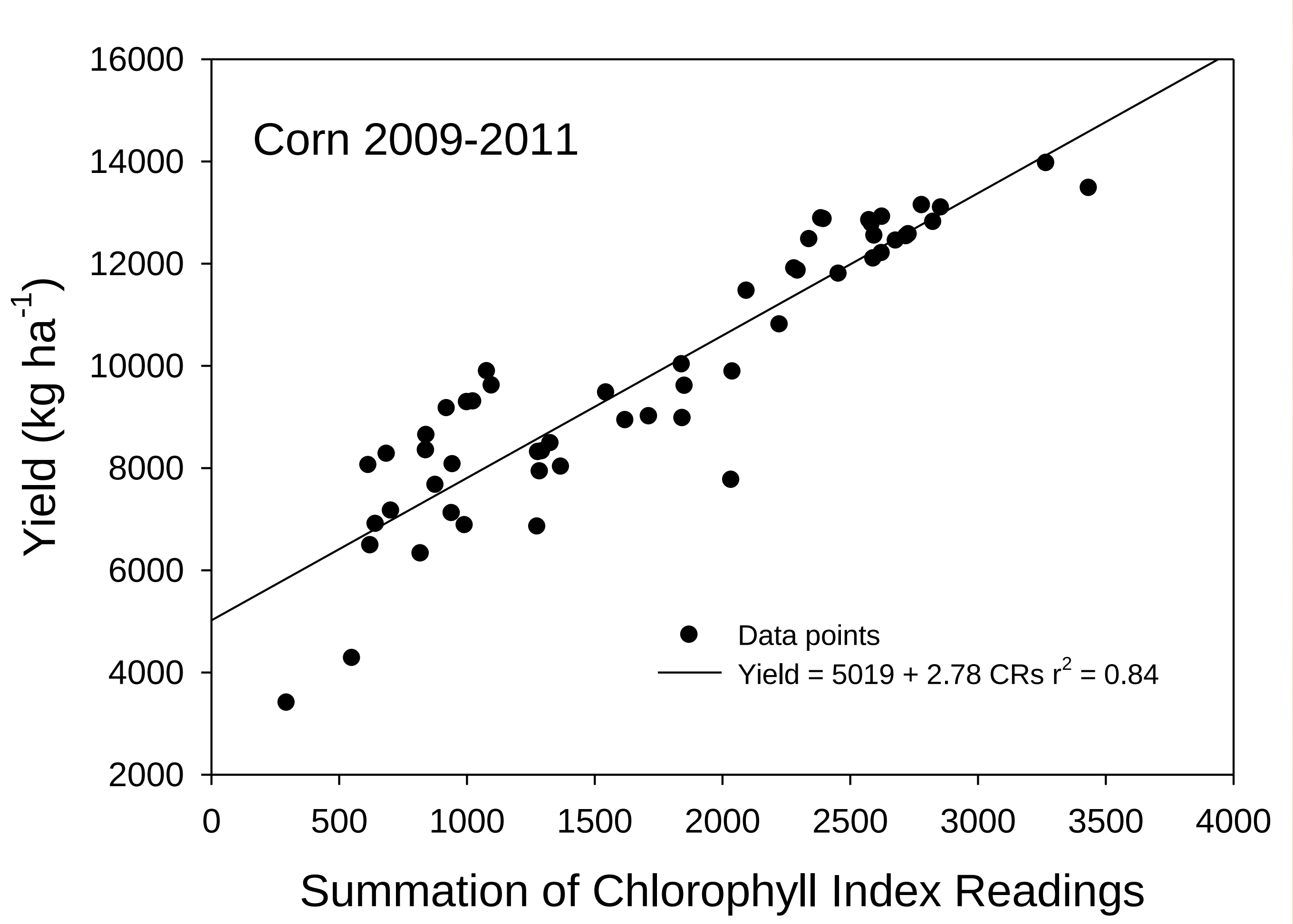


PERFECT BLEND COMBINATIONS

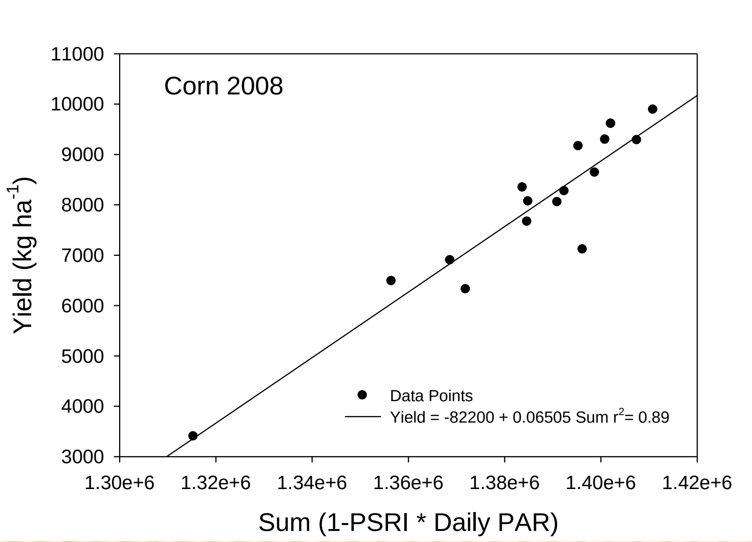


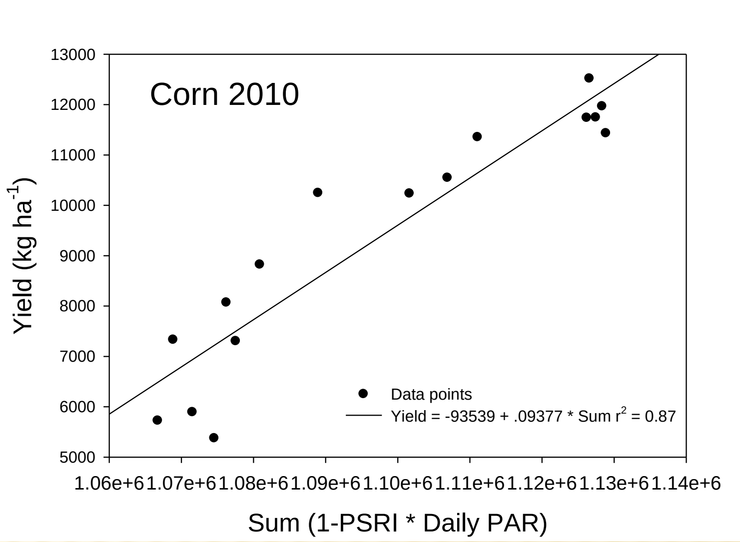
Yields PB2/3 = PB1/3 > SuperU

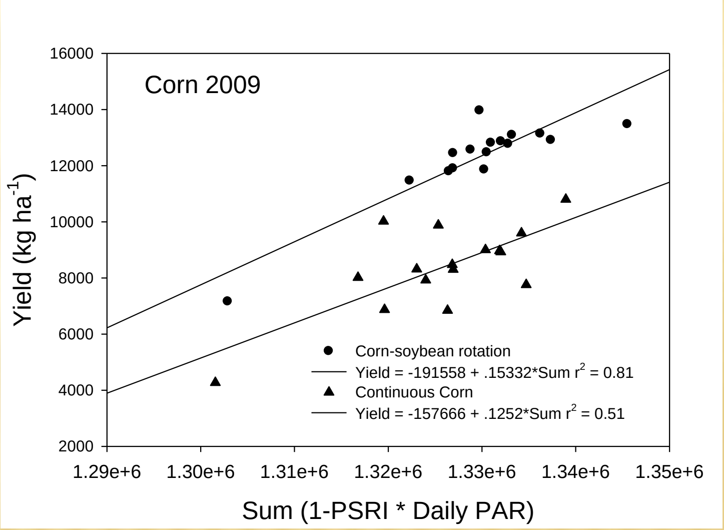
DURATION OF GREEN LEAF AREA



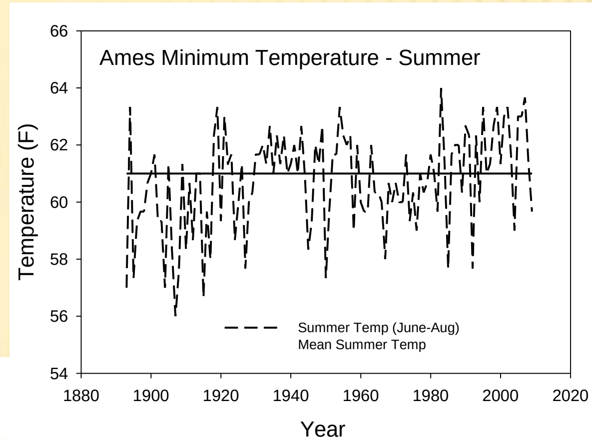
DURATION OF PHOTOSYNTHETIC CAPACITY

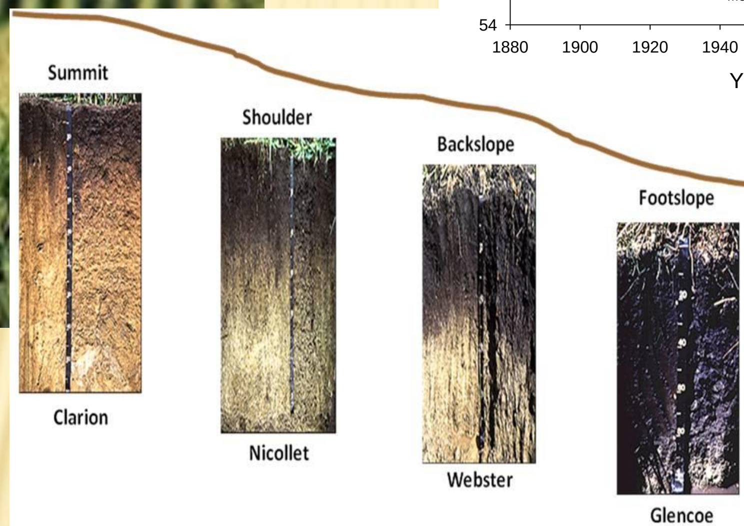






G X E X M





Environment

CHALLENGES

- Have the genetic potential to achieve high yields, yield gaps are a combined result of weather and management practices, how do we close the yield gap?
- How do we link nutrient management into G x E x M?
- What management practices need to implemented to offset the impacts of increasing variable weather?