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Climate Change Impacts on Iowa Agriculture

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August 2024

Recommended Citation

Bendorf, J., Baule, W., Licht, M., Reynolds, B., Fillius, D., Vos, R., Glisan, J., Wuestenberg, M., Nowatzke, L., Andresen, J., Wilson, A. B., Todey, D., & Ontl, T. (2024). Climate Change Impacts on Iowa Agriculture. Ames, Iowa: United States Department of Agriculture Climate Hubs, and Great Lakes Research Integrated Science Assessment.

Methods and Supplementary Materials

Please visit https://www.climatehubs.usda.gov/hubs/midwest/topic/assessing-impacts-climate-change-midwest-agriculture for the methods and supplementary materials associated with this report.

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Acknowledgements

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Climate Change Impacts On Iowa Agriculture

Agriculture is a critically important aspect of economic and social life across Iowa. As of the 2022 Census of Agriculture, the state has approximately 86,900 farms with a total of 30 million acres of farmland.[1] In 2022, the market value of agricultural products sold totaled more than $43 billion, which ranks 2nd nationally; trailing only California.[2] Iowa ranks #1 in the nation for grain production, with the common grain crops being corn, soybeans, and oats.[3] Iowa is also the national leader in ethanol and biodiesel production, ranking #1 in gallons of ethanol produced in 2022.[4] Wind energy is another renewable energy source produced in Iowa, as the state ranks #3 in total megawatt capacity of wind turbines (~9,900 MW as of 2023).[5] Livestock production is focused on poultry, hogs, beef, dairy, and sheep/goats. Iowa is ranked 1st in the nation for hogs and egg production, 4th for milk goats, and 4th for cattle on feed and beef exports.[6]

Like other regions in the United States, agricultural productivity in Iowa is vulnerable to weather and climate variability. In recent decades, changes in Iowa's climate, including temperature and precipitation variability, have emerged, with continued change expected in the future. Although some of these shifts may appear minor now, agriculture is already being impacted by observed climate changes. Importantly, the impacts of climate change on the agricultural sectors extend beyond physical impacts to farms but also bring direct and indirect impacts to the overall cultural, social, and economic resilience of Iowa's communities. Therefore, when considering impacts on the agricultural sector in Iowa, climate change-driven stressors and disruptions can emerge well outside the geography of the state, nationally and internationally.

Observed Changes to Iowa's Climate

Observational changes in Iowa's climate are calculated from gridded meteorological data from 1979 to 2021 (period of record for the dataset) by partners at Michigan State University and GLISA, the Great Lakes CAP/RISA Team (GLISA).[7] A summary of the recent historical, observed changes in Iowa's climate are described as follows:

Temperature

- Average annual temperature increased by 1.0°F between 1979 and 2021.
- The change in average temperature between 1979 and 2021 was most extreme in the fall months (Sep. – Nov.), with an increase of 1.8°F.
- Temperatures in summer have not warmed substantially, with an observed below-average number of very hot days (> 95°F) since 1990 and no significant change in the number of warm nights (minimum temp ≥ 70°F).
- Since 1900, minimum temperatures have increased at a faster rate than maximum temperatures for all seasons. Winter minimum temperatures have increased at the most rapid rate (+0.3°F/decade).[8,9]

Precipitation

- Average annual precipitation has risen by 4.1" between 1979 and 2021, with the greatest increases observed during the winter (1.4") and spring (1.8").
- Extreme precipitation events (>2.0") have become more frequent, increasing by 1.6 days per year between the beginning and end of the analysis period.
- Most of the state experiences > 40% of its annual precipitation total on the 10 wettest days of the year.[9]
- Iowa's planting season (Apr.–Jun.) has been trending 2.8" above average since 2008.[9]

Table 1. Observed changes in Iowa's climate based on data from 1979 – 2021.

	Annual (Jan – Dec)		Summer (Jun – Aug)		Fall (Sep – Nov)		Winter (Dec – Feb)		Spring (Mar – May)	
	Average	**Change**	**Average**	**Change**	**Average**	**Change**	**Average**	**Change**	**Average**	**Change**
Temperature	48.6 °F	+1.0 °F	72.1 °F	+0.6 °F	50.3 °F	+1.8 °F	22.7 °F	0 °F	48.9 °F	+0.1 °F
Precipitation	35.0"	+4.1"	13.5"	+0.5"	8.0"	+0.6"	3.4"	+1.4"	10.1"	+1.8"
Vapor Pressure Deficit*	6.0 mb	+0.1 mb	10.2 mb	+0.7 mb	5.9 mb	0 mb	1.6 mb	0 mb	6.2 mb	-0.5 mb
Extreme precipitation (days with 2")	0.8 days	+1.6 days**								
Growing Season Length (frost-free days)	170.5 days	+2.2 days								

*Vapor pressure deficit (VPD) is an important variable for plant physiology. A higher VPD means that plants will lose more water to the air and dry out more rapidly. See page 9 for more information on how VPD relates to changes in relative humidity.

**This value represents a positive linear slope (from a linear regression) in days with extreme precipitation events between 1979 and 2021. "0.8 days per year" is the average value of all years between 1979 and 2021. The difference in extreme precipitation days between the beginning and end of this time period was 1.6 days per year.

Observed Impacts on Agriculture

- Longer growing seasons and increased temperature provide opportunities to plant alternative varieties of crops and trees.
- Greater frequency of heat stress (from heat and humidity) on trees, crops, livestock, and farmworkers.
- Increased risk of both drought and seasonal flooding.
- Increased weed, pest, and disease pressure as well as animal pathogens.
- More erratic spring freeze/thaw cycles that may damage trees and fruit crops, as well as affect insect and pathogen survival.
- Higher production costs and lower yields for some crops.[10,11]
- Wetter soils, resulting in delayed agricultural planting, higher erosion, and nutrient loss.

Future Climate Change

Models of future climate indicate that temperatures are projected to continue to warm, precipitation is expected to become more variable and extreme, and the growing season is anticipated to continue to lengthen. The climate projections in this section are based on the average of 17 different regional climate models.[7] Two possible futures are presented:

- an intermediate scenario in which greenhouse gas emissions peak around mid-century (RCP 4.5) and then slowly decline, and
- a very high scenario in which emissions continue to rise throughout the 21st century (RCP8.5).[12]

Careful planning and adaptive actions can lower the risks of climate change impacts for producers and the agricultural and forestry sectors more broadly. There are many ways to adapt to climate change based on emerging impacts and the needs of a particular farm, crop, or community, and some examples are presented below.

Projected Temperature Change

All available climate model projections indicate that Iowa can expect to see continued warming in the future, with fewer extremely cold nights, more very warm nights, and more very hot days (Table 2). Climate models project that annual average temperatures in Iowa will increase over historical baselines by 2.9°F to 7.9°F by mid-century (2040-2059) under a higher emission scenario, and increases may exceed 14.9°F by late century (2080-2099) under the same scenario.

Although these changes are most pronounced at the end of the century and in the high-emissions scenarios, even the moderate, mid-century projections indicate major changes in Iowa's cold and hot-weather climatologies that could have important ramifications for agriculture and forestry.

Table 2. Mean temperature threshold changes and model ranges for Iowa compared to the 1979 – 2005 period, under intermediate and very high future emissions scenarios.

	Low temp. ≤ 32°F	Low temp. ≥ 80°F	High temp. ≥ 86°F	High temp. ≥ 95°F
Mid-century, intermediate	-29.9 days *(-45.9 to -16.4)*	+1.0 days *(+0.1 to +3.0)*	+74.7 days *(+58.0 to +87.1)*	+11.8 days *(+2.6 to +21.3)*
Mid-century, very high	-34.5 days *(-55.7 to -16.5)*	+2.2 days *(+0.3 to +6.3)*	+81.7 days *(+65.7 to +92.0)*	+17.3 days *(+5.9 to +29.4)*
Late century, intermediate	-39.9 days *(-58.4 to -19.6)*	+3.6 days *(+0.1 to +13.7)*	+83.6 days *(+63.7 to +100.4)*	+20.2 days *(+4.4 to +44.9)*
Late century, very high	-65.2 days *(-86.1 to -33.9)*	+18.7 days *(+2.5 to +42.2)*	+107.8 days *(+86.4 to +124.5)*	+51.6 days *(+20.8 to +83.7)*

What Does This Mean for Agriculture?

Heat

- Increased heat stress severely impacts farmers and animals. Among livestock, high heat can decrease meat and milk quality and quantity, and egg production.[10,13,14,15]
- Farmworkers who work predominantly outdoors are also particularly vulnerable to heat-related illness.
- The frequency of short-term and rapid onset drought during the summer is potentially higher due to warmer temperatures and increased precipitation variability.[16]
- High heat during the growing season may stress cool season crops like lettuce, broccoli, and cabbage.[15] Prolonged, extreme heat can impact warm season crops like tomatoes and peppers by negatively impacting pollination at temperatures above 90°F.[18]

Soil Impacts

- Decreased soil moisture affects agricultural plant physiology, potentially leading to an increased risk of reduced yields or crop losses, but uncertainty about these impacts remains.[10,15] Crop genetics and field management will be key to mitigating these potential yield losses.
- Increased soil temperatures affect the appropriate timing and form of fertilizer application. Areas of the state where fall nitrogen applications are effective management will likely shift to spring and/or in-season application timings.
- With soils remaining above 50°F later into the fall season and potentially early in the spring, fields are prone to nitrogen loss and subsequent water quality impacts following nitrogen applications.[17]

Growing Conditions

- Elevated overnight temperatures speed up corn development, reducing the length of the grain-filling period which negatively impacting yields.[15]
- Research suggests warm and dry years narrow the area with optimal growing conditions for corn while soy has a higher tolerance for heat.

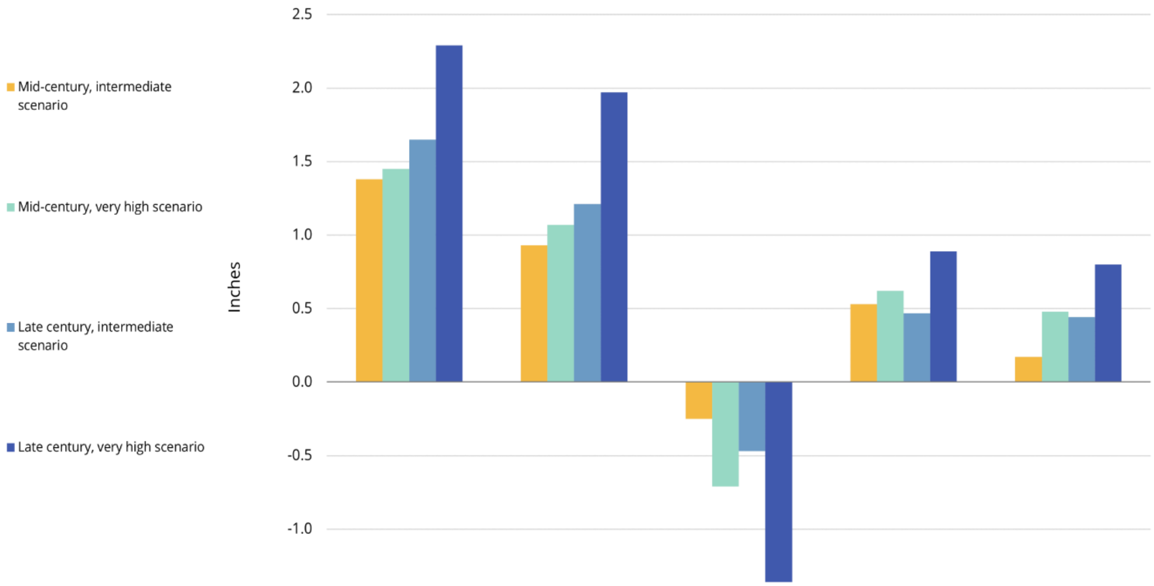
- Warming is expected to increase the severity and frequency of crop and animal diseases. Certain diseases (charcoal rot, pod & stem blight, etc.) can also become more problematic when the crops are under stress.
- Warming may also allow for pathogens more adapted to southern conditions to become problematic in Iowa. An increase in freezing/thawing cycles also will affect survival of organisms in the soil – for good or bad.

Adaptation Options

- Integrate alternative crop species via conservation crop rotations to maintain or improve soil health.[19]
- Choose crop species or varieties that are more suited to future conditions including heat tolerance and water stress.
- Utilize cover crops or reduce tillage to increase infiltration and water holding capacity while building soil strength and aggregation.
- Choose longer maturity corn cultivars to take advantage of longer growing season (potentially increasing yields), or plant shorter maturity corn varieties earlier in the season to avoid reproductive stages happening during worst risk of drought in later summer (likely to give average, but more consistent yields).[19]
- Be prepared with farming strategies that help manage too much soil moisture in the spring (such as cool season cover crops or improved drainage) and not enough soil moisture during late summer (such as high residue systems, drainage water recycling, or controlled drainage structures).
- Consider the use of high tunnels in smaller-scale plots to moderate plants' exposure to extreme temperatures.
- Explore options to reduce farmworkers' exposure to high temperatures like providing shade, improved personal safety equipment, access to drinking water, and alternative working hours.
- Monitor for pathogens or insect pests that are currently found further south.

Precipitation

Annual precipitation is expected to increase in the future, with the largest seasonal increases likely during spring. Decreases in total precipitation and greater variability are projected during the summer. These changes are larger under the very high scenario and for the late 21st century (2080-2099) (Figure 1).



	Annual	Spring	Summer	Fall	Winter
Mid-century, intermediate scenario	1.38 (4%)	0.93 (9%)	-0.25 (-2%)	0.53 (7%)	0.17 (6%)
Mid-century, very high scenario	1.45 (4%)	1.07 (11%)	-0.71 (-5%)	0.62 (8%)	0.48 (15%)
Late century, intermediate scenario	1.65 (5%)	1.21 (12%)	-0.47 (-4%)	0.47 (6%)	0.44 (14%)
Late century, very high scenario	2.29 (7%)	1.97 (20%)	-1.36 (-10%)	0.89 (12%)	0.80 (25%)

Figure 1. Projected precipitation changes for Iowa, annually and seasonally, in inches based on two different emission scenarios (intermediate (RCP4.5) and very high (RCP8.5)).

What Does This Mean for Agriculture?

- Winter and spring increases in precipitation will lead to further loss of field workdays, impaired root growth and function, and prolonged field wetness.[15]
- Wetter pastures and paddocks increase susceptibility to animal foot diseases and may impact livestock nutrition maintenance schedules and gestational weight.[20,21]
- Decreased soil moisture in summer will likely lead to greater crop irrigation demand.

Adaptation Options to Changing Precipitation

- Consider planting earlier in the season, which may be possible due to small increases in field workability days in late March to early April, coupled with an earlier last frost date.[19]
- Utilize cover crops or reduce tillage to increase infiltration and water holding capacity while building soil strength and aggregation.
- Consider 'redefining the field edge' in perennially flood prone areas by replacing row crops with perennial grasses for haying/grazing or native mixes.[22,23]
- Increase soil health by improving soil structure and organic matter content to be better able to infiltrate precipitation, increase water-holding capacity, and maintain plant-available water during periods of dryness. Management to improve soil health can reduce risk of climate-related impacts as well as improve productivity.[15] Options include conservation crop rotations, cover crops, and reduce tillage.

- Consider implementing water retention basins to capture water during periods of excess moisture to be used as irrigation water during dry periods.

Growing Season Length

Growing season trends across Iowa since 1950 are variable across the state (Figure 2). Many counties have seen an increase of one to a few days per decade; counties with a statistically significant increase in growing season length are scattered across the state. This is a result of later first frosts in the fall and an earlier onset of frost-free conditions in spring.

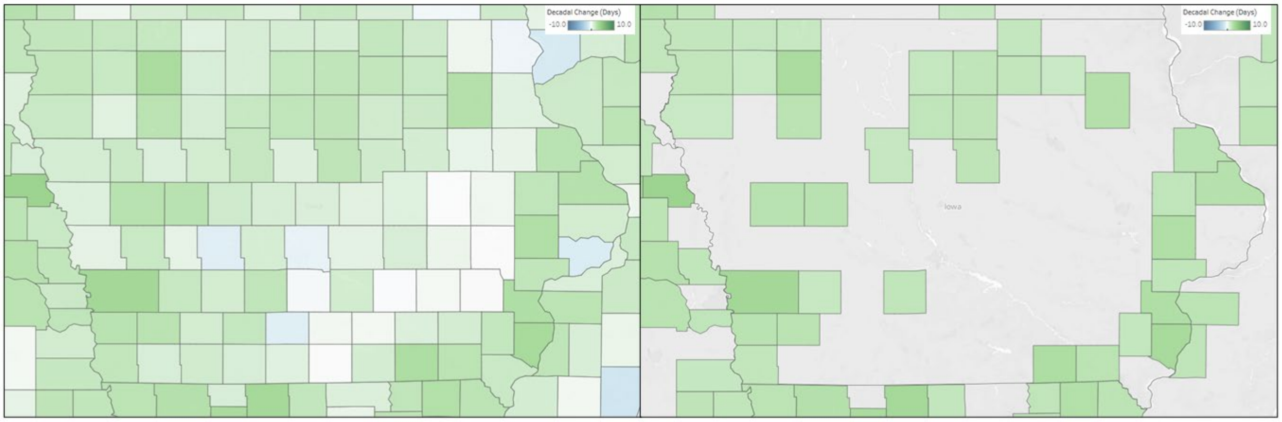


Figure 2. Historical changes in average annual growing season length for Iowa counties, 1950-2023, based on gridded Applied Climate Information System dataset. The right-hand image displays only those counties with a statistically significant trend ($p < 0.05$). Image source: Freeze Date Tool, Midwestern Regional Climate Center, https://mrcc.purdue.edu/freeze/freezedatetool.html. Original data source is https://www.rcc-acis.org/.

What Does this Mean for Agriculture?

- Pests, diseases, and weeds may expand their ranges. Additionally, the number of pest generations per season may increase, resulting in a greater impact on crops or livestock.
- An increased need for chemical treatments to address these impacts may lead to greater pesticide and herbicide resistance, greater input costs for farmers, and greater environmental exposure to these chemicals.
- Increased tree loss due to pest damage may increase wildfire risk.
- Longer growing season length may provide additional time for agricultural harvest and other end-of-season processes. Also, cover crops may experience increased post-harvest growth. Both of these effects will be heavily influenced by fall soil moisture trends. However, it may reduce the winter forestry harvest period and drive changes in forest composition.
- Warmer winters increase risk of spring freeze injury by accelerating the deacclimation from dormancy.
- Chilling hours for fruit have been on the rise in Iowa in recent decades, and the time required to reach certain thresholds may become shorter (e.g., happen earlier in the spring) with warming winters.[24] The earlier timing of budbreak will make plants more susceptible to freeze damage.[15]
- Later first frosts in the fall and earlier frost-free conditions in spring may shorten the winter harvest timber period, as well as making it more difficult to harvest some species that primarily inhabit wetter habitats.

Adaptation Options

- Plant agricultural crops earlier in the spring or consider options for double or relay cropping.[22]
- Address pest, weed, and disease issues by diversifying crop rotations, enhancing use of Integrated Pest Management (IPM) techniques, and planting species and varieties that are more adapted to changing conditions.[22]
- Consider planting fruit species and cultivars which require greater chilling hours to mitigate the potential risk of trees and shrubs breaking dormancy during late-winter warm spells.

Relative Humidity

Despite increased water vapor in the atmosphere and precipitation, uncertainty remains in whether current trends of relative humidity will continue. This uncertainty is due to relative humidity's dependence on both air temperature and absolute moisture content in the air. A larger increase in temperature would decrease relative humidity, and a larger increase in absolute moisture content would increase relative humidity. Models indicate that relative humidity is projected to decrease annually and across all seasons in Iowa. However, if minimum (nighttime) temperature trends continue to outpace maximum (daytime), vapor pressure deficits will not increase, and relative humidity will stay higher.

What Does this Mean for Agriculture?

- If relative humidity decreases:
  - Plants will be more prone to wilting and stunted growth.
  - Certain animal respiratory viruses may have a longer survival duration.[25]
  - Tree mortality may increase, especially for younger trees.[26]
- If relative humidity increases:
  - Wetness duration may increase leading to enhanced disease potential for crops.[27]
  - Plants will have a decreased ability to evaporate water (part of the transpiration process) or take up nutrients dependent on the flow of water from the soil.[28]
  - The ability for animals to utilize evaporative cooling will be reduced, increasing the effects of heat stress related health and performance issues.[29]

Adaptation Options

- Plant varieties adapted to drier or wetter climates (or those that may withstand high variability) if available (including crops, pasture grasses, and tree fruit).[22]
- Use of mulch, cover crops, no-till, or reduced tillage to retain soil moisture and reduce soil temperatures during the summer.[22]
- Where appropriate, establish trees to reduce evaporative water loss from the soil surface. Additionally, soils within agroforestry systems are better able to infiltrate and store water, which will be critically important in climates with warmer, drier summers.[30]

Iowa Climate Change Resources and Extension Programs

- Carbon markets (2022): https://store.extension.iastate.edu/product/16214
- Severe weather preparedness (2017): https://store.extension.iastate.edu/product/5071
- Climate and corn-soybean systems (2017):
  - VOLUME 1 – https://store.extension.iastate.edu/product/14878
  - VOLUME 2 – https://store.extension.iastate.edu/product/15130
- Climate, weather and grapes (2017): https://store.extension.iastate.edu/product/15142
- Climate, weather and apples (2017): https://store.extension.iastate.edu/product/15144
- Climate and climate change (2012): https://store.extension.iastate.edu/product/14374

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