Building Resiliency For Tomorrow's Climate

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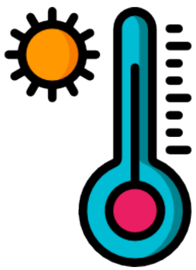
Purdue Climate Change Research Center
DISCOVERY PARK

Dr. Jeff Dukes

Director
@DukesJeff

Weather Vs. Climate



Weather is what happens in a specific place, at a specific time

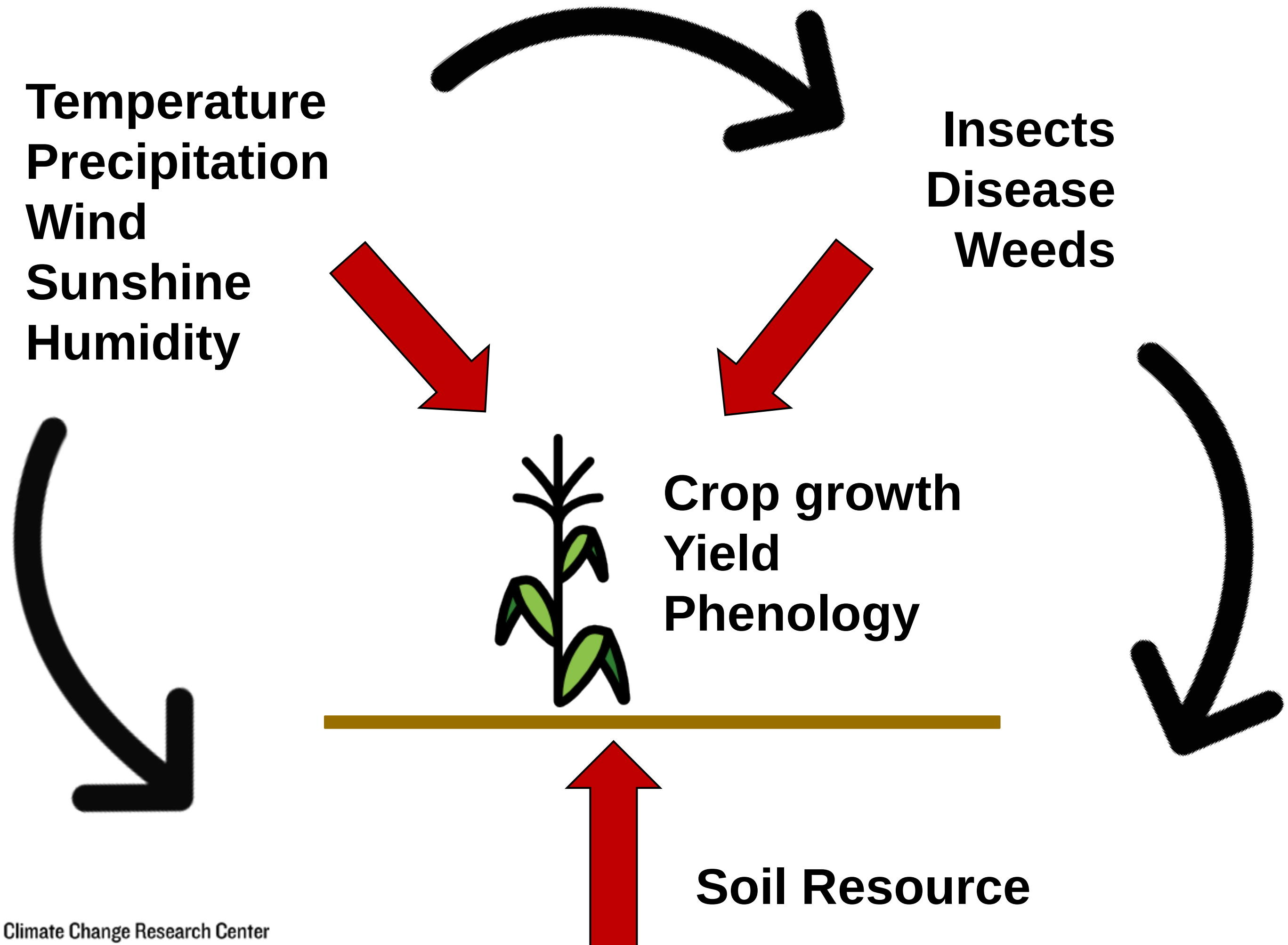
Climate is the long-term average of weather over many decades

Weather Vs. Climate

Climate determines where we can grow a crop

Weather determines how much we produce

Weather and Agriculture

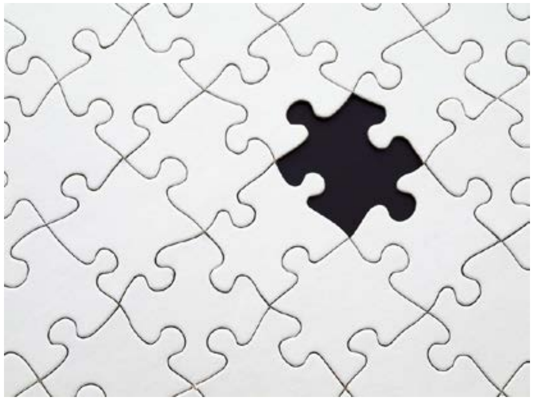


Weather and Agriculture

Climate determines where we can grow a crop

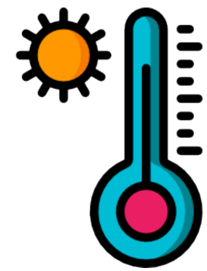
Weather determines how much we produce

We use our climate to help us plan for our weather!



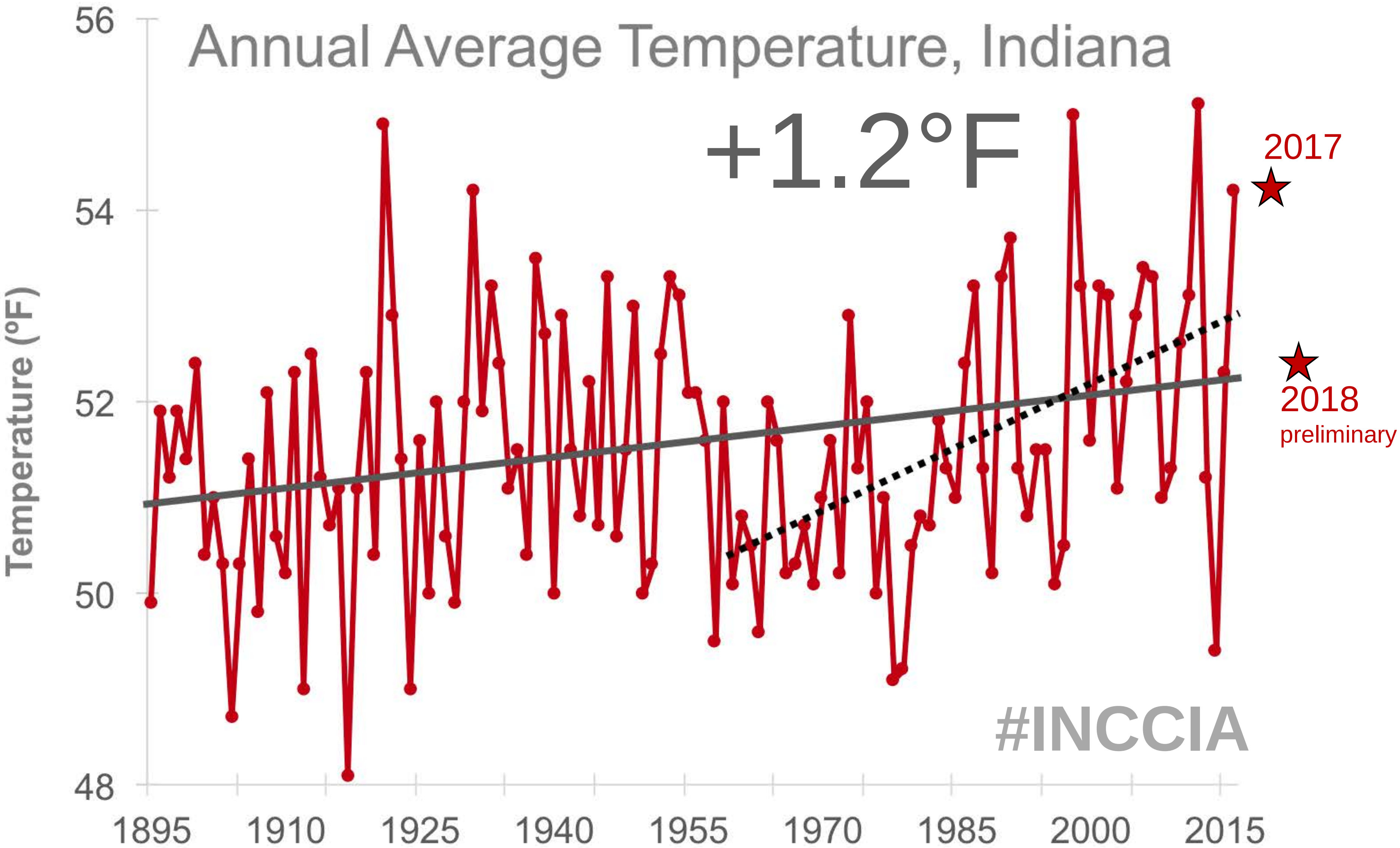
Climate and Agriculture

- Length of growing season
- Date of first freeze
- Heat extremes
- Variable winter temperatures
- Spring freeze/thaw cycles
- Spring wetness
- Heavy precipitation events
- Water availability during the growing season



Climate is what you expect

Indiana is getting warmer



Indiana is getting warmer

Annual temperature has increased 1.2°F over the last century.

- Longer frost-free season
- Fewer cold days
- Significantly warmer overnight temperatures

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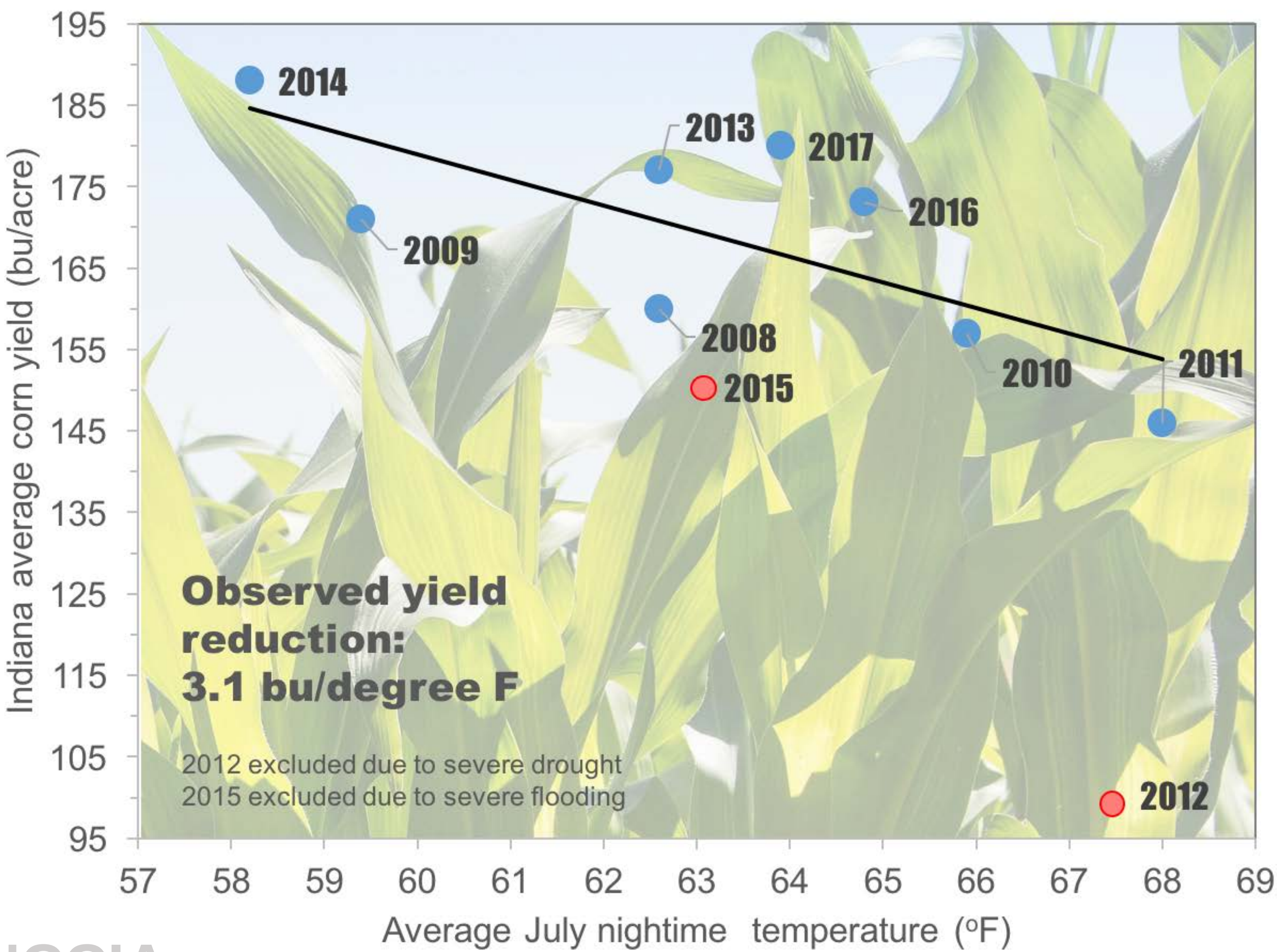
Warm July Nights = Lower Corn Yields



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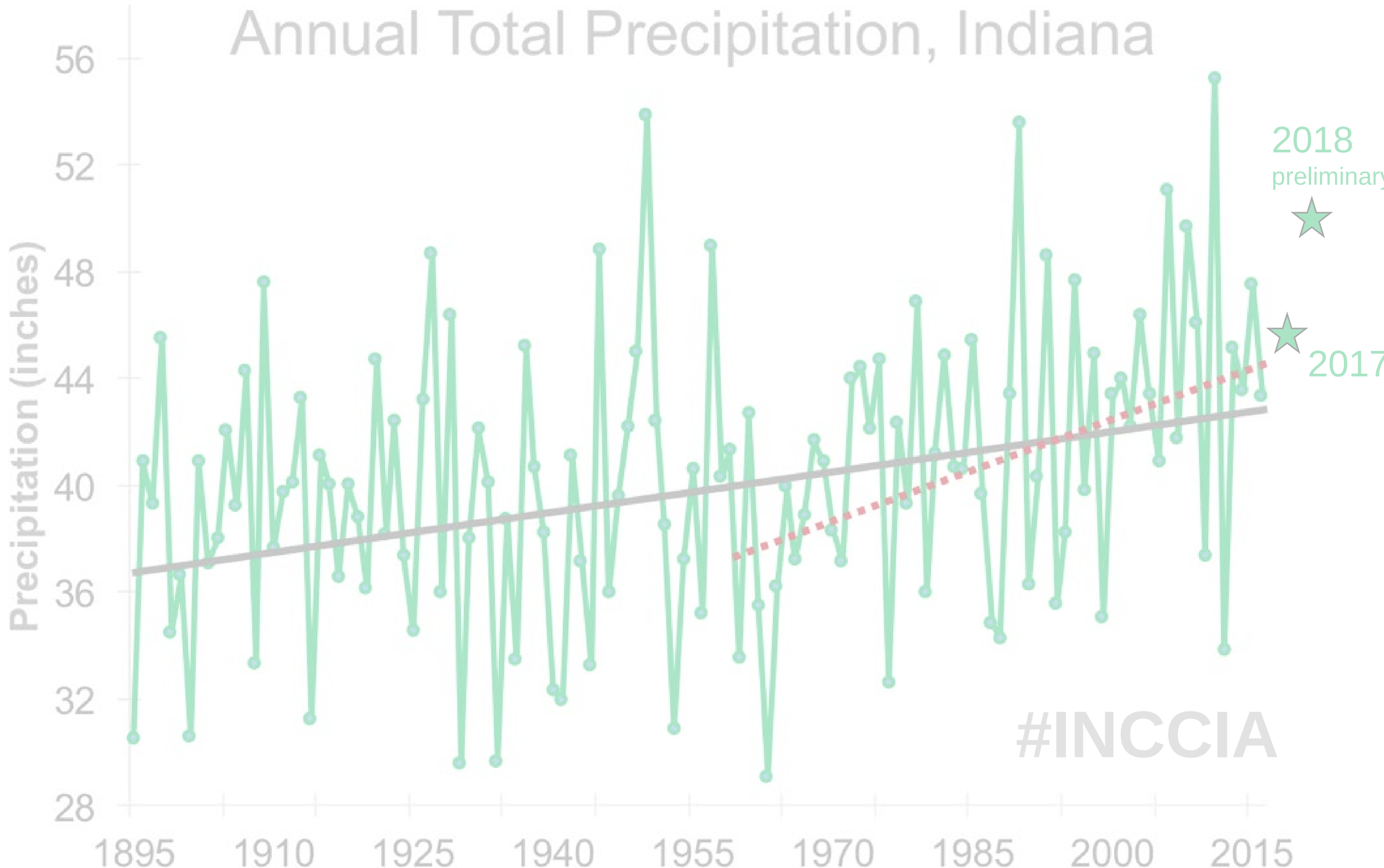
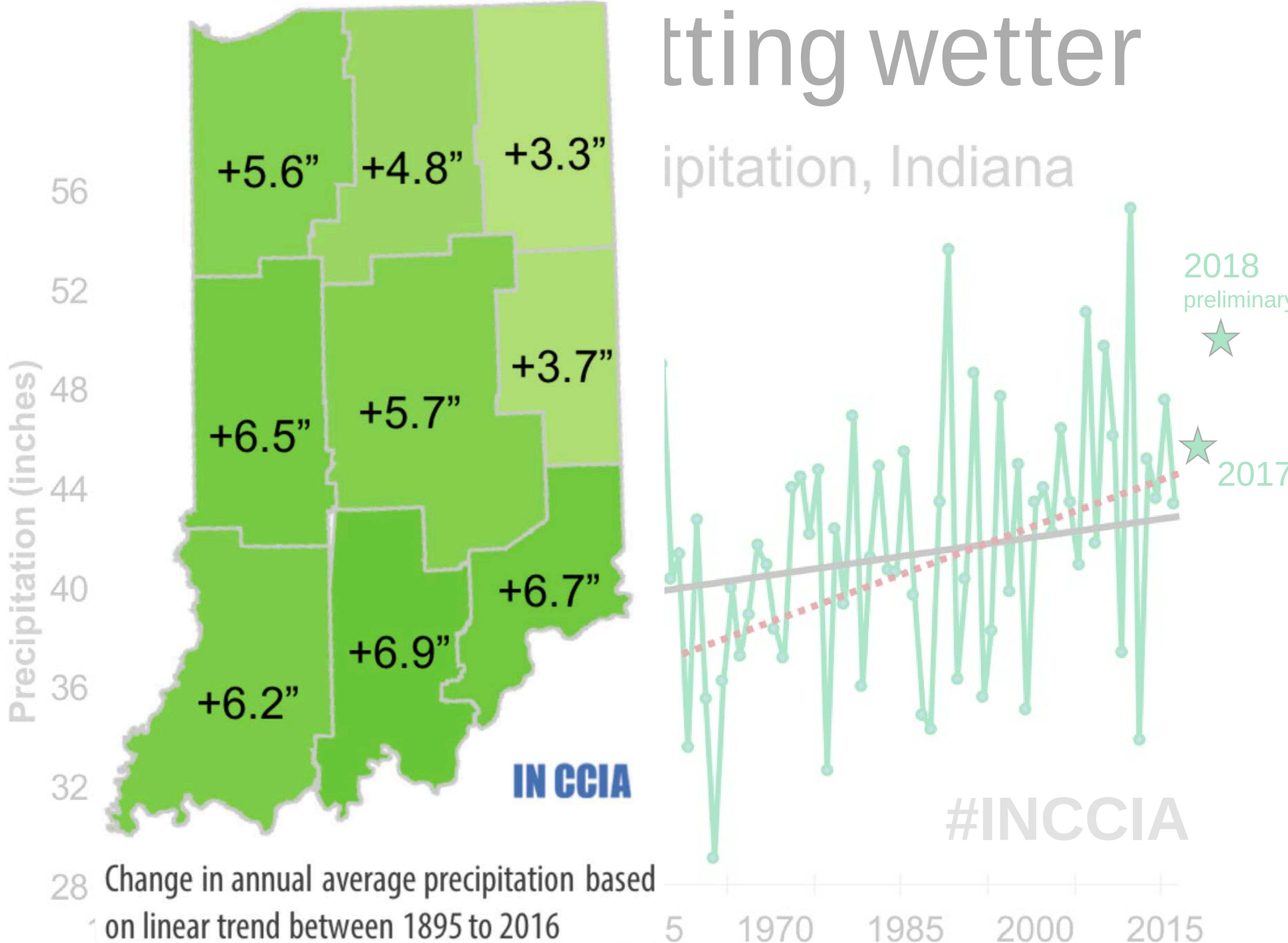
Indiana is getting wetter





Change in annual average precipitation based on linear trend between 1895 to 2016

Heavy rainfall is more intense & happening more often.

↑ 42%

In the amount of rain
falling in heavy downpours

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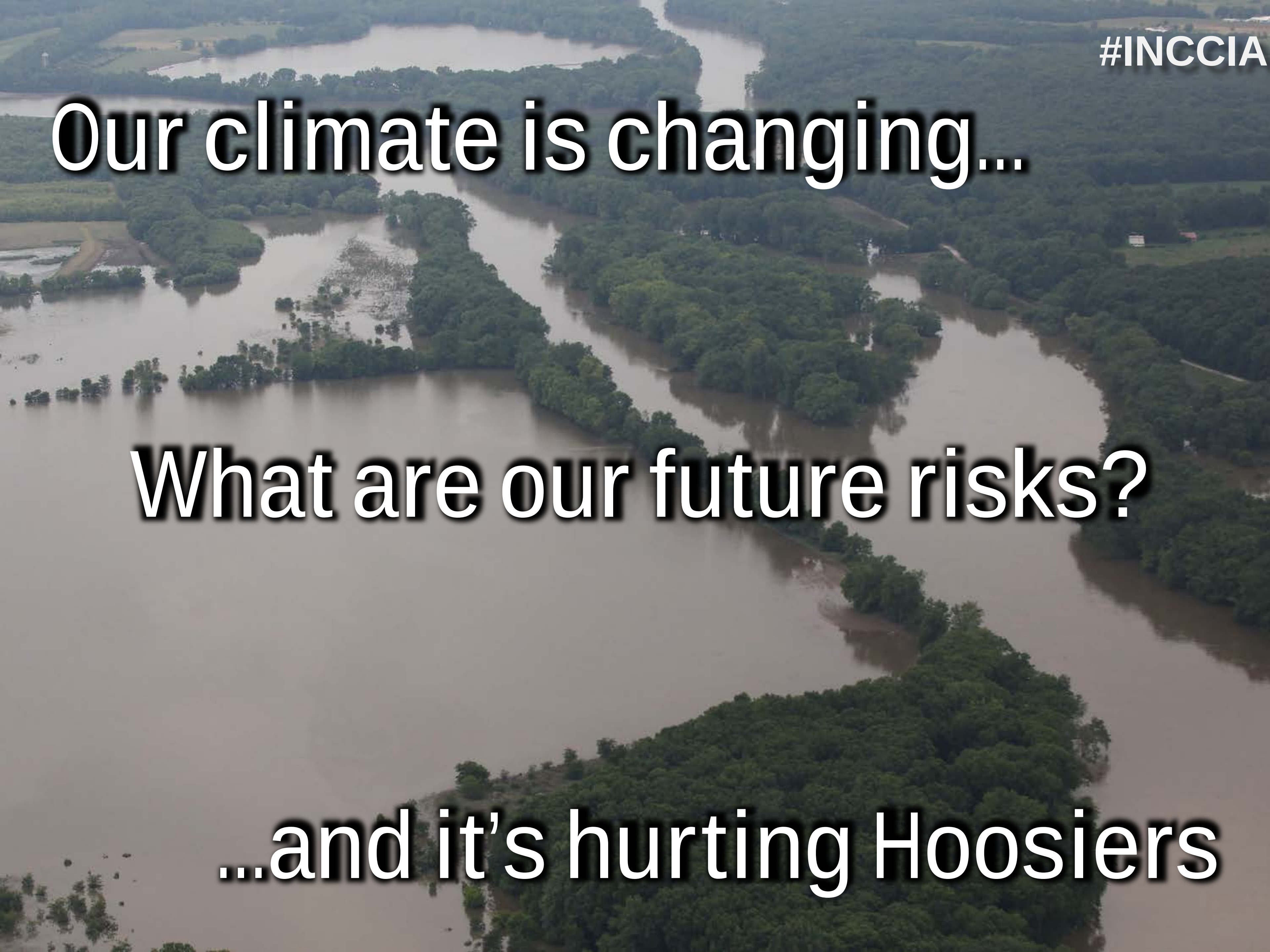
Data for Midwest U.S., 1958 – 2016. Source: NOAA

Photo credit: NOAA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Our climate is changing...
What are our future risks?
...and it's hurting Hoosiers

What does climate change mean for INDIANA?

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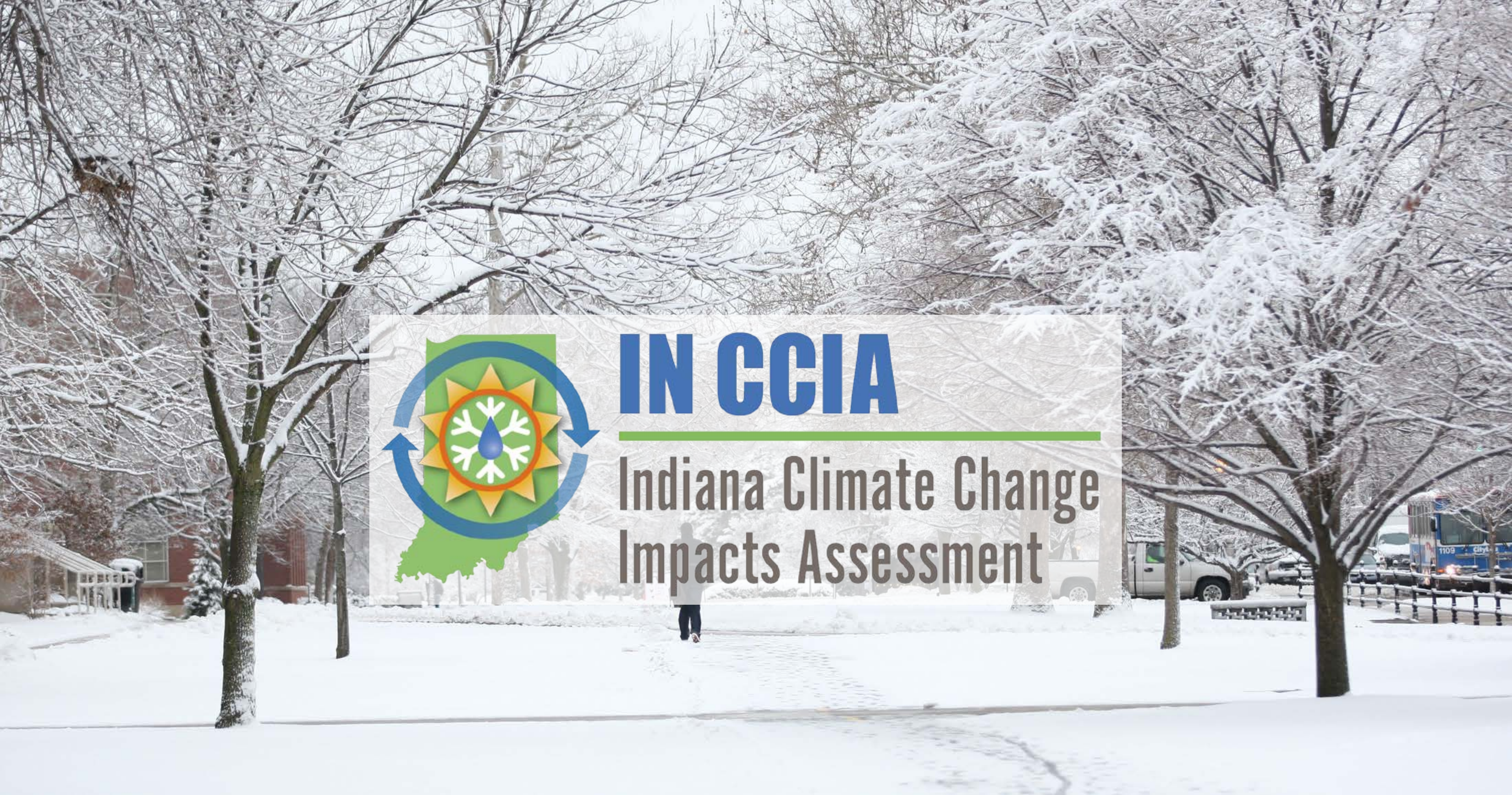

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Technical contributions from:

Purdue Climate Change Research Center
University of Notre Dame
Illinois-Indiana Sea Grant
IUPUI
Indiana University
Indiana University Northwest
Ball State University
Indiana State University
Purdue University Northwest
Midwest Regional Climate Center
U.S. Forest Service
Northern Institute of Applied Climate Science
Indiana Department of Natural Resources
Marion County Public Health Department
Mesh Coalition
State Utility Forecasting Group
U.S. Geological Survey

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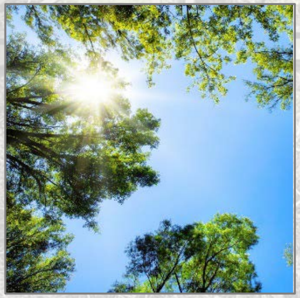
IN CCIA Reports

Putting global change into local perspective


Climate


Health


Forest Ecosystems


Urban Green Infrastructure

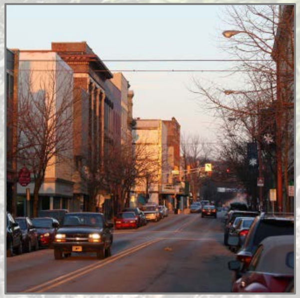

Agriculture


Aquatic Ecosystems


Tourism & Recreation

Energy

Water Resources


Infrastructure

www.IndianaClimate.org

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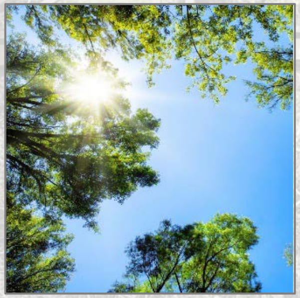
IN CCIA Reports

Putting global change into local perspective

Climate

Health



Forest Ecosystems

Urban Green Infrastructure

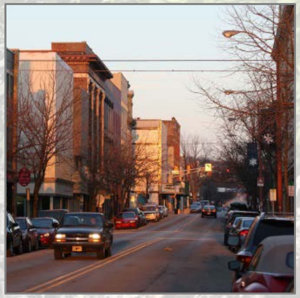
Agriculture

Aquatic Ecosystems

Tourism & Recreation

Energy

Water Resources



Infrastructure

www.IndianaClimate.org

Indiana will get warmer

Annual temperature has already increased 1.2°F over the last century.

Warming expected to continue and intensify

Indiana scientists used 10 climate models to look at future warming.

Range of outcomes based on medium- and high-emissions scenarios

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Indiana will get warmer

5°F to 6°F of warming expected by mid-century.

- Warming expected in ALL seasons
- Longer growing season
- More frequent and intense extreme heat

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Indiana will get wetter

**Annual precipitation has increased 5.6”
over the last century.**

**6% to 8% increase in annual rainfall
is projected by mid-century.**

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Some seasons will be wetter

WINTER: 16 to 20% increase by mid-century

SPRING: 13 to 16% increase by mid-century

- More falling as rain, not snow
- Increased early-season soil saturation

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Some seasons will be drier

***Summer & fall* show slight declines by mid-century, with less certainty in the projections**

- Increased water demand from added heat
- Reduced plant available water

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Seasonal Analogs

Based on seasonal average temperature and precipitation

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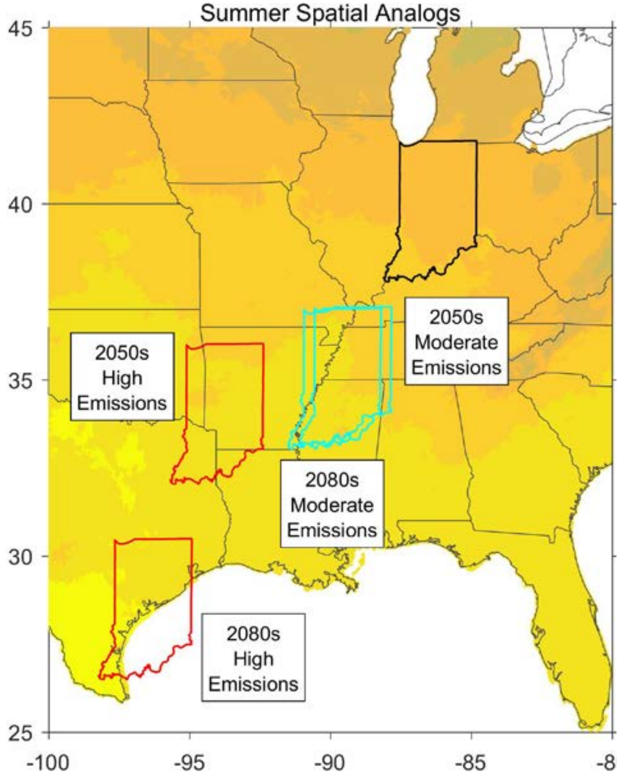
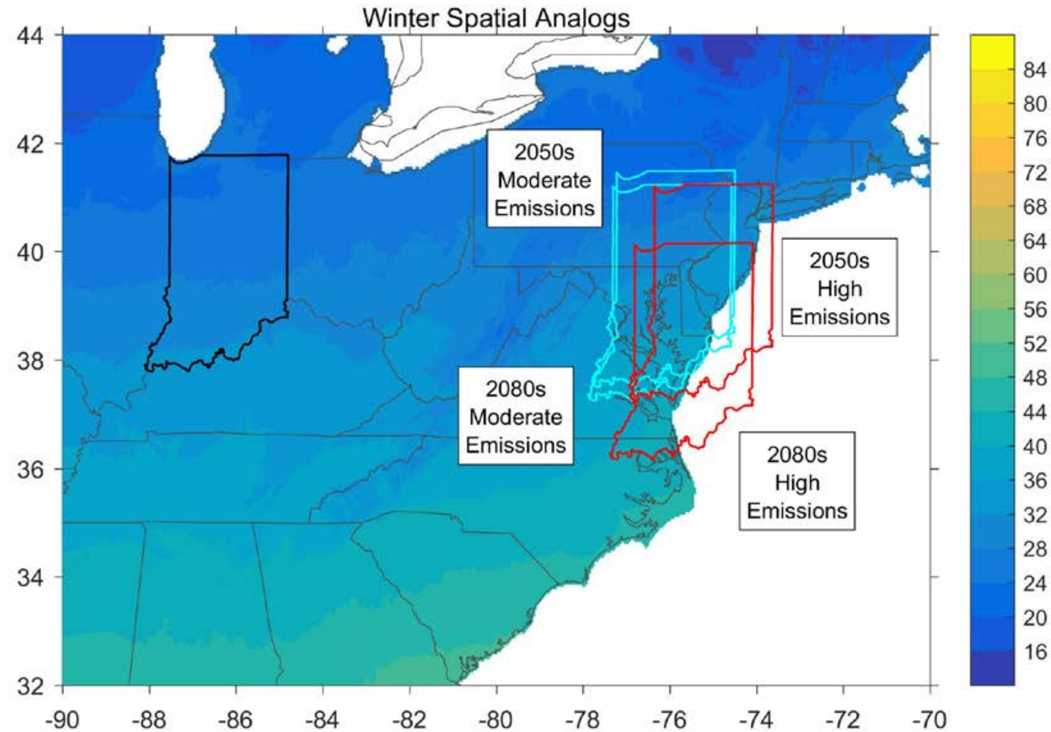




Statewide Average
2050s represents average from 2041 to 2070
2080s represents average from 2071 to 2100

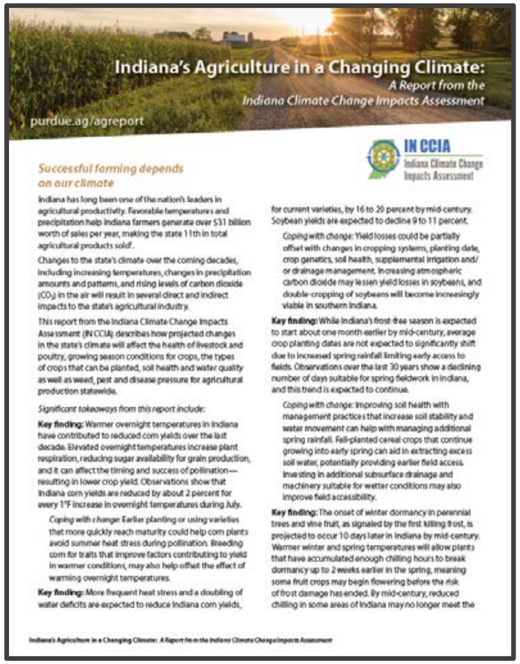
Base map shows 1981 to 2010 average seasonal temperature from PRISM archive

What do these changes mean for Hoosier agriculture?

Indiana's Agriculture in a Changing Climate

Impacts + Coping With Change

- ★ Agronomic crops
- Specialty crops
- Livestock & poultry
- ★ Soil health and water resources
- Pests and disease



Indiana's Agriculture in a Changing Climate:
A Report from the Indiana Climate Change Impacts Assessment

purdue.ag/agreport

IN CCIA Indiana Climate Change Impacts Assessment

Successful farming depends on our climate

Indiana has long been one of the nation's leaders in agricultural productivity. Favorable temperatures and precipitation help Indiana farmers generate over $31 billion worth of sales per year, making the state 11th in total agricultural products sold[1].

Changes to the state's climate over the coming decades, including increasing temperatures, changes in precipitation amounts and patterns, and rising levels of carbon dioxide (CO_2) in the air will result in several direct and indirect impacts to the state's agricultural industry.

This report from the Indiana Climate Change Impacts Assessment (IN CCIA) describes how projected changes in the state's climate will affect the health of livestock and poultry, growing season conditions for crops, the types of crops that can be planted, soil health and water quality as well as weed, pest and disease pressure for agricultural production statewide.

Significant takeaways from this report include:

Key finding: Warmer overnight temperatures in Indiana have contributed to reduced corn yields over the last decade. Elevated overnight temperatures increase plant respiration, reducing sugar availability for grain production, and it can affect the timing and success of pollination—resulting in lower crop yield. Observations show that Indiana corn yields are reduced by about 2 percent for every 1°F increase in overnight temperatures during July.

Coping with change: Earlier planting or using varieties that more quickly reach maturity could help corn plants avoid summer heat stress during pollination. Breeding corn for traits that improve factors contributing to yield in warmer conditions, may also help offset the effect of warming overnight temperatures.

Key finding: More frequent heat stress and a doubling of water deficits are expected to reduce Indiana corn yields, for current varieties, by 16 to 20 percent by mid-century. Soybean yields are expected to decline 9 to 11 percent.

Coping with change: Yield losses could be partially offset with changes in cropping systems, planting date, crop genetics, soil health, supplemental irrigation and/or drainage management. Increasing atmospheric carbon dioxide may lessen yield losses in soybeans, and double-cropping of soybeans will become increasingly viable in southern Indiana.

Key finding: While Indiana's frost-free season is expected to start about one month earlier by mid-century, average crop planting dates are not expected to significantly shift due to increased spring rainfall limiting early access to fields. Observations over the last 30 years show a declining number of days suitable for spring fieldwork in Indiana, and this trend is expected to continue.

Coping with change: Improving soil health with management practices that increase soil stability and water movement can help with managing additional spring rainfall. Fall-planted cereal crops that continue growing into early spring can aid in extracting excess soil water, potentially providing earlier field access. Investing in additional subsurface drainage and machinery suitable for wetter conditions may also improve field accessibility.

Key finding: The onset of winter dormancy in perennial trees and vine fruit, as signaled by the first killing frost, is projected to occur 10 days later in Indiana by mid-century. Warmer winter and spring temperatures will allow plants that have accumulated enough chilling hours to break dormancy up to 2 weeks earlier in the spring, meaning some fruit crops may begin flowering before the risk of frost damage has ended. By mid-century, reduced chilling in some areas of Indiana may no longer meet the

Indiana's Agriculture in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment

Indiana's Agriculture in a Changing Climate

Agriculture Working Group

Laura Bowling (lead), **water resources**
Janna Beckerman, **plant disease**
Sylvie Brouder, **nutrient management**
Jonathan Buzan, **heat stress**
Keith Cherkauer, **water resources**
Otto Doering, **agricultural economics**
Jeffrey Dukes, **invasive species**
Paul Ebner, **animal science**
Jane Frankenberger, **water management**
Benjamin Gramig*, **agricultural economics**
Eileen Kladivko, **soil management**
Charlotte Lee, **water resources**
Jeffrey Volenec, **crop physiology/ecology**
Cliff Weil, **crop genetics**

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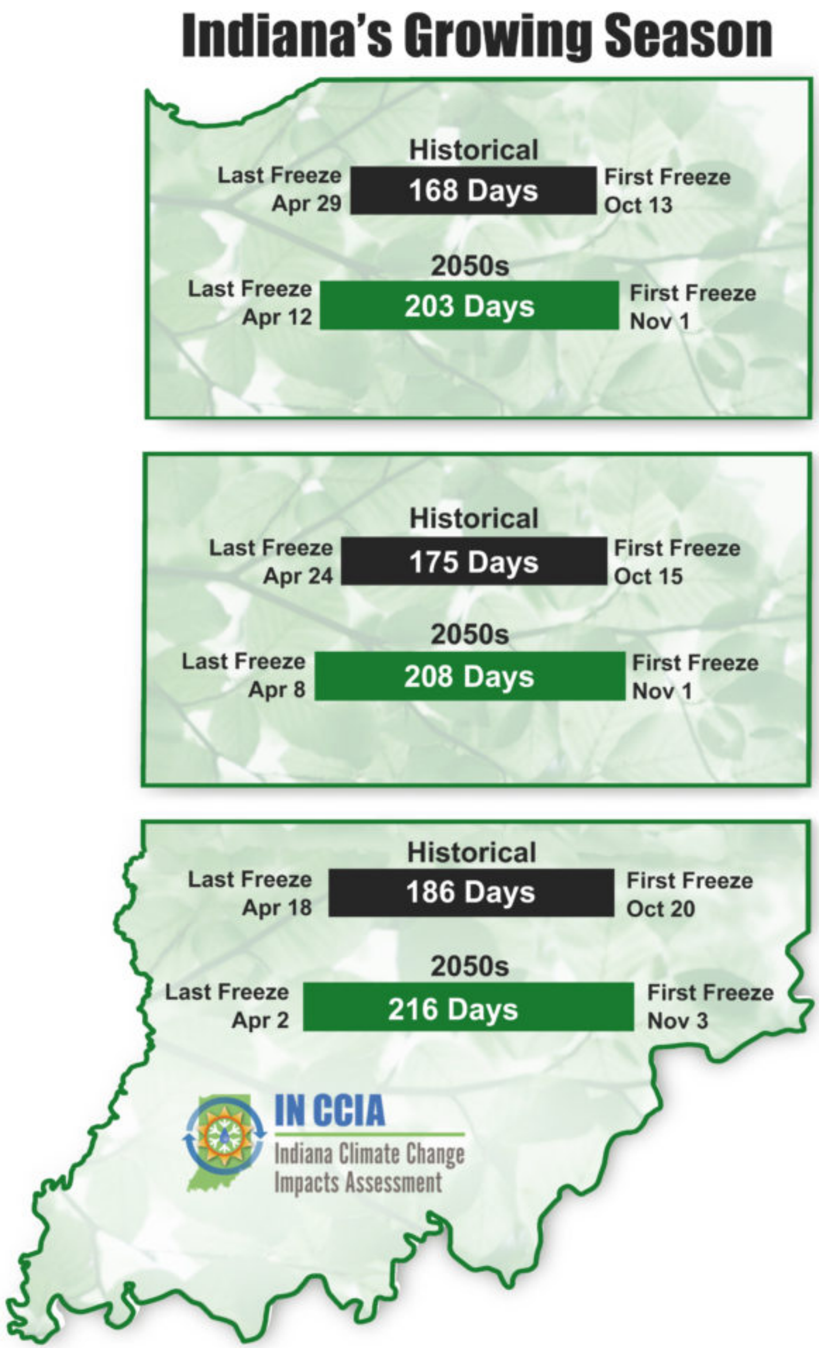
** Currently at University of Illinois*

Consecutive period between last spring freeze (32F) and first fall freeze.



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Future data based on high emissions scenario

Historical represents average from 1915 to 2013

2050s represents average from 2041 to 2070

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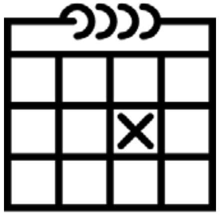
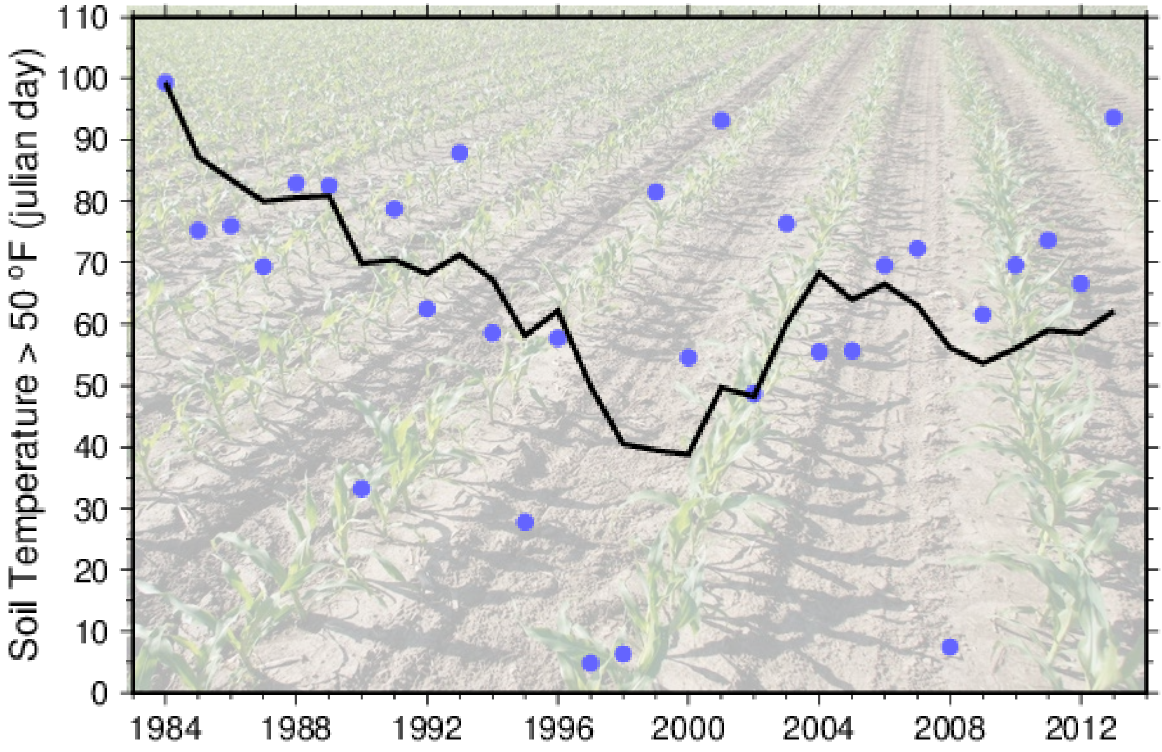
Growing seasons will be longer....



Average date when soil temperature reaches 50ºF



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Results for West Central Indiana

Growing seasons will be longer….

Average date when soil temperature reaches 50ºF

Feb. 6-12

Future

Mar. 4

Historical

21 - 27 days earlier

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Results for West Central Indiana


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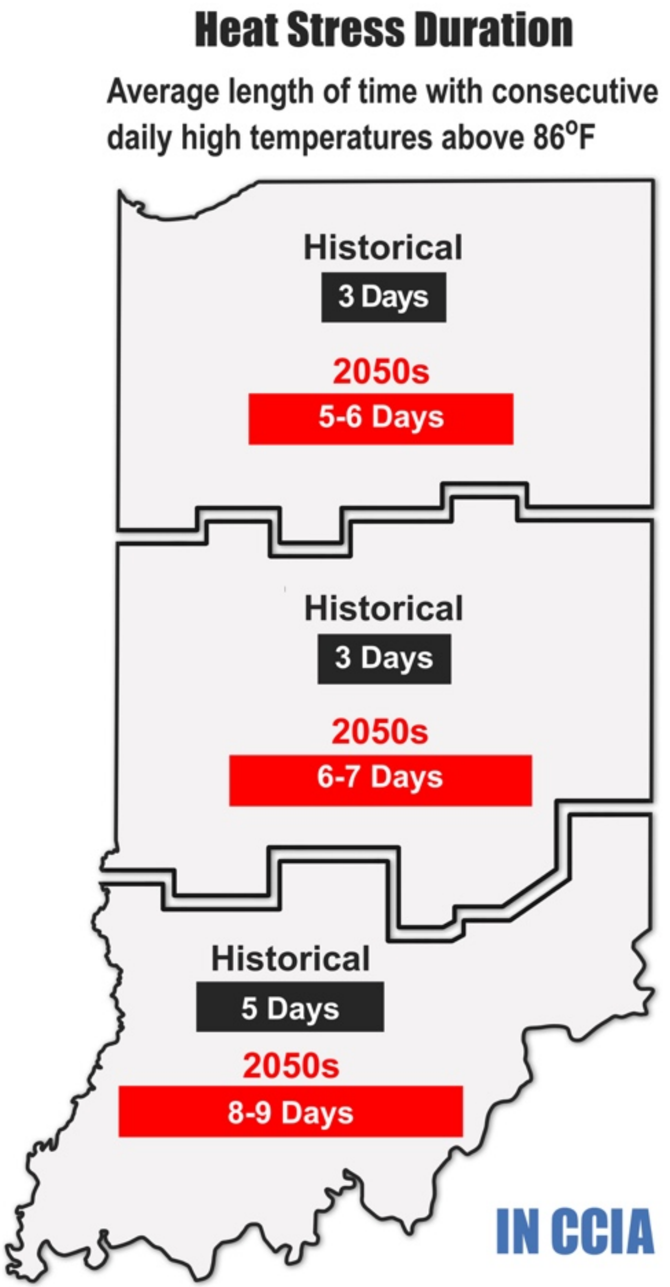
WINTER: 16 to 20% increase
SPRING: 13 to 16% increase
Mid-century
Precipitation
...but planting may not be much earlier



Historical period is from 1981 to 2010. Mid-century represents the period from 2041 to 2070. Range of results based on medium and high emissions scenarios.

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More days with high temps

Longer durations

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Coping with growing season changes

- Breeding for heat tolerant, flood tolerant and disease resistant varieties
- Opportunities to grow different crops, double-crop
- Improving soil health & fall-planted cereal crops may help w/ managing additional spring rainfall
- New tractors better suited for wet conditions

Agronomic crops

Declining crop yields

Change in dryland crop yield at mid-century

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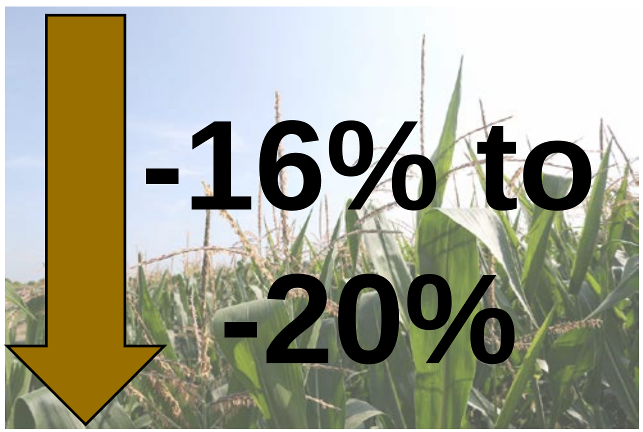
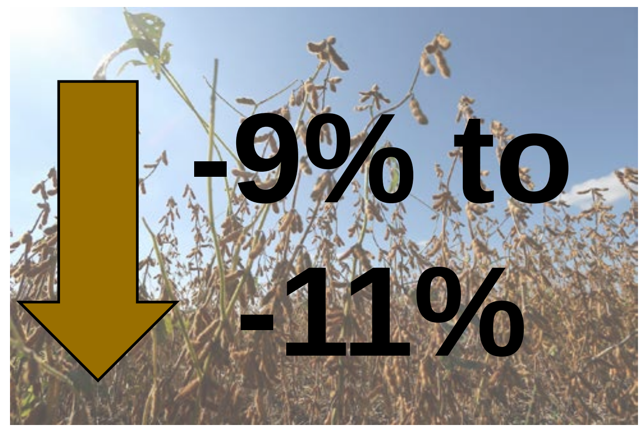
Corn

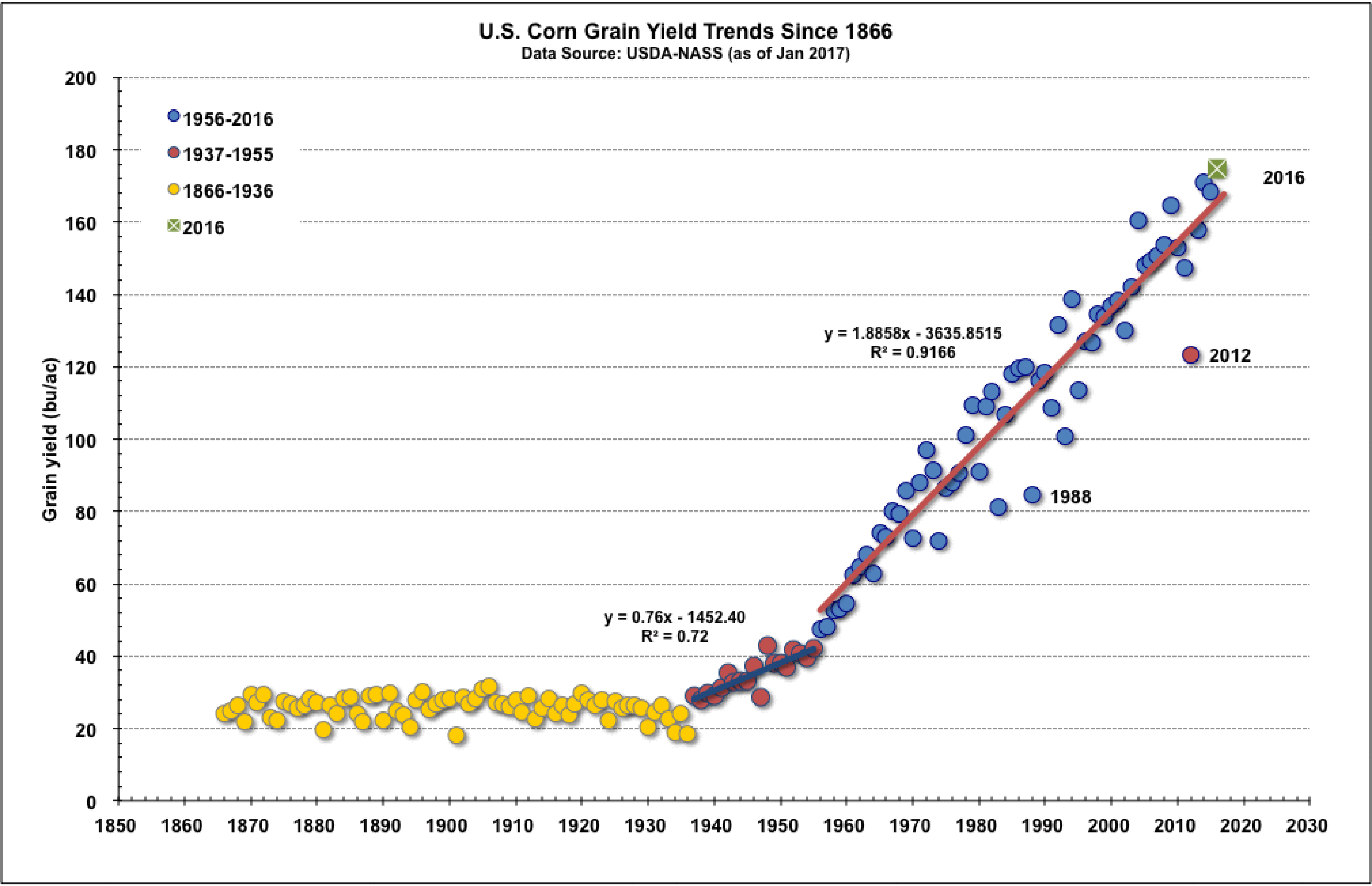


Soybean



Projections based on currently available varieties with no management changes

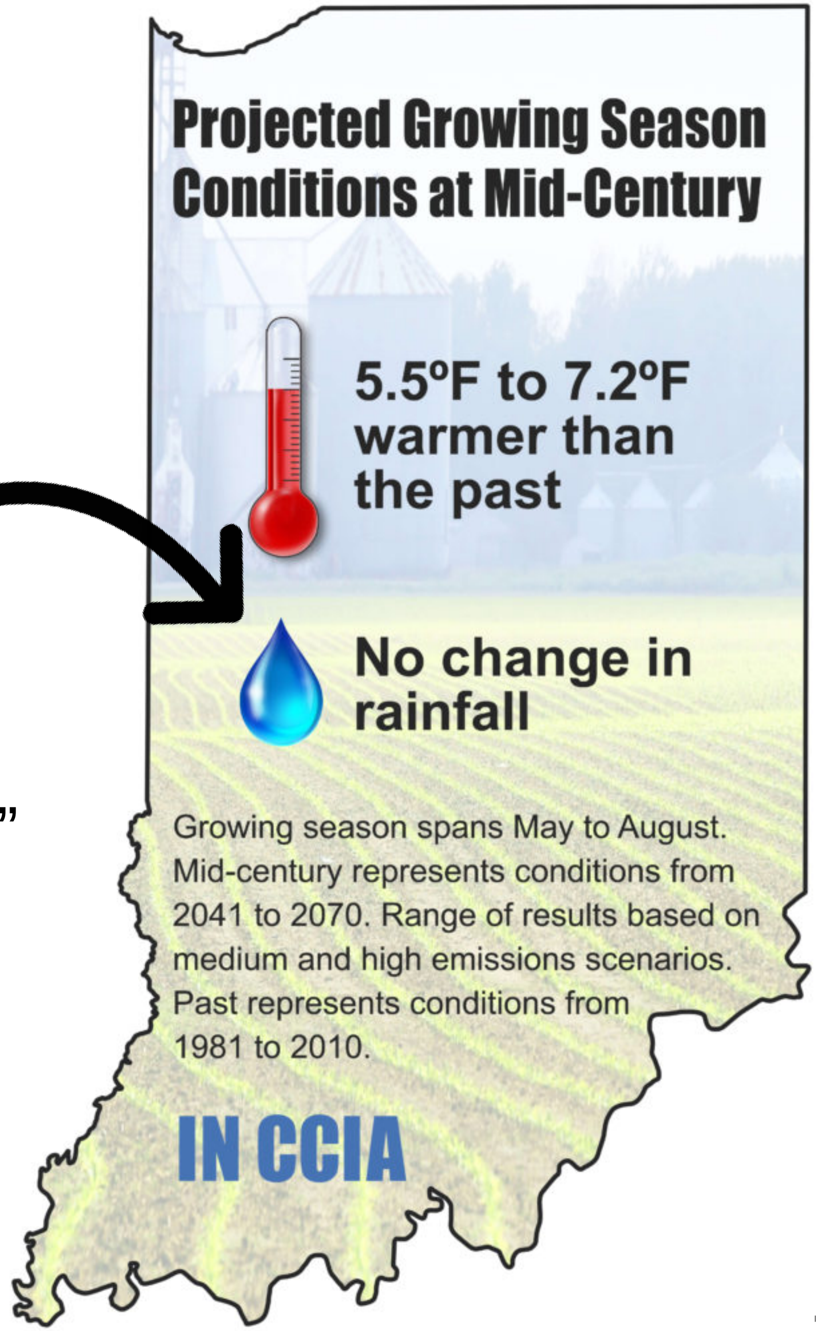
Future data based on medium and high emissions scenario;
Mid-century represents average from 2041 to 2070;
Percent change is relative to 1984-2013 average


U.S. Corn Grain Yield Trends Since 1866
Data Source: USDA-NASS (as of Jan 2017)
Grain yield (bu/ac)
1956-2016
1937-1955
1866-1936
2016
y = 1.8858x - 3635.8515
R² = 0.9166
y = 0.76x - 1452.40
R² = 0.72
2016
2012
1988
0
20
40
60
80
100
120
140
160
180
200
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030

Statewide Average
May – August

Growing season
WATER DEFICIT
projected to double

PAST	3.7”
FUTRUE	7.6” to 8.1”



Future data based on medium & high emissions scenario

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But irrigation will still not pay for itself

- Irrigation can offset yield losses;
- At current prices, increased income is not greater than the cost of investment in irrigation systems;
- The Net Present Value of the difference between investing in irrigation and farming without irrigation remains negative; and
- NPV continues to decrease in the future.

Coping with change to row crops

- Breed for reduced plant respiration in response to high night temperatures
- In addition to improved genetics, partially offset corn yield losses with:
  - Changes in cropping systems, planting date, soil health, supplemental irrigation and/or drainage management
- Increasing atmospheric CO_2 may stimulate photosynthesis of soybean and lessen yield losses
- Soybean double cropping with small grains like wheat may be increasingly viable in southern Indiana

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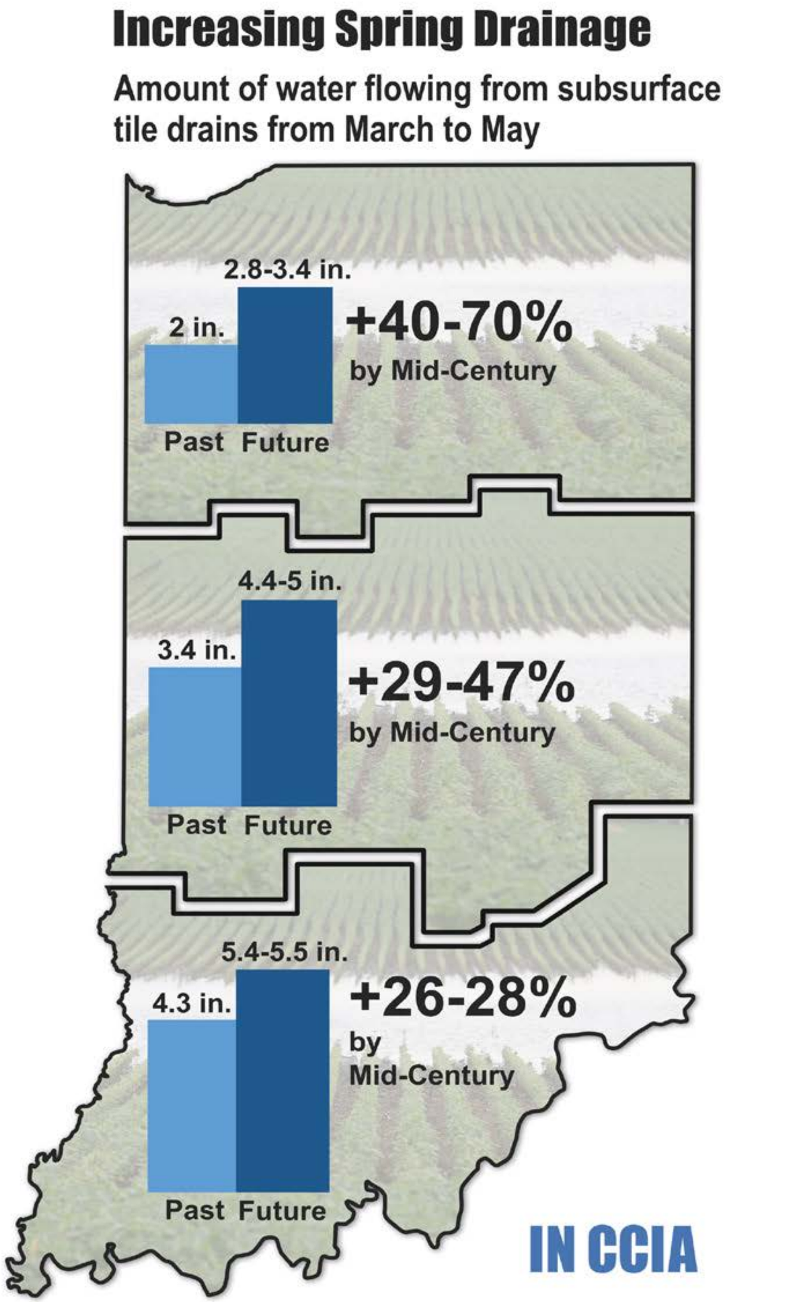
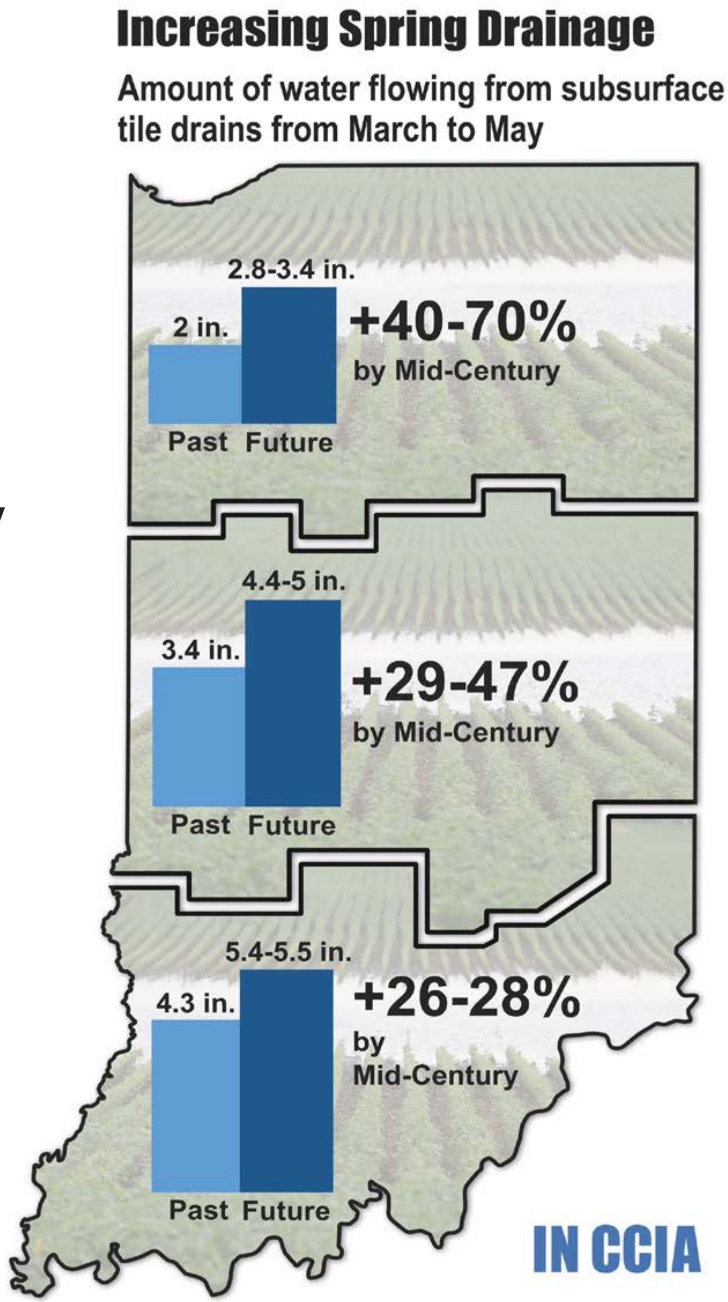
Soil Health & Water Resources



Historical period is from 1981 to 2010. Mid-century represents the period from 2041 to 2070. Range of results based on medium and high emissions scenarios.

Declining *summer & fall* precipitation by mid-century

Growing season WATER DEFICIT projected to double



Historical period is from 1981 to 2010. Mid-century represents the period from 2041 to 2070. Range of results based on medium and high emissions scenarios.

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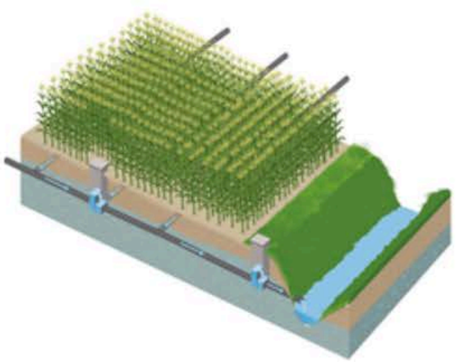
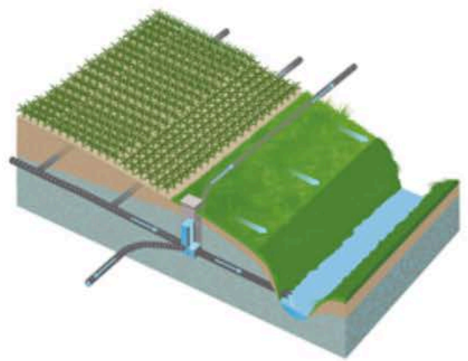
Increased potential for drainage water storage and reuse

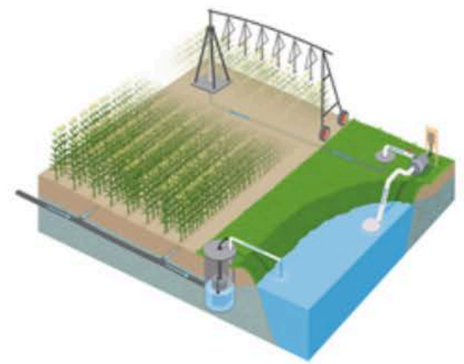
CONTROLLED DRAINAGE



SATURATED BUFFERS



DRAINAGE WATER RECYCLING



Additional information and resources at:
TransformingDrainage.org

Coping with soil and water changes

Building **SOIL ORGANIC MATTER** is critical for holding nutrients and water in the soil

It will be harder to build soil organic matter

Increased spring rainfall → erosion

Warmer soils → increased decomposition

Reduced crop yield → decreased biomass input

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Conservation Practices: Cover Crops

- More cover crop growth, but not <u>too much!</u>
  - More growth reduces nitrate leaching, builds soil health faster
  - Makes management more challenging, especially before corn
- Learning curve that can impact farmers (and researchers!) greatly. Extension education, guidelines, workshops.
- Tradeoffs; consider purposes

Dr. Eileen Kladivko
Purdue Agronomy

More rain (winter and spring)

- Erosion—Keep it covered! (no-till, cover crops)
- Too wet—Transpire more water (cover crops)
- Too wet—Drainage (surface, subsurface)
- Too wet—Different machinery?
- Too wet—Store water for later in year?
- Nutrient loss—in-field and edge-of-field conservation practices, and recycling (cover crops, buffers, filters, drainage water recycling)

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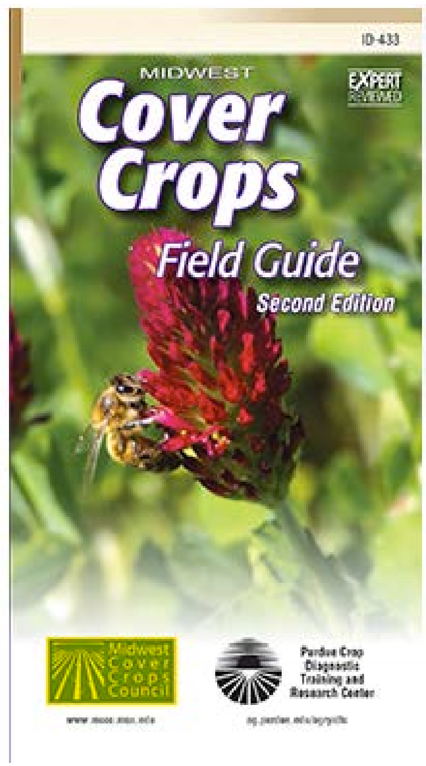
Warmer air temps; water availability in summer

- Keep it covered! No-till & cover crops as mulch for greater infiltration, less evaporation
- Increase soil organic matter (SOM), for increased water holding capacity; but harder to build SOM w/warmer temps
- Irrigation, water recycling
- Earlier planting- but may be too wet
- Deeper root growth?

Adaptation Resources

Web-Based Cover Crop Decision Tool



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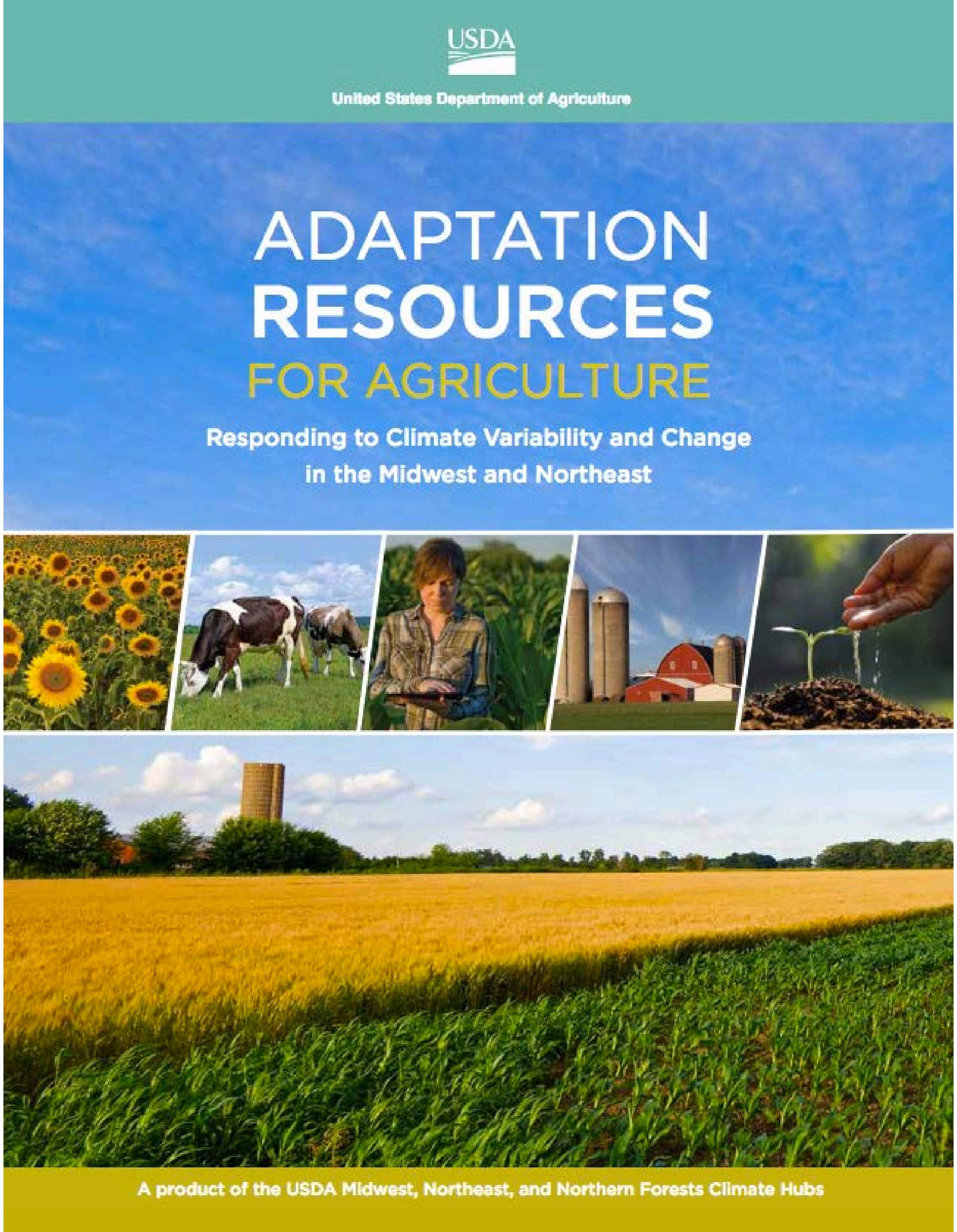


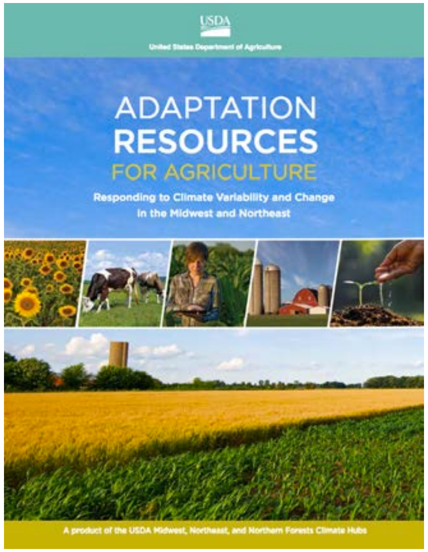
October 2016

Box 3.2: Menu of Adaptation Strategies and Approaches

Strategy 1: **Sustain fundamental functions of soil and water.**
- Approach 1.1: Maintain and improve soil health.
- Approach 1.2: Protect water quality.
- Approach 1.3: Match practices to water supply and demand.

Strategy 2: **Reduce existing stressors of crops and livestock.**
- Approach 2.1: Reduce the impacts of pests and pathogens on crops.
- Approach 2.2: Reduce competition from weedy and invasive species.
- Approach 2.3: Maintain livestock health and performance.

Strategy 3: **Reduce risks from warmer and drier conditions.**
- Approach 3.1: Adjust the timing or location of on-farm activities.
- Approach 3.2: Manage crops to cope with warmer and drier conditions.
- Approach 3.3: Manage livestock to cope with warmer and drier conditions.



8 strategies in total

Box 3.2:
Menu of Adaptation Strategies and Approaches

Strategy 1:	**Sustain fundamental functions of soil and water.**
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Approach 2.2:	Reduce competition from weedy and invasive species.
Approach 2.3:	Maintain livestock health and performance.
Strategy 3:	**Reduce ris**
Approach 3.1:	Adjust the t
Approach 3.2:	Manage cro
Approach 3.3:	Manage live

- Minimize soil disturbance
- Provide year-round ground cover
- Increase soil organic matter
- Diversify crop rotations
- Shift planting date to avoid working in wet fields
- Integrate grazing
- Land leveling or subsurface drainage
- Etc....

8 strategies in total

Backed by science, references provided

Summary of Key Conclusions

- Increased heat (day and night) and water stress will reduce crop yields
- Warming winters put perennial crops at risk
- Heat stress and reduced forage quality will challenge livestock production
- Pests, disease and weeds will be a growing problem for Indiana agriculture
- Soil health and water quality are at risk

There is potential for significant impacts, but also many opportunities to cope with changes and keep Indiana agriculture productive.

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http://IndianaClimate.org

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