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Climate Change:

Are you preparing for it?

Introduction

Elected officials, planners and policymakers face many issues concerning the environment, the economy, and the safety and well-being of the people they serve. Meanwhile, residents are better informed and demand more accountability from their elected officials on climate change, pollution problems and the preservation of natural areas. The American mindset is changing. Economic growth based on 20th-century tactics may no longer meet our needs. Communities are looking for new ways to build and grow that reduce their effect on the environment and climate without compromising budgets and other planning goals.

This publication provides an overview of how changing climate conditions will affect the Midwestern United States, focusing specifically on Indiana, along with sensible strategies for coping with these changes. It is intended to help regional policymakers understand past and future environmental changes to support local and regional planning efforts.

Climate Change in the Midwest

Earth's climate is changing at an alarming rate, around the world and in our own backyard. Ninety-seven percent of the world's scientists, including experts at Purdue University, agree that climate change is happening and that it is primarily due to human activities. Many climate change publications describe what happened in the past, what is happening now and what likely will happen in the future. The latest and most complete of these is the Fourth National Climate Assessment developed by a team of over 300 experts with guidance from the U.S. Global Change Research Program.

Some regions of the world are facing coastal flooding and sea level rise; others, more frequent wildfires. Drinking water is scarce in regions that rely on snowmelt as their water source. Heat waves are happening more frequently, and mosquitoes and ticks are spreading disease to new areas as their ranges expand (IPCC 2014; USGCRP 2014; USGCRP 2017).

The following is a general overview of some of the climate predictions made for the Midwestern United States (USGCRP 2014; USGCRP 2017).

- **Warmer summers and milder winters:** Milder winters mean more invasive species, pathogens, insects and weeds that wreak havoc on natural and agricultural systems. Increased numbers of pests, such as mosquitoes and ticks that can carry and spread disease, cause health concerns.
- **More heat waves:** Scientists predict an increase in hot days (above 95°F) and ozone-action days. Extreme temperatures and poor air quality threaten human health and increase energy costs for homes, businesses and industry. Agricultural crops will have increased water demands and reduced yields, and livestock health is threatened.
- **Increased evapotranspiration (movement of water into the air):** Less summer rain coupled with hot summers and mild winters causes evapotranspiration to exceed rainfall. As a result, lake and river levels will be reduced in the summer, and groundwater could be less available.
- **Changing rainfall patterns, more heavy rainfall events:** Scientists predict that annual total rainfall will increase but seasonal patterns will shift, causing problems for water infrastructure, agriculture and wildlife. Winter and spring will become wetter with more heavy rain events. Summer and fall are expected to be drier overall, but also with more rain falling in heavy downpours. Heavy rainfall contributes to increased flooding, soil erosion and an influx of pollutants into water bodies.

Past Trends in Indiana Climate

As the world warms, regional and local climate patterns shift in specific ways that vary by location. While Indiana's past and future climate shifts are similar to those outlined above for the entire Midwest, a more localized view of climate risks is more actionable for planning and decision making.

The information in this section provides that localized perspective on Indiana's climate trends. It is based on resources from the Purdue Climate Change Research Center, including the report Indiana's Climate Trends: A Resource for the Indiana Climate Change Impacts Assessment (Widhalm et al. 2018a).

Annual and Seasonal Precipitation

Adequate rainfall is necessary for crop production, ecosystem health, water supplies, power production and more. However, too much rainfall can have serious negative impacts on our road and water system infrastructure, human health and safety, and the natural environment.

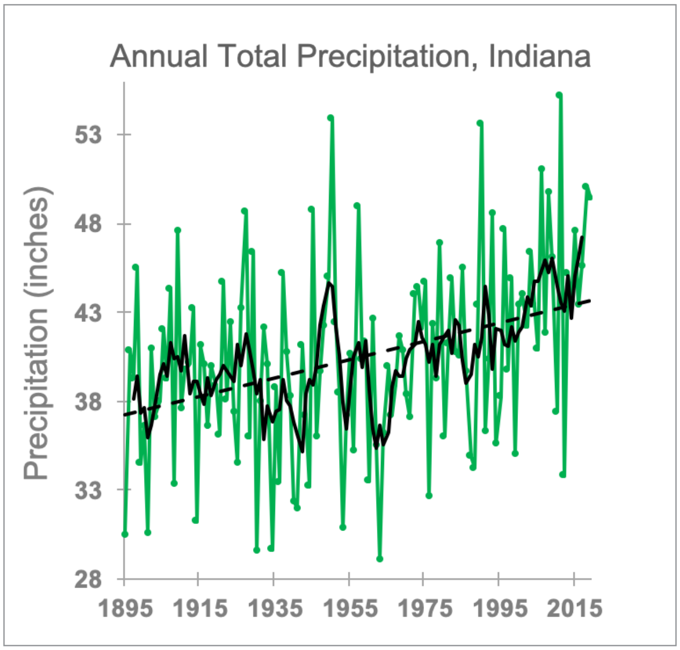


Figure 1: Statewide annual total precipitation for Indiana from 1895 to 2019, shown in green. The solid black line shows the five-year running average. The dashed black line shows the linear trend in annual precipitation (0.52"/decade) for the full period of record (1895 to 2019). Data are from the NOAA Climate At A Glance Database, accessed January 2020.

Understanding changes in precipitation patterns is useful for both short- and long-term community planning.

Indiana's annual precipitation has increased 6.5 inches from 1895 to 2019 (0.52 inch/decade), based on a linear trend. Increasing precipitation trends have been observed in all seasons from 1895 to 2019: winter, 0.04 inch/decade; spring, 0.15 inch/decade; summer, 0.2 inch/decade; and fall, 0.12 inch/decade.

Precipitation trends vary by location and time of year across the state. Annually, all climate divisions (see Figure 2 for locations and a definition) show large increases in annual precipitation totals since 1895, with the largest increases measured in the southern portion of the state (Figure 3). Seasonally, all climate divisions show increasing precipitation trends in spring, summer and fall with different spatial patterns emerging by season (Table 1).

Locations of Indiana’s Nine Climate Divisions

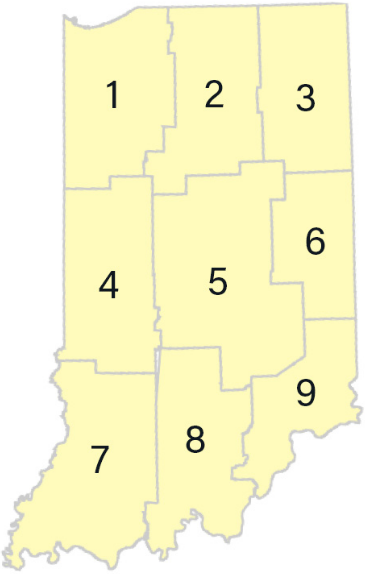
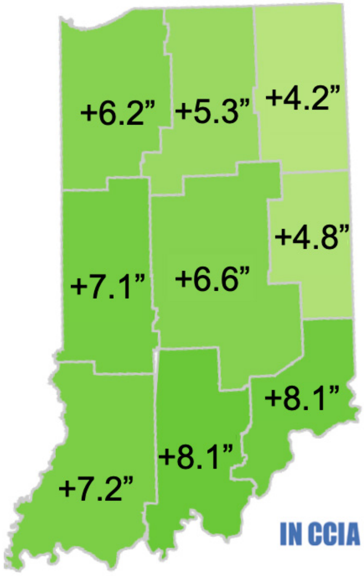


Figure 2: This map shows the locations of climate divisions in Indiana. A climate division is a grouping of counties with generally similar temperature and precipitation characteristics from which long-term climate statistics are calculated. Nationally, there are 344 climate divisions. Indiana has nine such divisions.



Change in annual average precipitation based on linear trend from 1895 to 2019

Figure 3: This map shows the increasing trend (inches per decade) in annual precipitation for each climate division. Precipitation changes were calculated based on a linear trend from 1895 to 2019. Data are from the NOAA Climate At A Glance Database, accessed January 2020.

Indiana Precipitation Trend* (1895 to 2016)

Location	Winter	Spring	Summer	Fall
CD 1	0.02	0.05	0.29	0.1
CD 2	0.05	0.04	0.22	0.08
CD 3	0.01	0.05	0.13	0.07
CD 4	0.07	0.11	0.24	0.11
CD 5	0.06	0.12	0.21	0.09
CD 6	0.02	0.08	0.14	0.06
CD 7	0	0.25	0.12	0.14
CD 8	-0.01	0.26	0.16	0.15
CD 9	0	0.23	0.18	0.14

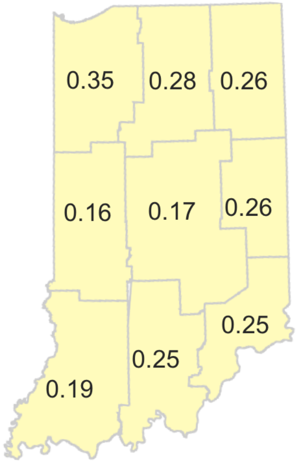
**Units: inches per decade*

Table 1: Seasonal precipitation trends for Indiana’s nine climate divisions. Data show the change in precipitation in inches per decade. Positive values indicate increasing precipitation, and negative values indicate decreasing precipitation. Zero indicates no trend. Data are from the NOAA Climate At A Glance Database, accessed October 2017.

Heavy Precipitation

The frequency of heavy rainfall events in Indiana has been increasing in recent decades. Heavy downpours contribute to increased soil erosion and nutrient runoff on agricultural land. Heavy precipitation events can overwhelm wastewater systems, leading to combined sewer overflow occurrences and subsequent water quality issues. Historical records show that across Indiana, the number of extreme precipitation days — days with average statewide precipitation greater than or equal to the 99th percentile for 1900 to 2016 — has increased by 0.2 days per decade from 1900 to 2016. Figure 4 shows the increasing trend in heavy rainfall frequency for each climate division in the state.

Trend in Extreme Precipitation, 1900 to 2016



Units = days per decade

Figure 4: This map shows the positive trend in the number of days per decade where precipitation totals exceed the 99th percentile. The linear trend reported here is based on the period 1900 to 2016, and values are reported for each Indiana climate division. (Source: Midwestern Regional Climate Center)

Annual and Seasonal Temperature

Statewide annual average temperature has increased about 1.3°F from 1895 to 2019 (Figure 5). Seasonally from 1895 to 2019, average temperatures rose 0.1°F per decade during winter and fall, and 0.2°F per decade in spring, with no detectable trend during summer. However, since 1960 all four seasons show increasing temperature trends, and the rate of change is accelerating, with the most warming observed in the winter (0.7°F per decade).

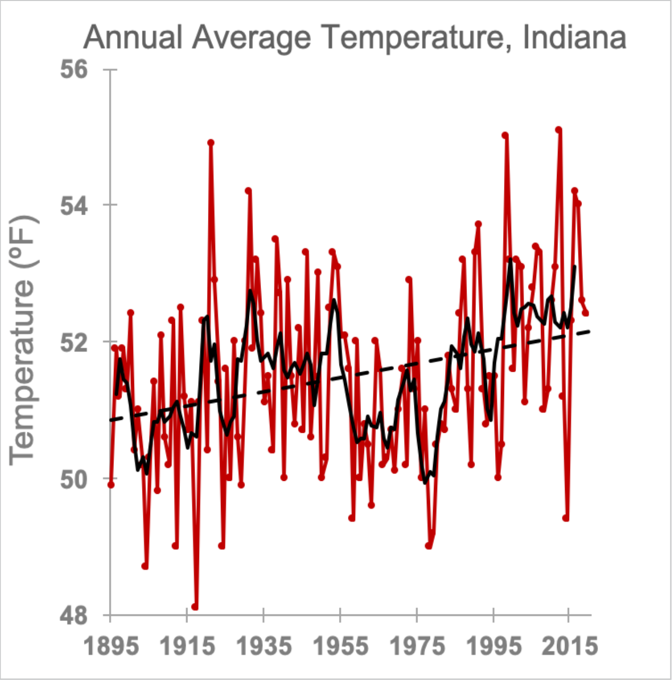
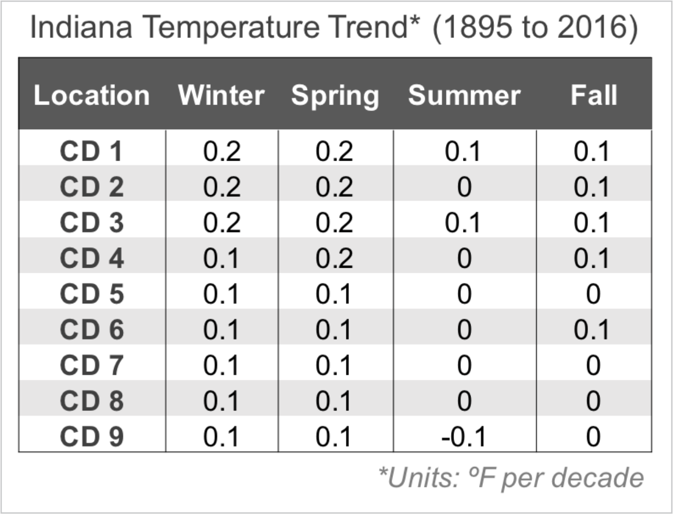


Figure 5: Statewide annual average temperature for Indiana from 1895 to 2019 is shown in red. The solid black line shows the five-year running average. The dashed black line shows the linear trend in annual temperature (0.1°F/decade) for the period of record (1895 to 2019). Data are from the NOAA Climate At A Glance Database, accessed January 2020.

Trends in average temperature from 1895 to 2016 for each climate division show slightly more warming in the northern portions of the state compared to the central and southern portions of the state in each season (Table 2, top).

Statewide, minimum temperatures increased annually by 0.2°F per decade from 1895 to 2019, with increasing trends in all four seasons: winter, 0.2°F/decade; spring, 0.2°F/decade; summer, 0.1°F/decade; and fall, 0.2°F/decade.

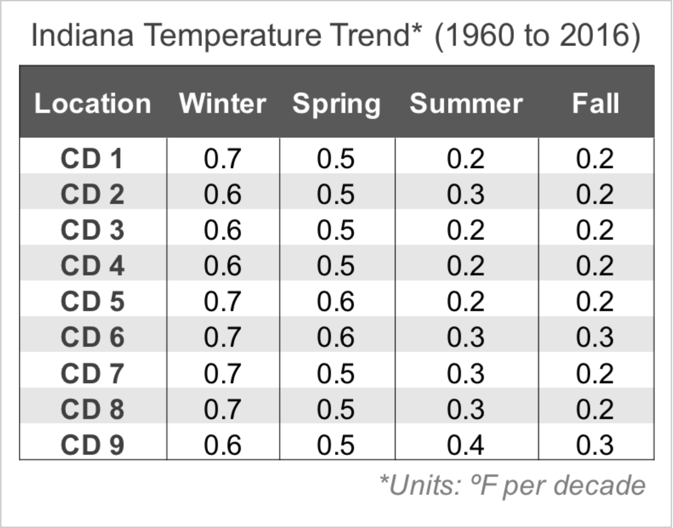


Indiana Temperature Trend* (1895 to 2016)

Location	Winter	Spring	Summer	Fall
CD 1	0.2	0.2	0.1	0.1
CD 2	0.2	0.2	0	0.1
CD 3	0.2	0.2	0.1	0.1
CD 4	0.1	0.2	0	0.1
CD 5	0.1	0.1	0	0
CD 6	0.1	0.1	0	0.1
CD 7	0.1	0.1	0	0
CD 8	0.1	0.1	0	0
CD 9	0.1	0.1	-0.1	0

Units: °F per decade

Table 2: Seasonal average temperature trends for Indiana's nine climate divisions are shown for the periods 1895-2016 (top) and 1960-2016 (bottom). Data show the change in average annual temperature (°F) per decade. Positive values indicate increasing temperatures, and negative values indicate decreasing temperatures. Zero indicates no trend. Data are from the NOAA Climate At A Glance Database, accessed October 2017.



Indiana Temperature Trend* (1960 to 2016)

Location	Winter	Spring	Summer	Fall
CD 1	0.7	0.5	0.2	0.2
CD 2	0.6	0.5	0.3	0.2
CD 3	0.6	0.5	0.2	0.2
CD 4	0.6	0.5	0.2	0.2
CD 5	0.7	0.6	0.2	0.2
CD 6	0.7	0.6	0.3	0.3
CD 7	0.7	0.5	0.3	0.2
CD 8	0.7	0.5	0.3	0.2
CD 9	0.6	0.5	0.4	0.3

Units: °F per decade

Maximum temperatures showed no trend annually over the full period of record, with distinct seasonal patterns. From 1895 to 2019, maximum temperatures increased during the winter and spring by 0.1°F/decade, decreased during the summer by -0.1°F/decade and showed no trend in the fall.

Temperature Extremes

The frequency and intensity of extreme cold temperatures have been declining statewide since 1960, which is reflected in the northward migration of the USDA Plant Hardiness Zone in recent years (Figure 6). The average annual number of days across Indiana with daily minimum temperatures below 5°F showed no trend from 1915 to 2013, but from 1960 to 2013 there were annually nine fewer days with minimum temperatures below 5°F.

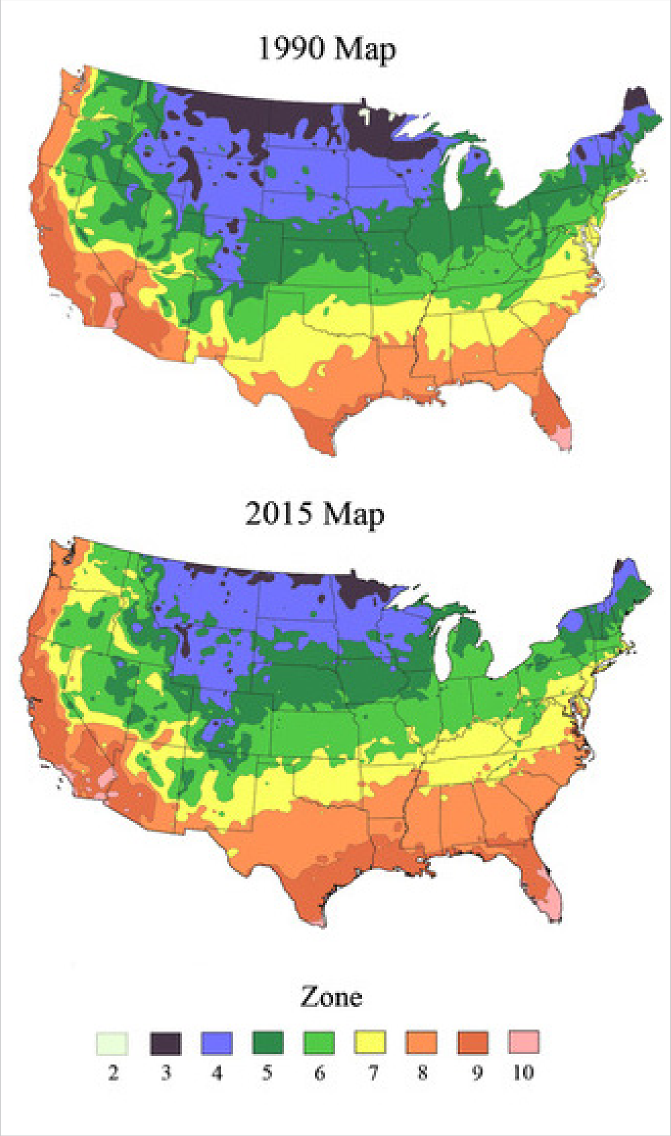


Figure 6. Plant Hardiness Zones, 1990 and 2015. Images from USDA and Arbor Day Foundation.

Despite overall warmer conditions during autumn, winter and spring, there has been little change in summer temperatures and associated extremes. From 1915 to 2013, the number of days per year with daytime high temperatures above 90°F has been declining. This decline is largely skewed by the record heat that occurred with the 1930s drought years.

The recent period from 1960 to 2013 shows no change in temperatures above 90°F. A possible contributing factor to the lack of summer temperature trends may be the increase in cropland intensification across the Midwest during the 20th century (Atler et al. 2018; Mueller et al. 2016). More intense cropping increases atmospheric humidity levels as plants transpire additional moisture into the air. Moist air heats and cools more slowly, acting to moderate temperature swings by reducing daytime warming (warming air more slowly) and increasing night time warming (cooling air more slowly).

Frost-Free Season

Statewide the frost-free season, defined as the time between the last 32°F spring freeze and the first 32°F fall freeze, lengthened by about nine days from 1915 to 2013, with the last spring freeze occurring about eight days earlier and the first fall freeze occurring about one day later. The change in frost-free season length by climate division is displayed in Figure 7. An extended frost-free season can increase the productivity of food crops and reduce heating demands. However, it also disrupts species interactions and the timing of biological events such as migration patterns, flower blooms, etc. Human health is negatively affected, too, as the allergy season lengthens following the longer growing season.

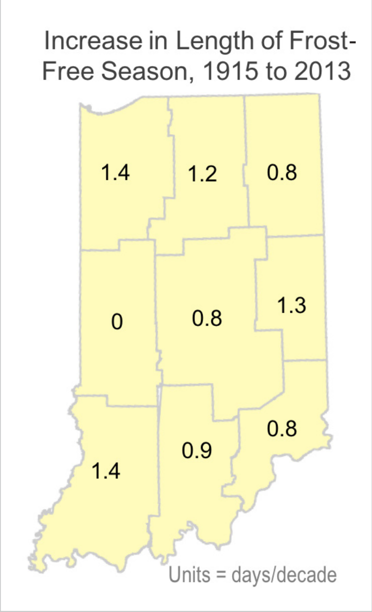


Figure 7: This map shows the per-decade trend in the length of the frost-free season for each climate division in Indiana. Season-length trends were calculated based on a linear trend from 1915 to 2013. Data are from Hamlet et al. 2019.

Future Climate Change Projections for Indiana

According to the Indiana Climate Change Impacts Assessment (Widhalm et al. 2018b; Hamlet et al. 2019), the state's annual average temperature is expected to warm between 5°F and 6°F by mid-century — the average period from 2041 to 2070. By late-century — the average period from 2071 to 2100 — Indiana is projected to warm between 6°F and 10°F.

This projected warming is relative to the historical period from 1971 to 2000. The projected temperature range depends on the amount of heat-trapping gases, such as carbon dioxide and methane, that are put into the atmosphere from human activities like generating electricity, growing food and powering a modern lifestyle. As average temperatures warm in all seasons, the frequency and magnitude of heat events is expected to increase (Table 3). Indiana has historically experienced a decline in extreme heat, which may indicate increased vulnerability to this shifting future trend. Communities need to critically evaluate their ability to cope with more frequent and intense heat events, and the resulting impacts on human life. Scientists also predict a continued decrease in the frequency of cold events.

Annual Number of Days Above 90°F -- Indiana

	Historical Average	2020s	2050s	2080s
St. Joseph County, IN	14	32-33	46-58	57-92
Marion County, IN	20	44-46	61-74	73-109
Vanderburgh County, IN	41	73-74	89-100	99-131

Source: Indiana Climate Change Impacts Assessment

Indiana scientists predict that on the current high emissions trajectory, statewide annual precipitation will increase between 6% and 8% by mid-century and up to 10% by late-century (relative to a 1971-2000 baseline), with distinct seasonal precipitation patterns. Substantial increases in winter and spring precipitation — 16-20% and 13-16%, respectively by mid-century; 17-32% and 10-17%, respectively by late-century — will increase flood risks during a period of the year when Indiana is already prone to flooding. More precipitation will be falling as rain compared to snow. Heavy downpours are expected to continue increasing in both frequency and intensity. Communities need to prepare for increased stress on water management and flood control infrastructure.

Conversely, in the summer and fall when water demands are high, precipitation is expected to decline between -2% and -3% in summer and about -2% in fall by mid-century (-3% to -8% in summer and -2% to -3% in fall by late-century). This will affect water supply for humans and the environment. Analysis concludes little spatial variation in the percent change in precipitation across Indiana, which is why only state-level data are being reported.

The trend for future summer and fall precipitation shows a shift in direction compared to past observations. Over the last century Indiana has been getting slightly wetter during these seasons, but the next century shows drying conditions. This shift to drier conditions is driven by significant projected warming that will alter the water cycle (increase evaporation) and a general shift in broad-scale weather patterns at different times of the year.

What does climate change mean for Indiana?

Shifting weather patterns are expected to result in the following notable impacts in Indiana by mid-century, according to the Indiana Climate Change Impacts Assessment:

- With warmer temperatures, Indiana residents can expect increased heat-related illnesses like heat stroke and dehydration, and more hospital trips and deaths. Excessive heat reduces air quality, increases crop stress, and increases the demand for air conditioning and electricity.
- Lyme disease transmissions will increase as earlier springs allow ticks to emerge more quickly and reproduce longer throughout the year. Warmer and wetter springs will increase numbers of mosquitos carrying diseases like malaria and Zika.
- The growing season is projected to lengthen by about one month by mid-century. While this can increase productivity of food crops and forests, it will also increase growth of noxious plants like ragweed and extend the lifecycle of pest insects. Over time, the benefits of a longer growing season are likely be outweighed by damages from longer, more intense heat waves.
- More frequent heat stress and a doubling of water deficits will reduce corn yields, for current varieties, by 16-20%. Livestock productivity and fertility will decline as heat stress events more than double.
- Warmer winters will reduce the time available to harvest wood without damaging forest soils.
- More heavy rainfall events could increase storm and sewer overflows into lakes and rivers, polluting drinking water and recreation spaces. Reduced water quality and warmer water temperatures also threaten aquatic species and habitats.

Preparing Communities and Local Governments for Climate Change

Indiana communities can use a number of strategies to prepare for future climate stress (adapt) and reduce its effects (mitigate). Local governments can use adaptation strategies developed through plans, incentives, standards and regulations. Mitigation strategies minimize future impacts created by climate change by reducing emissions of heat-trapping gases, the primary factor driving today's changes in climate, and/or enhancing the removal of carbon dioxide from the atmosphere (IPCC 2014; American Planning Association 2011). These approaches include activities like reducing vehicle emissions, improving energy efficiency in buildings, and preserving green space and forestland.

Community Solutions

The following examples illustrate how Indiana communities are implementing innovative mitigation strategies.

- **Roundabouts:** More than 100 roundabouts in Carmel have eliminated stoplights and signs that cause vehicles to needlessly idle. Fuel savings per roundabout is estimated at up to 23,000 gallons per year. City-wide, drivers save over $5 million annually.
- **Traffic lights:** During non-peak traffic times, some Fort Wayne intersections have changed to flashing yellow or red lights to reduce wait times and fuel usage.
- **Wastewater treatment:** West Lafayette's wastewater treatment facility uses an anaerobic digester to produce energy from waste. Methane is recovered from treated sludge, which is then used for heating and electricity generation.

Adaptation strategies include making adjustments to natural or human systems that will improve a community's ability to cope with and recover from climate change impacts such as extreme weather events. Community-level adaptation strategies include shifting development from flood prone areas and supporting green infrastructure practices, such as rain garden installations, through incentives and regulations (IPCC 2014; American Planning Association 2011).

In Indianapolis the DigIndy Tunnel System is increasing the city's capacity to store and treat wastewater that otherwise would overflow into local waterways. As heavy rainfall events continue to increase and stress combined sewer systems, this will enable Indianapolis to improve water management and water quality in the short- and long-term. The City of Bloomington naturalized the creek bank of a primary waterway and established native plantings. This project helped reduce creek flow rates and improve stormwater quality, both important adaptations in coping with climate change, while also improving wildlife habitat and reducing the cost of mowing (ERIT 2020).

To further support the integration of climate change issues and impacts into local government planning, the American Planning Association provides guidance on best practices for addressing climate change policy and planning. The Policy Guide on Climate Change outlines recommendations for the planning sectors of land use, transportation, energy, green development, natural resources management, economic development, hazards management, public health and public infrastructure. Their framework includes five strategic points of intervention for state and local government:

- Long-range community visioning and goal setting
- Plan making
- Standards, policies and incentives
- Development work
- Public investment

In addition to integrating climate change into planning efforts, communities can consider organizing around disaster preparedness and response. The Extension Disaster Education Network (EDEN) provides guidance on how to form Community Organizations Active in Disaster (COAD) groups. The online learning, publications and guidance documents help community organizations and individuals understand how collaborative efforts can prepare communities for disaster.

Communities that are developing or updating plans should include multiple stakeholders and perspectives. Local businesses, industry and residents each have unique viewpoints for how to engage with environmental issues. Additionally, when communities are considering new projects, think about how changing weather patterns could impact your project's success. Policymakers can be under pressure to invest resources to solve current, pressing issues at the expense of long-term projects.

Climate change preparation does not have to be the primary purpose for a policy or project, but may be part of it. Many projects underway in communities across the United States were designed to relieve traffic congestion, improve air and water quality, and develop emergency response procedures. These projects are desirable for those reasons, but they also help reduce the impact of future climate change.

Additional Resources

American Planning Association, Climate Change Resources

The American Planning Association provides multiple resources such as policy guides, frameworks, case studies, reports, articles and multimedia related to climate chang issues.

American Planning Association, Policy Guide on Planning and Climate Change

The APA policy guide provides planners, engaged citizens and elected officials with strategies to slow the pace of climate change and to adapt to its impacts.

American Planning Association, Using Climate Information in Local Planning: A Guide for Communities in the Great Lakes

The APA guide outlines how community planners in the Great Lakes can use available data resources, existing science, and current policies and programs to adapt to climate change and its impacts.

Chicago Climate Action Plan

This website provides information regarding how climate change is expected to affect the Chicago area, and how Chicago is planning to cope with climate change. The website itself is a good example of communicating climate change predictions and action plans to a greater audience.

Community Organizations Active in Disaster (COAD) Extension Disaster Education Network (EDEN)

The online learning, publications and guidance documents help community organizations and individuals understand how collaborative efforts can prepare communities for disaster.

Digital Coast

This NOAA-sponsored website focuses on helping communities address coastal issues and includes climate adaptation tools.

Environmental Protection Agency Green Infrastructure Wizard

This site is a repository of EPA-supported Green Infrastructure tools and resources. It includes case studies, technical information and possible sources of funding.

Environmental Resilience Institute Toolkit, Indiana University

ERIT is an interactive resource to support small to midsize communities with preparing for climate change impacts.

Indiana Prepared, Purdue Extension

INPREP provides training, resources and information on rural emergency preparedness topics.

Indiana State Climate Office

Provides maps, tools and data about Indiana's current and past climate.

Purdue Climate Change Research Center (PCCRC)

This site provides access to the Indiana Climate Change Impacts Assessment reports, data and experts.

Sustainable Development Code

This online tools helps communities integrate climate resilience information into zoning codes and comprehensive plans.

Resilience Dialogues

The Resilience Dialogues is a public-private collaboration that works to build climate-resilient communities through facilitated dialogues among scientists, practitioners and community leaders.

U.S. Climate Resilience Toolkit

This resource provides a detailed five-step framework to help communities identify climate hazards and workable solutions in addition to providing access to case studies, climate tools, experts, reports and training courses.

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