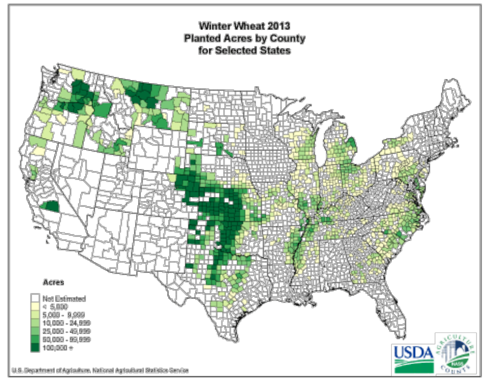
Climate Change and Agroclimatology

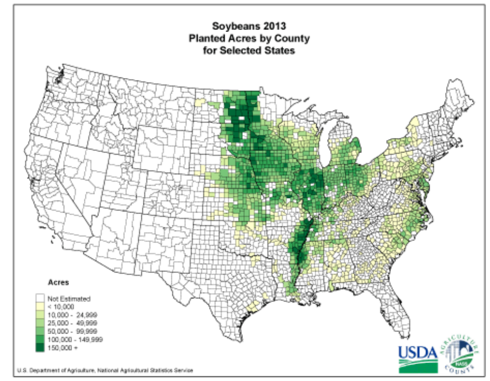
Implications for Our Food Security

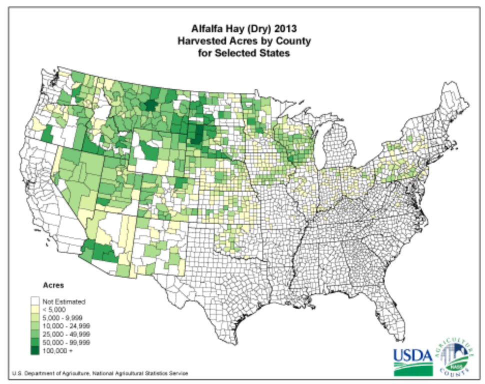
Definitions

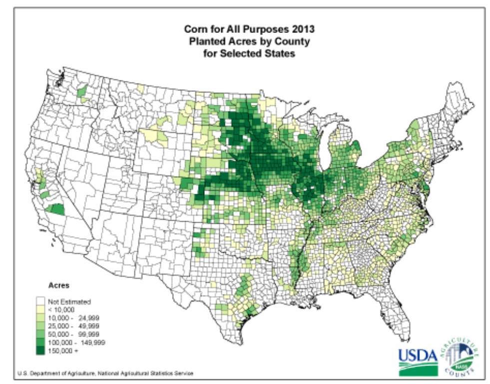
- Climate – determines where we grow a crop
- Weather – determines how much we produce of a crop
- Agroclimatology – matches crops to the climate for optimal productivity and quality

Crop Production in US





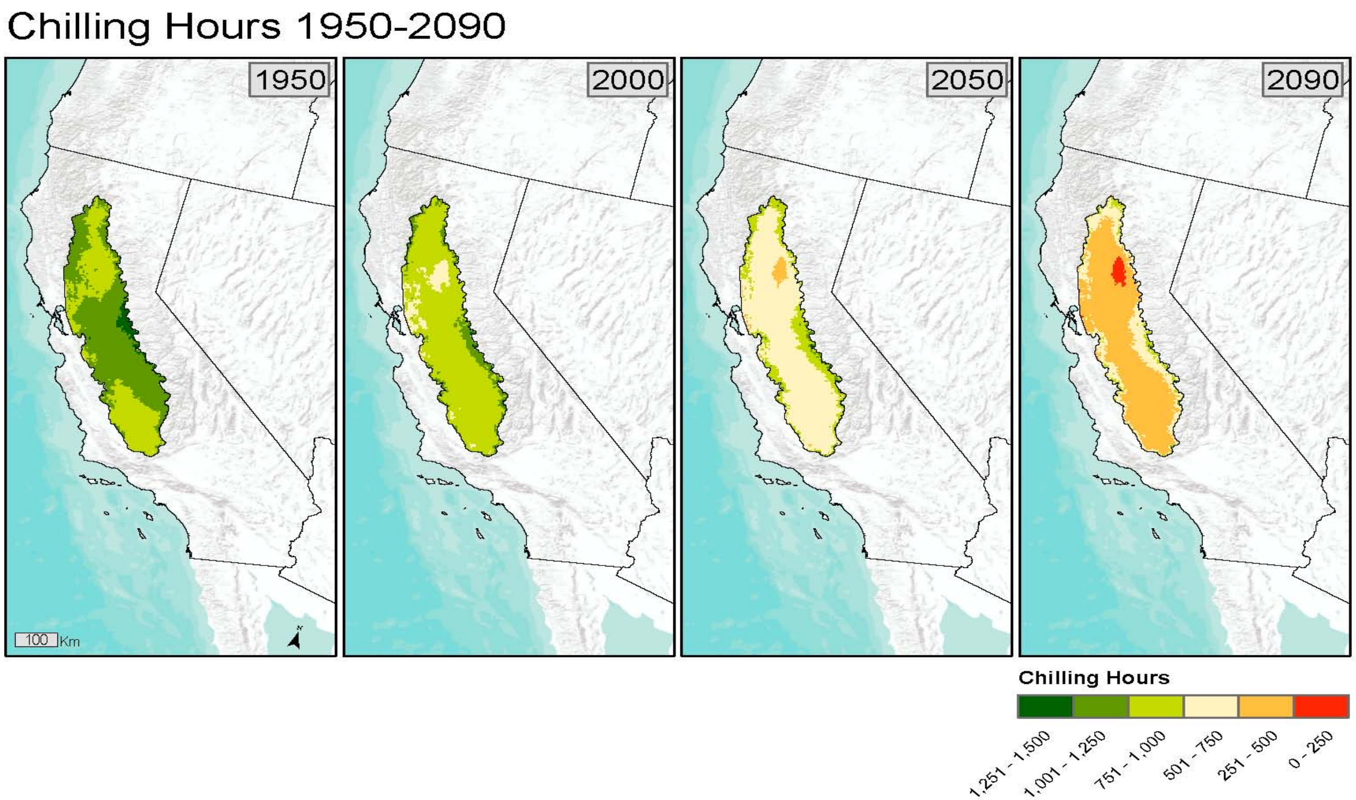




Examples

- Grapes, vineyards, and wine quality
- Coffee
- Cocoa
- Cherries

Chilling Hours

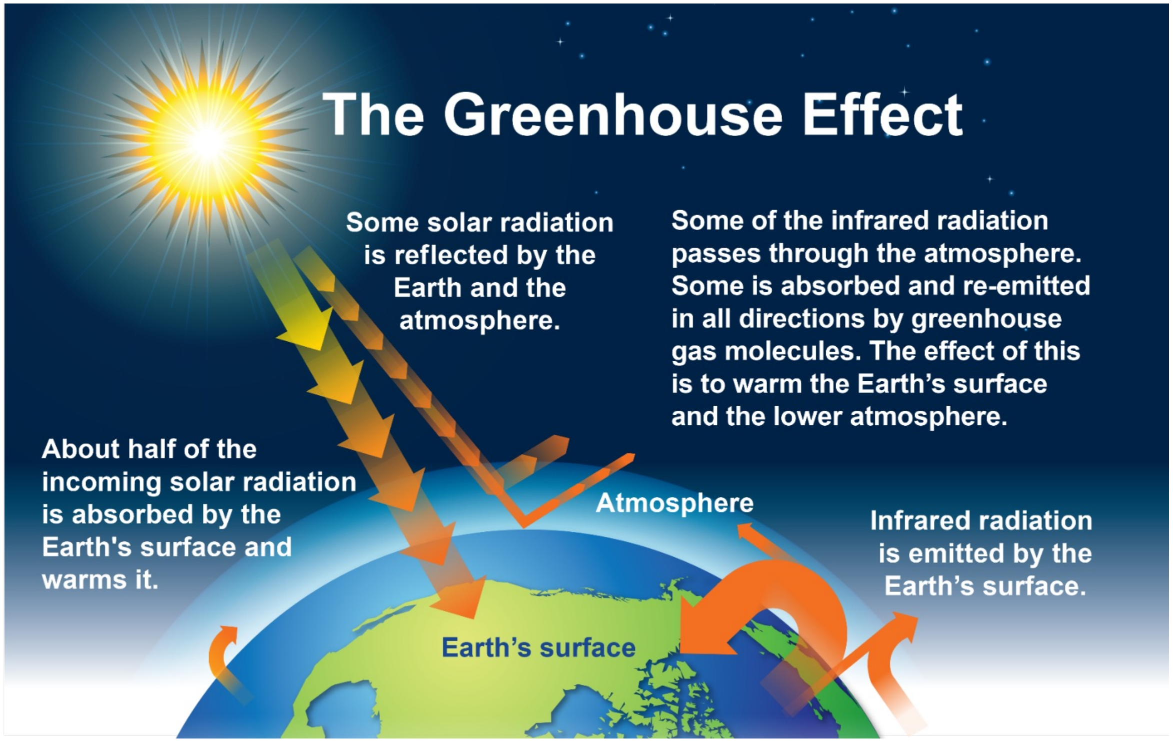


Our Changing Climate

Greenhouse Effect

- Greenhouse Gases
- Carbon Dioxide
- Methane
- Nitrous Oxide

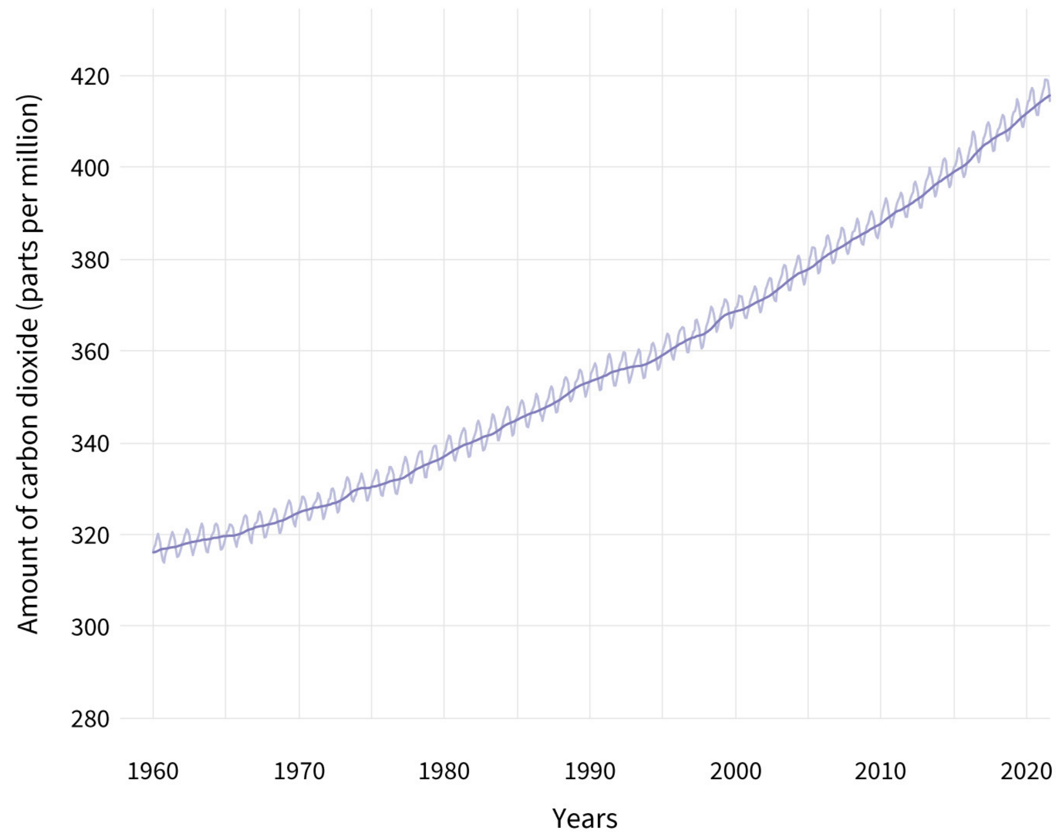
- Water vapor



Why the Concern

- Climate Change
- Increasing greenhouse gases in the atmosphere
- Potential role of agriculture as a mitigation strategy

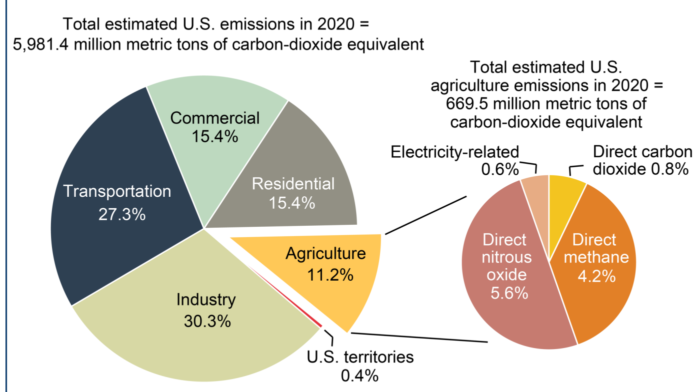
ATMOSPHERIC CARBON DIOXIDE (1960-2021)



Agriculture’s role in GHG emissions

- U.S. agriculture emitted an estimated 669.5 million metric tons of carbon-dioxide equivalent in 2020: 50.5 percent as nitrous oxide, 37.5 percent as methane, and 12.0 percent as carbon dioxide (EPA 2022).

Estimated U.S. greenhouse gas emissions by economic sector, 2020



Note: Carbon dioxide emissions associated with electricity consumption are allocated to each end-use sector in the left pie chart.
Source: USDA, Economic Research Service using data from U.S. Environmental Protection Agency, April 2022: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*, Table 2-12.

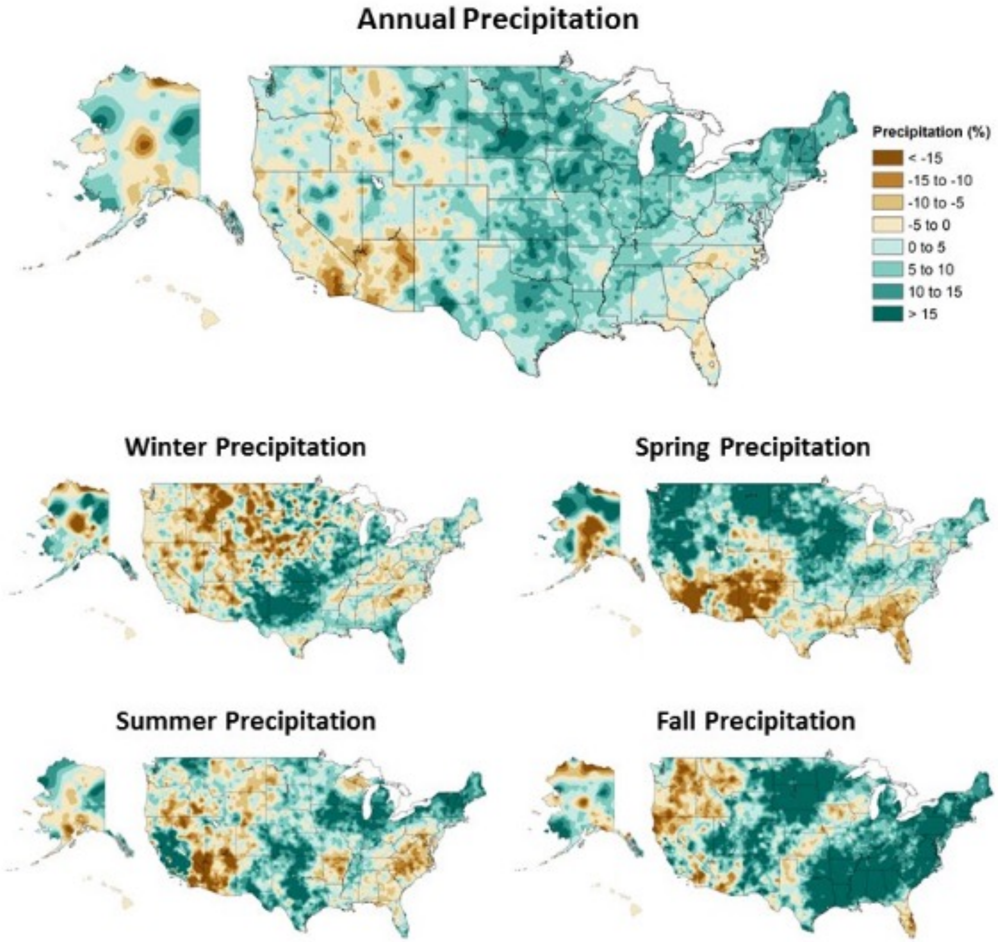
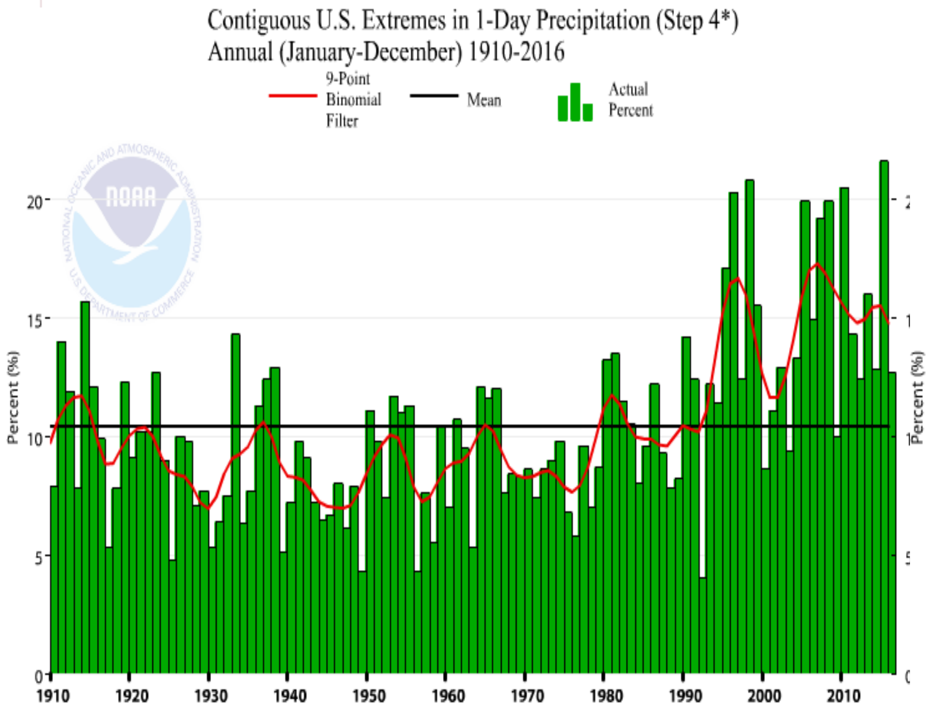
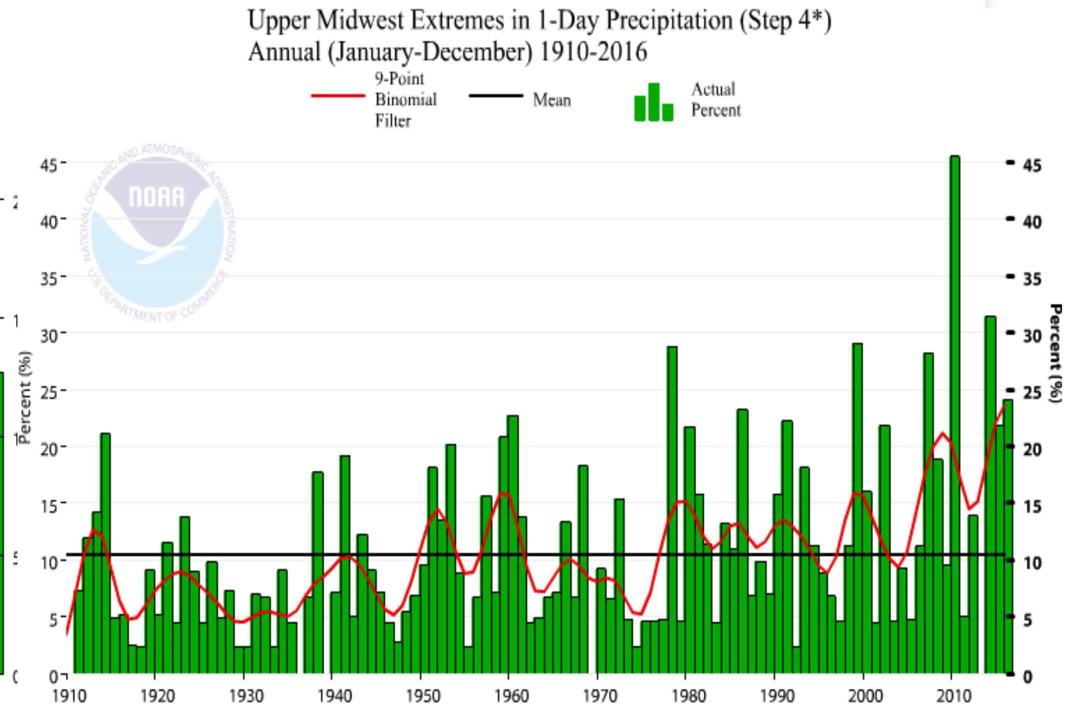
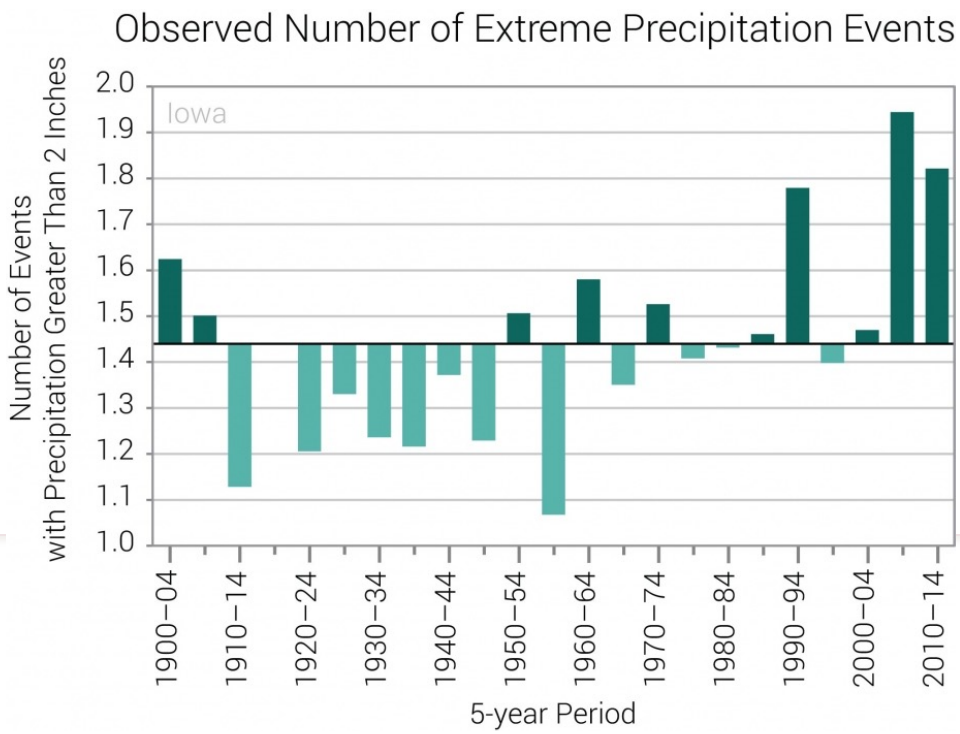


Figure 7.1: Annual and seasonal changes in precipitation over the United States. Changes are the average for present-day (1986–2015) minus the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i) divided by the average for the first half of the century. (Figure source: [top panel] adapted from Peterson et al. 2013,[78] © American Meteorological Society. Used with permission; [bottom four panels] NOAA NCEI, data source: nCLIMDiv].


Contiguous U.S. Extremes in 1-Day Precipitation (Step 4*)
Annual (January-December) 1910-2016
9-Point Binomial Filter
Mean
Actual Percent
Percent (%)

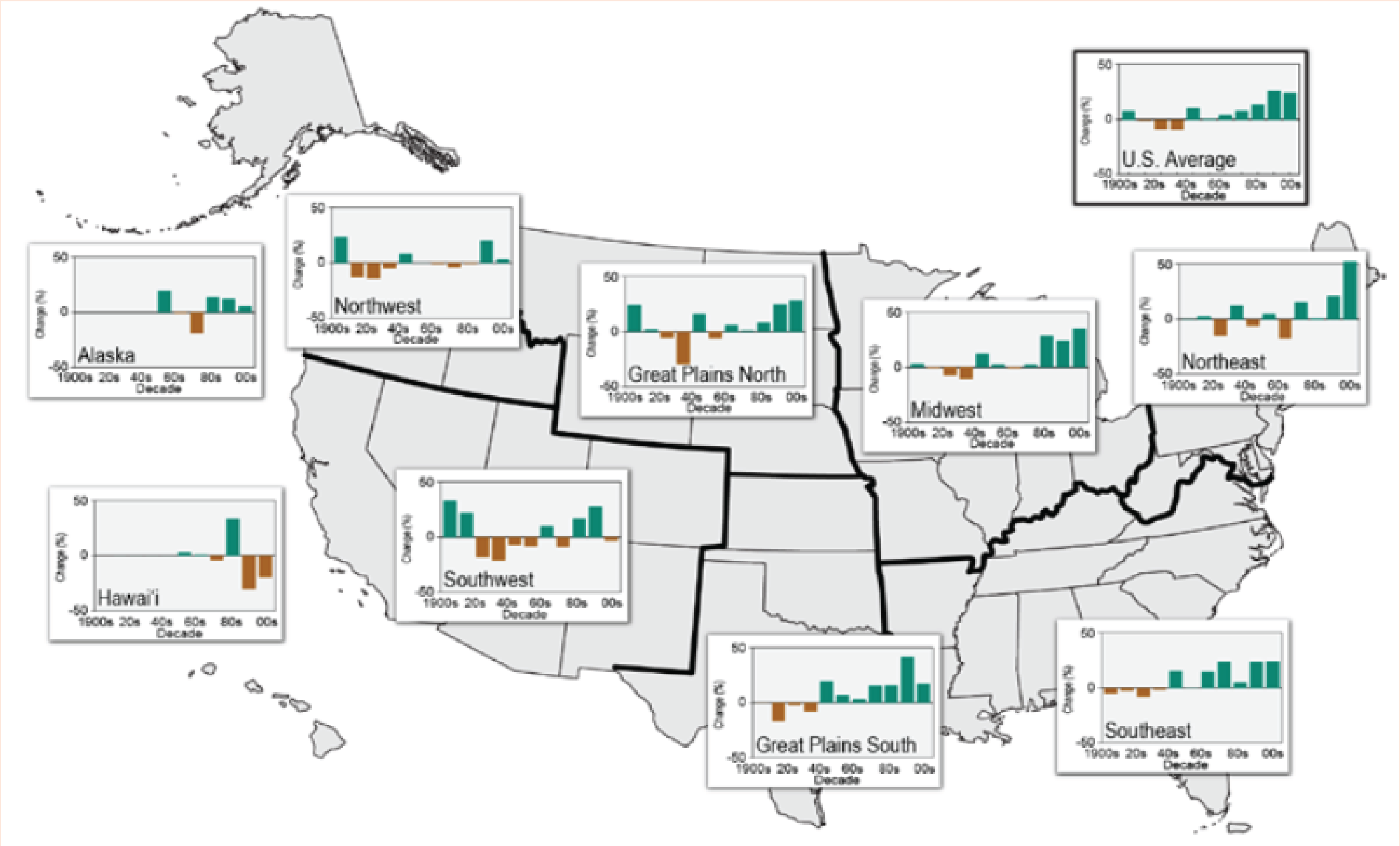

Upper Midwest Extremes in 1-Day Precipitation (Step 4*)
Annual (January-December) 1910-2016
9-Point Binomial Filter
Mean
Actual Percent
Percent (%)

Extreme precipitation – Iowa

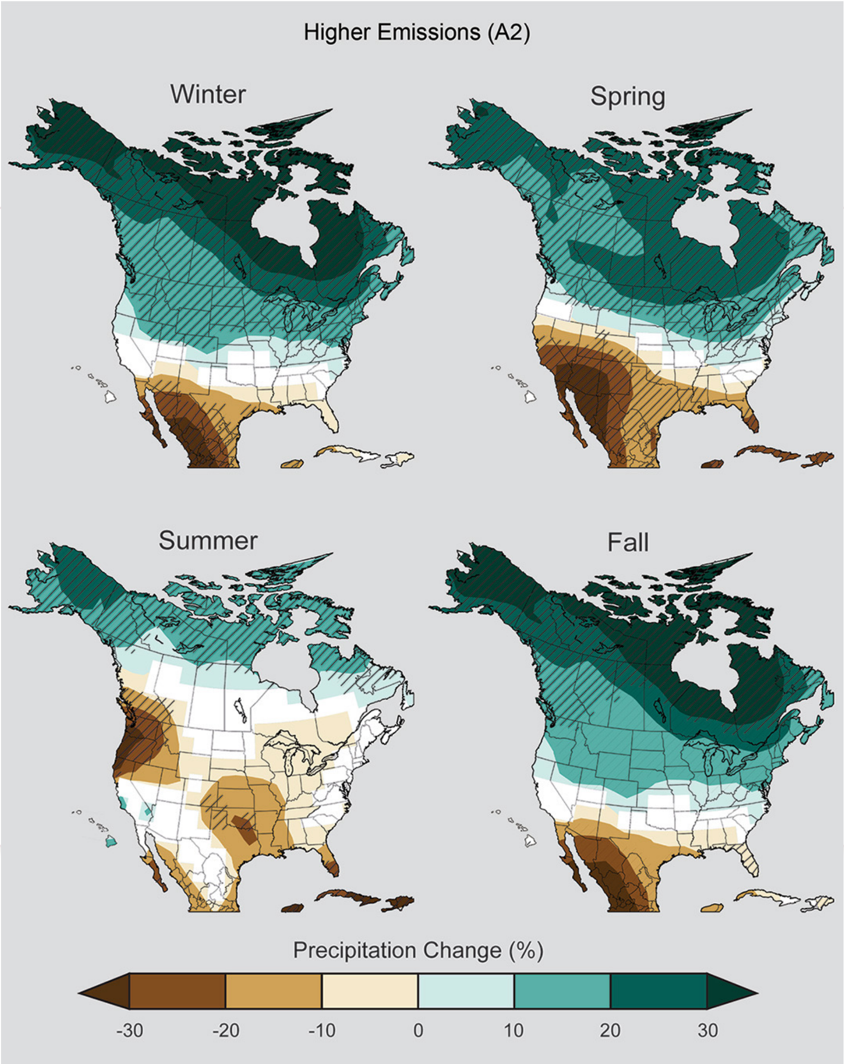


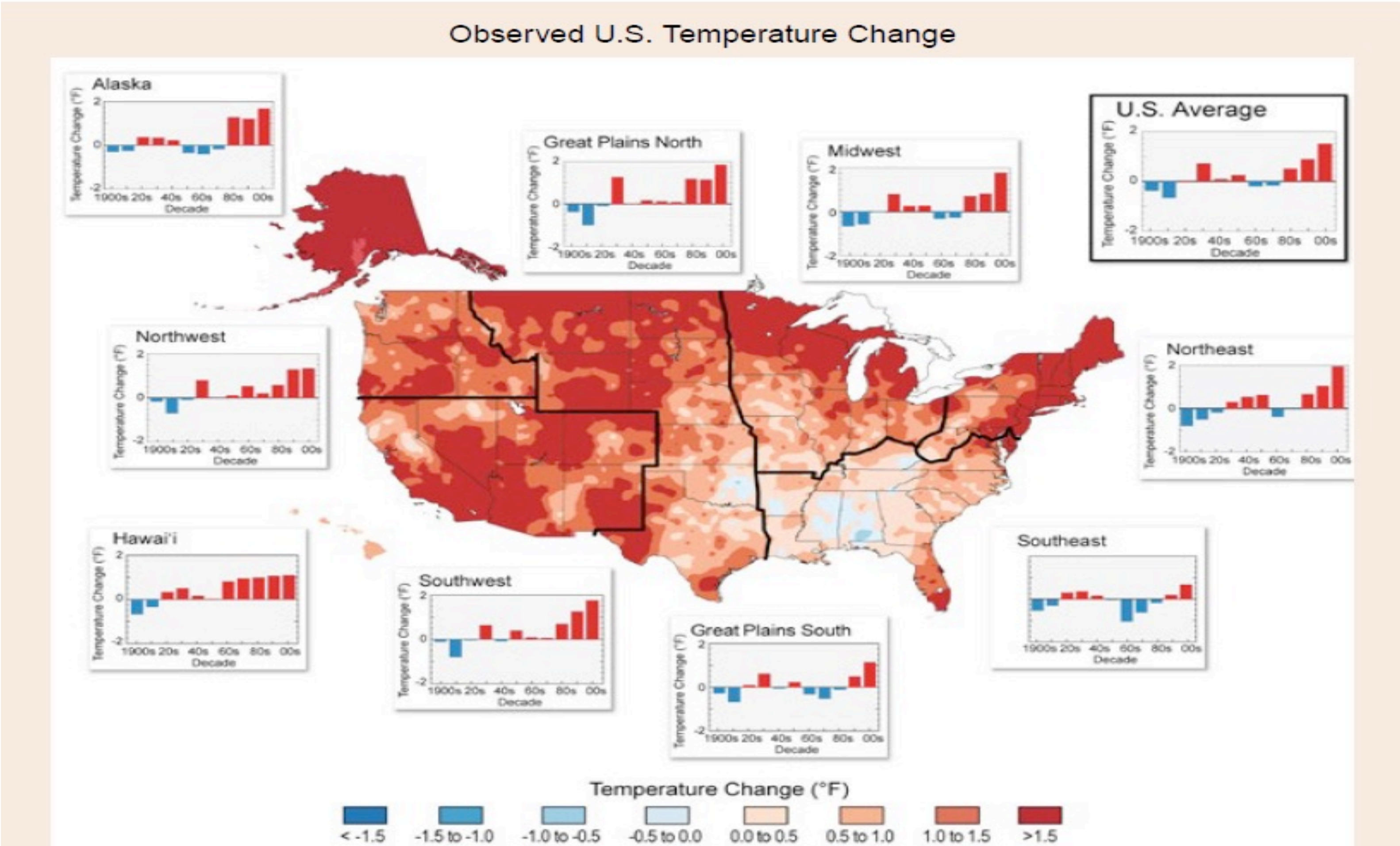
https://statesummaries.ncics.org/ia

Observed Change in Very Heavy Precipitation

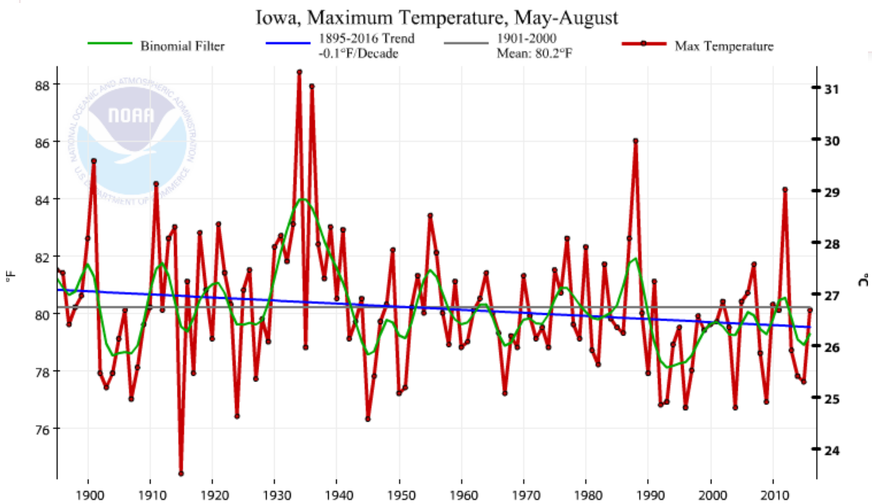


Projected Precipitation Change by Season

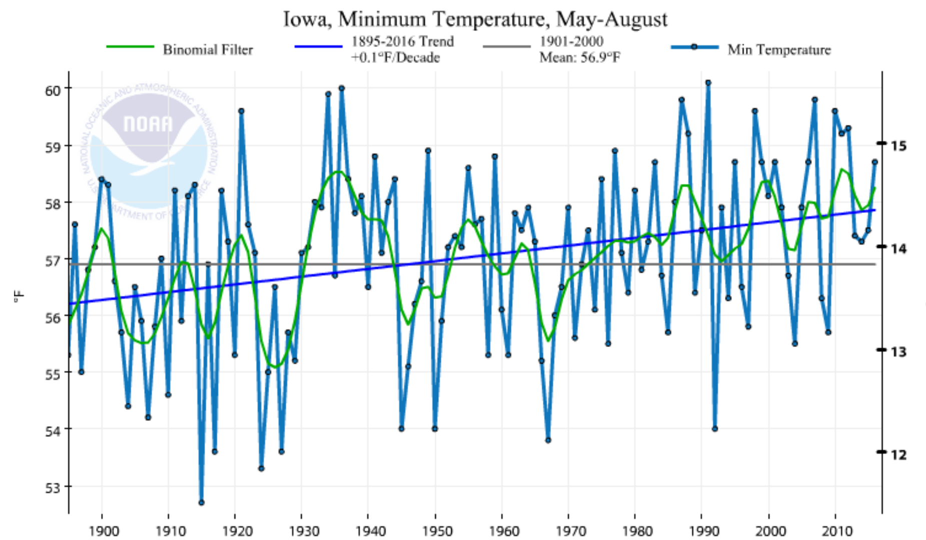



Observed U.S. Temperature Change
Alaska
Great Plains North
Midwest
U.S. Average
Northwest
Northeast
Hawai'i
Southwest
Southeast
Great Plains South
Temperature Change (°F)
Decade
1900s 20s 40s 60s 80s 00s
Temperature Change (°F)
< -1.5
-1.5 to -1.0
-1.0 to -0.5
-0.5 to 0.0
0.0 to 0.5
0.5 to 1.0
1.0 to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

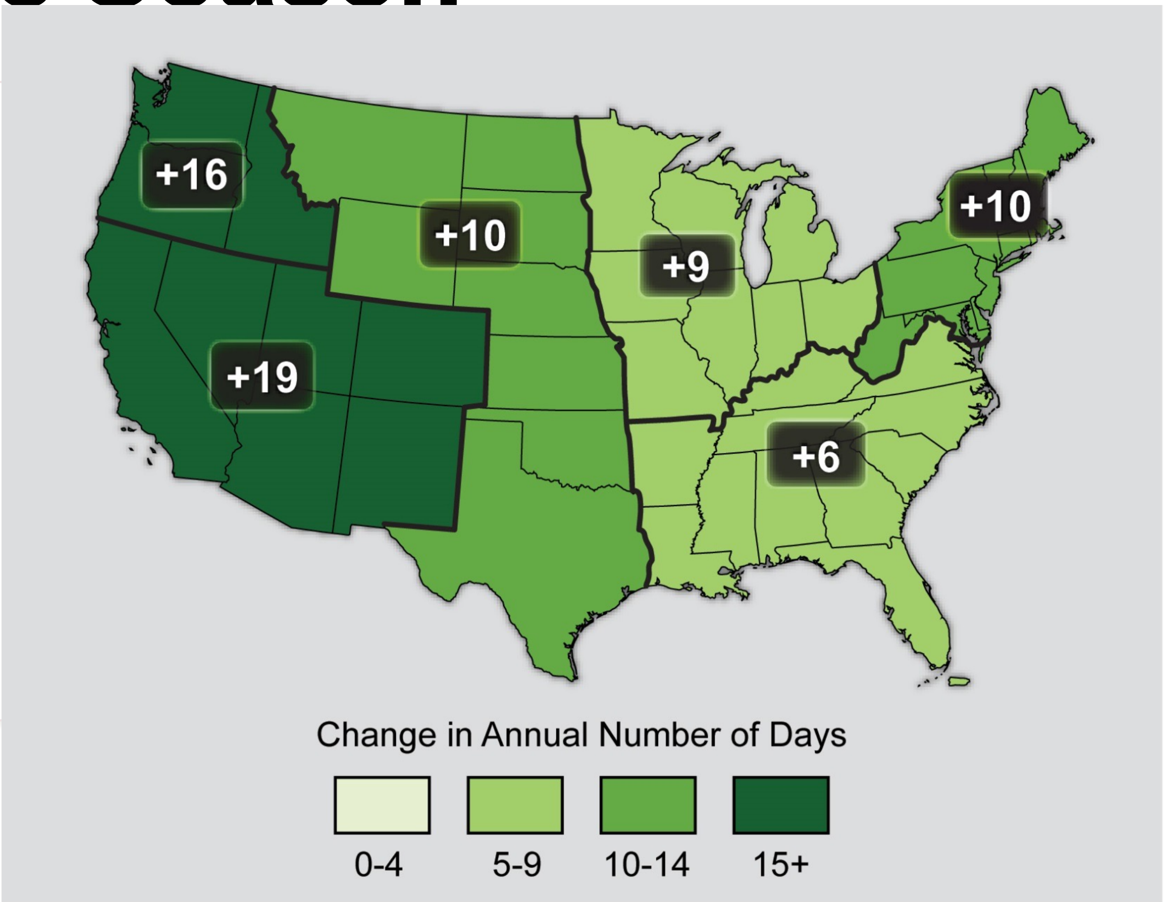
Iowa Temperature Patterns



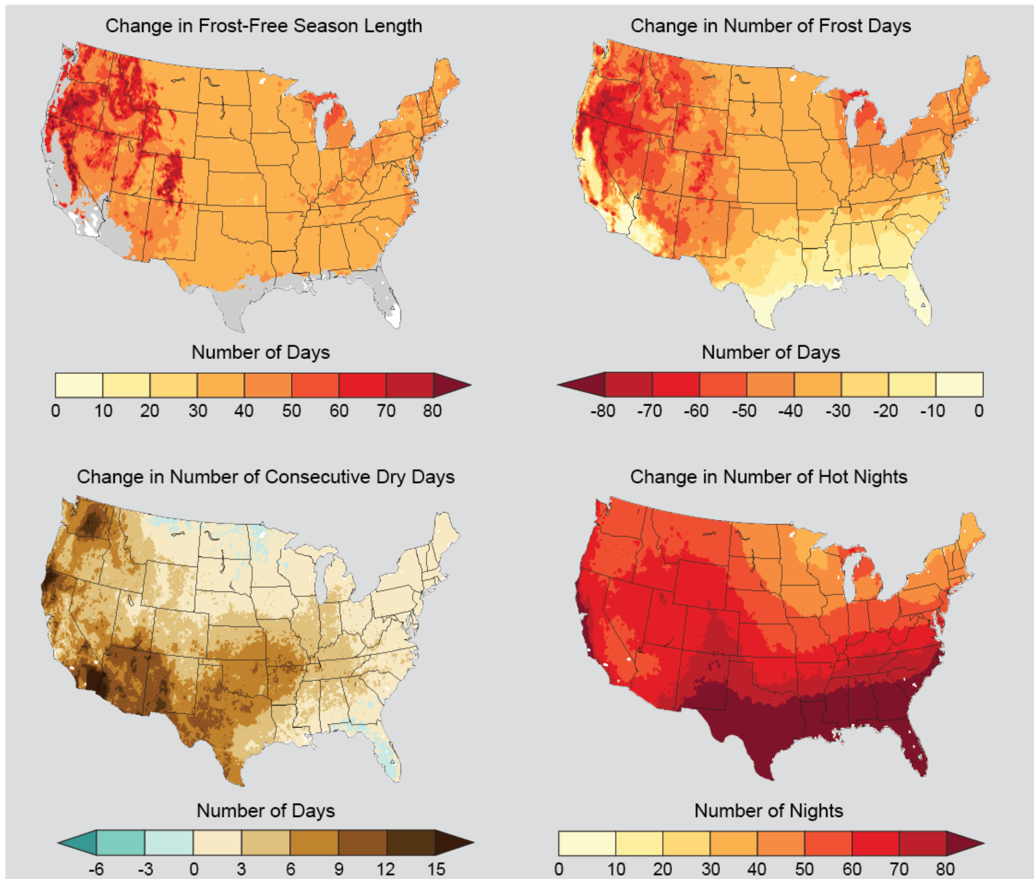
https://www.ncdc.noaa.gov/cag



Observed Increases in Frost-Free Season

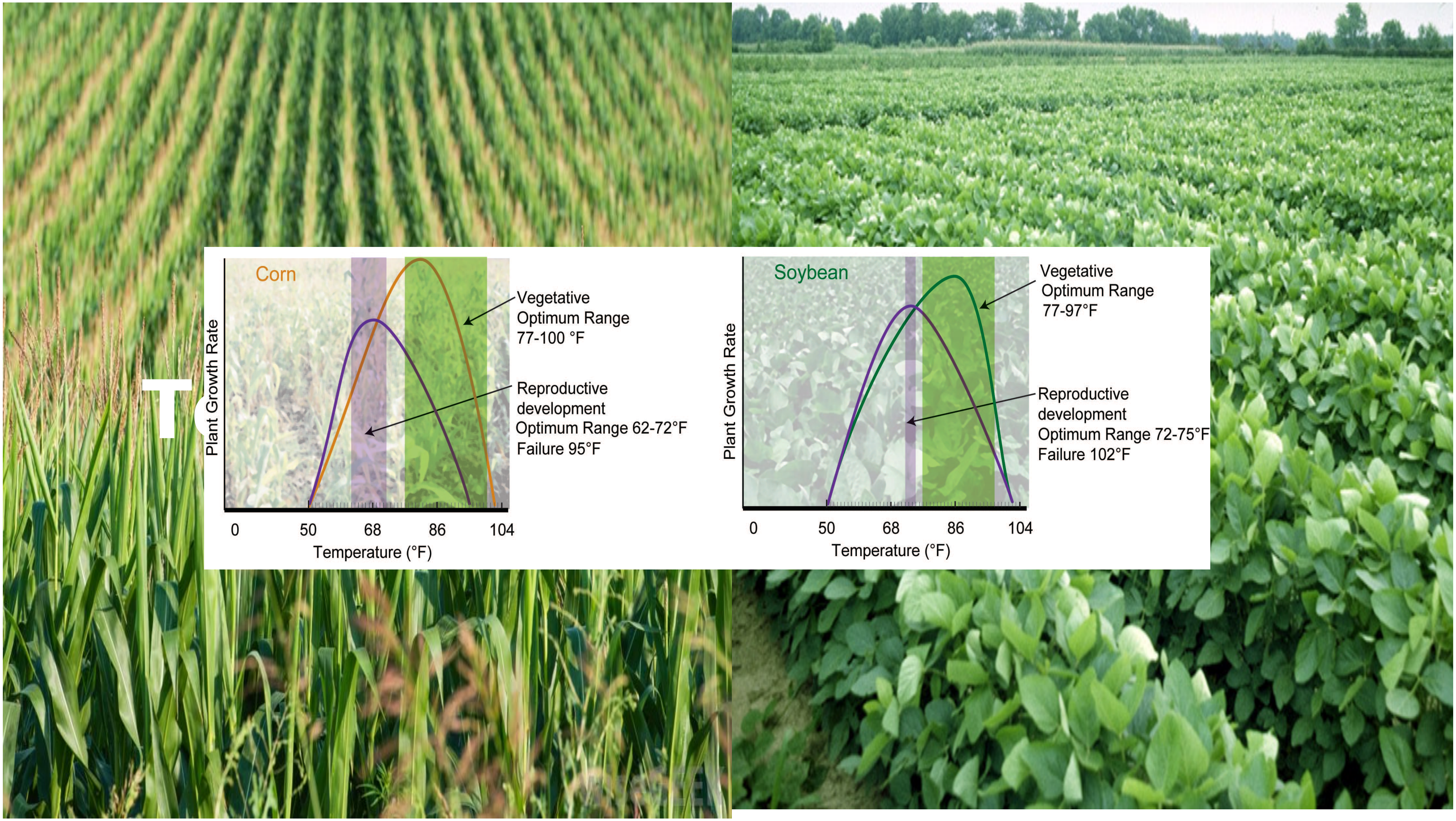


Projected changes in key climate variables affecting agricultural productivity



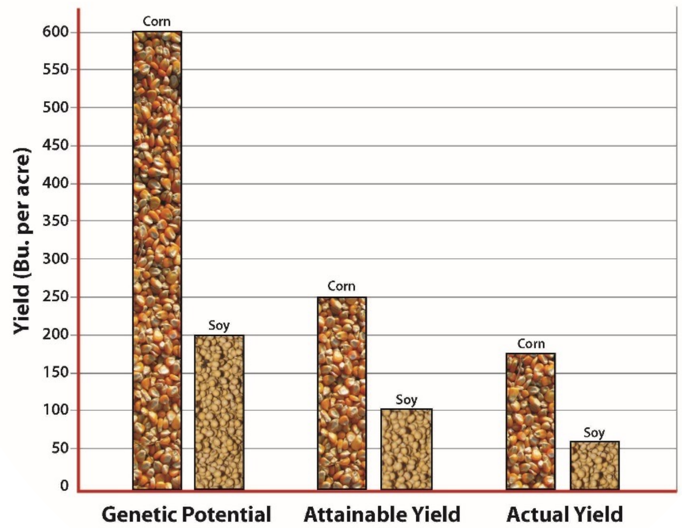
National Climate Assessment

Impacts on Crops


Corn
Plant Growth Rate
Vegetative
Optimum Range
77-100 °F
Reproductive
development
Optimum Range 62-72°F
Failure 95°F
0
50
68
86
104
Temperature (°F)
Soybean
Plant Growth Rate
Vegetative
Optimum Range
77-97°F
Reproductive
development
Optimum Range 72-75°F
Failure 102°F
0
50
68
86
104
Temperature (°F)

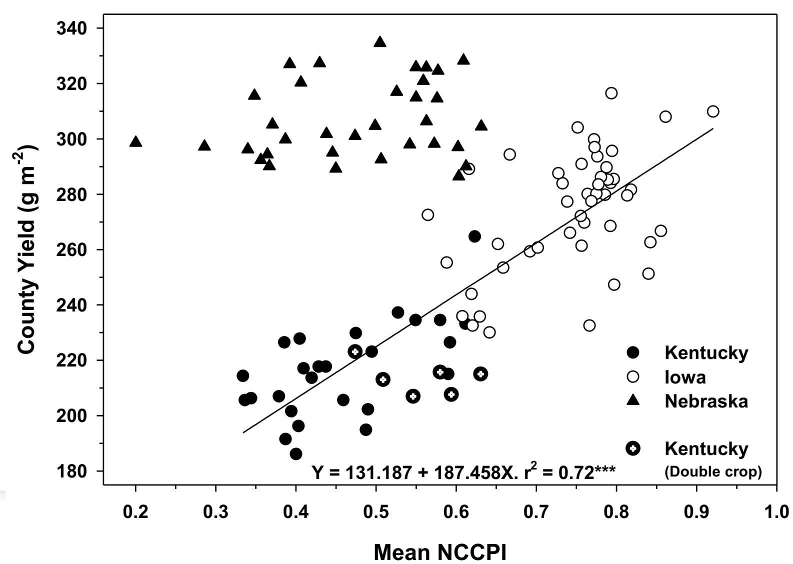
Definitions

- Actual Yield- what the producer obtains
- Attainable yield – highest county level yield for a given year
- Potential yield – maximum yield under all optimum conditions
- Yield gap – (Attainable – Actual Yield) or (Potential – Actual)



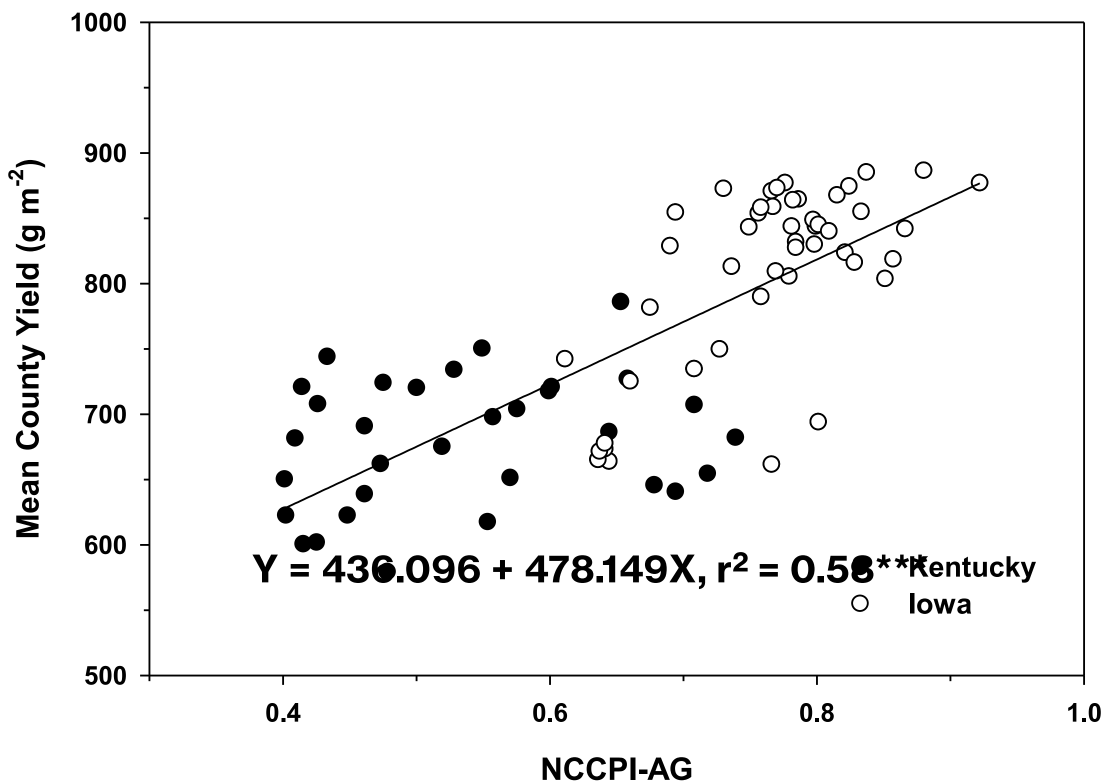
Good Soils = Good Yields

Soybean yields across Iowa, Kentucky, and Nebraska

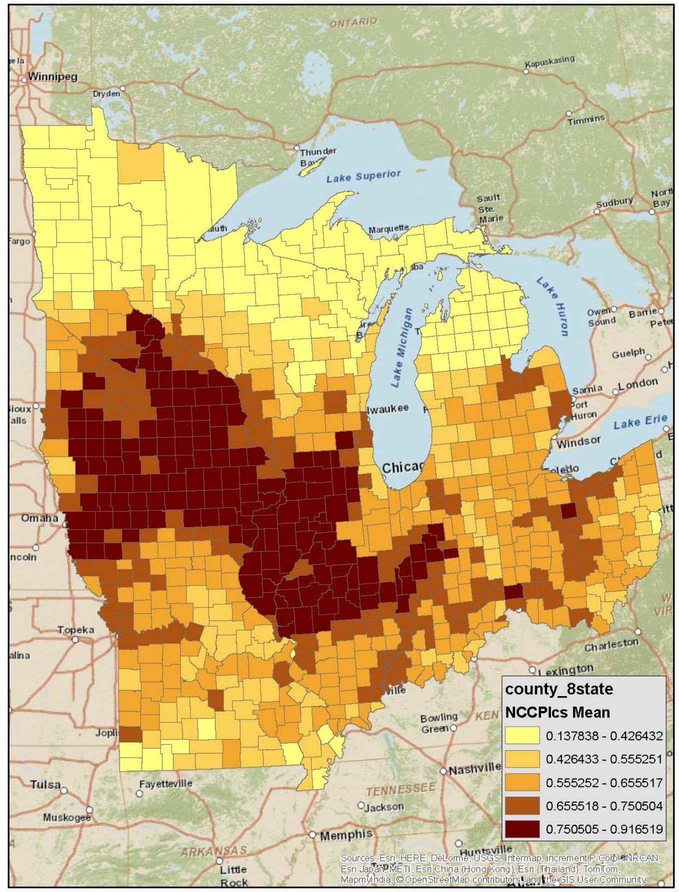


Climate resilience is derived from good soils in rainfed agricultural systems

Maize County Yields



Variation in NCCPI across the Midwest



Major Limitations to Yield

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

Analysis of Yield Gaps

Corn and Soybean

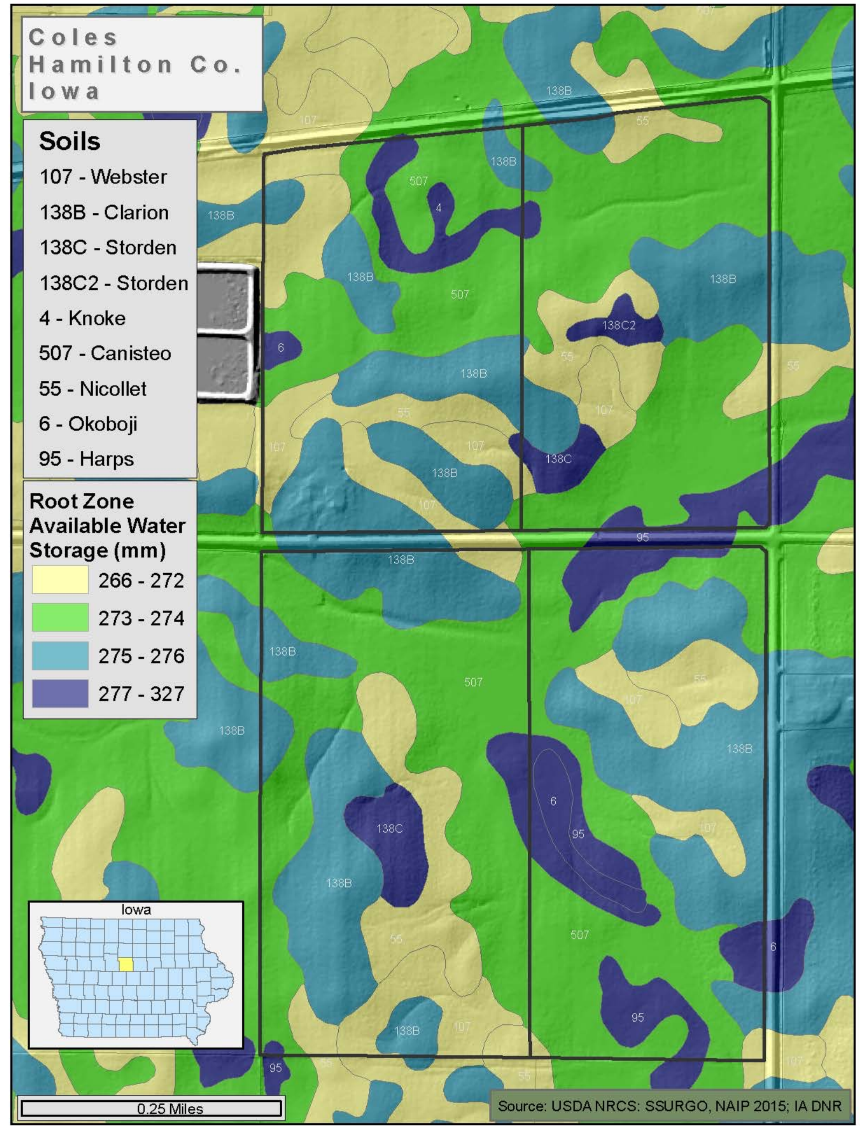
- Maximum July Temperatures
- Minimum August Temperatures
- July –August Rainfall

Winter Wheat

- Rainfall during Grain-fill

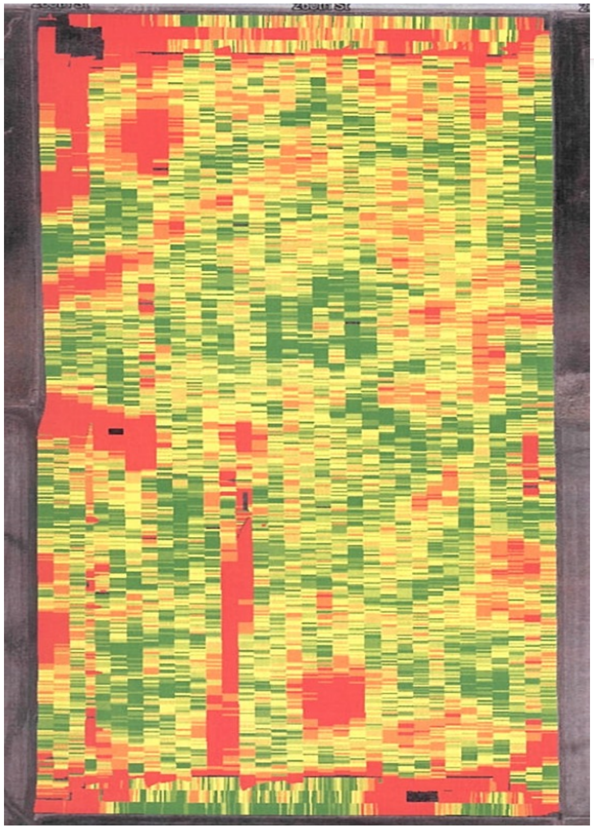
Rainfall during the growing season is the primary determinant of grain yield of crops.

Variation in available soil water drives yield variation in a field

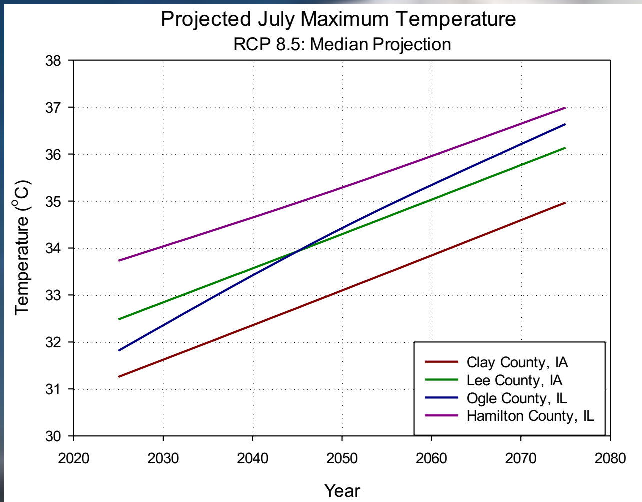


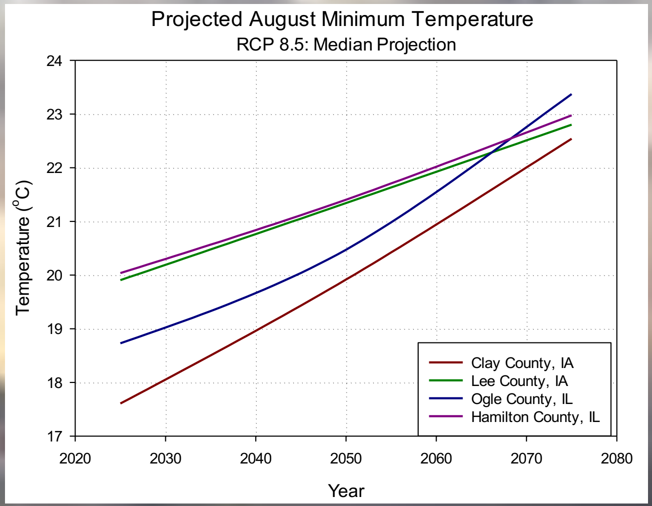
Yield Variation

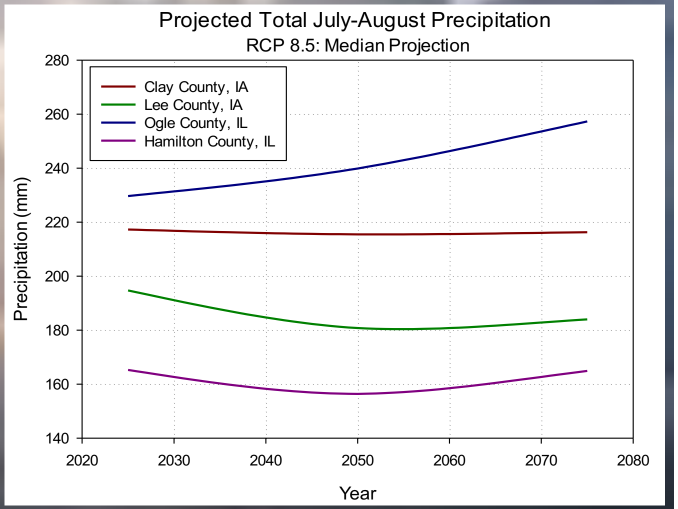
- Patterns within fields are directly related to soil water dynamics of the field



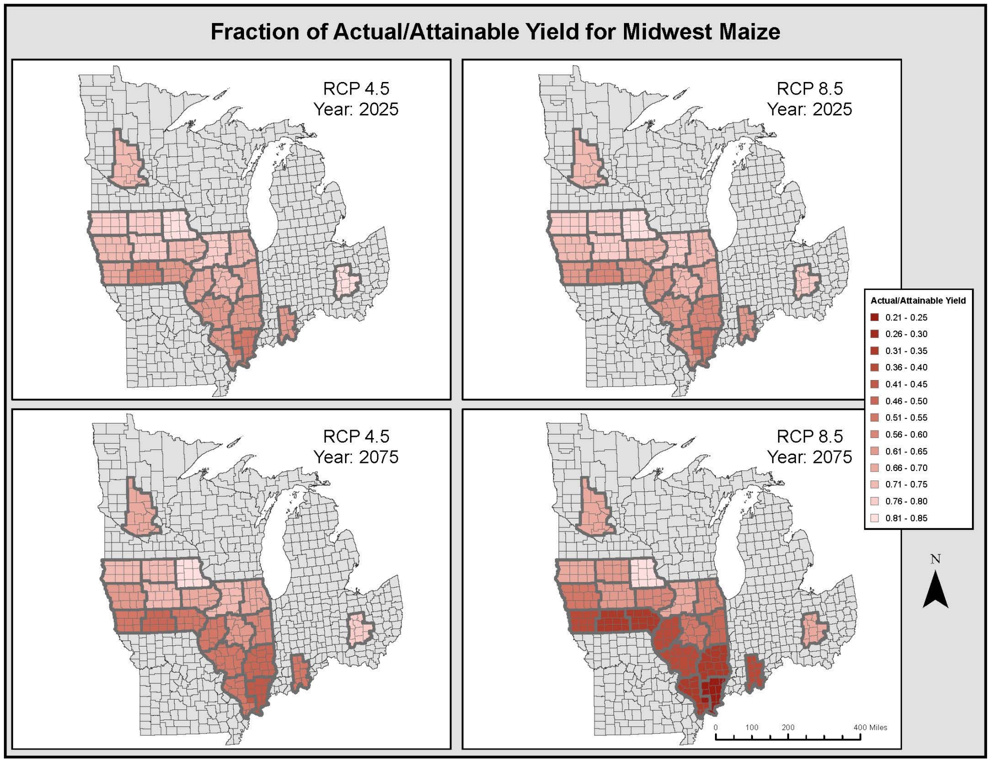
Projected Climate Change with Climate Models

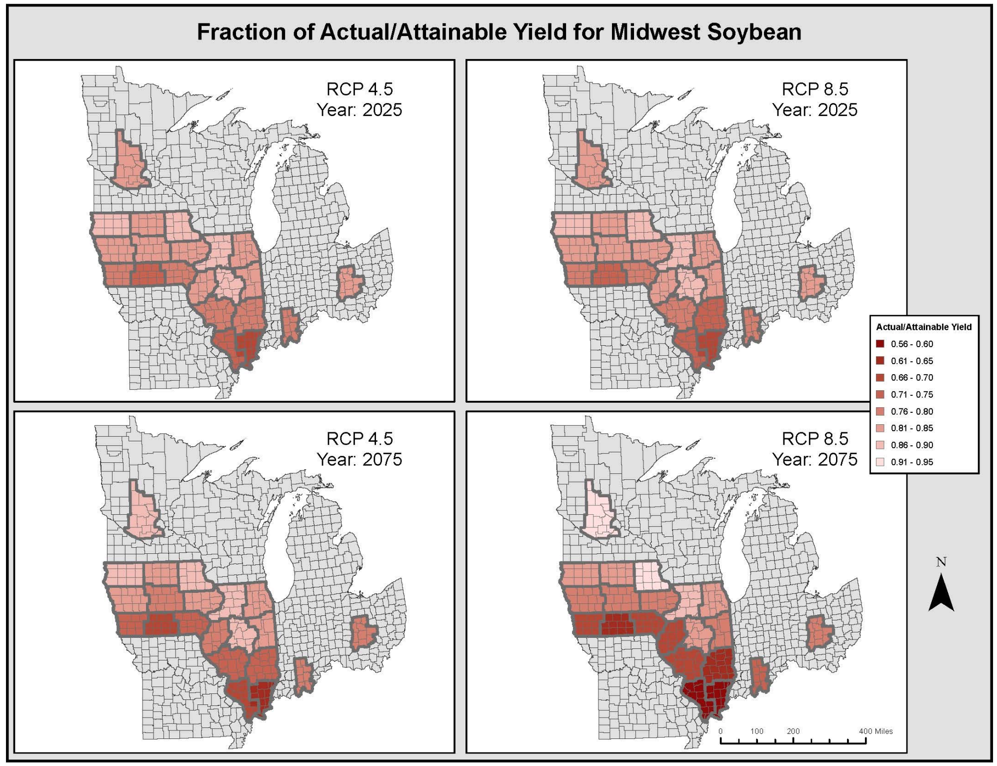






Climate Impacts on Future Yields





Increases of atmospheric carbon dioxide (CO_2), rising temperatures, and altered precipitation patterns will affect agricultural productivity.

- Corn: high nighttime temperatures, high temperatures during pollination, water stress
- Soybean: water stress, high temperatures
- Wheat and small grains: extreme events, frost during flowering, water stress
- Rice: temperature extremes during pollination, water management
- Cotton: high temperatures during boll fill
- Pasture and rangeland: water stress
- Fruit trees: chilling requirements not met, high temperatures during fruit development
- Specialty crops: water stress, high temperatures

Climate Change and Agricultural Pests

1) Expanding geographic ranges northward

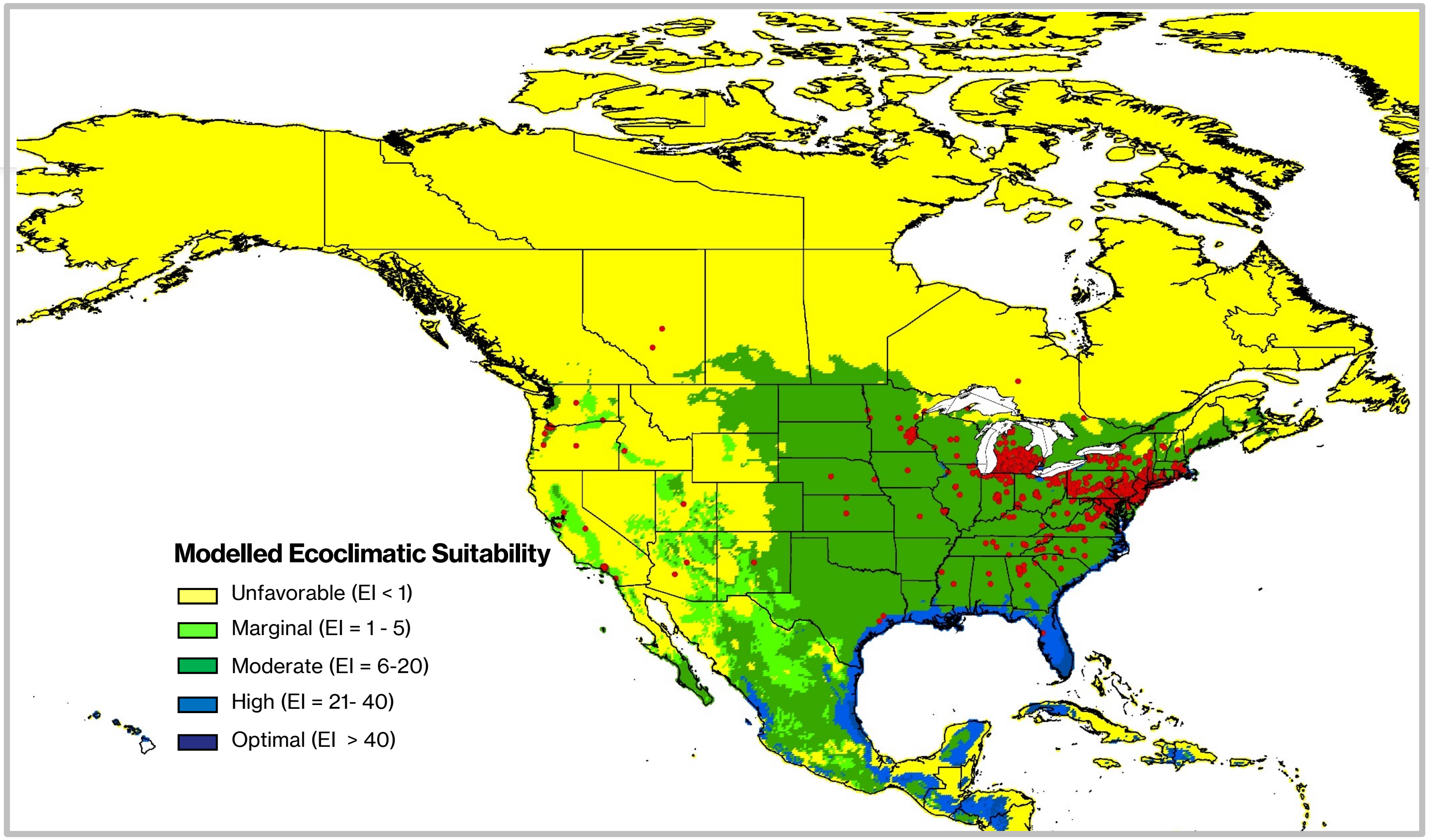
2) Reducing winter die offs

3) Shifts in phenology (Earlier Spring Emergence)

4) Increased generations per year

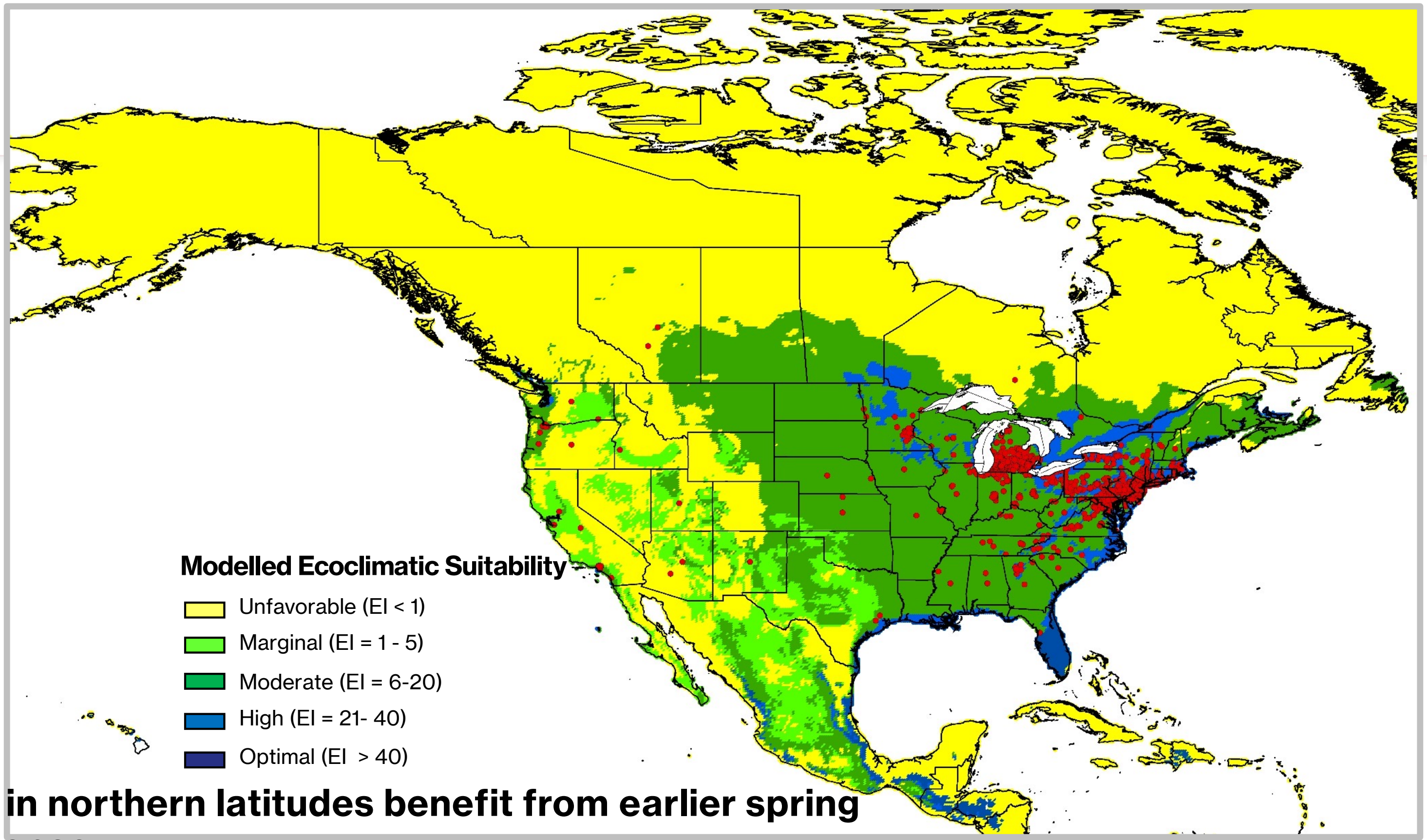
- **Invasive insects are of particular concern since they often limited more by climate in their non-native ranges (no natural enemies and abundant food)**

BMSB's North America Distribution
Present Time



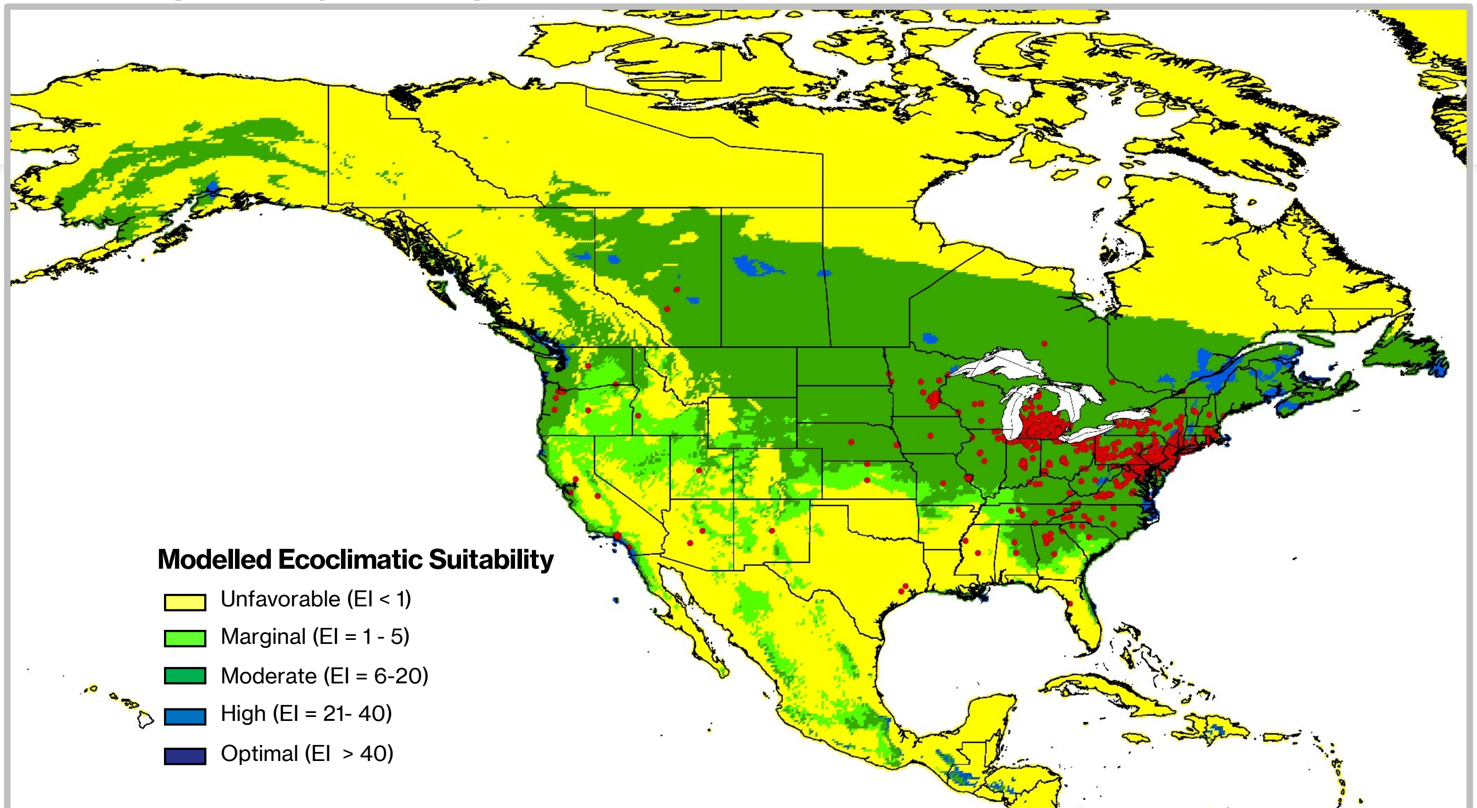
- **Predicted distribution has 94% match with known distribution**

BMSB's North America Distribution 2050 SRES A2 Scenario



- **BMSB in northern latitudes benefit from earlier spring emergence**
- **Two generations per year in eastern WA, Southern MI, and WV**

BMSB's North America Distribution 2100 SRES A2 Scenario



- **Southern latitudes no longer meet BMSB's winter diapause temperature requirements**
- **Two generations per year in Mid-Atlantic, Midwest, and Pacific Northwest regions**

IMPLICATIONS

Increasing variation in climate and weather will place a strain on our ability to efficiently produce crops.

Built a concept of G (genetics) x E (environment) x M (management) to help produce identify and implement adaptation strategies to increase climate resilience

Changing climate and weather will also affect insects, diseases, and weed requiring innovative pest management strategies

We have opportunities to agriculture to adapt to climate change and also provide mitigation strategies

Contact

Jerry L. Hatfield

Retired USDA-ARS Plant Physiologist/Laboratory Director

jerryhatfield67@gmail.com

515-509-5331