Why it is important for agriculture

THE SCIENCE OF SOIL HEALTH

CONTACT INFORMATION

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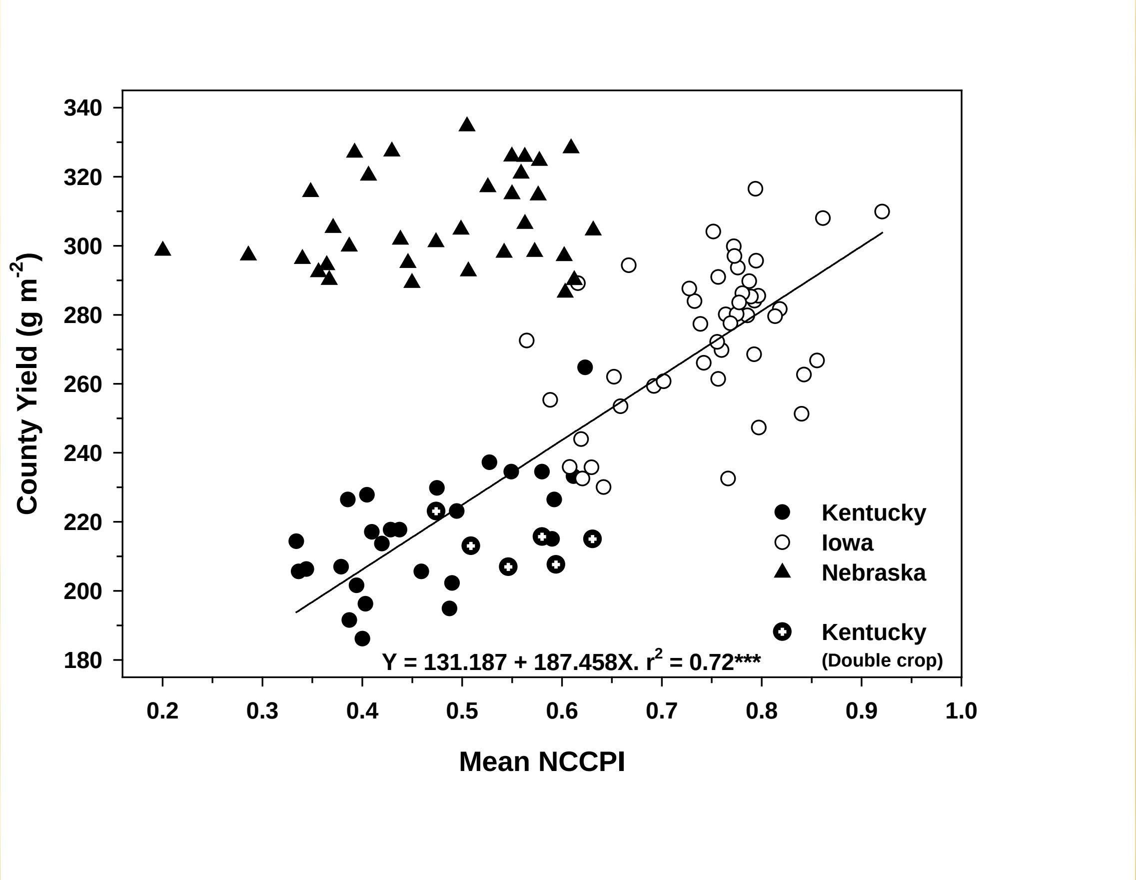
OUTLINE

- Why is soil health important?
- Soil degradation
- Soil enhancement
- Future demands of agriculture

WHY IS SOIL HEALTH IMPORTANT?

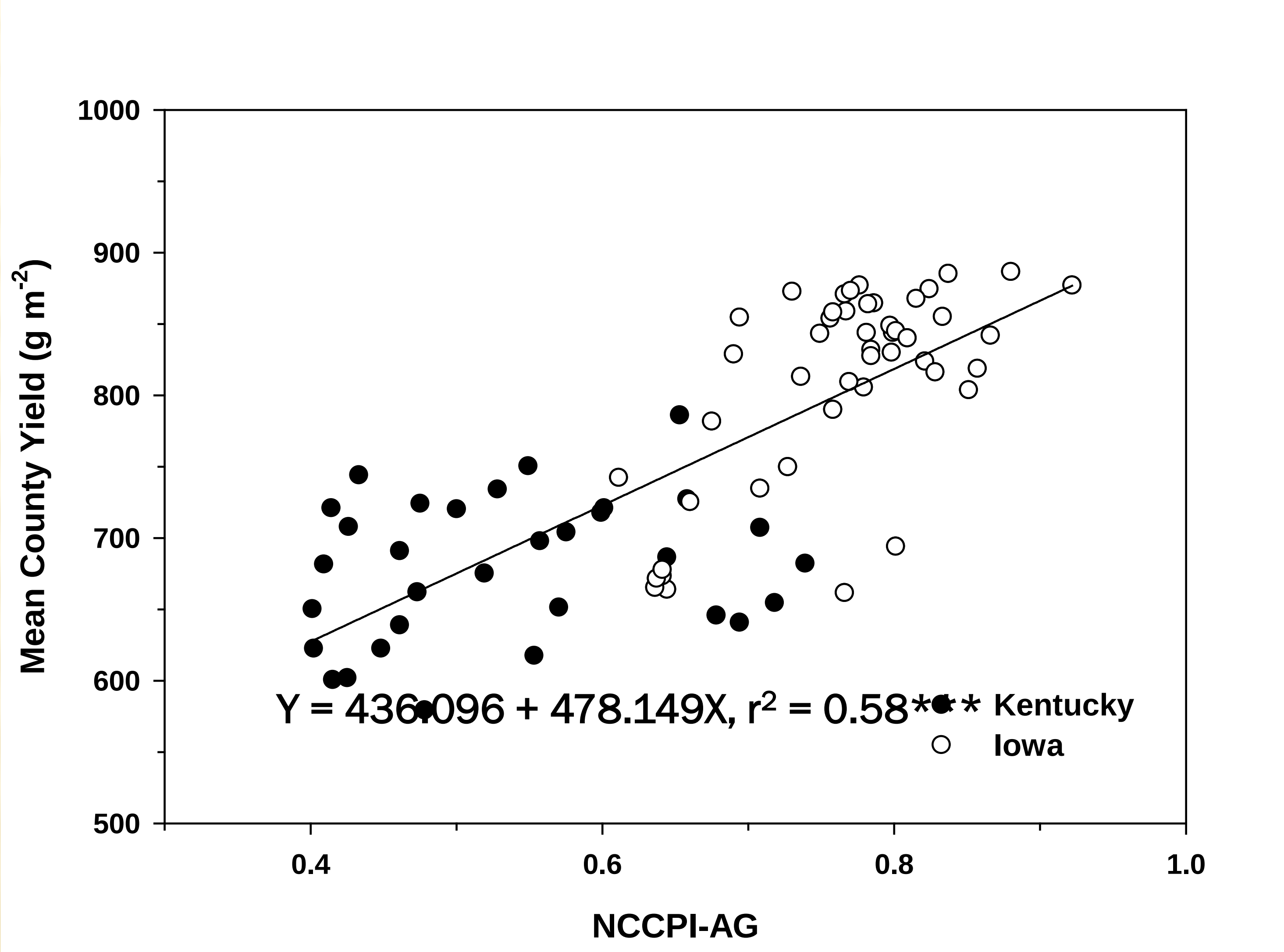
GOOD SOILS = GOOD YIELDS

Soybean yields across Iowa, Kentucky, and Nebraska

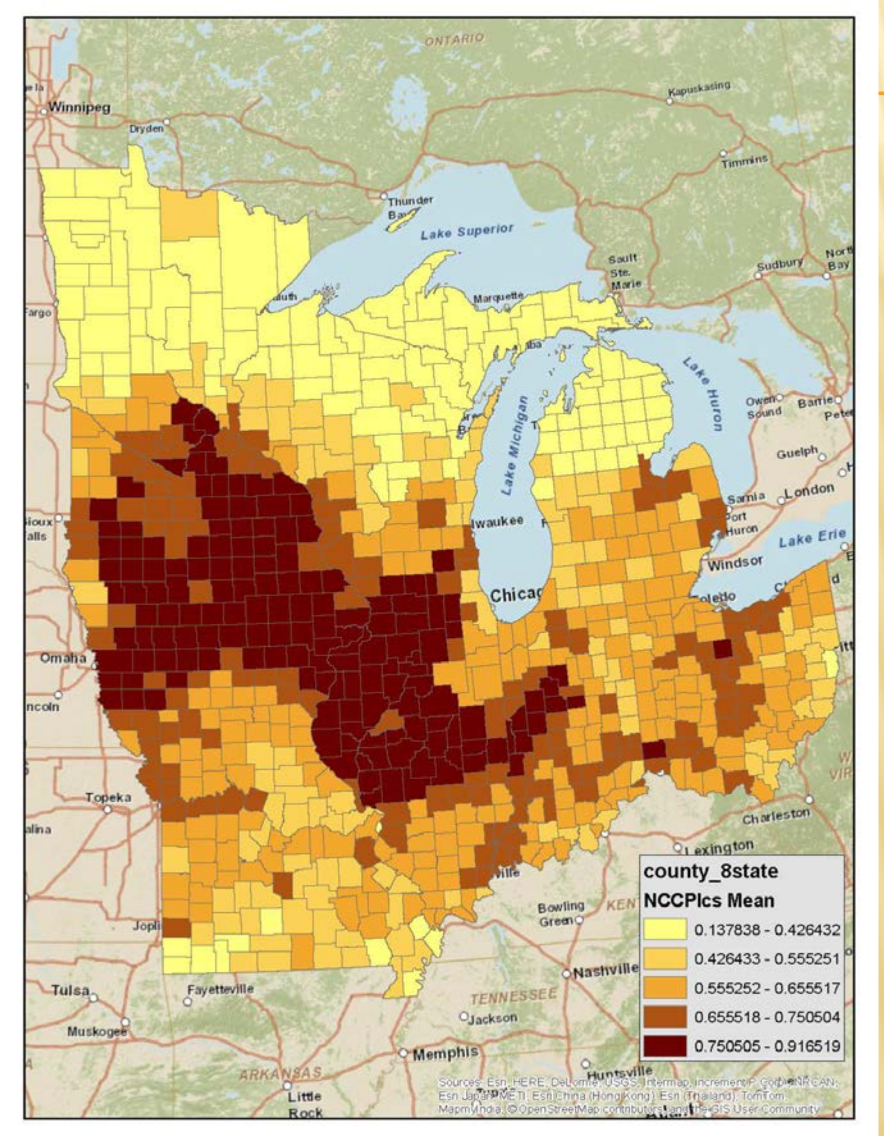


Climate resilience is derived from good soils in rainfed agricultural systems

MAIZE COUNTY YIELDS

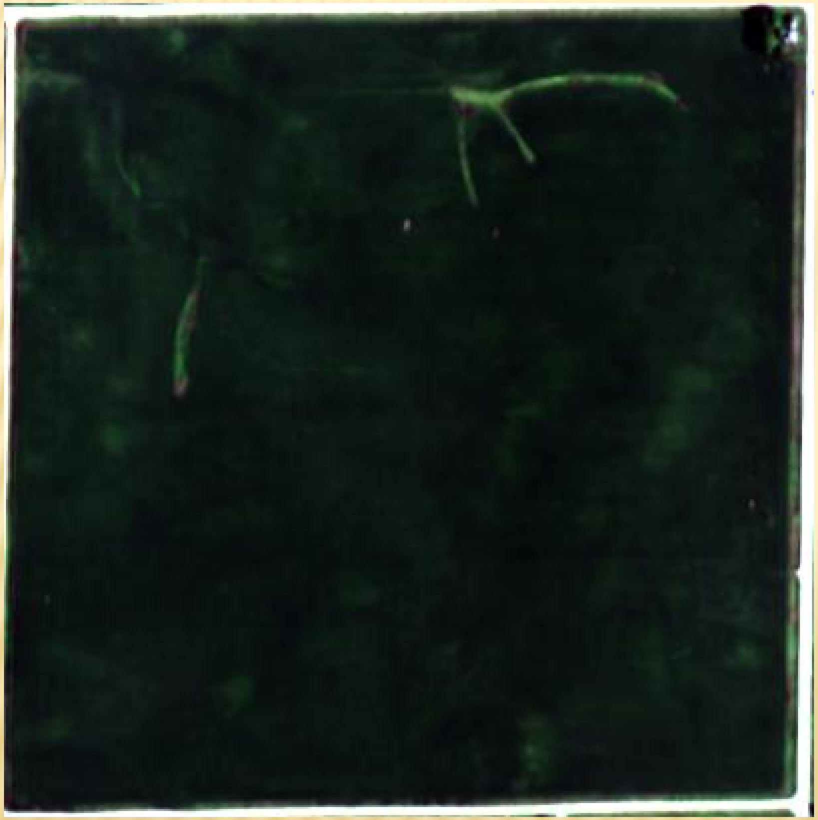


VARIATION IN NCCPI ACROSS THE MIDWEST



SOYBEAN PRODUCTION FIELD

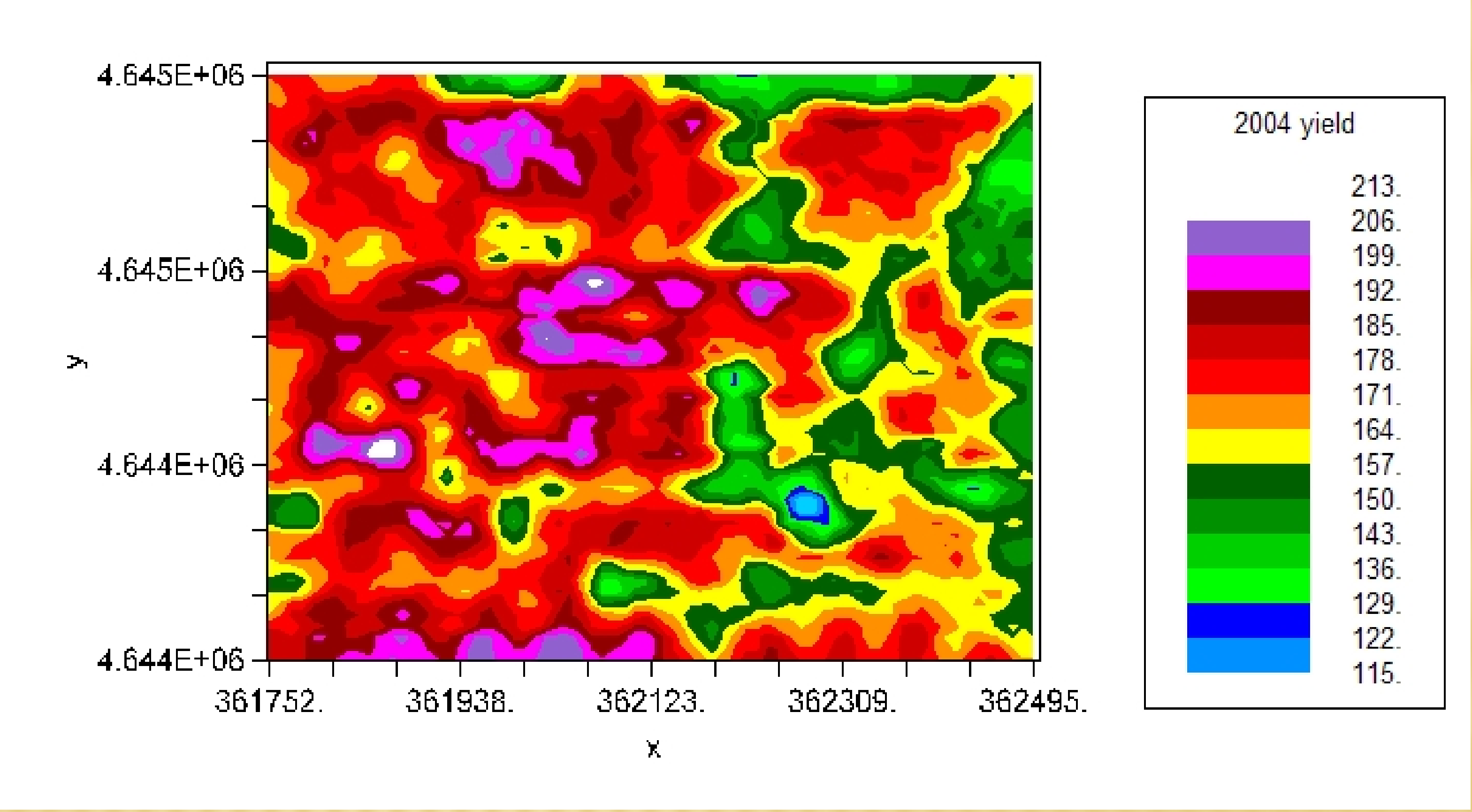
Early August



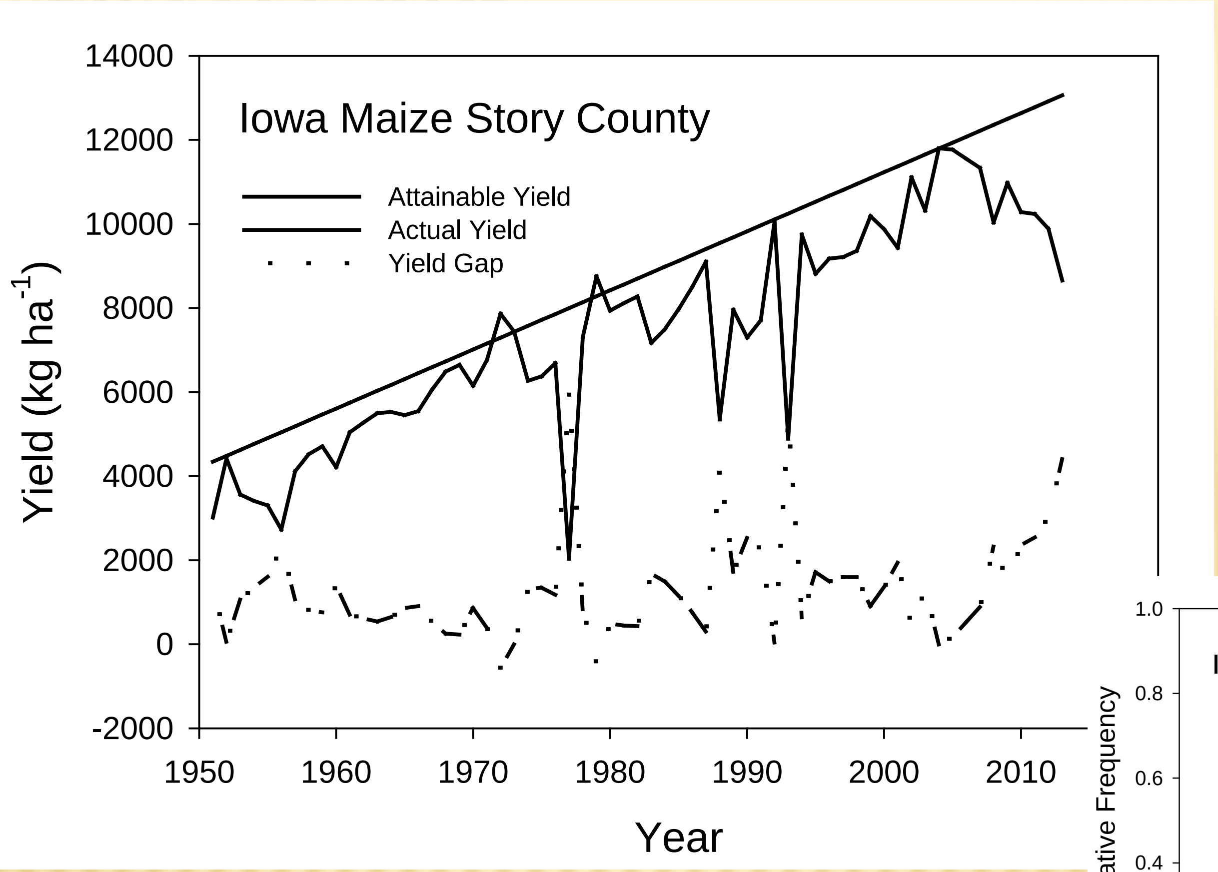
Late August

Yield variability in a field comes from soils inability to supply water during grain-filling

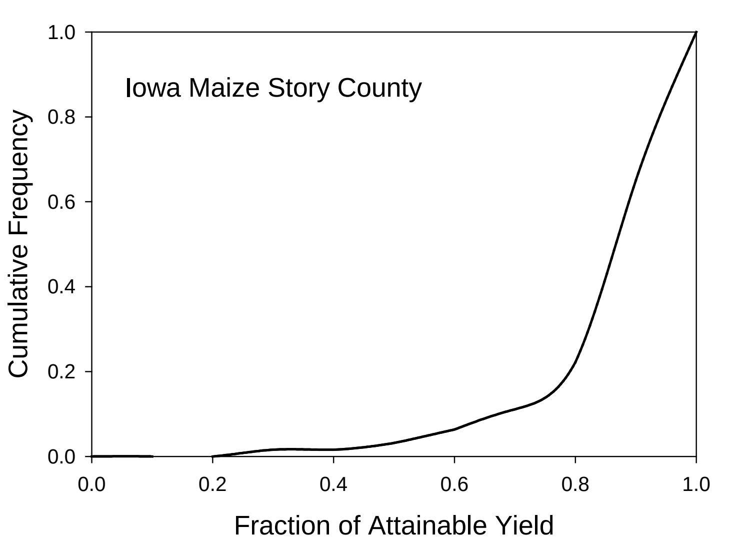
CROP YIELD VARIATION



YIELD GAPS

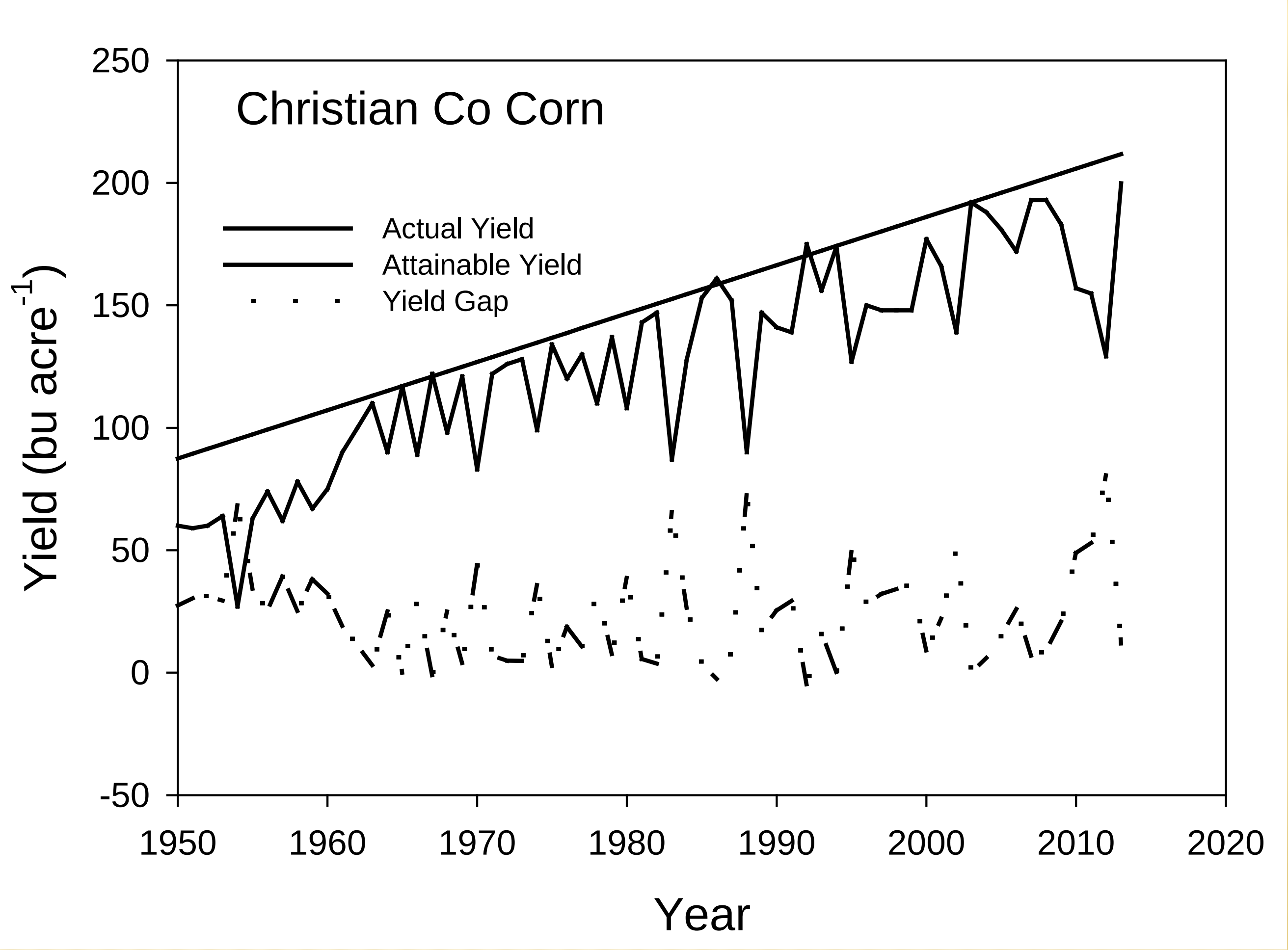


Iowa Maize Story County
Attainable Yield
Actual Yield
Yield Gap
Yield (kg ha-1)
14000
12000
10000
8000
6000
4000
2000
0
-2000
1950
1960
1970
1980
1990
2000
2010
Year

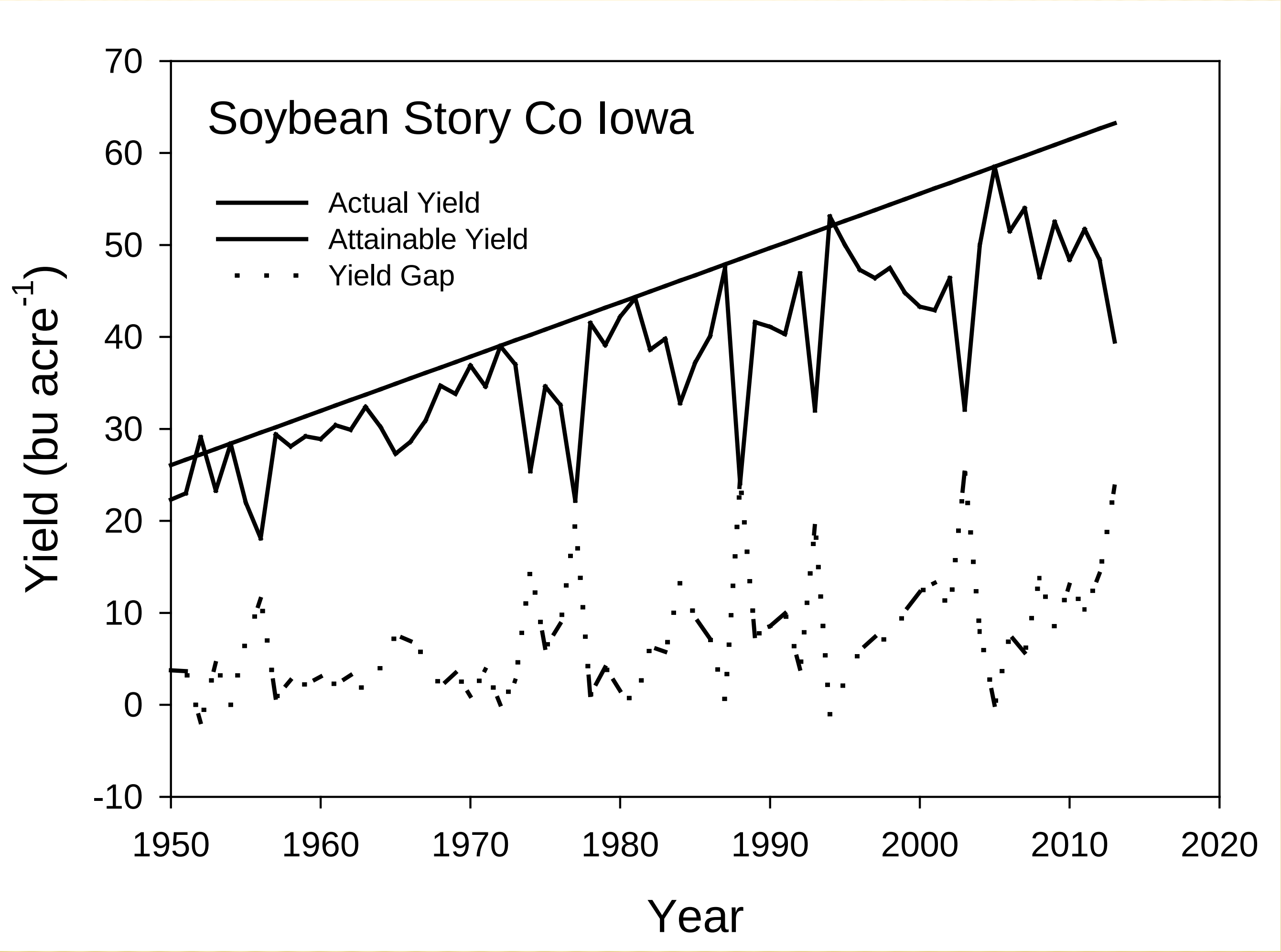


Iowa Maize Story County
Cumulative Frequency
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of Attainable Yield

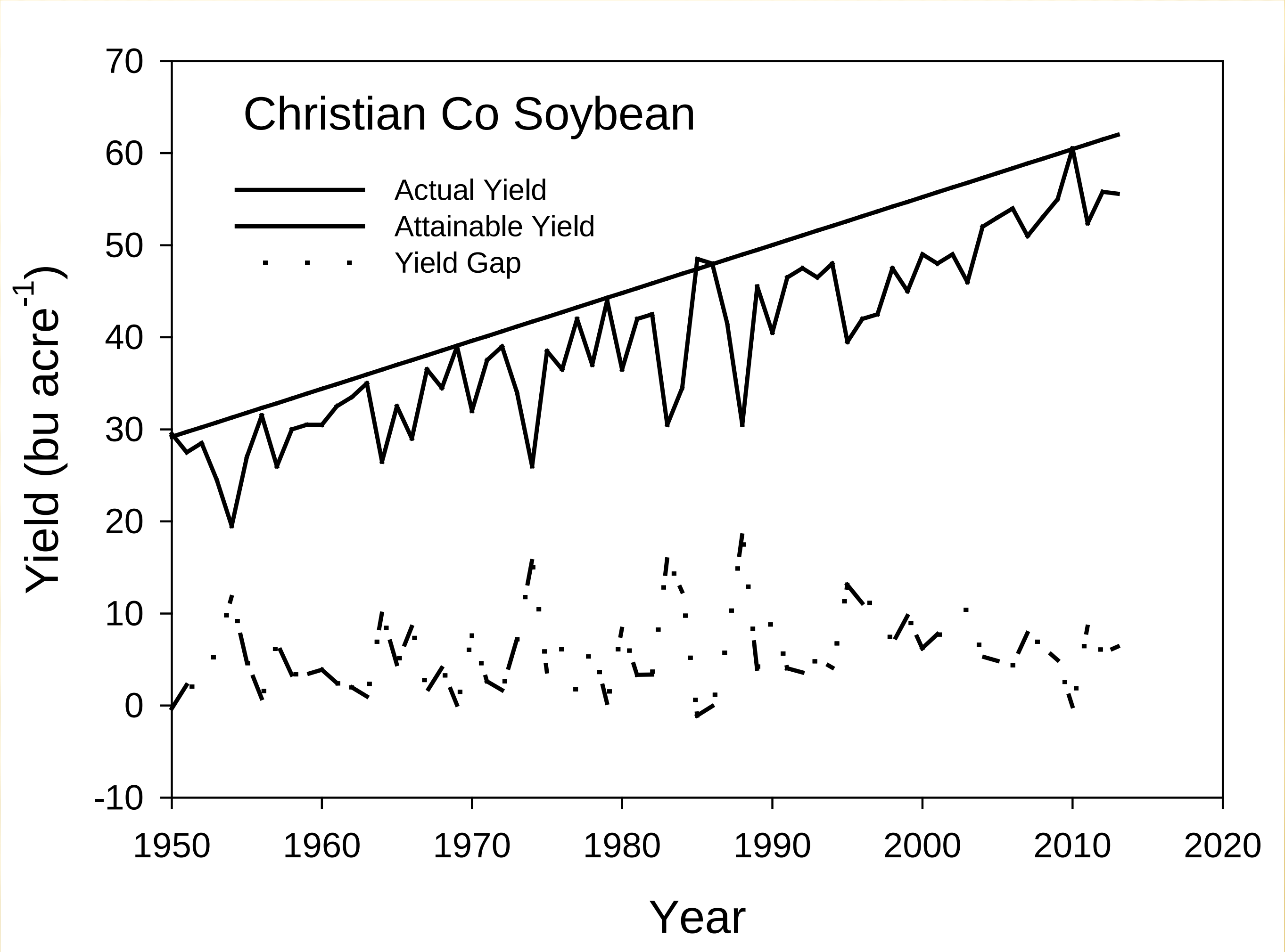
CHRISTIAN COUNTY ILLINOIS CORN



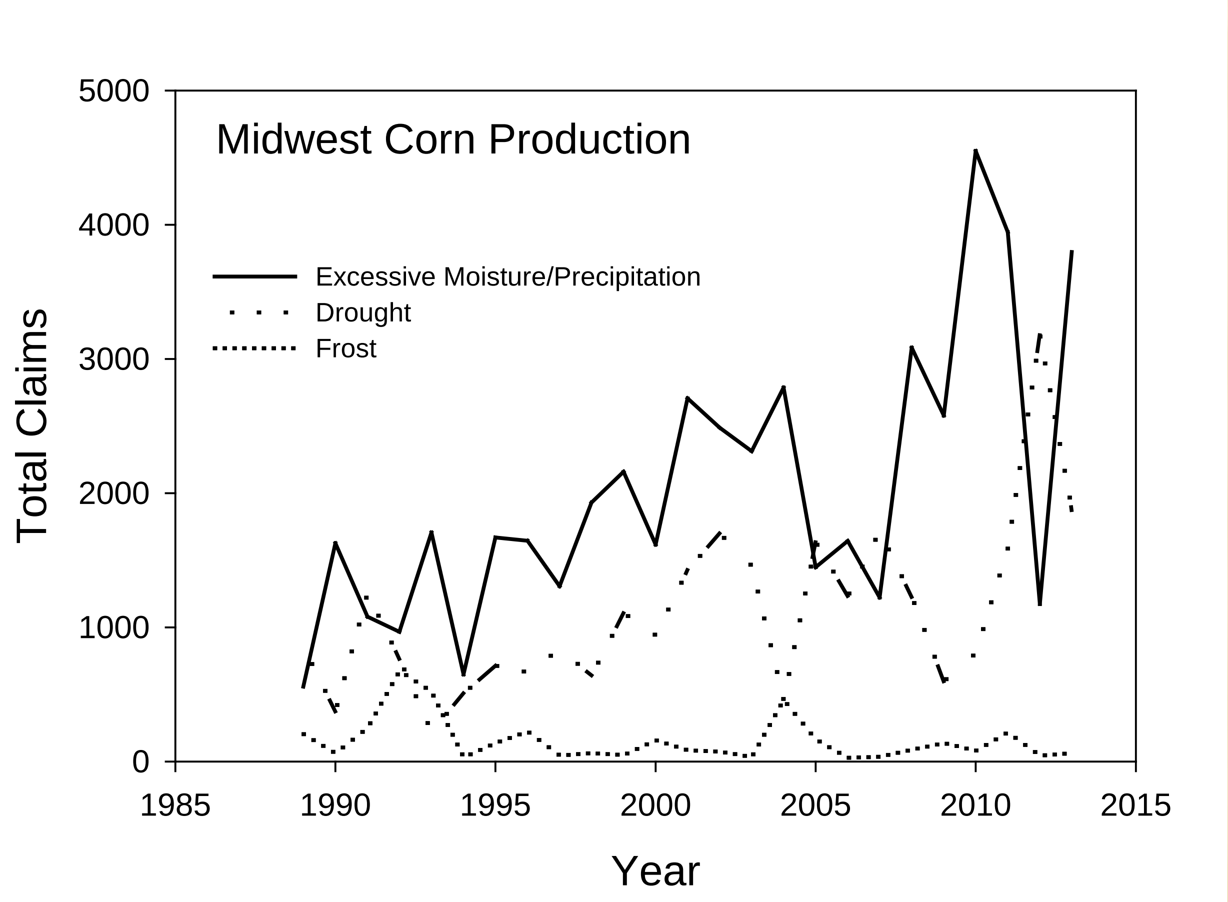
STORY COUNTY IOWA SOYBEAN



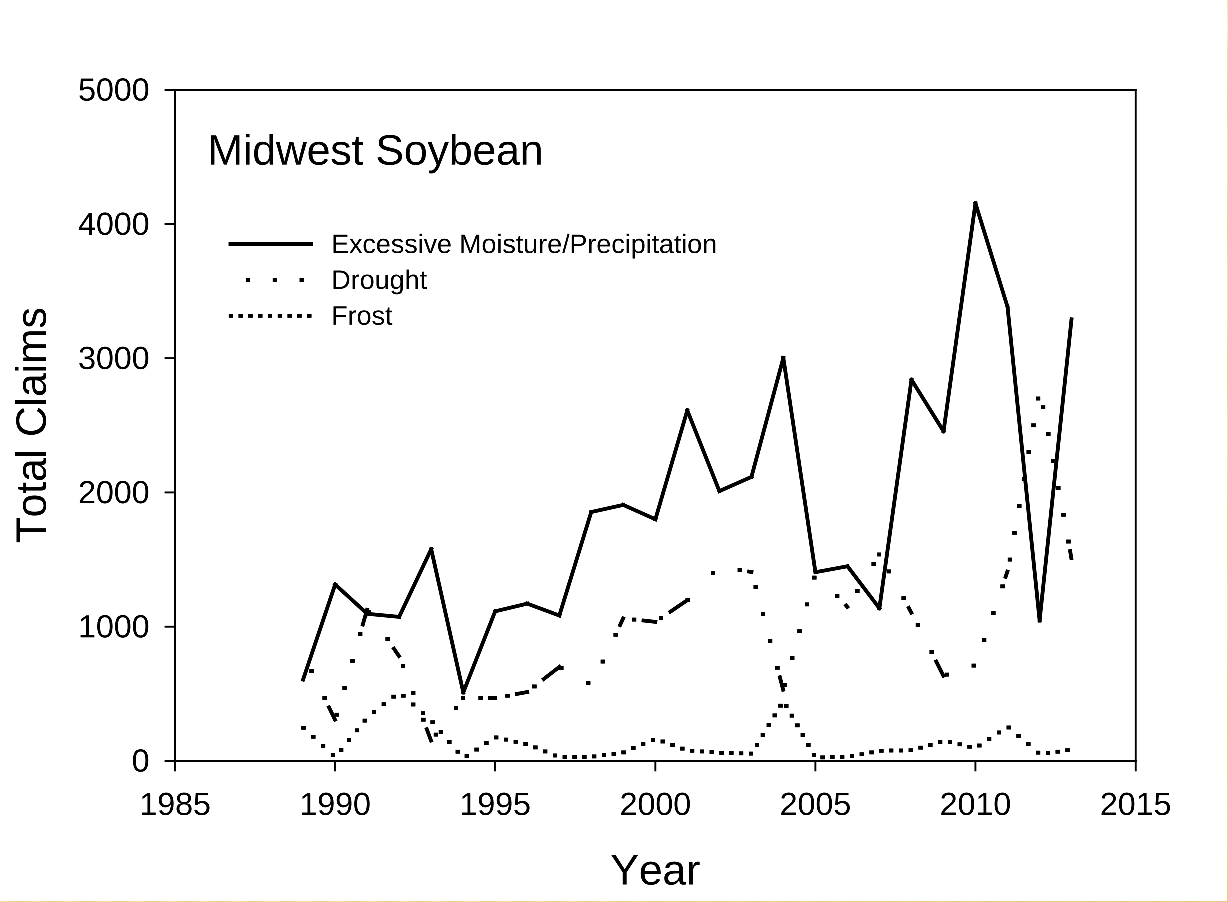
CHRISTIAN COUNTY ILLINOIS SOYBEAN



CORN: SPECIFIC CLAIMS



SOYBEAN: SPECIFIC CLAIMS



SOIL DEGRADATION SPIRAL

Poor Land Management

Aggregation Degradation

Compaction
& crusting

Water & Wind Erosion

Plant Growth

Soil Biology

Yield

Reduced Soil
Productivity

Susceptible to extremes

Negative responses to
weather variation

Hatfield, 1999

EROSION: HOW MUCH IS TOLERABLE?

NLAE
National Laboratory for Agriculture and the Environment

Erosion from 1 acre of land (43,560 ft^2)!

after 1 year
0.025 inch soil loss
~4 tons/yr

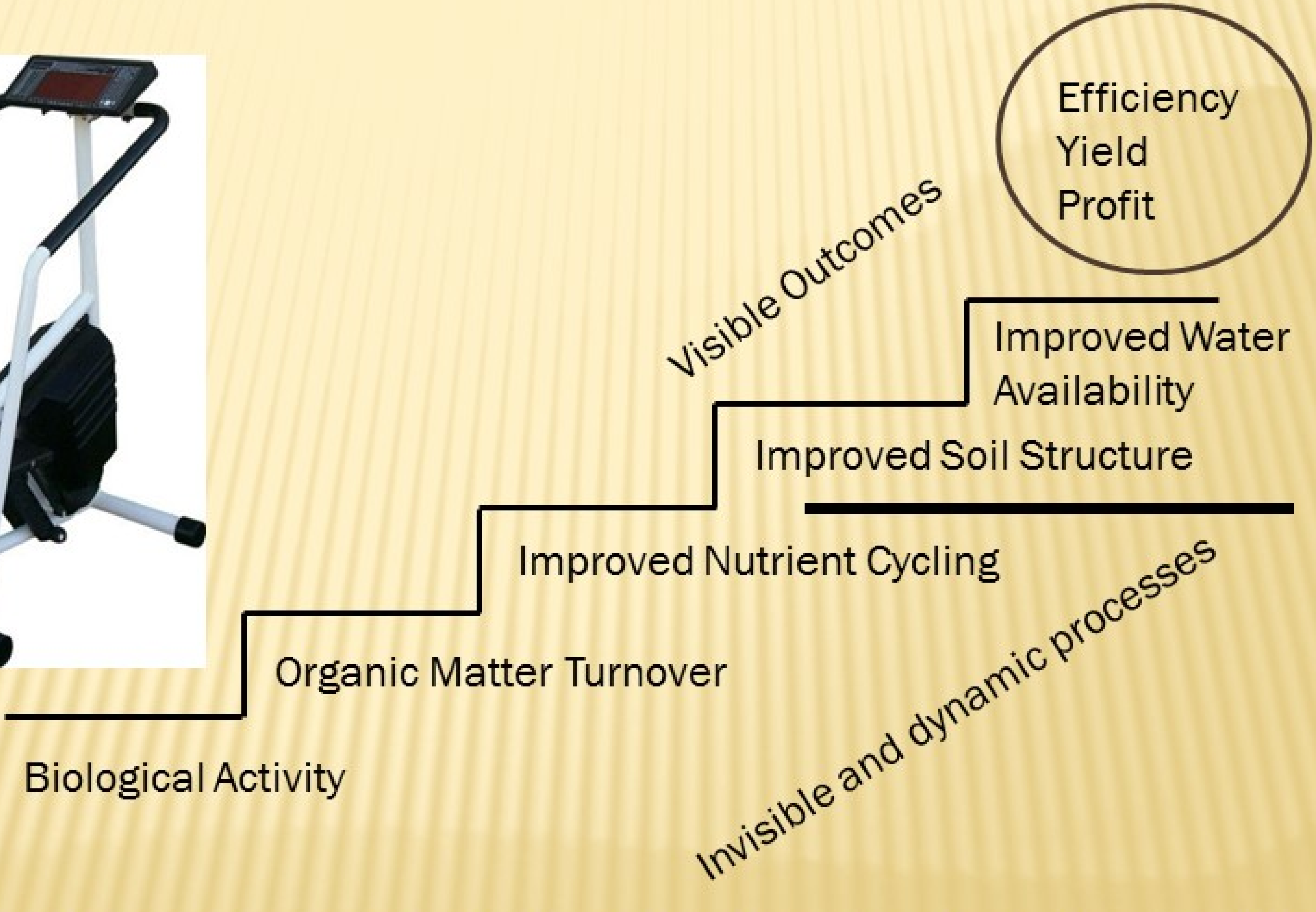
after 40 years
1.0 inch soil loss
~160 tons

Credit: Roger Wolfe, Baltimore, OH

THE WIND BLOWS TOO

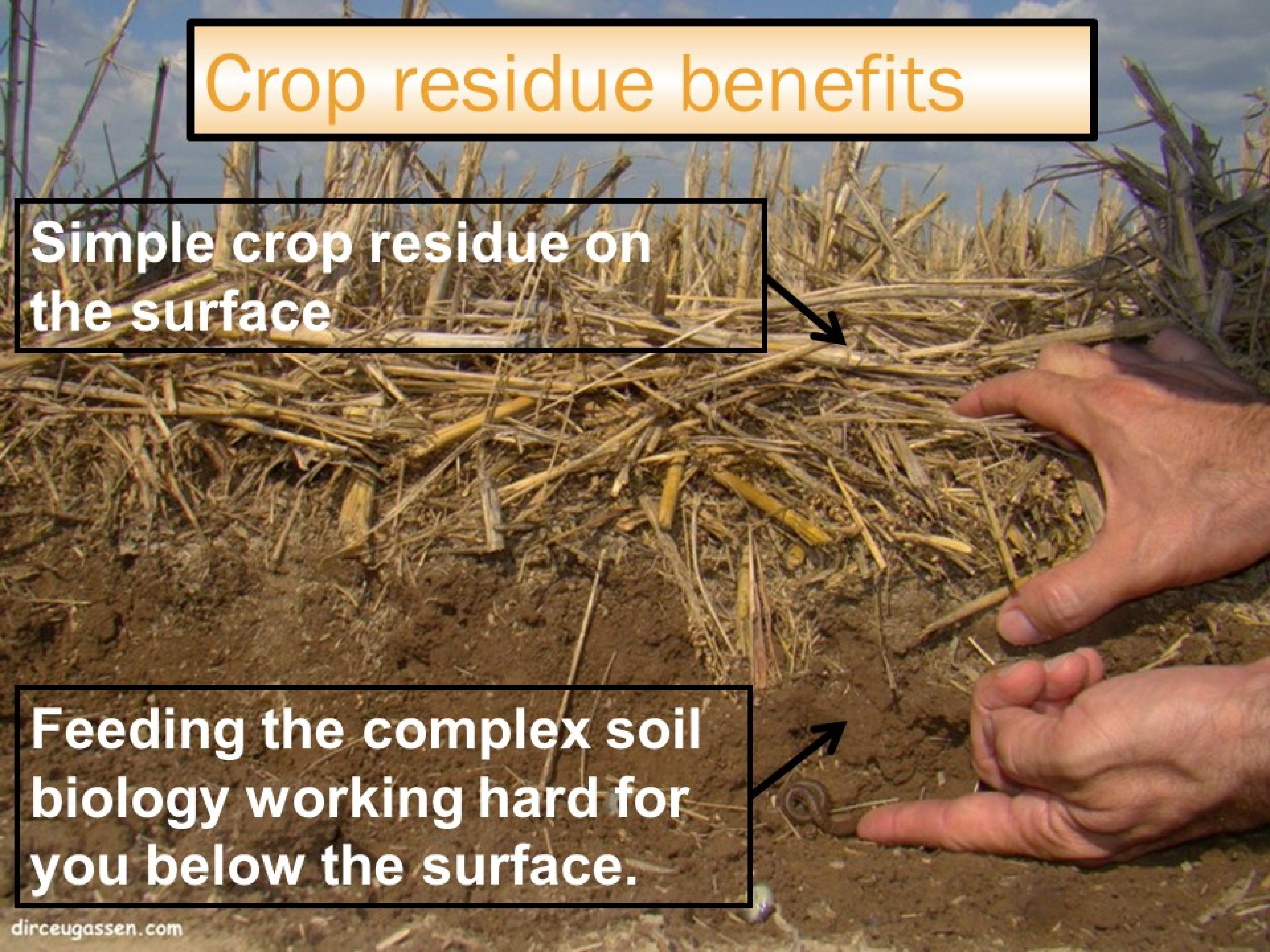
NLAE
National
Laboratory
for Agriculture
and the Environment

SOIL AGGRADATION CLIMB



We build soil through biological activity not by physical or chemical manipulation

Hatfield, 2004


Crop residue benefits
Simple crop residue on the surface
Feeding the complex soil biology working hard for you below the surface.
dirceugassen.com

“Passive protective blanket”

“Active protective blanket”

The "living soil", a biological system.

Mammals - gophers, moles, mice, groundhogs
Earthworms - night crawlers, garden worms
Insects and mollusks - ants, beetles, centipedes, snails, slugs
Microfauna - nematodes, protozoa, rotifers≈
Microflora - fungi, yeast, molds, mychorhiza
Actinomycetes - smaller than fungi, act like bacteria
Bacteria - autotrophs, heterotrophs, rhizobia, nitrobacter
Algae - green, blue-green

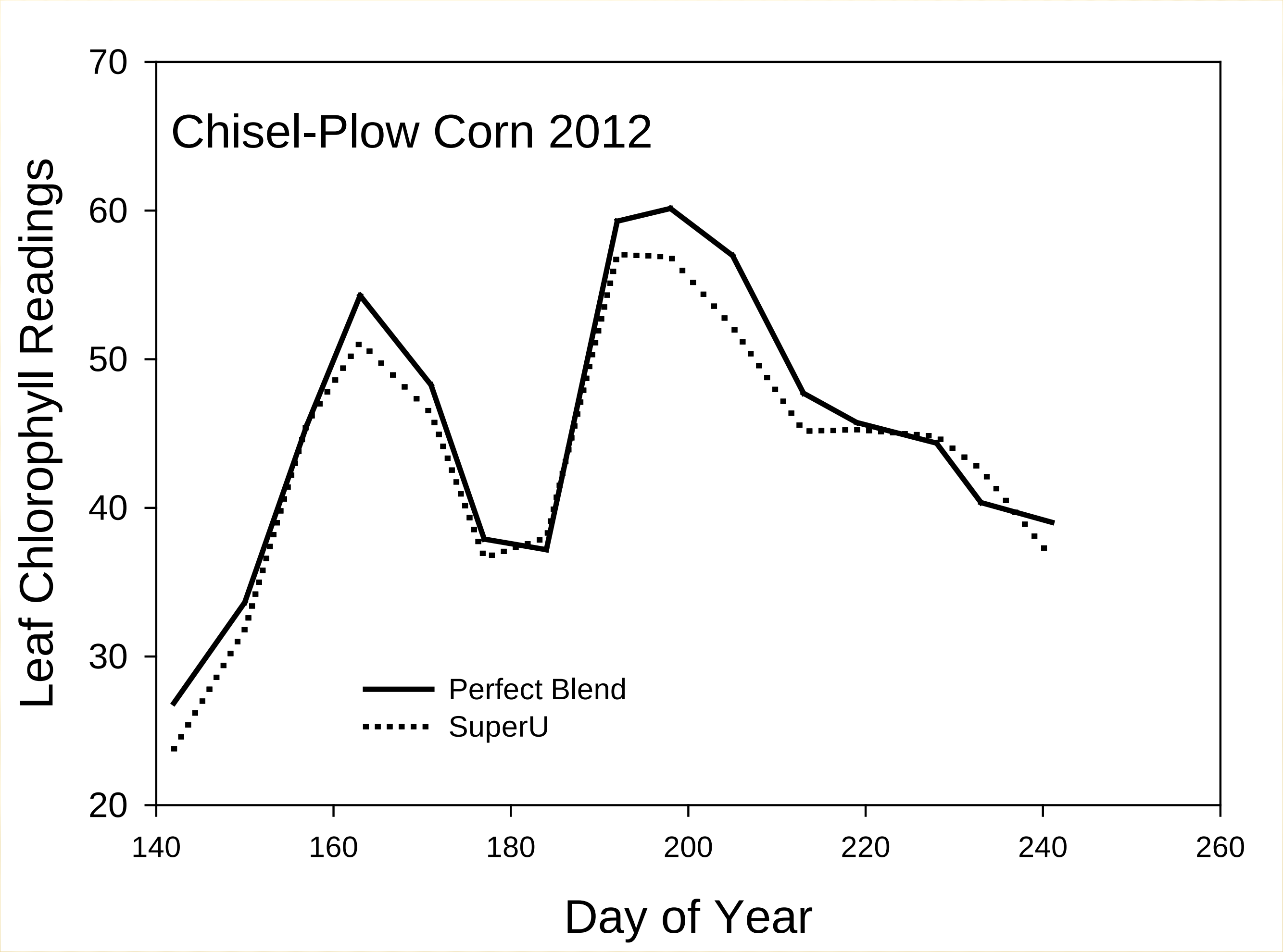
≈

Earthworms, insects and rodents are "nature's plow" and the most visible components of the "living soil" team. They work in tandem with other soil fauna, soil microorganisms and fungi to contribute to aeration and nutrient cycling as part of a "soil factory" team effort.

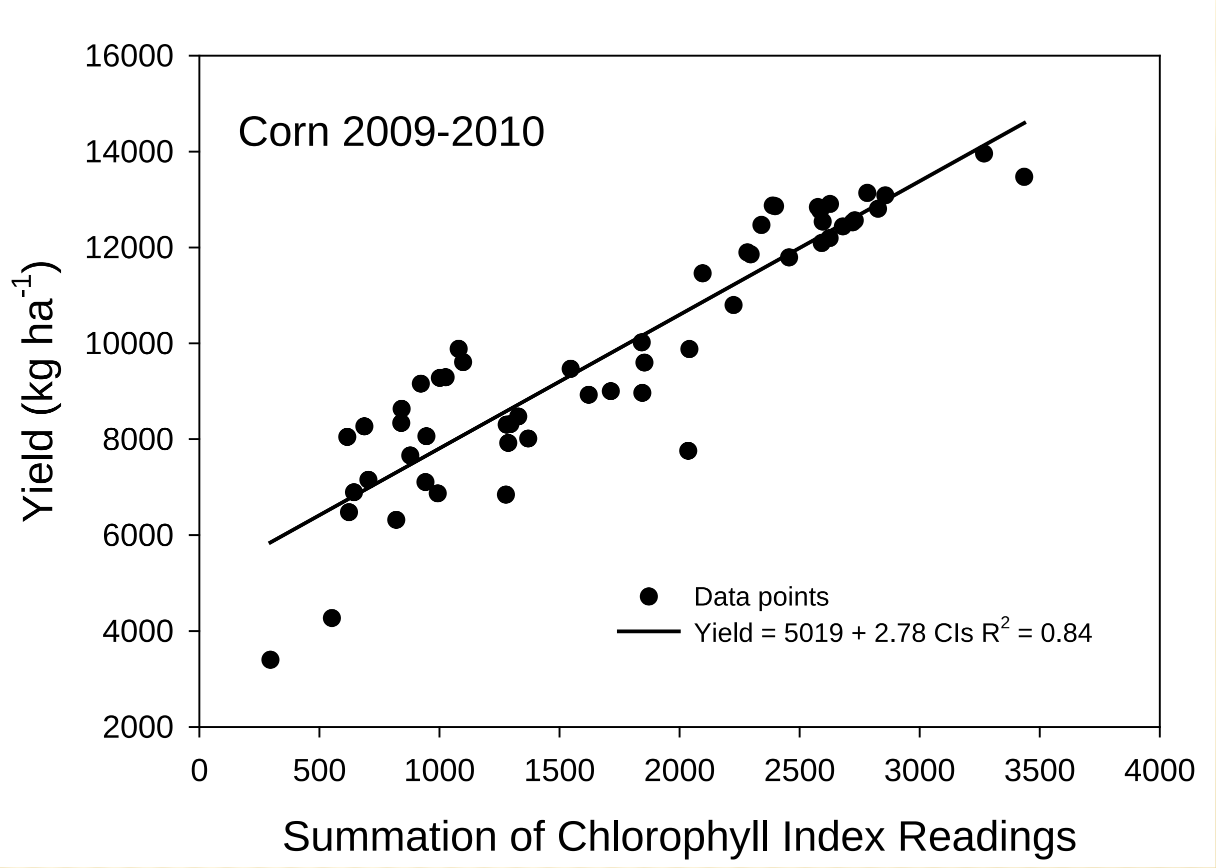
RESIDUE AND COVER CROPS

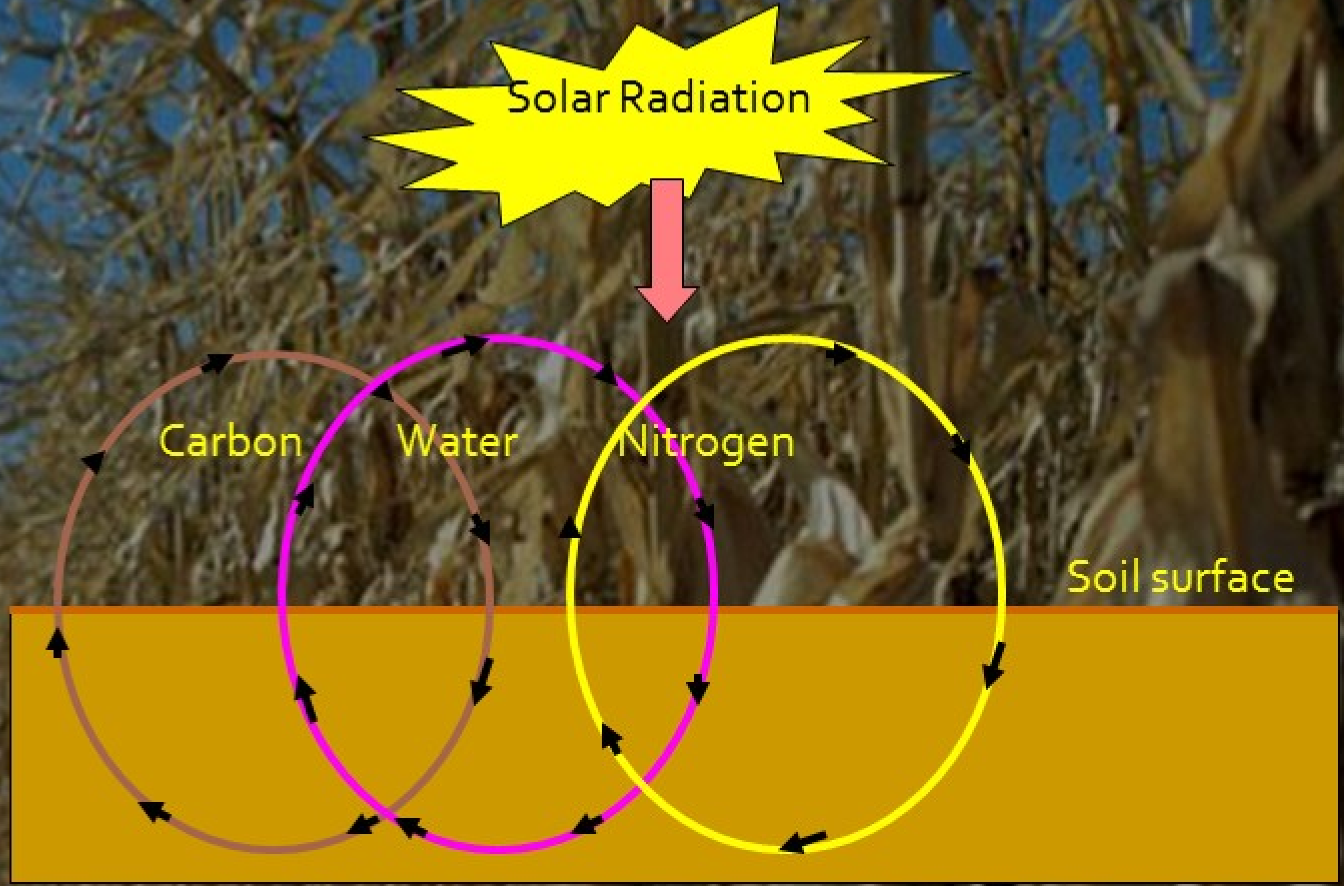
- Stabilize the microclimate of the upper soil surface
- Provide a food source for microbes
- Source of nutrients to be recycled

LEAF CHLOROPHYLL 2012



CHLOROPHYLL SUMMATION INDEX





Key Processes

Photosynthesis	Precipitation	N Fixation
Respiration	Evaporation	Mineralization
Org Matter decomp	Infiltration	Denitrification
Plant decomposition	Runoff	Plant decomposition
	Percolation	

Cycles interact over time and space with different rates

Evolution of a continuous no till systems: 4 phases

Initial (0-5)

- Rebuild aggregates
- Low 0M
- Low crop residues
- Reestablish microbial biomass
- > N

Transition (5-10)

- Increase soil density
- Start increasing crop residue
- Start increasing soil OM
- Start increasing P
- Immobilize N >= Minimum

Consolidation (10-20)

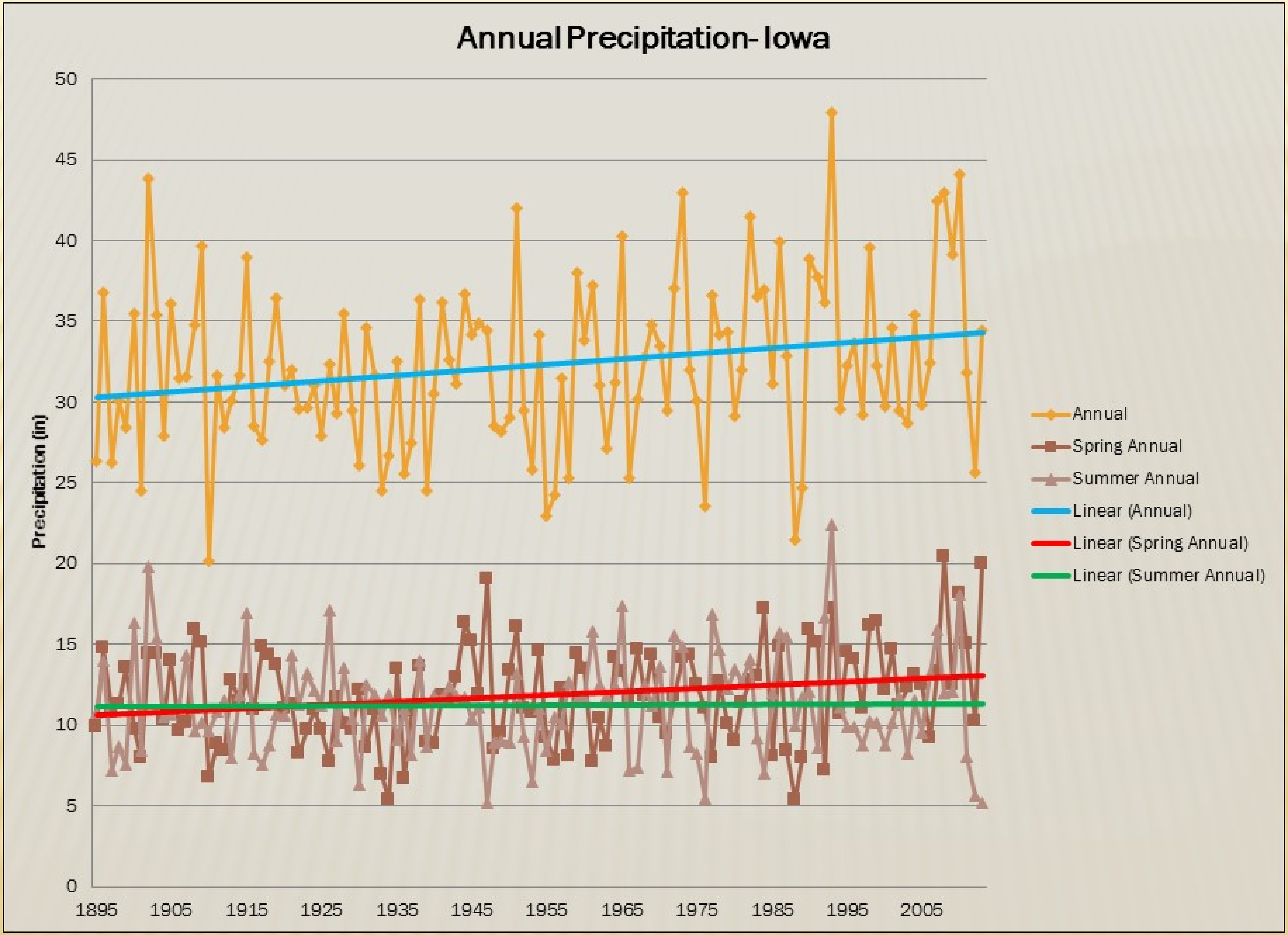
- High Crop Residue
- High C
- > CEC
- > H2O
- Immobilize N < Min.
- > Nutrient Cycling

Maintenance (>20)

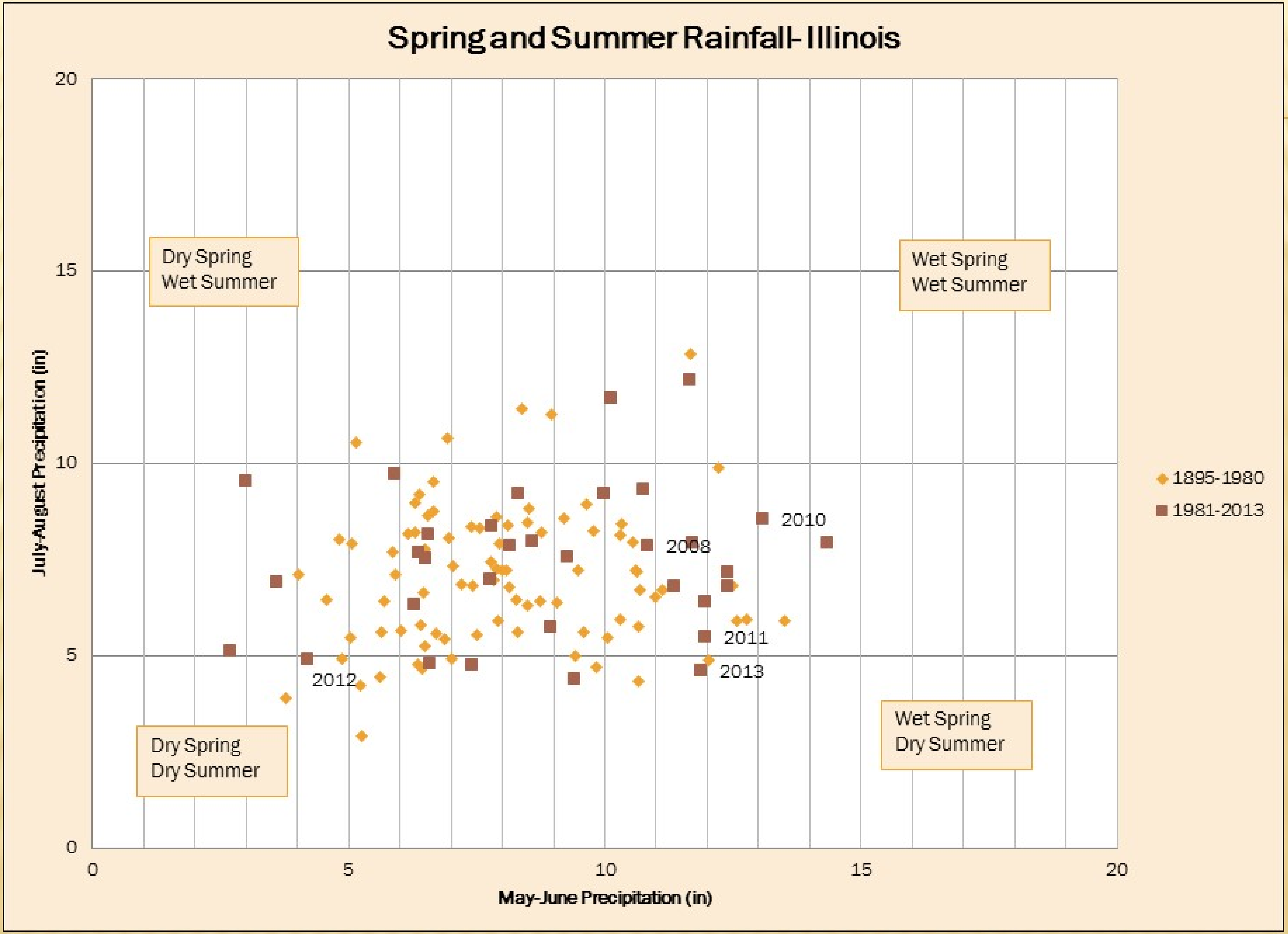
- High accum. of crop residue
- Continuous N and C flux
- Very high C
- > H2O
- High nutrient cycling
- Less N & P use

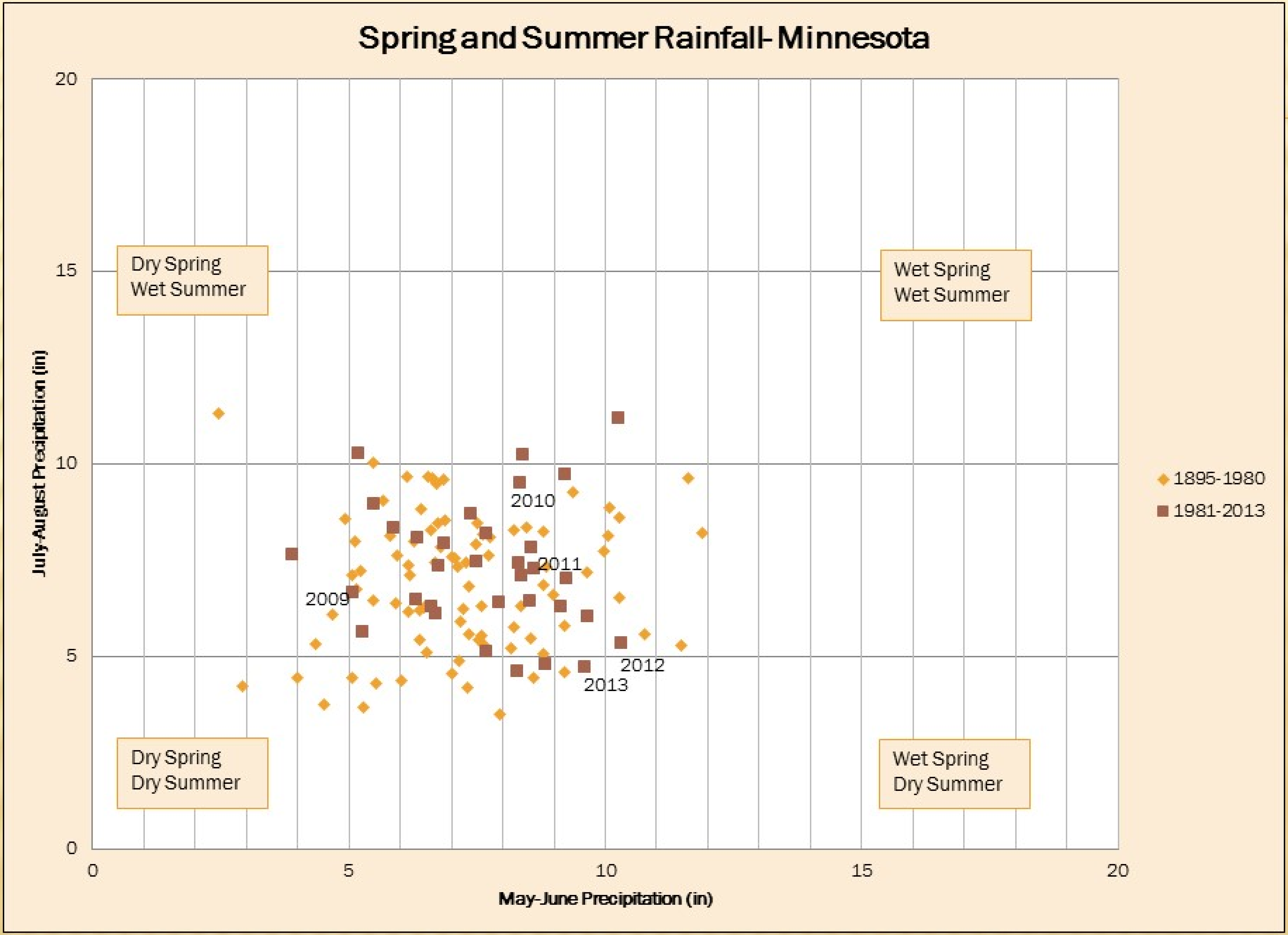
Time (years)

Source: Sa, 2004



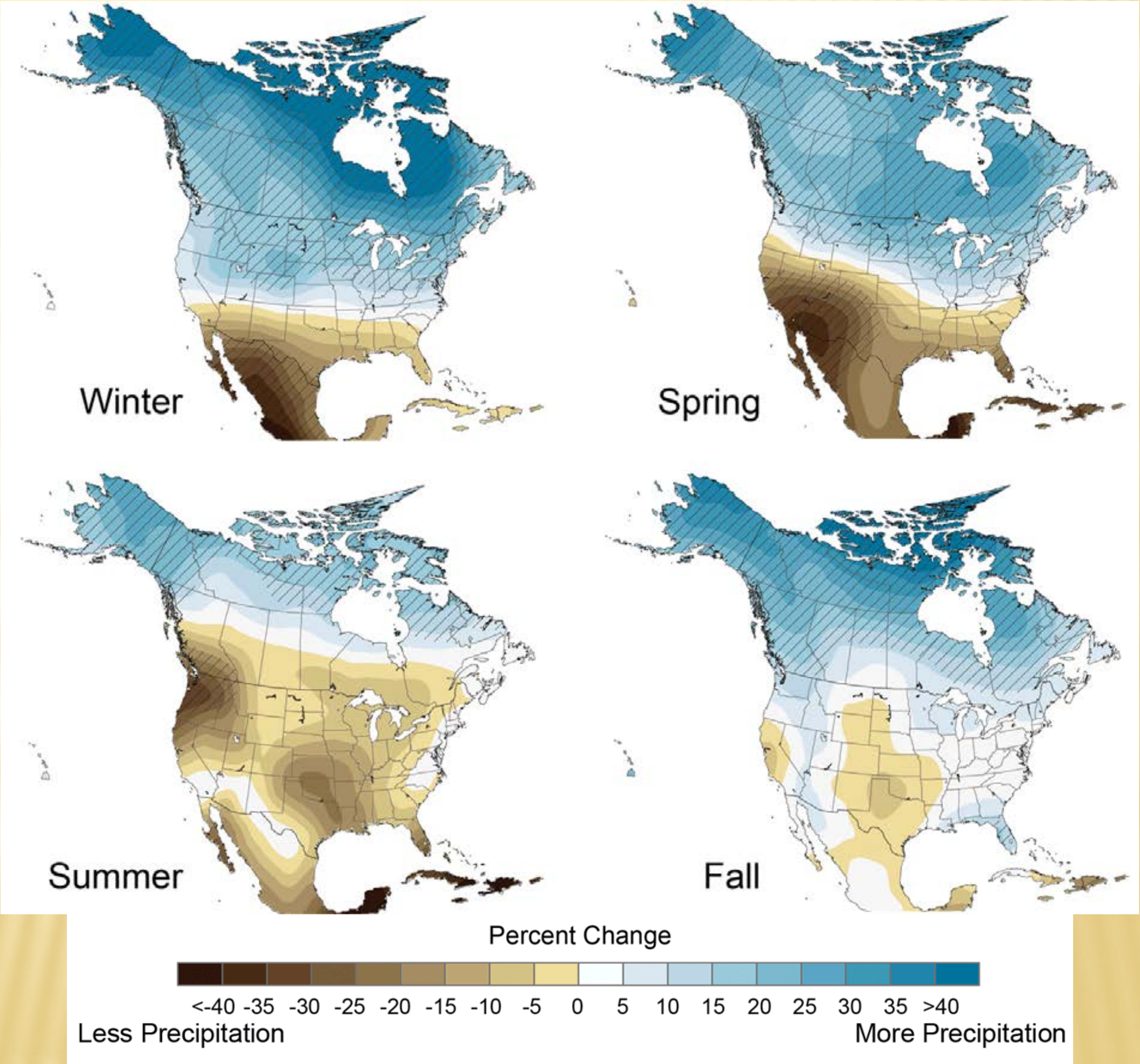
Annual Precipitation- Iowa
Precipitation (in)
50
45
40
35
30
25
20
15
10
5
0
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
Annual
Spring Annual
Summer Annual
Linear (Annual)
Linear (Spring Annual)
Linear (Summer Annual)


Spring and Summer Rainfall- Illinois
Dry Spring
Wet Summer
Wet Spring
Wet Summer
Dry Spring
Dry Summer
Wet Spring
Dry Summer
2008
2010
2011
2012
2013
1895-1980
1981-2013
July-August Precipitation (in)
May-June Precipitation (in)
0
5
10
15
20
0
5
10
15
20



Spring and Summer Rainfall- Minnesota
Dry Spring Wet Summer
Wet Spring Wet Summer
Dry Spring Dry Summer
Wet Spring Dry Summer
2009
2010
2011
2012
2013
July-August Precipitation (in)
May-June Precipitation (in)
0
5
10
15
20
1895-1980
1981-2013

PROJECTED CHANGE IN N. AMERICAN PRECIPITATION
BY 2080-2090



CLIMATE EFFECTS SOIL BIODIVERSITY

(R.D. BARDGETT AND W.H. VAN DER PUTTEN)

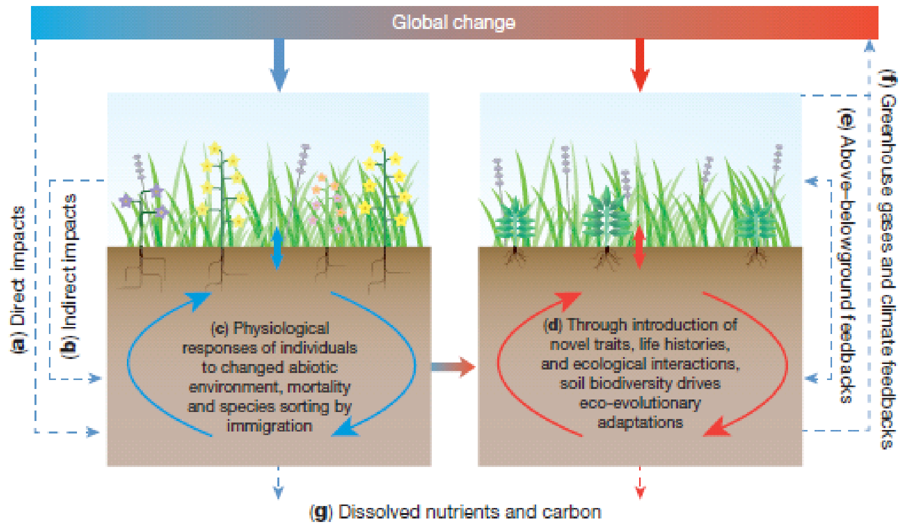


Figure 2 | Belowground responses and feedbacks triggered by climate change. Climate change impacts soil biodiversity directly (**a**), through changes in temperature and moisture, and indirectly (**b**), through shifts in resource supply from plants. Combined, these cause changes in the physiology and growth of individual soil organisms, leading to changes in the diversity and composition of soil communities through altered functional responses and biotic interactions (**c**). As a result, selection for new traits and life histories within soil communities will take place, which in turn drives eco-evolutionary dynamics of aboveground communities (**e**) and ecological feedbacks to ecosystem processes, including greenhouse gas emissions and leaching of dissolved carbon and nutrients from soil (**f**).

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Potential impacts on:
- Soil carbon and nutrient cycling
- Resilience to environmental changes: drought and diseases

SCIENCE OF SOIL HEALTH

- Assume we change soil health without considering that we need to use soil biology as the first step
- Recognize that biology is linked to all of attributes we consider as soil health

FUTURE DEMANDS OF AGRICULTURE

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

THE PROBLEM

The challenge to produce enough food will be greater over the next 50 years than in all human history

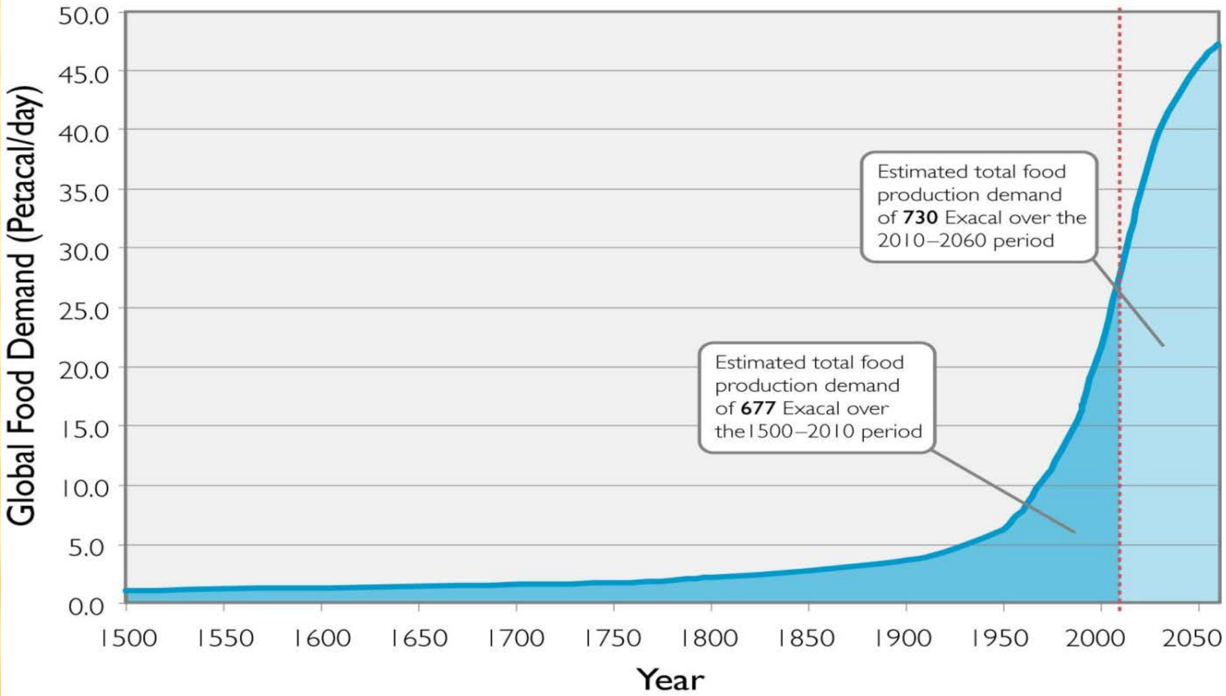
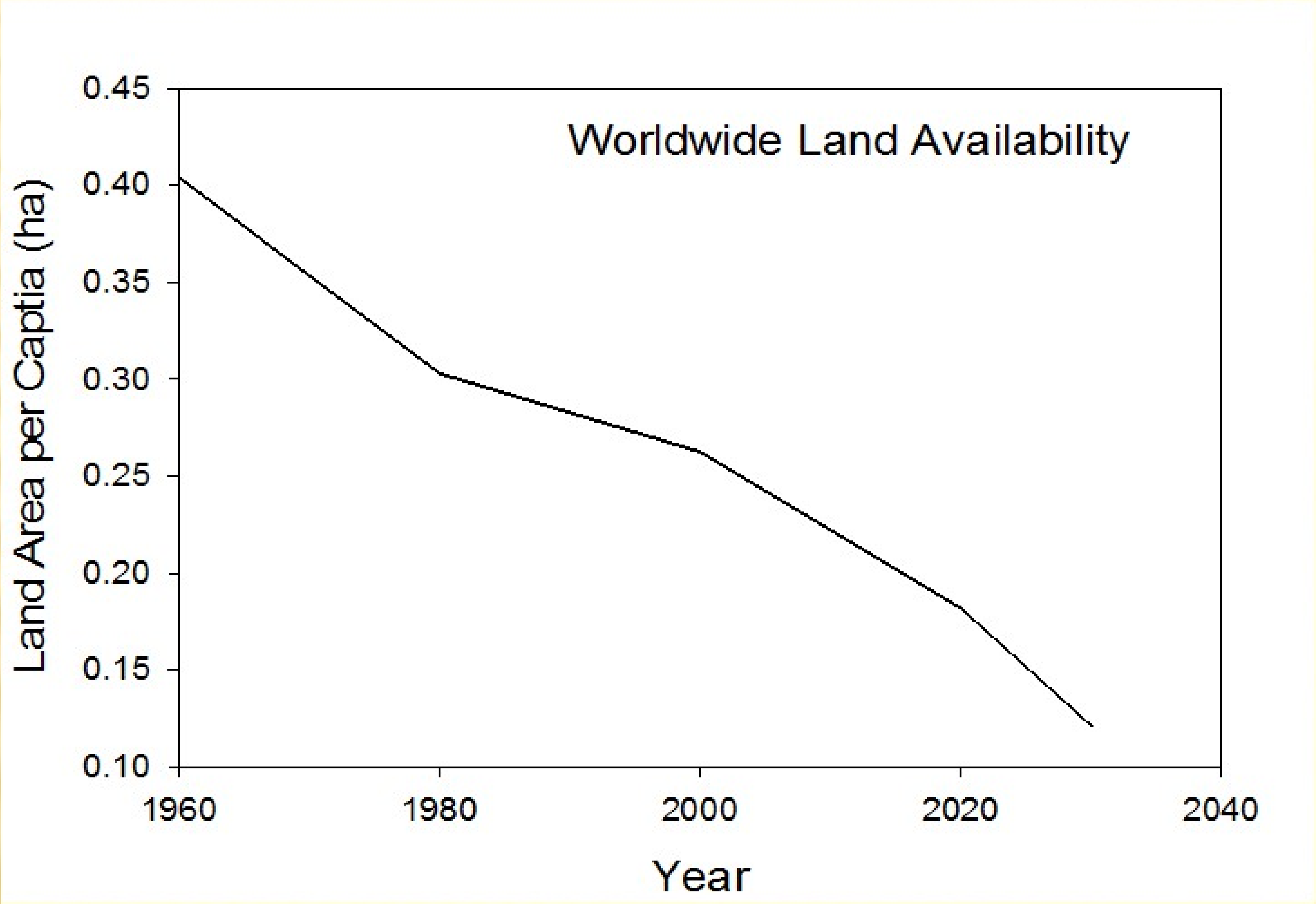


Figure 1. Explanatory notes:

- Based on data from FAOSTAT and UN Population Division, with simple scenario modelling from CSIRO 2009 (BA Keating, unpublished)
- Assumes growth trends in per capita food consumption growth in developing countries (currently 2668 kcal per capita per day) are maintained such that current developed country food consumption levels (3331 kcal per capita per day) are reached by 2050
- Assumes that diversion of food products (or production resources) to biofuels grows from current levels to 15% by 2050
- Assumes no food wastage prior to 1920 ramping up to current estimates of food wastage of 30% and these are not reduced going forward.
- A Petacal is 10^{15} calories, an Exacal is 10^{18} calories.

WORLDWIDE LAND AREA



CHALLENGES

- Enhance the soil resource through soil health to increase water availability to the crop
- Increase the biological activity in the soil to increase organic matter cycling and nutrient cycling through a stable microclimate at the soil surface
- Protect the soil against the extremes in climate