CITY OF BLOOMINGTON

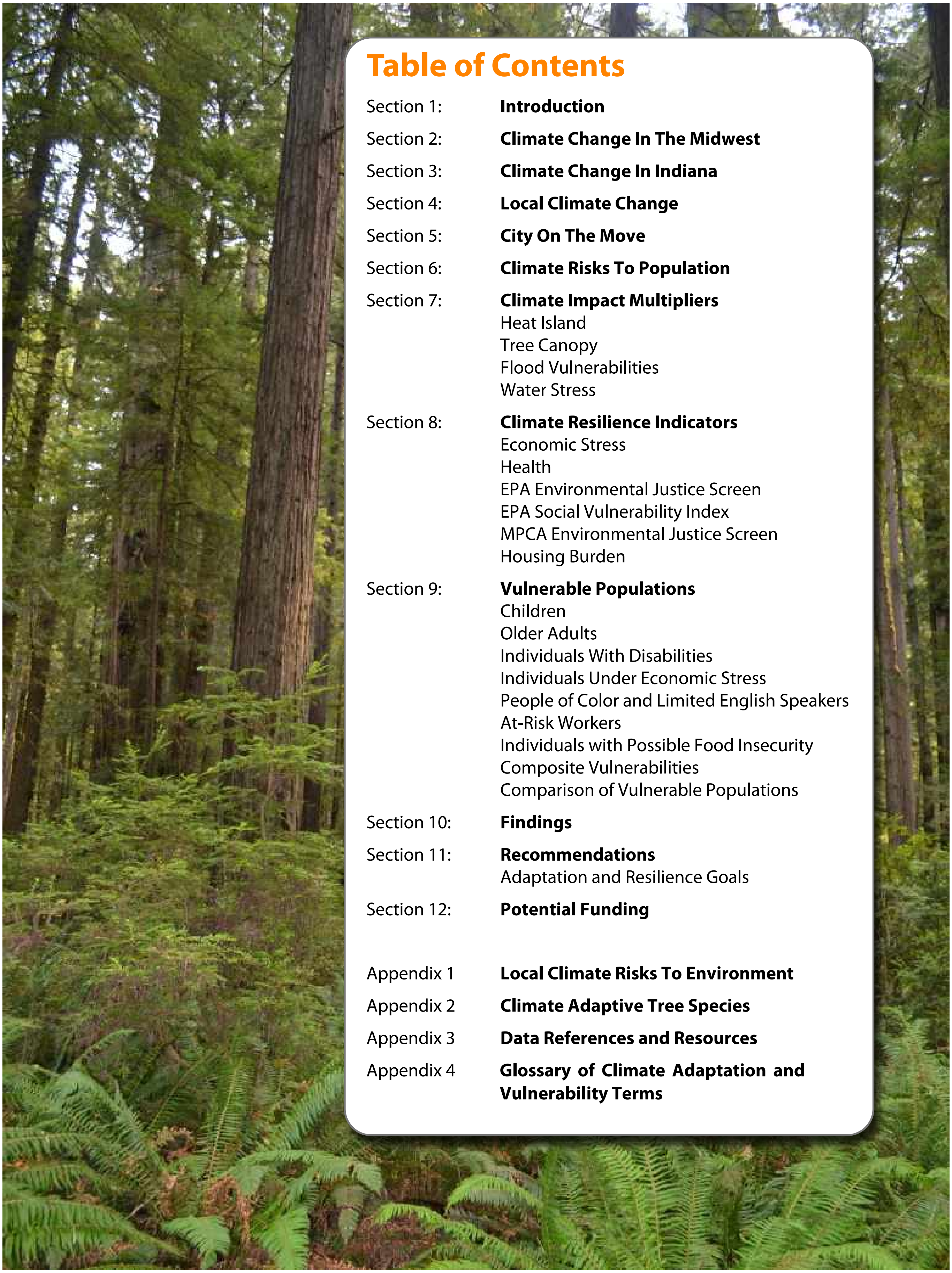
Climate Risk and Vulnerability Assessment

March 2020

Revised May 2020

Prepared by:

paleBLUEdot LLC



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Introduction

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Introduction

Climate change is a global phenomenon that creates local impacts. Two changes to Indiana's climate are occurring already: shorter winters with fewer cold extremes, and more heavy and extreme precipitation. In the future, there is relatively high confidence that those two changes will continue to increase in frequency and intensity, and also that Indiana will begin to experience heat extremes beyond the historical variability of the climate. There is somewhat lower confidence that drought, and also tornadoes, hail and straight-line wind will increase in frequency and/or intensity as a result of climate change in the future.

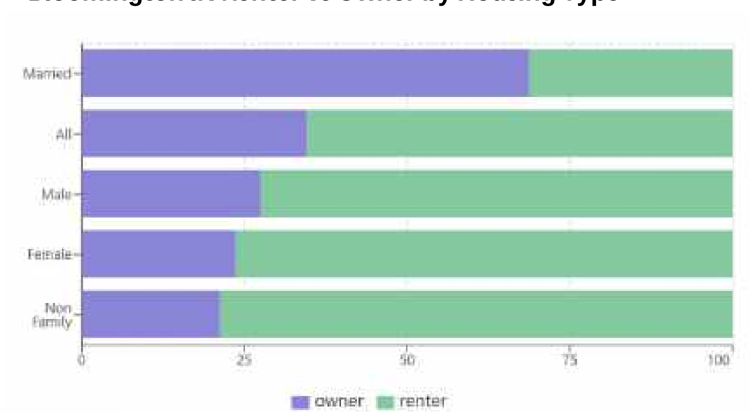
While the science behind climate change is complex, many of the solutions to reducing impacts are already a part of Bloomington municipal government expertise. In many instances, responding to climate change does not require large scale changes to municipal operations, but simply requires adapting exiting plans and polices to incorporate knowledge about changing levels of risk across key areas such as public health, infrastructure planning and emergency management.

Incorporating this knowledge not only protects our communities from growing risk, but climate adaptation strategies can also increase jobs, improve public health and the overall livability of our communities. Strategies which strengthen resilience in time of emergency also help communities thrive even more during good times.

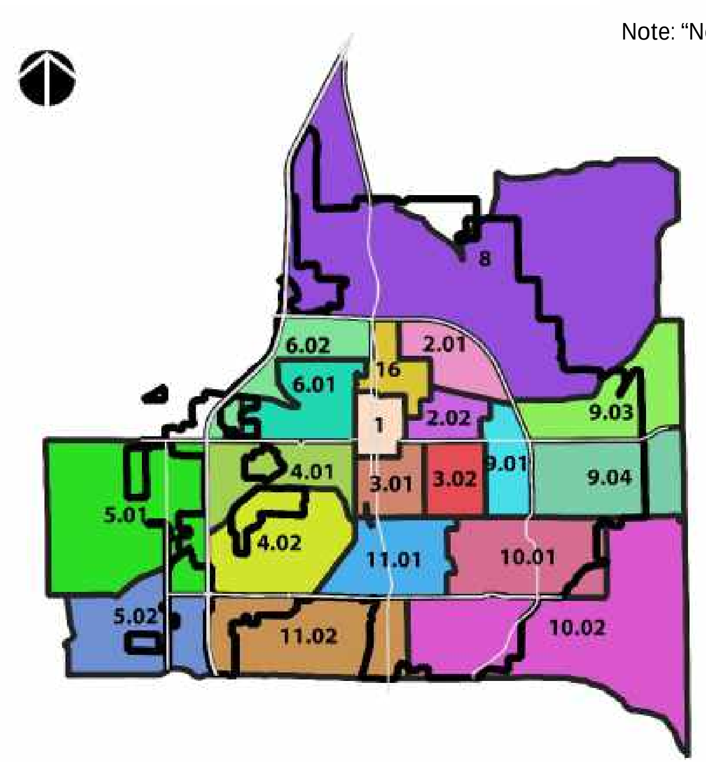
City of Bloomington

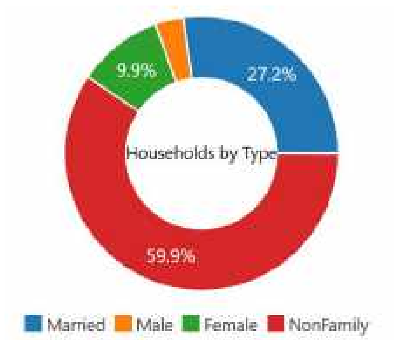
Area	23.4 sq miles 15,002 Acres
Parks, Recreation & Preserves (in 2020)	2,275 Acres
Population (2017)	85,071
Households (2017)	30,569
Number of Companies (2017)	6,040
Employment (2017 all jobs)	50,700

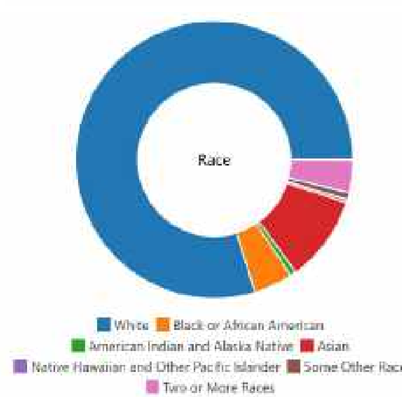
Bloomington IN Renter vs Owner by Housing Type



Note: "Non-Family" households include college student populations.







City of Bloomington Census Tract Map

What is Climate Change Vulnerability?

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". Vulnerability is a function of both impacts (the effects of climate change and variability on a given system or resource) as well as adaptive capacity (the ability of the economy, infrastructure, resources, or population to effectively adapt to such events and changes).

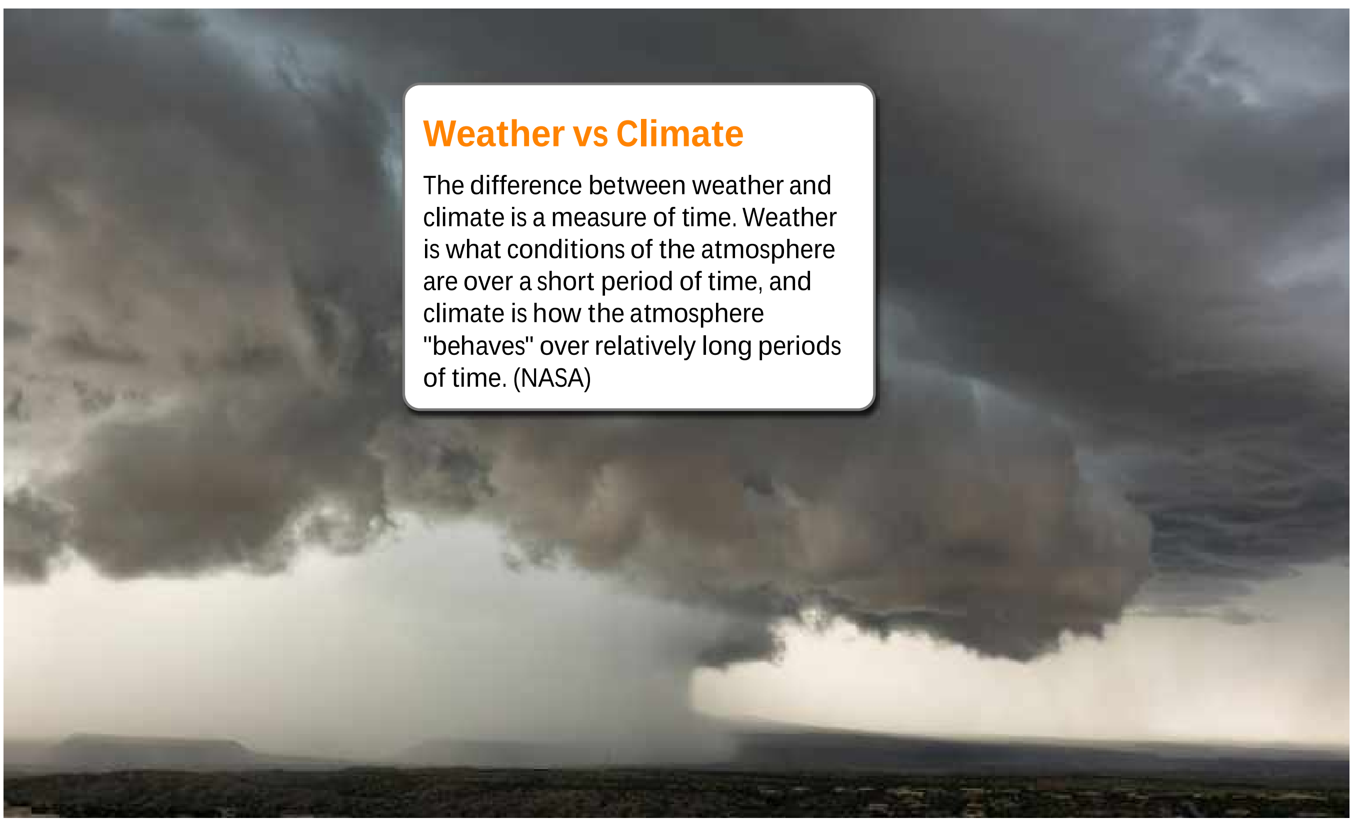
Why Study Climate Change Vulnerability?

Increases in the global surface temperature and changes in precipitation levels and patterns are expected to continue and intensify for decades, regardless of mitigation strategies currently being implemented. In turn, these changes in climate have impacts on the economy and health of local communities.

Weather and climate shape our economy. Temperature impacts everything from the amount of energy consumed to heat and cool homes and offices to the ability for some workers to work outside. Temperature and precipitation levels not only determine how much water we have to drink, but also the performance of entire economic sectors, from agriculture to recreation and tourism. Extreme weather events, like tornadoes, hail storms, droughts, and inland flooding can be particularly damaging. In the last ten years alone, extreme weather events have cost Indiana and the Midwest $96 billion in damage and resulting in 440 deaths. (NOAA National Centers for Environmental Information).

In addition, climate conditions affect the quality of life and life safety of communities – particularly those populations especially sensitive to climate impacts. Extreme weather events linked to climate change have the potential to harm community member health in numerous ways. Rising temperatures, for example, can result in a longer-than-average allergy season, erode air quality, and prolong the stay and increase the population of insects increasing the risk of vector-borne diseases. Climate impacts also exacerbate additional economic challenges that can directly impact the ability of at-risk populations to cope with the additional risks exacerbated by climate conditions while creating more exposure to dangerous living/working conditions and poor nutrition.

Strengthening community resilience is rooted in an on-going assessment of potential vulnerabilities, anticipating potential climate impacts, development and implementation of strategies to address those vulnerabilities, and in communication and outreach to the members of the community.



Weather vs Climate

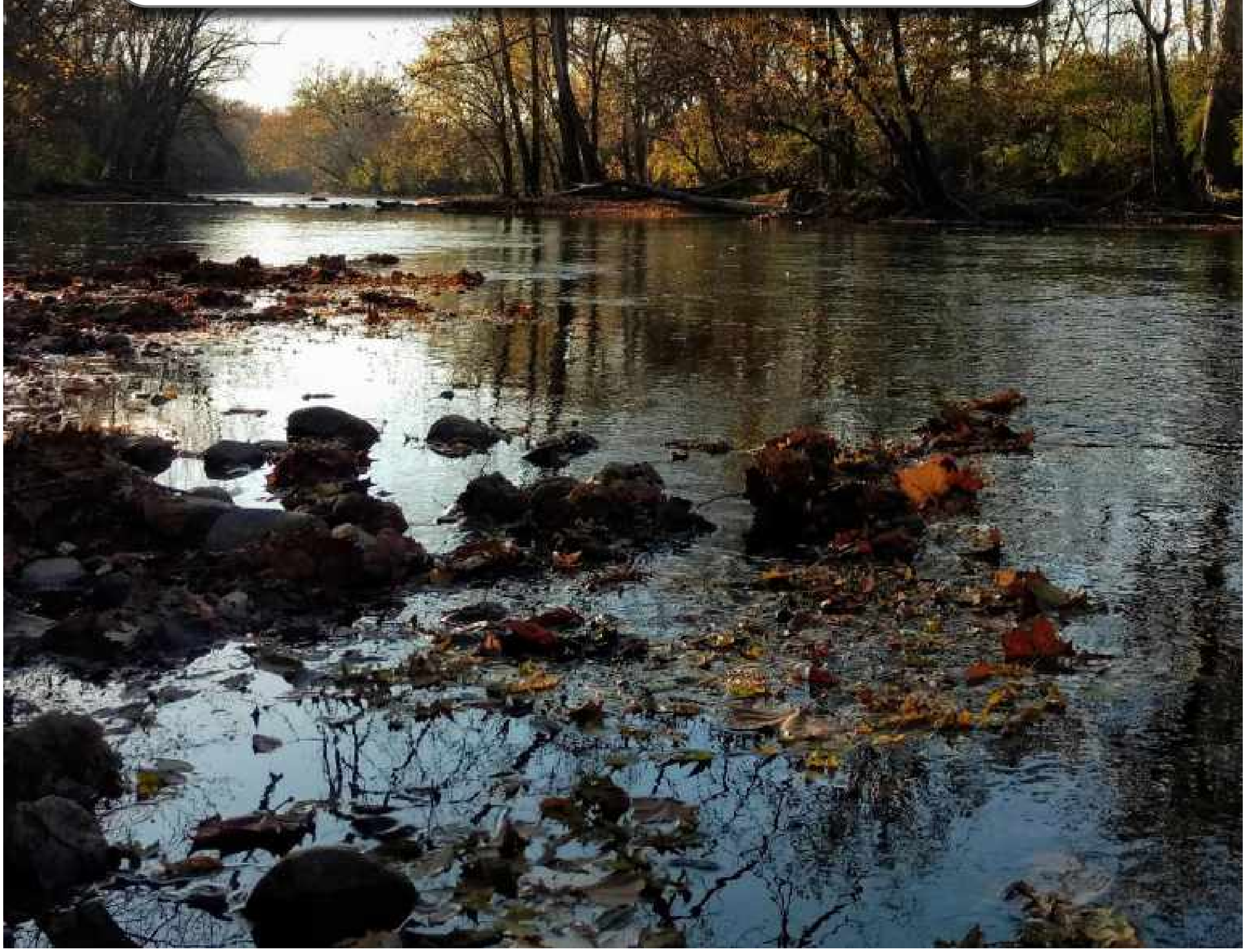
The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time. (NASA)

About This Report

This Climate Vulnerability Assessment has been developed in conjunction with the City of Bloomington's Climate Action Plan update effort. This report seeks to:

- Provide climate risk and vulnerability information in support of the City's Global Covenant of Mayors reporting requirements
- Increase awareness of potential climate impacts and population vulnerabilities.
- Increase inclusion of climate adaptation dialogue within City planning and decision making processes.
- Strengthen adaptive capacity based on the best available information on regional climate change projections and impacts.
- Outline priority risks, and vulnerabilities in support of establishing strategies and actions through the Climate Action Planning effort.
- Prevent or reduce the risks to populations most vulnerable to the impacts of climate change.

The Population Vulnerability Assessment portion of this report describes how climate affects the region today, the changes and impacts expected over the coming decades, and identifies population vulnerabilities.



Section 02

Climate Change In The Midwest

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Climate Change in The Midwest

According to the United States National Climate Assessment on the Midwest Region:

"In general, climate change will tend to amplify existing climate-related risks to people, ecosystems, and infrastructure in the Midwest. Direct effects of increased heat stress, flooding, drought, and late spring freezes on natural and managed ecosystems may be multiplied by changes in pests and disease prevalence, increased competition from non-native or opportunistic native species, ecosystem disturbances, land-use change, landscape fragmentation, atmospheric pollutants, and economic shocks such as crop failures or reduced yields due to extreme weather events. These added stresses, when taken collectively, are projected to alter the ecosystem and socioeconomic patterns and processes in ways that most people in the region would consider detrimental. Much of the region's fisheries, recreation, tourism, and commerce depend on the Great Lakes and expansive northern forests, which already face pollution and invasive species pressure that will be exacerbated by climate change.

Most of the region's population lives in cities, which are particularly vulnerable to climate change related flooding and life-threatening heat waves because of aging infrastructure and other factors. Climate change may also augment or intensify other stresses on vegetation encountered in urban environments, including increased atmospheric pollution, heat island effects, a highly variable water cycle, and frequent exposure to new pests and diseases. Some cities in the region are already engaged in the process of capacity building or are actively building resilience to the threats posed by climate change. The region's highly energy-intensive economy emits a disproportionately large amount of the gases responsible for warming the climate.

Primary Issues for Midwest

1: Impacts to Agriculture
Increases will continue in growing seasons, likely boosting some crop yields. Increases in extreme weather, number of very-hot days, flooding, and days without precipitation will likely decrease other yields. Overall, Midwest productivity is expected to decrease through the century.

2: Forest Composition
Rising air and soil temperatures, and variability in soil moisture will stress tree species. Forest compositions will change as habitats are driven Northward by as much as 300 miles. Due to these ecosystem disruptions, the region's forests may cease acting as a carbon sink, exacerbating greenhouse gas emission impacts.

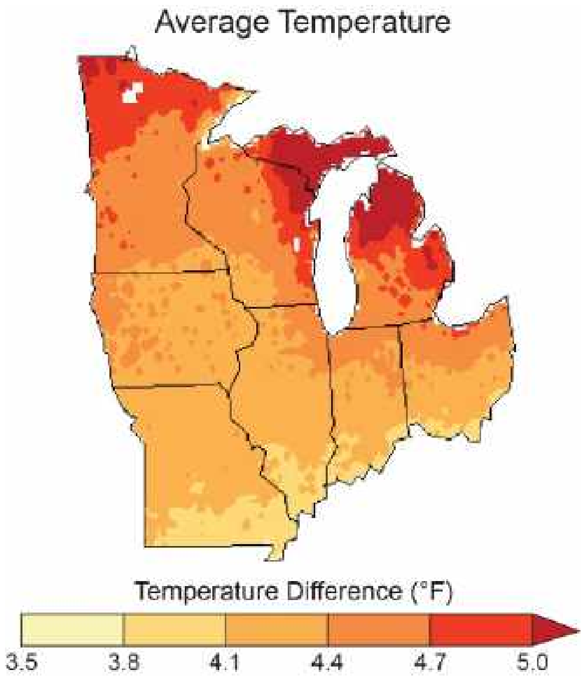
3: Public Health Risks

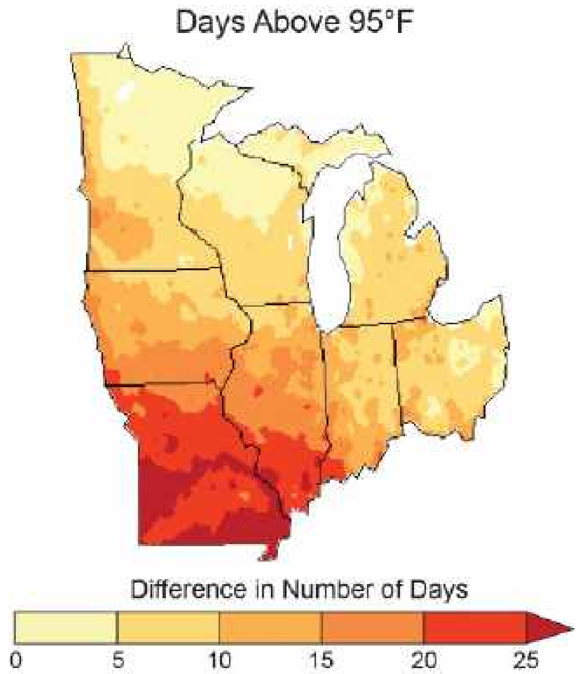
Increases incident rate of days over 95 degrees, and humidity are anticipated to contribute to degradations in air and water quality. Each of these will increase public health risk, especially for at-risk populations.

4: Increased Rainfall and Flooding
The frequency and size of extreme rainfall events and flooding has increased over the last century. In addition, the number of days without precipitation have increased. These trends are expected to continue, causing erosion, declining water quality, and impacts on human health, and infrastructure.

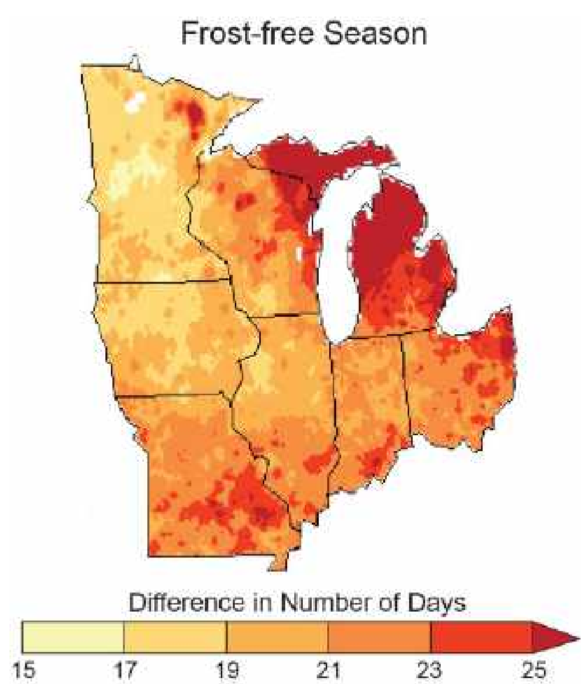
According to the US National Climate Assessment, based on current emissions trends, by mid-century (2040 - 2070) the Midwest region is projected to experience a climate that is…

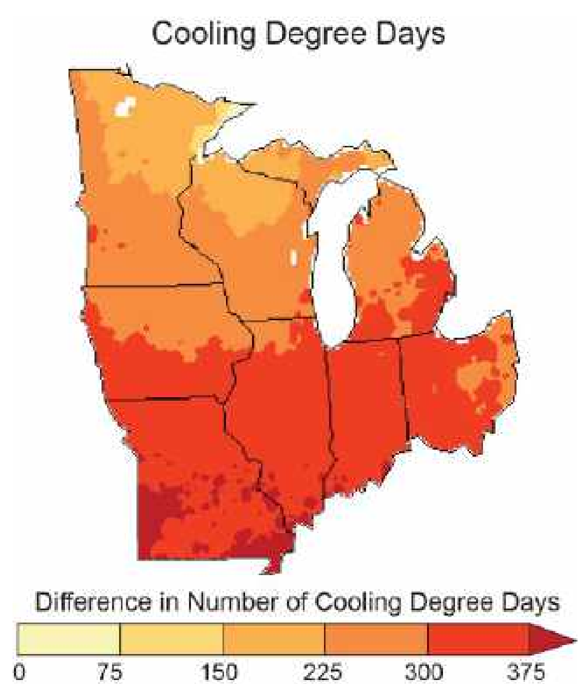
Hotter…





(Source: United States National Climate Assessment)

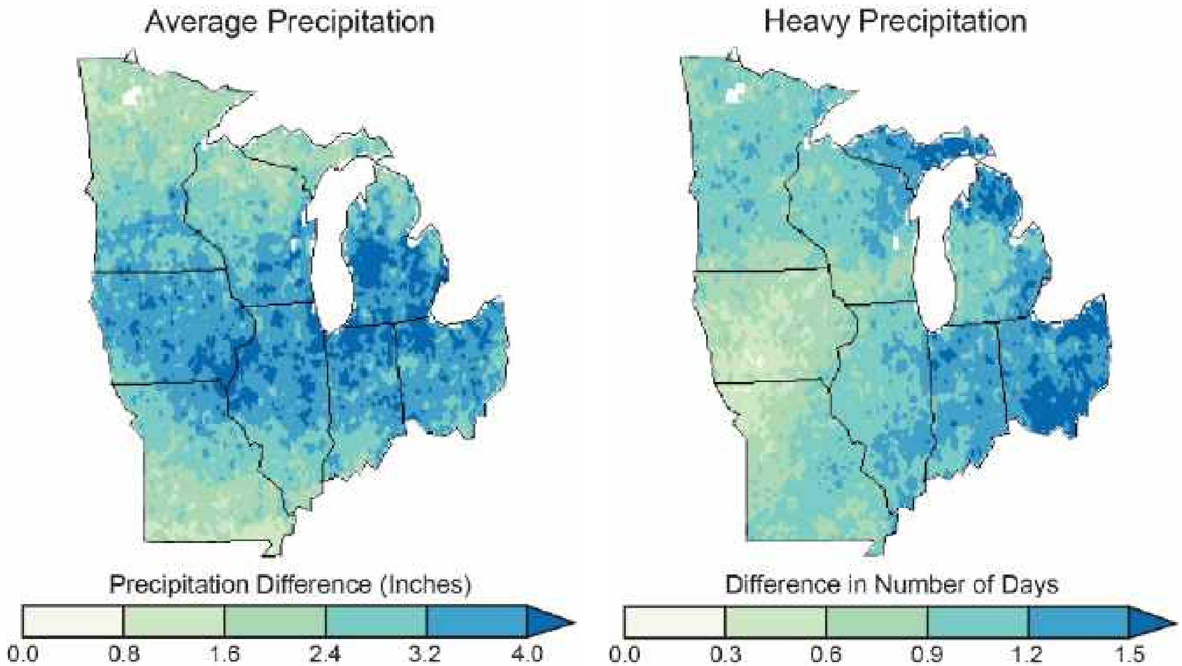




(Source: United States National Climate Assessment)

According to the US National Climate Assessment, based on current emissions trends, by mid-century (2040 - 2070) the Midwest region is projected to experience a climate that is…

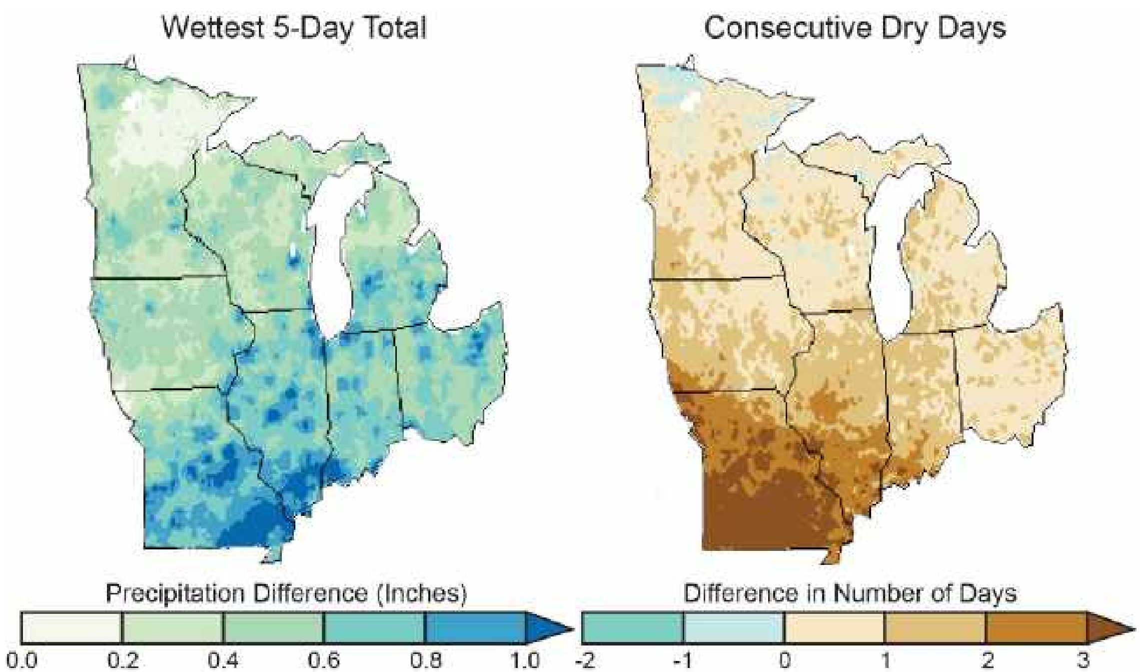
Hotter…with more rain



The Midwest can expect continued increases in annual average precipitation, the number of days with heavy precipitation, making the wettest days of the year even wetter.

(Source: United States National Climate Assessment)

…and drought



The Midwest can also expect an increase in the average number of days between rainfall events. This, combined with heavier rain events which have a higher tendency of "runoff" means that the potential for drought and reduced water tables will increase .

(Source: United States National Climate Assessment)

Section 03

Climate Change In Indiana

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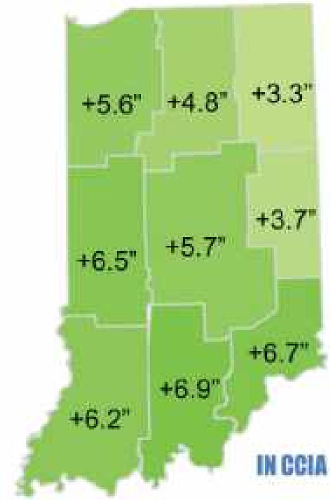
Climate Change in Indiana

Annual Rainfall

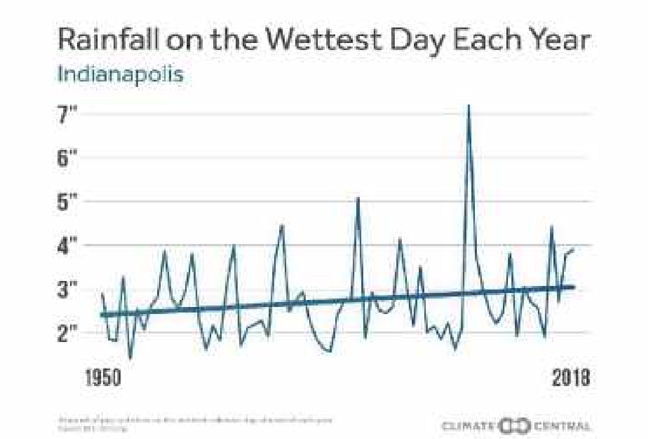
Heavier precipitation is a signature of climate change. For every 1°F of temperature increase, the atmosphere can effectively hold 4 percent more water vapor. So as the world warms from the increase in greenhouse gases, the amount of evaporation also increases from oceans, lakes, rivers, and soils. The extra water vapor is available to produce additional rain and snow, creating an environment ripe for heavy precipitation events.

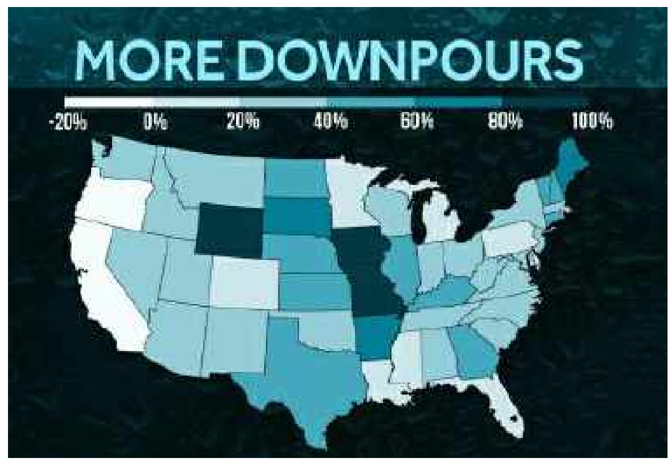
Indiana, home to a number of recent significant flooding events, has strong trends in heavy precipitation events. The State has seen an increase in the magnitude of heavy rain events - the top 1% annual rain events have increased over 20% in the volume of water deposited since 1950.



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

(Graphic Source: Purdue University "Indiana's Past & Future Climate: A Report from the Indiana Climate Change Impacts Assessment")





Observed Indiana Regional Precipitation and Temperature Data

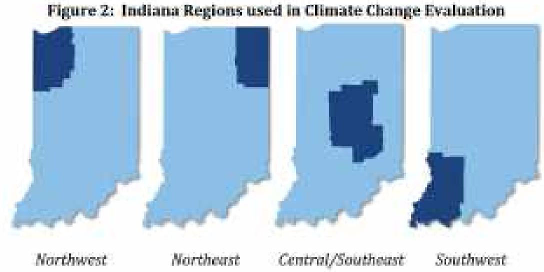
(Source: Midwest Economic Policy Institute "*Climate Change and Its Impact on Infrastructure Systems in Indiana*")

		Precipitation		Temperature	
		Current (in)*	Observed Change**	Current (degrees F)^	Observed Change (degrees F)^^
Central / Southeast	Annual	42.29	8.19%	51.74	0.92
	Winter	7.97	6.13%	29.58	1.80
	Spring	12.16	8.86%	51.29	1.07
	Summer	12.3	1.74%	72.31	0.32
	Fall	9.85	17.82%	53.88	0.68
Northwest	Annual	38.95	5.78%	50.13	0.98
	Winter	6.43	9.35%	27.05	1.97
	Spring	10.35	0.29%	49.48	1.16
	Summer	12.47	2.30%	71.45	0.41
	Fall	9.73	15.70%	52.61	0.57
Southwest	Annual	46.52	9.69%	54.85	0.82
	Winter	9.68	7.92%	33.31	1.63
	Spring	14.08	10.95%	54.58	0.82
	Summer	11.62	-2.11%	75.02	0.38
	Fall	11.13	24.64%	56.57	0.62
Northeast	Annual	38.14	8.32%	49.85	1.01
	Winter	6.83	9.98%	27.12	1.87
	Spring	10.22	2.30%	49.02	1.19
	Summer	11.88	9.19%	71.05	0.47
	Fall	9.27	14.02%	52.25	0.61

* Total precipitation in inches for 1981-2010
** % change between the 1981-2010 period and historical 1951-1980 period
^ Average temperature for 1981-2010
^^ Difference between the 1981-2010 period and historical 1951-1980 period

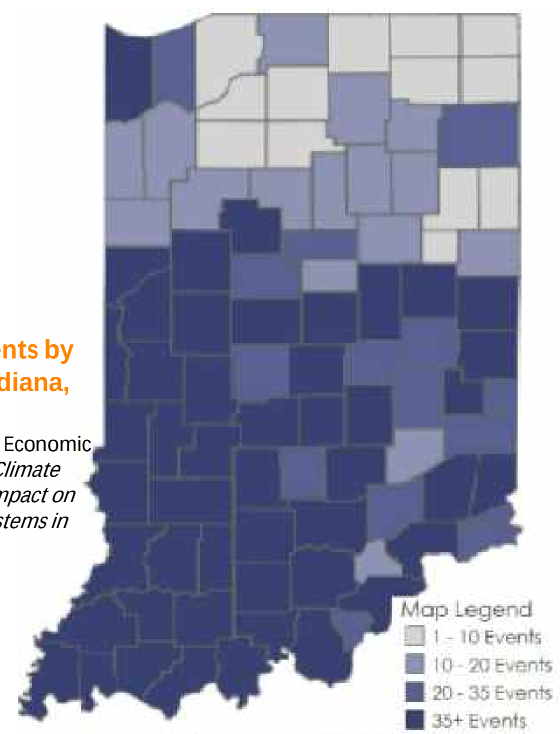
Source(s): University of Michigan Cities Impact and Adaptation Tool

Figure 2: Indiana Regions used in Climate Change Evaluation



Flooding Events by County in Indiana, 1996-2016

(Source: Midwest Economic Policy Institute "*Climate Change and Its Impact on Infrastructure Systems in Indiana*")



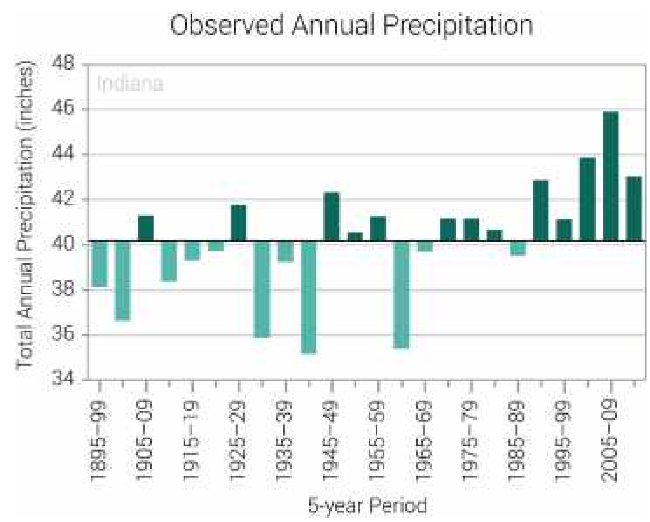
Source(s): FEMA, 2018

Climate Change in Indiana

Observed Annual Precipitation in Indiana

The observed annual precipitation across Indiana for 1895–2014, averaged over 5-year periods; these values are from NCEI's version 2 climate division dataset. Annual precipitation varies widely, but has been above average since 1990. The dark horizontal line represents the long-term average. Annual precipitation during the driest period on record (1940–1944) averaged 35.16 inches, while 46.03 inches was the annual average during the wettest period (2007–2011). Source: CICS-NC and NOAA NCEI.

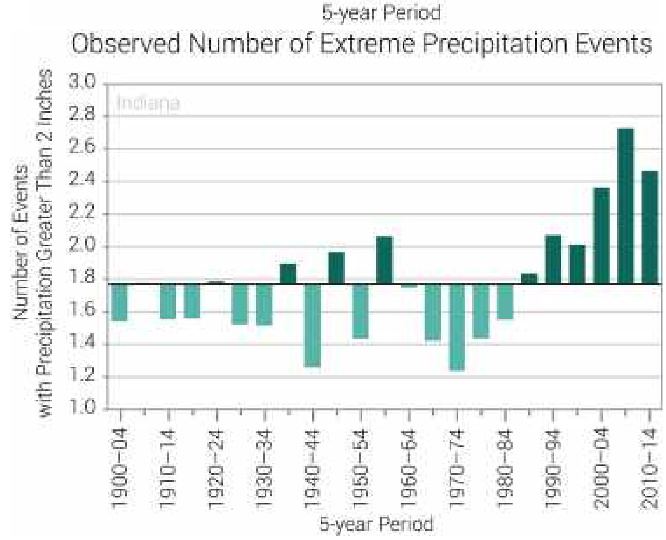
(NOAA National Centers for Environmental Information; State of Indiana Summary)



Observed Extreme Precipitation Events in Indiana

The observed number of days with extreme precipitation events (annual number of days with precipitation above 2 inches) for 1900–2014, averaged over 5-year periods; these values are averages from 21 available long-term reporting stations. The dark horizontal line represents the long-term average. A typical station experiences between 1 and 2 such events per year. The number of extreme precipitation events has been above average since the late 1980s. Between 2005 and 2009, Indiana experienced a record high number of events when stations averaged almost 3 events annually. Source: CICS-NC and NOAA NCEI.

(NOAA National Centers for Environmental Information; State of Indiana Summary)

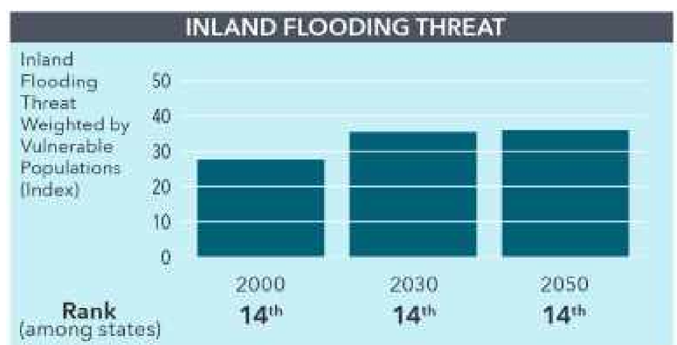


Inland Flooding Threat in Indiana

By 2050, Indiana is projected to see an increase of inland flooding threat of 25 percent. With this increase, by 2050, Indiana is projected to be ranked 14th for inland flooding threat within the United States.

In Indiana, there are more than 270,000 people living in areas at an elevated risk of inland flooding

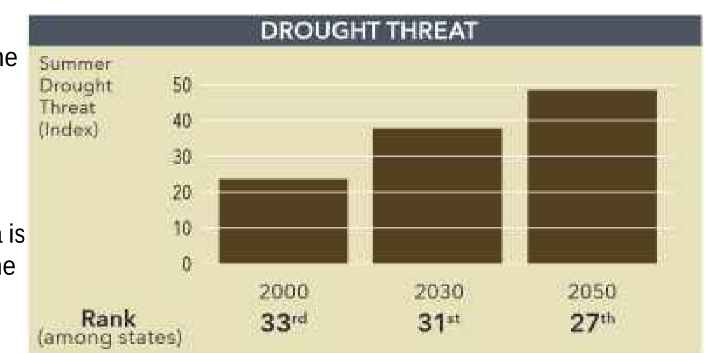
(Threat is calculated by severity of flooding weighted by the State's estimated flood vulnerable population)



Summer Drought in Indiana

According the the U.S. Drought Monitor, since 2000, the longest duration of drought in Indiana lasted 42 weeks beginning on July 23, 2002 and ending on May 6, 2003. The most intense period of drought occurred the week of August 7, 2012 where D4 droughts affected 25.0% of Indiana land.

By 2050, the severity of widespread summer drought is projected to see an increase of up to 200 percent. Indiana is projected to see an 105 percent increase for its index of the severity of widespread drought by 2050. Vulnerability of soils to dry winters could increase the risk of multi-year droughts in Indiana. Threat is calculated by severity of drought



(Sources: Purdue University "Indiana's Past & Future Climate: A Report from the Indiana Climate Change Impacts Assessment", University of Michigan, Climate Central, National Climate Assessment)

Climate Change in Indiana

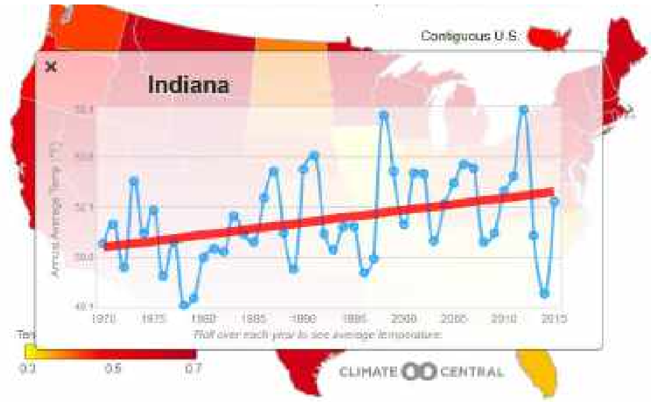
Annual Temperatures

Annual temperatures have increased throughout Indiana over the last few decades. Typically, all seasons are warming across the US, with winter temperatures increasing the fastest. Indiana is no exception to this trend. Since 1981, Indiana temperatures have risen an average of 1.78 degrees in the winter and 0.81 degrees annually.

There have been marked changes in temperature extremes across the contiguous United States. The frequency of cold waves has decreased since the early 1900s, and the frequency of heat waves has increased since the mid-1960s. The number of high temperature records set in the past two decades far exceeds the number of low temperature records. Even with the trend towards increasing temperatures for the region, climate variability is anticipated which may create extreme fluctuations such as weakening of the Jet Stream and increased incidence of polar vortex "wobble" delivering extreme cold to the region. Increased climate variability can have significant impacts on trees, perennial agriculture (fruit and nut trees), insect populations/balance, and agricultural impacts. These trends are expected to continue and increase.

Dangerous Heat Days in Indiana

Indiana currently averages fewer than 5 dangerous heat days a year. By 2050, the states is projected to see almost **40** such days each year.
Source: Climate Central



(Graphic: Climate Central)

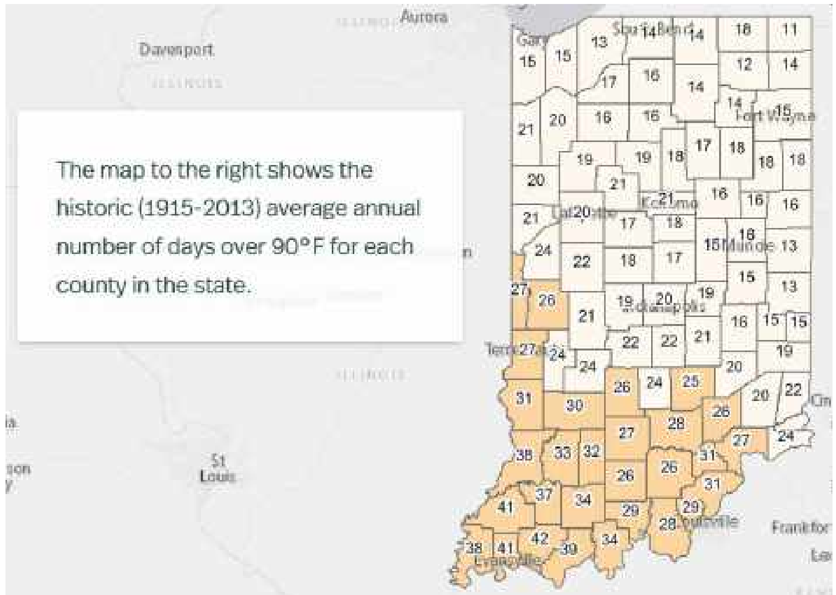
***Above:** Date when soil temperature at 4-inch depth first exceeds 50°F for the historical period (1981 to 2010) and mid-century projections (2041 to 2070) based on a high-emissions scenario. Soil temperatures greater than 50°F are recommended for spring planting of corn. These results suggest that soils will be warm enough to plant 18 to 29 days earlier by mid-century. Results for medium emissions scenario are available. Source: Bowling et al. (in review).*

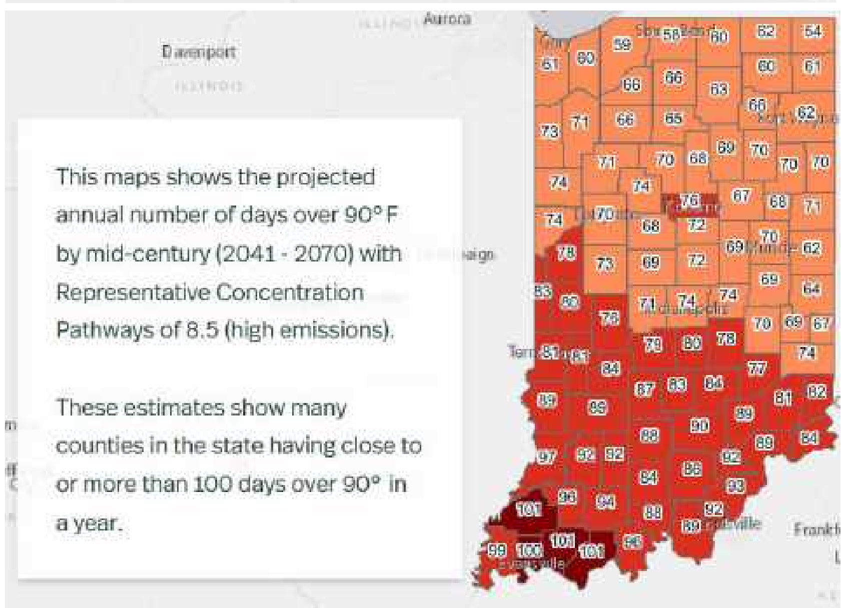
(Source: "*Indiana's Agriculture in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*")

***Above:** Average date when the first hard freeze of autumn, defined as temperatures at or below 25°F, occurs for the historical period (1981 to 2010) and mid-century projections (2041 to 2070) based on a high-emissions scenario. Air temperatures at or below 25°F trigger the onset of winter dormancy in some fruit trees and vines. These results suggest that winter dormancy will start about nine to 13 days later by mid-century. Results for medium-emissions scenario are available. Source: Bowling et al. (in review).*

Climate Change in Indiana

Annual Temperatures



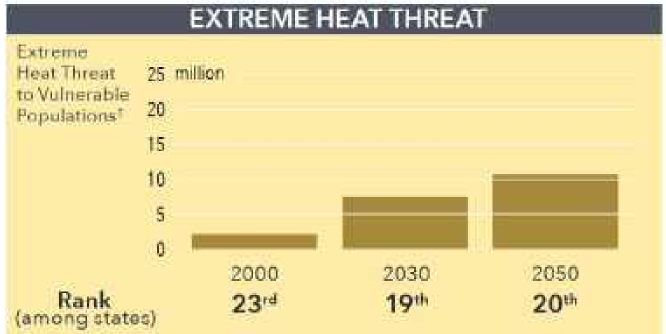


(Graphic Source: Indiana's Multi-Hazard Mitigation Plan, Impacts of climate change on the state of Indiana)

Climate Change in Indiana

Extreme Heat Threat in Indiana

By 2050, Indiana is projected to see an increase in the Extreme Heat Threat of 275%. With this increase, by 2050, Indiana is projected to be ranked 20th for extreme heat threat within the United States.
(Threat is calculated by number of heat wave days multiplied by the State's estimated extreme heat vulnerable population)



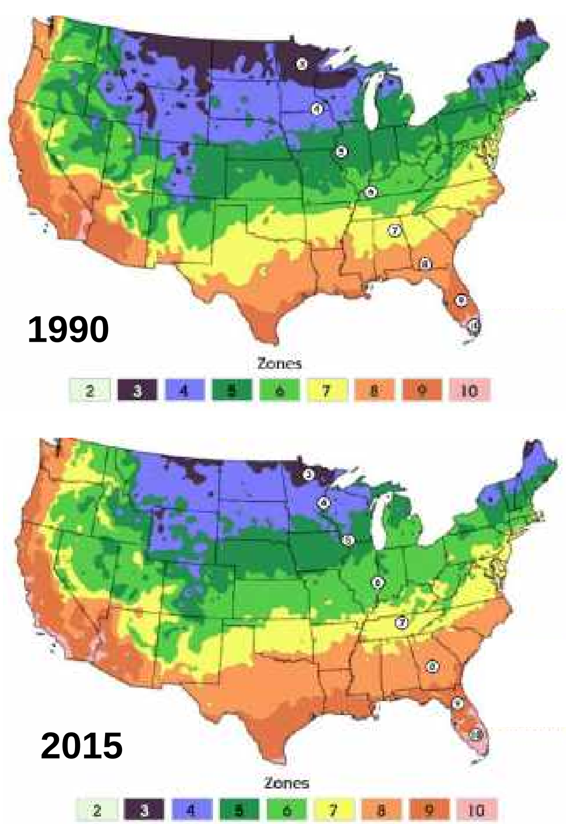
(Graphic: Climate Central)

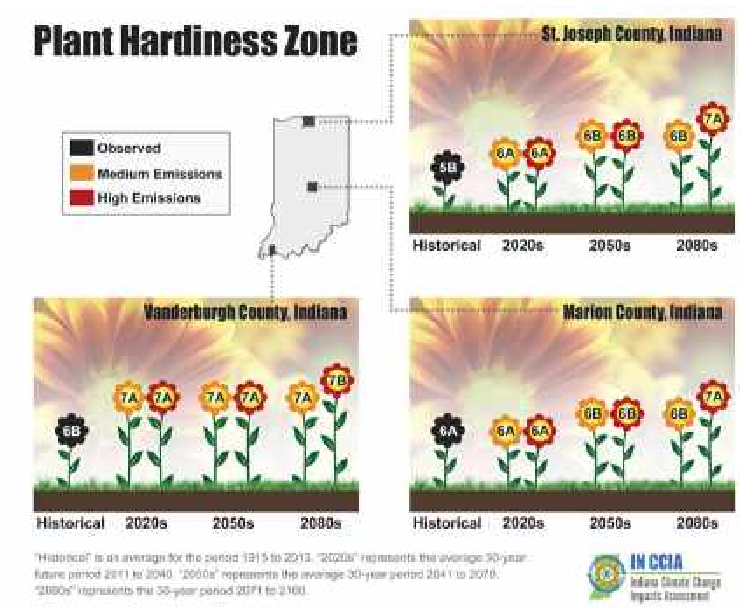
Changing USDA Zones

In addition to warmer weather, Indiana is experiencing less spring snow cover and earlier thaw dates resulting in more rapidly warming soil. The cumulative effects is a shift of USDA Hardiness zones to the North. In 1990 Central Indiana was a Zone 5, today almost the entire State is a Zone 6.

(Graphic Sources: "*Indiana's Agriculture in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*:, Arbor Day Foundation)

Hardiness Zone Changes





***Above:** USDA Plant Hardiness Zones for three Indiana counties. "Historical" is an average for the period 1915 to 2013. For the future projections, "2020s" represents the average of the 30-year period from 2011 to 2040, "2050s" represents the average from 2041 to 2070, and "2080s" represents the average from 2070 to 2100. Data for other locations and time periods available. Source: Hamlet et al. (2019).*

Climate Change in Indiana

Severe Weather - Observed Tornadoes in Indiana

By May of 2019, the US had experienced one of its worst tornado outbreaks of the past decade, with more than 500 reported over 30 days, with the total year to date over 200 higher than average.

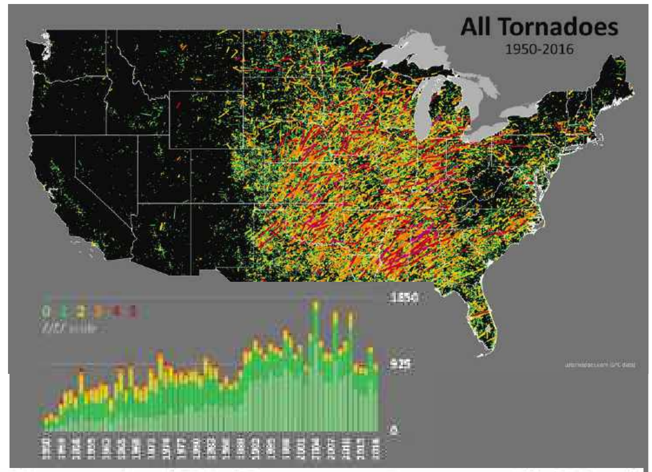
Research by Proceedings of The National Academies of Science of The United States of America, like the report “Robust increases in severe thunderstorm environments in response to greenhouse forcing” by Noah S. Diffenbaugh, et al, has suggested that climate change will create conditions more favourable to the formation of severe thunderstorms and tornadoes. The chart to the right shows the path and numbers of observed tornadoes across the US since 1950. Overall, the number of tornadoes appears to be increasing, however, the increase is currently observed only in weaker category storms.

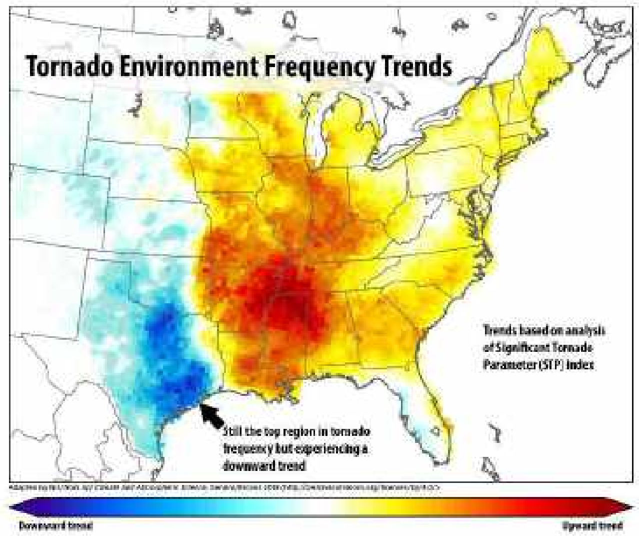
The study “Report Increased variability of tornado occurrence in the United States” by Harold E. Brooks, et al found that there has been considerably more clustering of tornadoes in recent decades. In other words, there are more days in which multiple tornadoes occur, but fewer overall days with tornadoes.

Records by the Indiana State Climate Office of Purdue University (shown below) appear to support the findings of this study, showing an increase in the number of lower category storms.

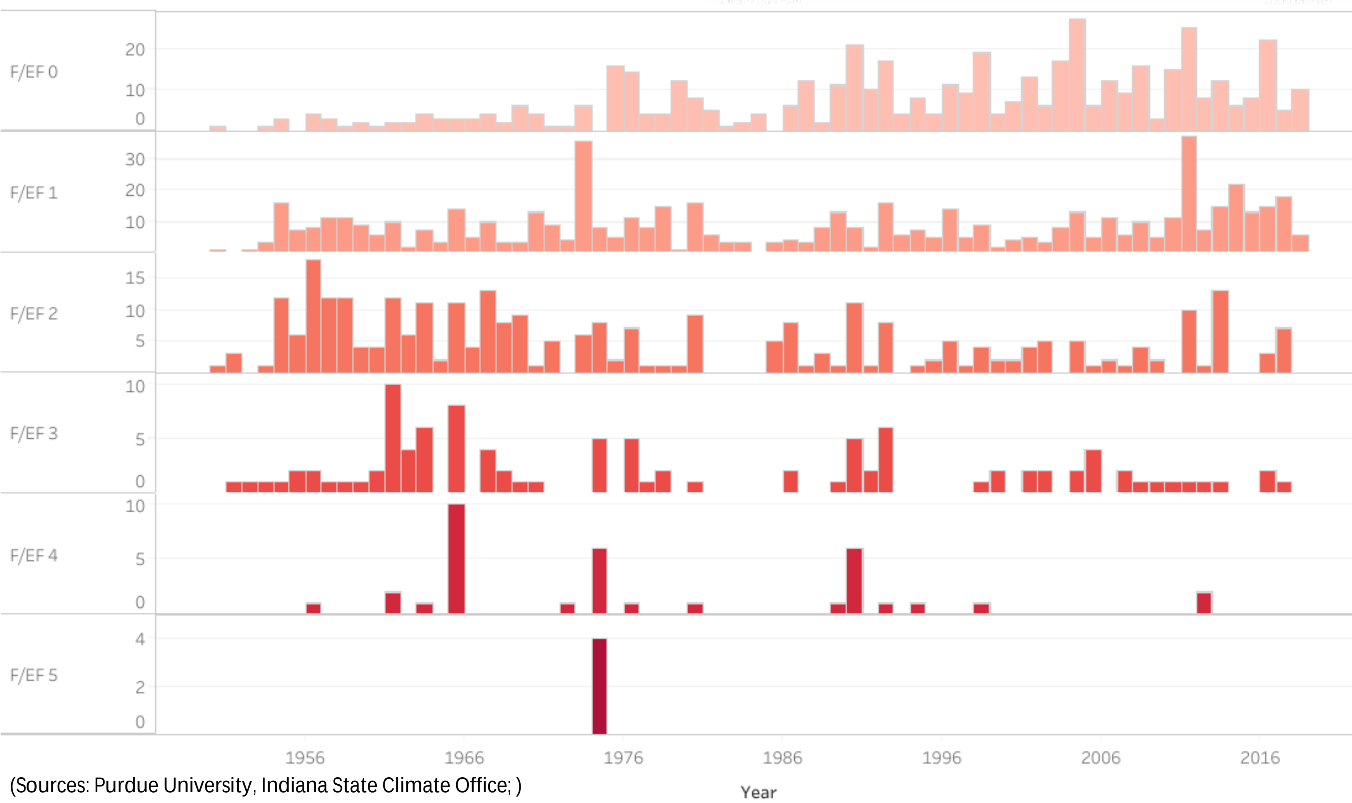
(Sources: Perdue University State of Indiana Climate Office, State of Indiana Multi-Hazard Mitigation Plan, Proceedings of The National Academies of Science of The United States of America, Carbon Brief,)

Observed Tornadoes In United States Since 1950





Observed Tornadoes In Indiana Since 1950

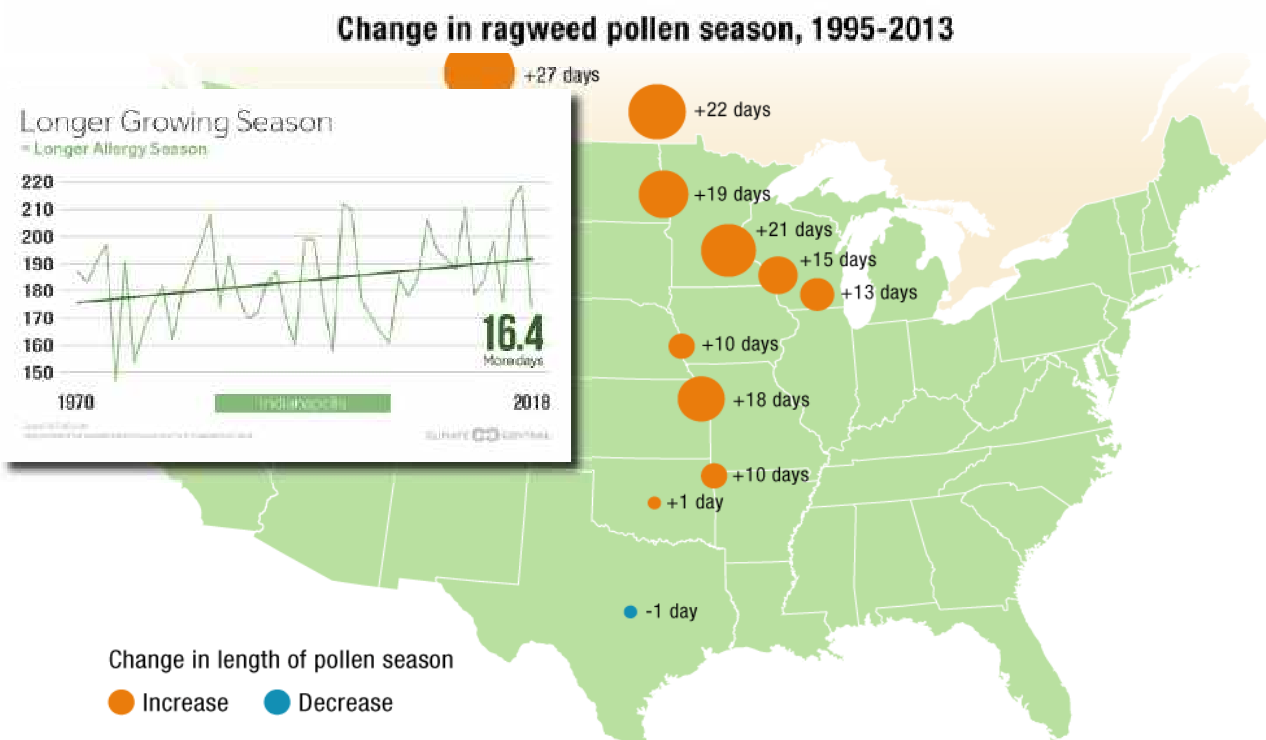


(Sources: Purdue University, Indiana State Climate Office;)

Climate Change in Indiana

Human Allergies

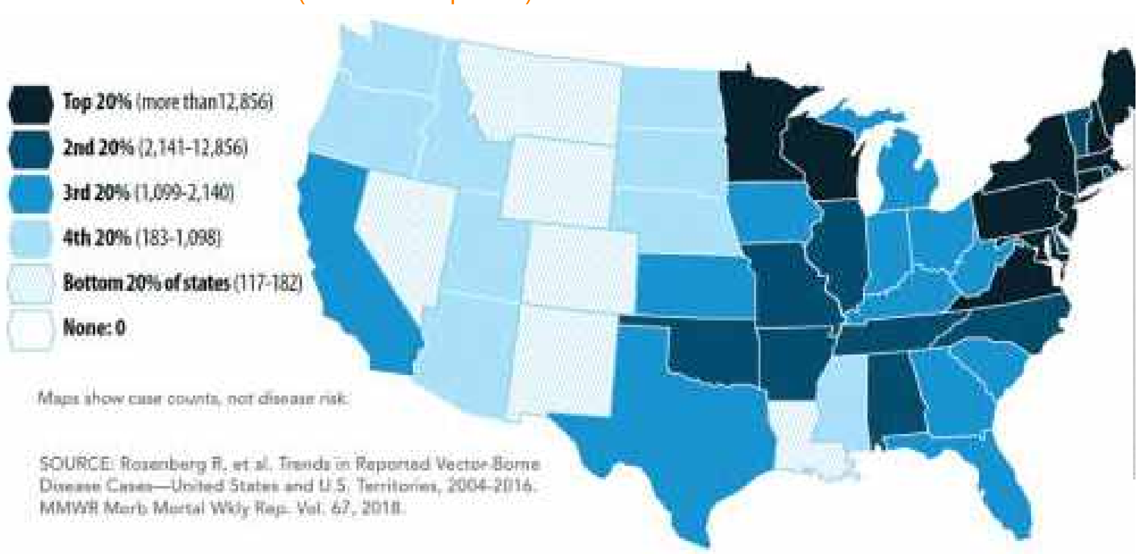
With the shift in hardiness zones and increasing growing season, increases in pollen quantity and duration have been experienced and projected to continue. Beyond inflammation and irritation associated with allergic reactions, some studies indicate pollen can affect the cardiovascular and pulmonary system. Since 1995, the State of Indiana has experienced an increase in allergy season of 10-15 days. (Graphic: Jaime Chrismar MPRnews.org)



Vector Borne Disease

Vector borne diseases are spread through insects and are highly sensitive to climatic factors. Warmer weather influences survival and reproduction rates of vectors, in turn influencing the intensity of vector activity throughout the year. The increase in Lyme disease cases are an illustration of the impacts of a warming Indiana climate will have on vector borne disease intensity. (Graphic: Jaime Chrismar MPRnews.org)

Disease Cases From Ticks (2004-2006 reported)



Section 04

Local Climate Change

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Climate Change in Bloomington

The climate in City of Bloomington has already changed. From 1980 through 2018, the City has experienced an increase in annual average temperature, an increase in the number of days above 95 degrees, an increase in the number of heavy rain events, and a decrease in the number of days below 32 degrees.

Some of the most significant changes in the climate relate to variability. Climate variability can be seen in the changes in annual precipitation for Bloomington. Overall annual precipitation has increased, however, this increase is not evenly distributed throughout the year. Spring and Fall precipitation have increased up to 17%, while Summer precipitation has decreased 2.45% and Winter precipitation has increased 3.22%.

(Sources: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*", US Climate Resilience Toolkit, Climate Science Special Report, University of Indiana Hoosier Resilience Index, US NOAA, Union of Concerned Scientists)

Looking Back

Climate Change Bloomington has already experienced:

Increase in annual average temperature (since 1895):	2°F
Increase in annual precipitation (since 1895):	15%
Increase in heavy precipitation (Since 1980):	25%
Increase in Days above 95 (Since 1980):	3 days
Decrease in Days below 32 (Since 1980):	-10 days
Increase in growing season: (Since 1980):	10 days

Storm Weather Events

Number of Events Reported In Monroe County:

From March 1999 to March 2009: 90 events

From March 2009 to March 2019: 96 events - an increase of 7%

Average Annual Storm Weather Economic Damage 1999-2019: $714,150

(source: NOAA National Centers for Environmental Information)

The City 's climate is anticipated to continue to warm through this century. Precipitation is anticipated to increase in Spring and Fall while remaining the same or decreasing in the Summer and Winter seasons. The primary changes to climate characteristics for the City include:

- Warmer annual average temperatures with a more significant warming in winter months.
- Increase in extreme heat days.
- Increase in heavy rain fall events, with increase in flood potential.
- Increase in time between precipitation with increase in drought potential.
- Greater variability in temperature and precipitation trends.

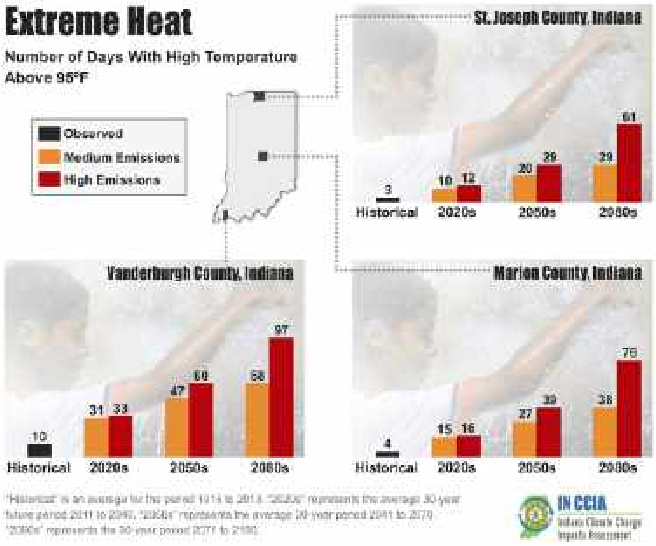
(Sources: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*", US Climate Resilience Toolkit, Climate Science Special Report, University of Indiana Hoosier Resilience Index, US NOAA, Union of Concerned Scientists)

Looking Forward

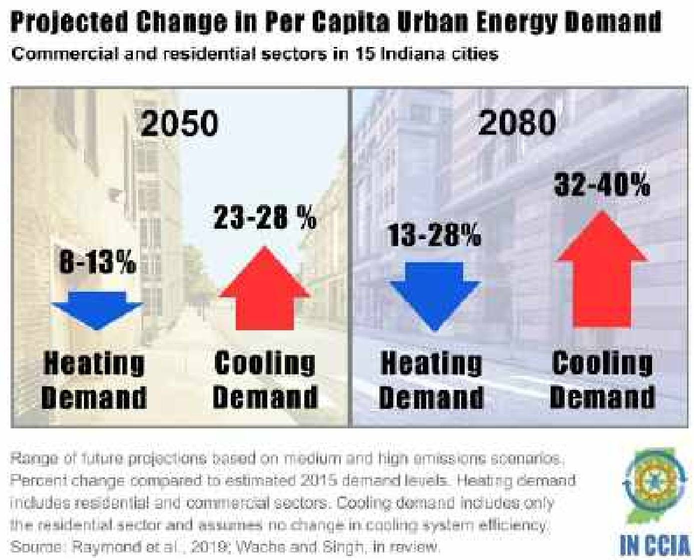
By 2100, Bloomington Can Expect:

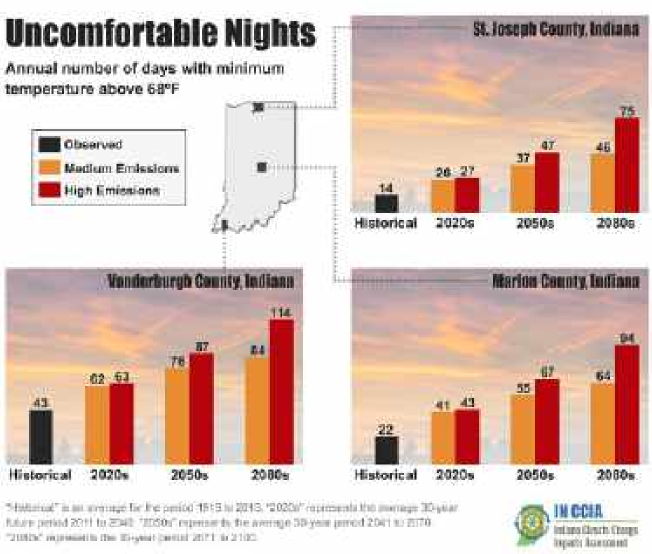
Increase in annual average temperature:	8-11°F
Change in annual precipitation:	-16 to 10% With Significant Seasonal Variation
Increase in heavy precipitation events:	30%
Increase in Days above 95:	+70 days
Decrease in Days below 32:	-52 days
Increase in growing season:	53 days
Increase in Air Conditioning Demand:	40-50%

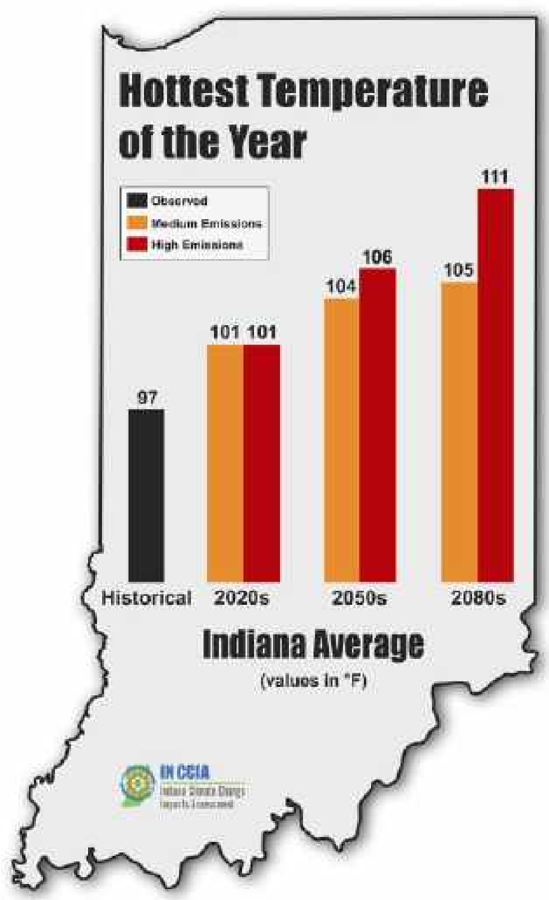
Climate Change in Bloomington - Extreme Heat



Above: *Extreme heat days per year for three representative Indiana counties. An extreme heat day occurs when the daily high temperature is above 95°F. "Historical" is the average for the period from 1915 to 2013. For future projections, "2020s" represents the average 30-year period from 2011 to 2040, "2050s" represents the average from 2041 to 2070, and "2080s" represents the average from 2071 to 2100.* Data for other locations available. *Source: Hamlet et al. (in review) and Widhalm et al. (2018a).*







Above: *Uncomfortable nights per year for three representative Indiana counties. An uncomfortable night occurs when the daily low temperature is above 68°F. "Historical" is the average for the period from 1915 to 2013. For future projections, "2020s" represents the average 30-year period from 2011 to 2040, "2050s" represents the average from 2041 to 2070, and "2080s" represents the average from 2071 to 2100.* Data for other locations available. *Source: Hamlet et al. (in review) and Widhalm et al. (2018a).*

(Graphic Source: The Indiana Climate Change Impacts Assessment, Purdue University)

Climate Change in Bloomington - Precipitation

According to Purdue University's report "*Indiana's Past and Future Climate: A Report from the Indiana Climate Change Impacts Assessment*"

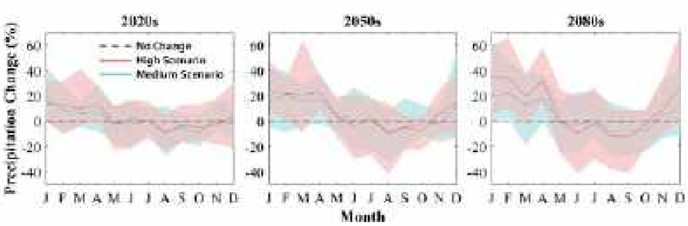
> Extreme rainfall events, defined as having a daily rainfall total in the top 1 percent of all events, have increased over the last century and are expected to continue to do so. Heavy downpours contribute to soil erosion and nutrient runoff, which affects both water quality and crop productivity. These events can also overwhelm wastewater systems and create challenges for flood-control infrastructure.
>
> Averaged across the entire state, historically, an extreme rain event occurs when more than 0.86 inches of rain falls in a day. Since 1900, the number of days per year with extreme rain has been increasing by 0.2 days per decade on average. However, most of that increase has occurred since 1990. The northwestern part of the state has seen the largest increase — a rate of about 0.4 days per decade.

Projected Changes in Indiana's Precipitation

Scenario	Period	Winter	Spring	Summer	Fall	Annual
Medium Emissions	2050s	16%	13%	-2%	-2%	6%
	2080s	17%	10%	-3%	-3%	5%
High Emissions	2050s	20%	16%	-3%	-2%	8%
	2080s	32%	17%	-8%	-2%	10%

Above: *Projected annual and seasonal percent change in precipitation for Indiana compared to the historical period (1971 to 2000). Values represent state-level averages from 10 climate model projections. For the future projections, "2050s" represents the average from 2041 to 2070, and "2080s" represents the period from 2071 to 2100. Source: Hamlet et al. (in review).*

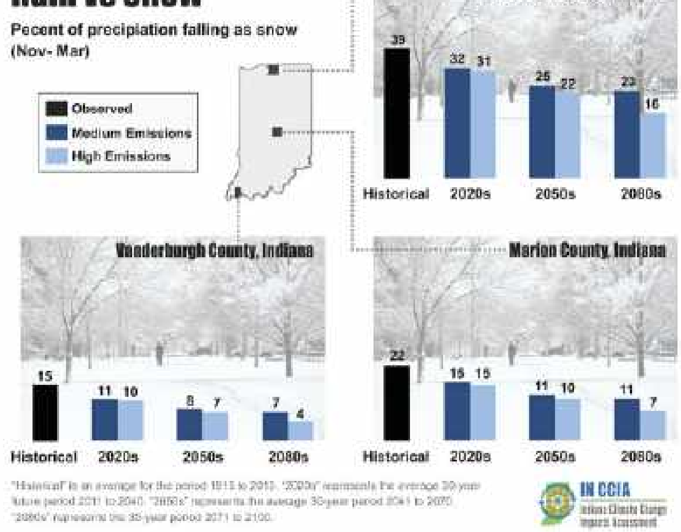
Projected Changes in Indiana's Precipitation



Above: *Projected changes in monthly average precipitation for Indiana for the 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-2100), relative to a 1971 to 2000 historical baseline. The solid red and blue lines show the 10-model average for the high and medium emissions scenarios, respectively. Shaded areas show the corresponding range of results across the 10 climate models. Source: Hamlet et al. (2019).*

> Winters and springs will be wetter with more precipitation falling as rain in **heavy downpours**.
>
> *- Indiana Climate Change Impacts Assessment*

Rain vs Snow



Above: *Percent of cold-season precipitation falling as snow for three Indiana counties. A value of 100 would mean that all precipitation from November to March fell as snow, while a value of 0 would mean none of the precipitation was snow. "Historical" is the average for the period 1915 to 2013. For the future projections, "2020s" represents the average of the 30-year period from 2011 to 2040, "2050s" represents the average from 2041 to 2070, and "2080s" represents the average from 2070 to 2100. Data for other locations and time periods available. Source: Hamlet et al. (2019).*

(Graphic Source: "*Indiana's Past and Future Climate: A Report from the Indiana Climate Change Impacts Assessment*")

Climate Change in Bloomington - National Climate Assessment Projections

How To Read These Charts

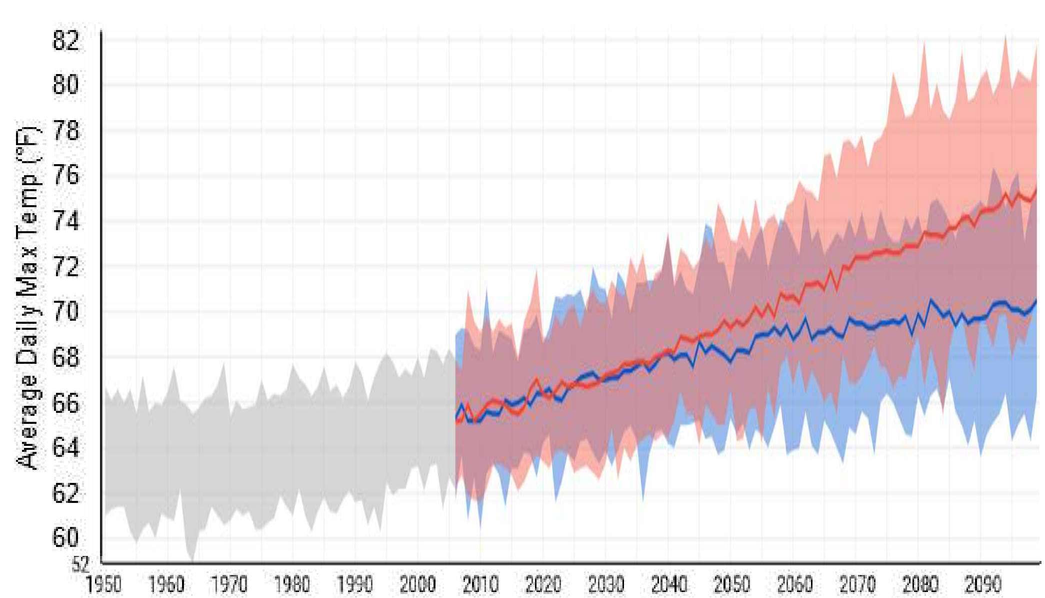
Starting from the left and moving towards the right, the dark gray bars which are oriented vertically indicate observed historic values for each year. The horizontal line from which bars extend shows the county average from 1960-1989. Bars that extend above the line show years that were above average. Bars that extend below the line were below average. The lighter gray band, or area, shows the range of climate model data for the historical period – in other words, the lighter gray area shows the range of weather for the historic period.

Starting from the left and moving right, the red toned band, or area, shows the range of future projections assuming global greenhouse gas emissions continue increasing at current rates. The darker red line shows the median of these projections. For planning purposes, people who have a low tolerance for risk often focus on this scenario.

The blue toned band, or area, shows the range of future projections for a scenario in which global greenhouse gas emissions stop increasing and stabilize. The darker blue line shows the median of these projections. Though the median is no more likely to predict an actual future than other projections in the range, both the red and blue lines help to highlight the projected trend in each scenario.

Mean Daily Maximum Temperature

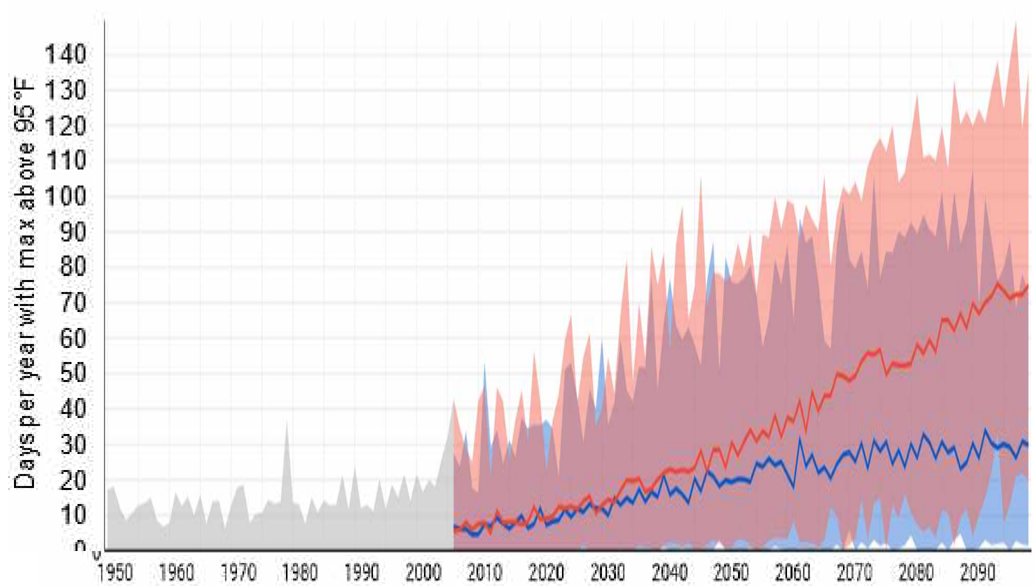
This chart shows observed average daily maximum temperatures for Monroe County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. Maximum temperature serves as one measure of comfort and safety for people and for the health of plants and animals. When maximum temperature exceeds particular thresholds, people can become ill and transportation and energy infrastructure may be stressed.



(Source: US Climate Resilience Toolkit)

Days with Maximum Temperature Above 95°F

This chart shows observed average number of days with temperatures above 95°F for Monroe County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The total number of days per year with maximum temperature above 95°F is an indicator of how often very hot conditions occur. Depending upon humidity, wind, and access to air-conditioning, humans may feel very uncomfortable or experience heat stress or illness on very hot days.



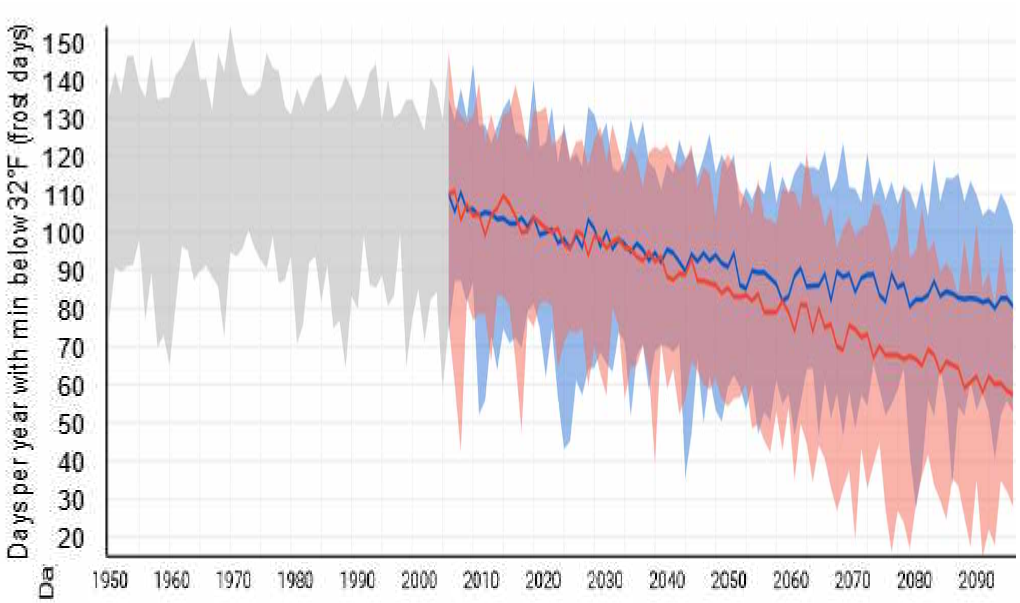
(Source: US Climate Resilience Toolkit)

Climate Change in Bloomington - National Climate Assessment Projections

Days with Minimum Temperature Below 32°F

This chart shows observed average number of days with temperatures below 32°F for Monroe County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The total number of days per year with minimum temperature below 32°F is an indicator of how often cold days occur.

Winter recreation businesses depend on days with below-freezing temperatures to maintain snow pack. Additionally, some plants require a period of days below freezing before they can begin budding or blooming.

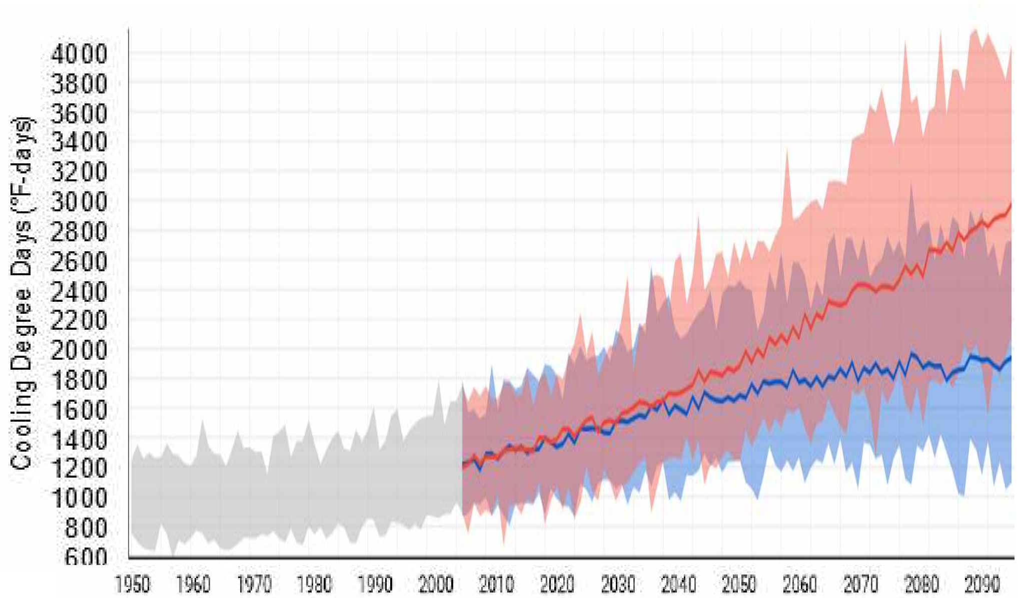


(Source: US Climate Resilience Toolkit)

Cooling Degree Days

This chart shows observed average degree cooling days for Monroe County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The number of cooling degree days per year reflects the amount of energy people use to cool buildings during the warm season.

Cooling degree days are calculated using 65°F degrees as the base building temperature. On a day when the average outdoor temperature is 85°F, reducing the indoor temperature by 20 degrees over 1 day requires 20 degrees of cooling multiplied by 1 day, or 20 cooling degree days.



(Source: US Climate Resilience Toolkit)

Section 05

City on The Move

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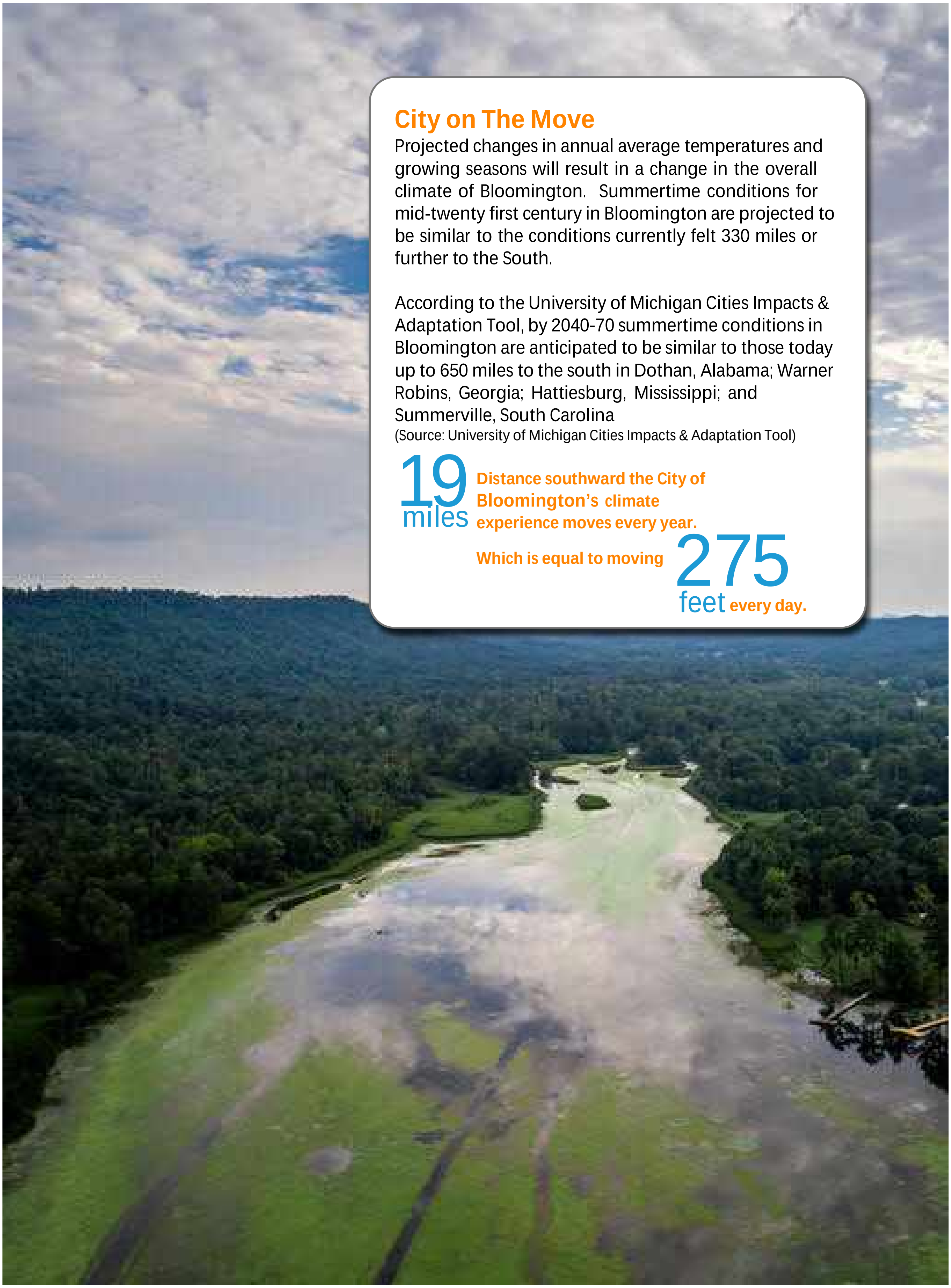


City on The Move

Projected changes in annual average temperatures and growing seasons will result in a change in the overall climate of Bloomington. Summertime conditions for mid-twenty first century in Bloomington are projected to be similar to the conditions currently felt 330 miles or further to the South.

According to the University of Michigan Cities Impacts & Adaptation Tool, by 2040-70 summertime conditions in Bloomington are anticipated to be similar to those today up to 650 miles to the south in Dothan, Alabama; Warner Robins, Georgia; Hattiesburg, Mississippi; and Summerville, South Carolina

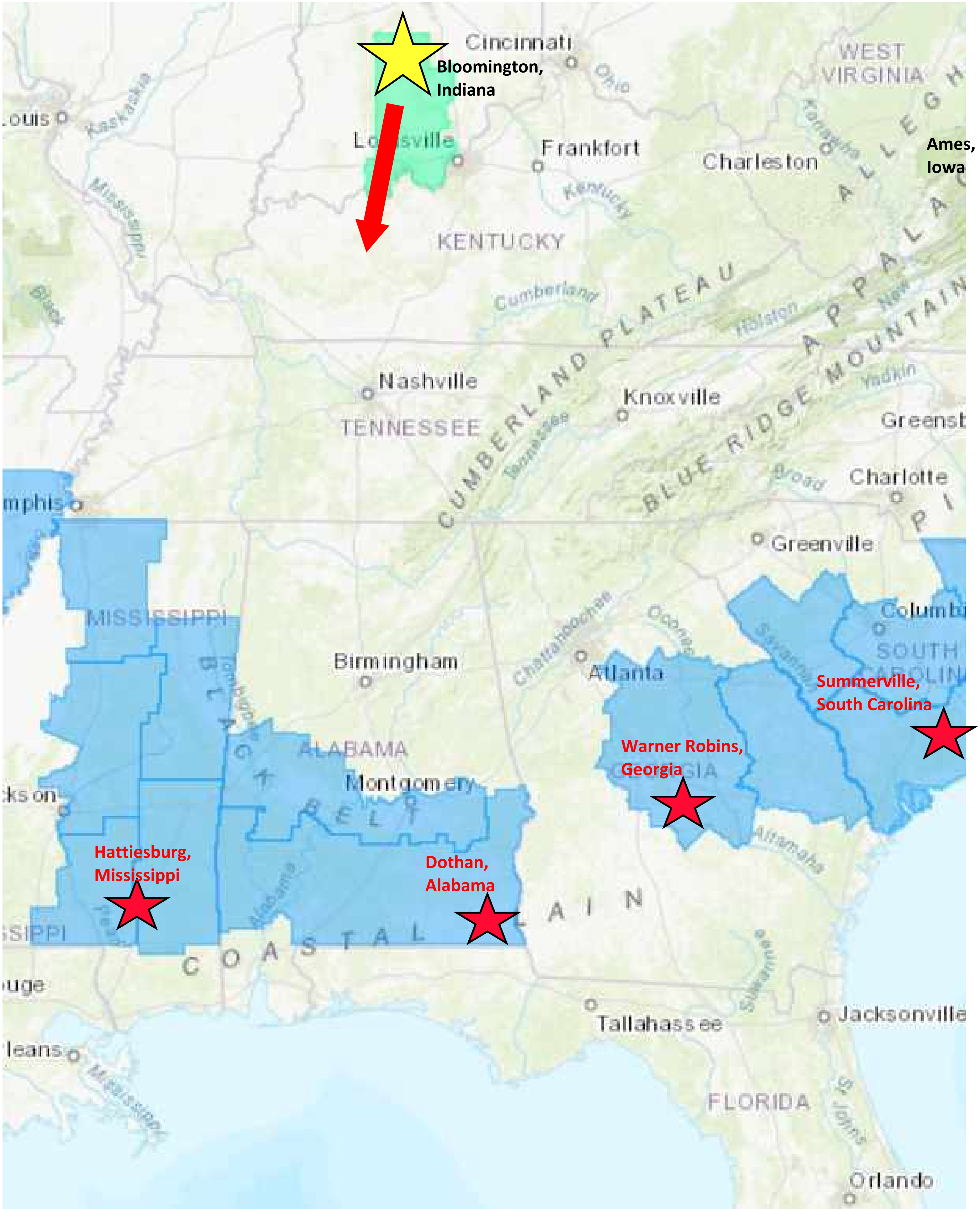
(Source: University of Michigan Cities Impacts & Adaptation Tool)

19 miles Distance southward the City of Bloomington's climate experience moves every year.

Which is equal to moving **275 feet** every day.

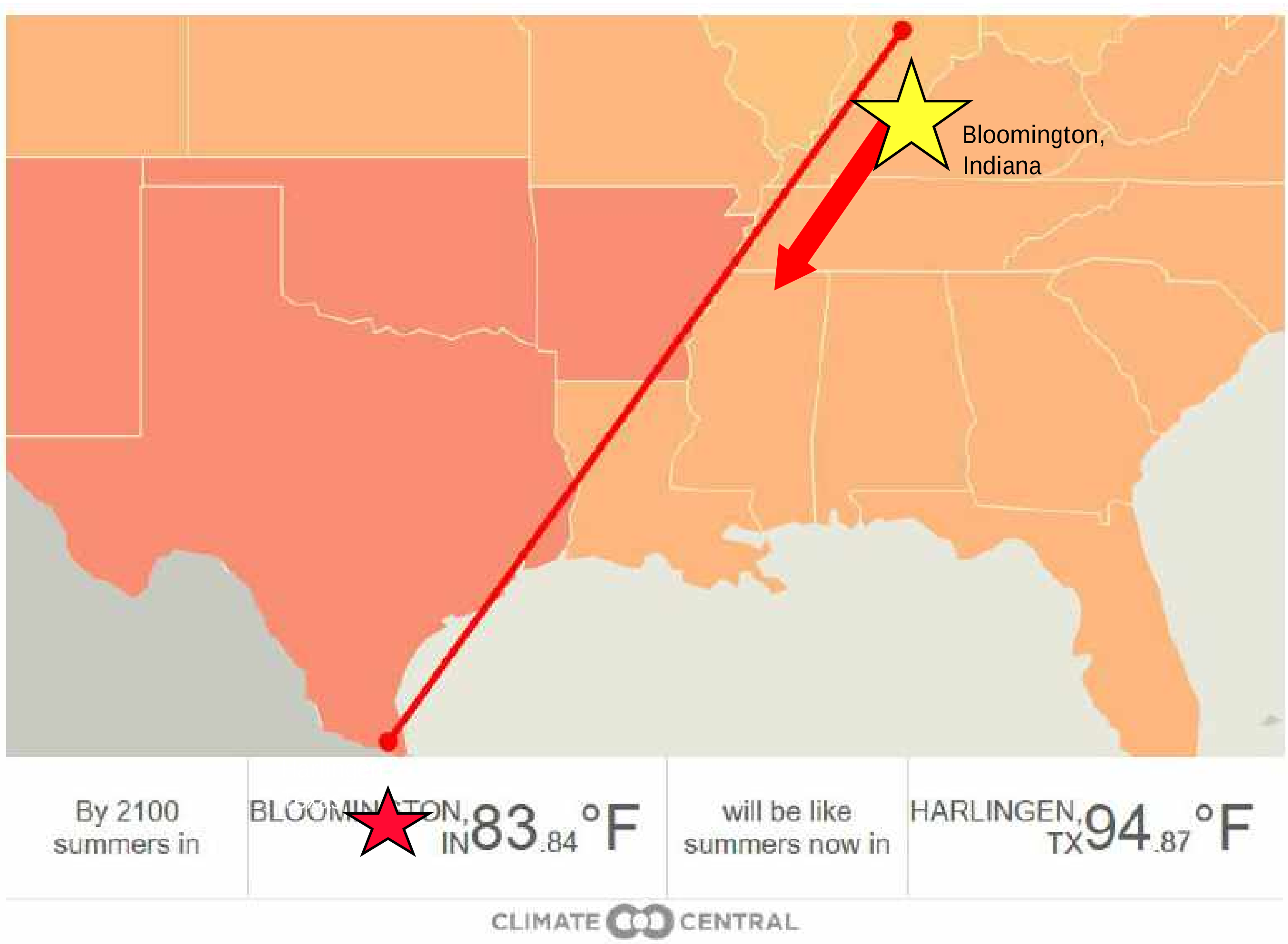
Climate Peers - Bloomington Summers by 2040-2070

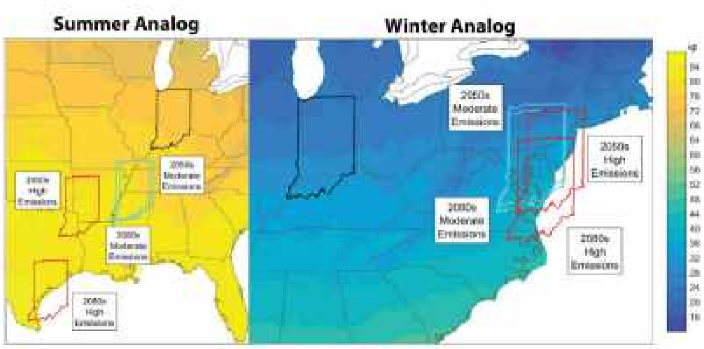
City Climate Peers experience current conditions which match the projected conditions for the City of Bloomington in the future.



Climate Peers - Bloomington Summers by 2100

City Climate Peers experience current conditions which match the projected conditions for the City of Bloomington in the future.





Above: *An illustration of what Indiana's summer and winter climates will feel like under future scenarios, as compared to today's climate in the United States. The colored Indiana outlines are centered over the regions with the most similar summer (left) and winter (right) climates to the projected future climate of Indiana for medium (blue outlines) and high (red outlines) emissions scenarios. Projections are based on statewide seasonal averages for temperature and precipitation. Underlying maps show current-day seasonal average temperatures based on data from PRISM.*

Bloomington Climate Peers - 2100

City Climate Peers experience current conditions which match the projected conditions for the City of Bloomington in the future. By the year 2100, summertime conditions in Bloomington, Indiana can be anticipated to be similar to those currently experienced by Harlingen Texas, over 1,300 miles to the Southwest.

(Source: *Indiana's Past and Future Climate: A Report from the Indiana Climate Change Impacts Assessment*",
US Climate Assessment, University of Michigan Cities Impacts & Adaptation Tool, Climate Central)

Section 06

Climate Risks to The Population

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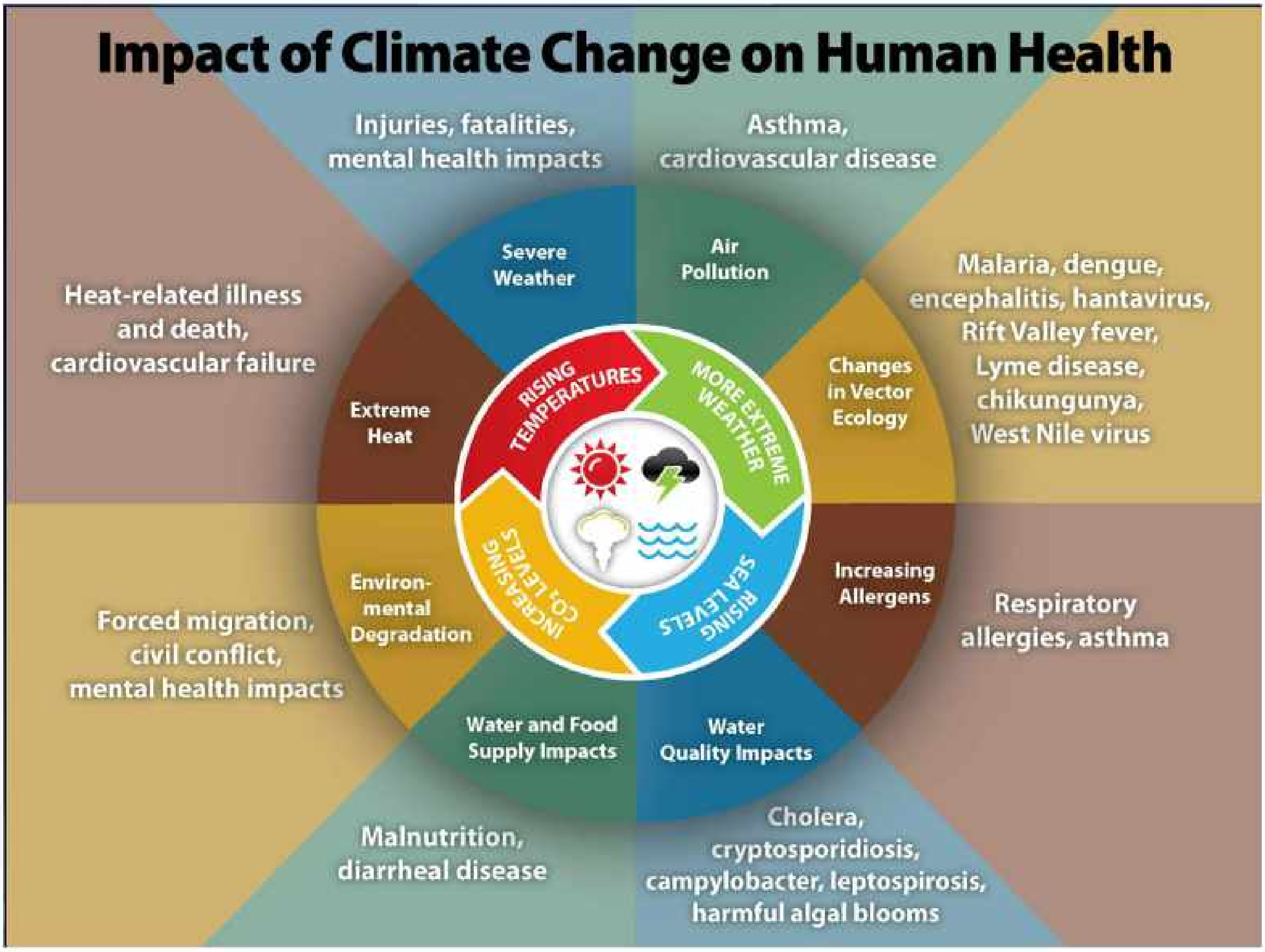
Primary Climate Risks to Bloomington

Climate change impacts a wide-range of health outcomes. The image below by the national Centers for Disease Control and Prevention illustrates the most significant climate change impacts (rising temperatures, more extreme weather, rising sea levels, and increasing carbon dioxide levels), their effect on exposures, and the subsequent health outcomes that can result from these changes in exposures.



The projected changes to the city's climate in the coming decades represent potential risks to residents. These risks are particularly acute in populations especially vulnerable to them such as children, seniors, those with disabilities, and individuals marginalized by race, homelessness, socioeconomic status, gender, or other factors – see Vulnerable Populations section for more information. Below are some of the more significant risks to the City's population:

Extreme Weather / Temperature:

Certain groups of people are more at risk of stress, health impacts, or death related to Extreme Weather events including heat stress, tornadoes, wind storms, lightning, wildfires, winter storms, hail storms, and cold waves. The risks related to extreme weather events include traumatic personal injury (tornadoes, storms), carbon monoxide poisoning (related to power outages), asthma exacerbations (wildfires, heat stress), hypothermia/ frostbite (cold waves, winter storms), and mental health impacts.

Vulnerability to heat stress can be increased by certain variables including the presence of health conditions like diabetes and heart conditions; demographic and socioeconomic factors (e.g. aged 65 years and older living alone); and land cover (e.g. Low percentage tree canopy cover). Studies of heat waves and mortality in the United States demonstrate that increased temperatures or periods of extended high temperatures have increased heat-related deaths. During heat waves, calls to emergency medical services and hospital admissions have also increased.

Primary Climate Risks to Bloomington

Below are some of the more significant risks to the City's population:

Extreme Weather / Temperature (Continued):

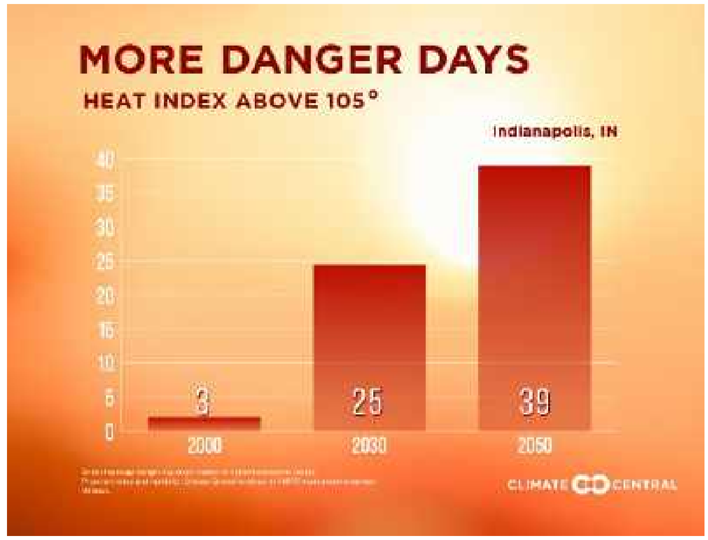
According to the US National Climate and Health Assessment:

> "While it is intuitive that extremes can have health impacts such as death or injury during an event (for example, drowning during floods), health impacts can also occur before or after an extreme event as individuals may be involved in activities that put their health at risk, such as disaster preparation and post-event cleanup. Health risks may also arise long after the event, or in places outside the area where the event took place, as a result of damage to property, destruction of assets, loss of infrastructure and public services, social and economic impacts, environmental degradation, and other factors. Extreme events also pose unique health risks if multiple events occur simultaneously or in succession in a given location, but these issues of cumulative or compounding impacts are still emerging in the literature."

In addition, extreme weather can cause economic stress. Property damage, business closure, crop loss, job loss, and employment "down time" can all be caused by extreme storms, weather, and temperatures. These economic impacts can affect individuals, families, businesses, and communities at large.

According to the North American Electric Reliability Corporation, the leading cause of electric transmission outages (in terms of electric outage count) in Indiana is Severe Weather - Heat Wave.

Increased Risk of Extreme Heat



More than **170,000** people in Indiana are especially vulnerable to extreme temperatures.

(Source: US Climate Resilience Toolkit, NASA, Climate Central)

Heat, Humidity and Health

As Midwesterners, we know that hot, humid weather can be dangerous, and even deadly. Together, heat and humidity make it difficult for the body to keep cool, increasing the risk of heat exhaustion and heat stroke. Dangerous humidity is especially problematic for the very young and elderly, and those people with underlying health conditions. However, even healthy individuals can succumb to heat extremes when the physical limits of the body are pushed too far.

Scientists use what is known as the "wet-bulb temperature"—a combined measure of heat and humidity—to determine risk of heat-related illness. The higher the wet-bulb temperature, which is measured in degrees Fahrenheit (°F), the more difficult it will be to maintain a safe body temperature. Wet-bulb temperatures above 80°F are considered dangerous, and exposure to wet-bulb temperatures above 95°F for more than a few hours is lethal.

In a warming world, dangerous humidity is expected to happen more frequently. Historically[10], Indiana has had about 1 to 10 days per year with wet-bulb temperatures between 80°F and 86°F. These conditions are much like the hottest summer months in the most humid parts of the Southern U.S. By mid-century[11], we are expected to have about 10 to 30 dangerous days per year, with far southern areas of the state reaching up to 50 days per year. (Sources: Hsiang et al., 2014; Sherwood and Huber, 2010))

(Graphic Source: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*")

Primary Climate Risks to Bloomington

Extreme Weather / Temperature (continued):

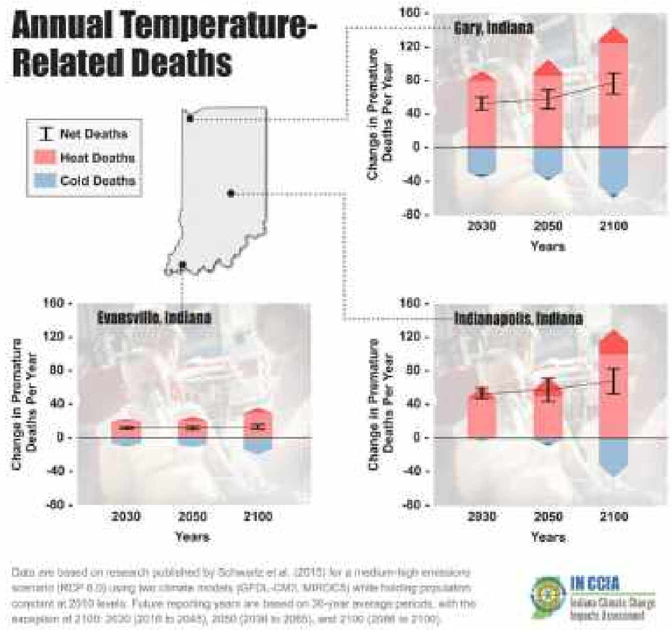
According to "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*" by Purdue University, the charts below show:

Projected number of premature temperature-related deaths per year for three Indiana cities. Red arrows show warm-season deaths (April to September). Blue arrows show cold-season deaths (October to March). Darker shades on arrow tips depict range of model results. Black bars show range of net annual temperature-related deaths. Data are based on research published by Schwartz et al. (2015) for a medium-high emissions scenario (RCP 6.0) using two climate models while holding population constant at 2010 levels. Future reporting years are based on 30-year average periods, with the exception of 2100, as follows: 2030 (2016 to 2045),2050 (2036 to 2065), 2100 (2086 to 2100). These results are based on historical relationships between temperature and mortality, which have changed over time. Efforts to help the most vulnerable Hoosiers avoid exposure to dangerous heat and treat heat-related symptoms could reduce or prevent the projected rise in warm-season deaths.

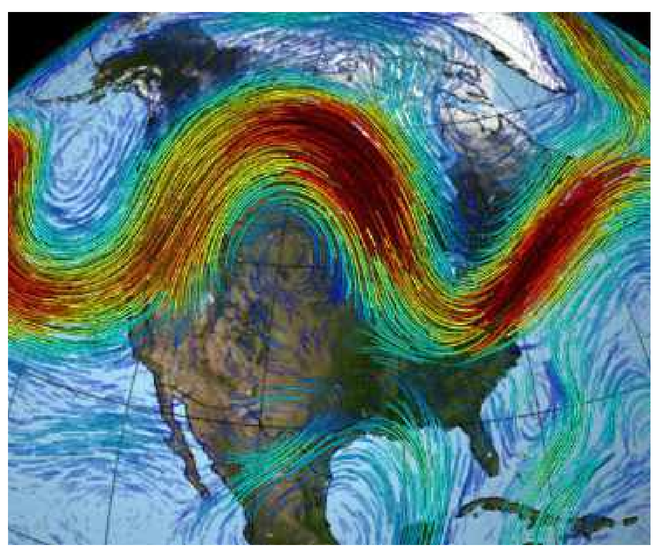
Increased Risk of Extreme Cold

Though global temperatures are rising, there is evidence that the region is at risk of increased likelihood of extreme cold temperatures during winter "cold snaps" due to variations in the jet stream caused by warming ocean temperatures and a warming Arctic region. The jet stream—a powerful river of wind high in the atmosphere—shapes the Northern Hemisphere's weather, and it plays a key role in weather extremes. This powerful river of wind transports moisture and moves masses of cold and warm air and storm systems along its path.

The jet stream is driven partly by the temperature contrast between masses of cold air over the North Pole and warmer air near the equator. Climate change has led to faster warming in the Arctic than in the temperate zones, reducing the temperature differences between the two regions and weakening the jet stream. As the jet stream becomes weaker, it has periods of "wobble" in which it coils much more significantly dipping far to the South. As the jet stream coils southward it brings bitter cold arctic air southward along with it. Studies indicate that as arctic temperatures continue to rise, increases in jet stream "wobble" and extreme winter cold snaps may increase in occurrence.



Increased Risk of Extreme Cold



The satellite weather image above, from NOAA, illustrates the changes in the "Jet Stream" which can occur due to climate change. As the Jet Stream slows it can become more pronounced and move more slowly across the continent.

Extreme Cold Impacts in Indiana

Due to polar vortex "wobble" temperatures in Indiana were 30°-40° below normal values Wednesday, January 30th 2019 (Source: WTTV Channel 4, Indianapolis)

Flood and Drought Vulnerability

According to the latest National Climate Assessment, the frequency of heavy precipitation events has already increased for the nation as a whole as well as for Indiana specifically. These heavy rain events are projected to increase throughout Indiana. Increases in both extreme precipitation and total precipitation have contributed to increases in severe flooding events in certain regions. Floods are the second deadliest of all weather-related hazards in the United States.

In addition to the immediate health hazards associated with extreme precipitation events when flooding occurs, other hazards can often appear once a storm has passed. Elevated waterborne disease outbreaks have been reported in the weeks following heavy rainfall, although other variables may affect these associations. Water intrusion into buildings can result in mold contamination that manifests later, leading to indoor air quality problems. Populations living in damp indoor environments experience increased prevalence of asthma and other upper respiratory tract symptoms, such as coughing and wheezing, as well as lower respiratory tract infections such as pneumonia, respiratory syncytial virus, and pneumonia.

Flooding causes economic stress. Property damage, business closure, crop loss, job loss, and employment "down time" can all be caused by extreme storms, weather, and temperatures. These economic impacts can affect individuals, families, businesses, and communities at large.

According to "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*":

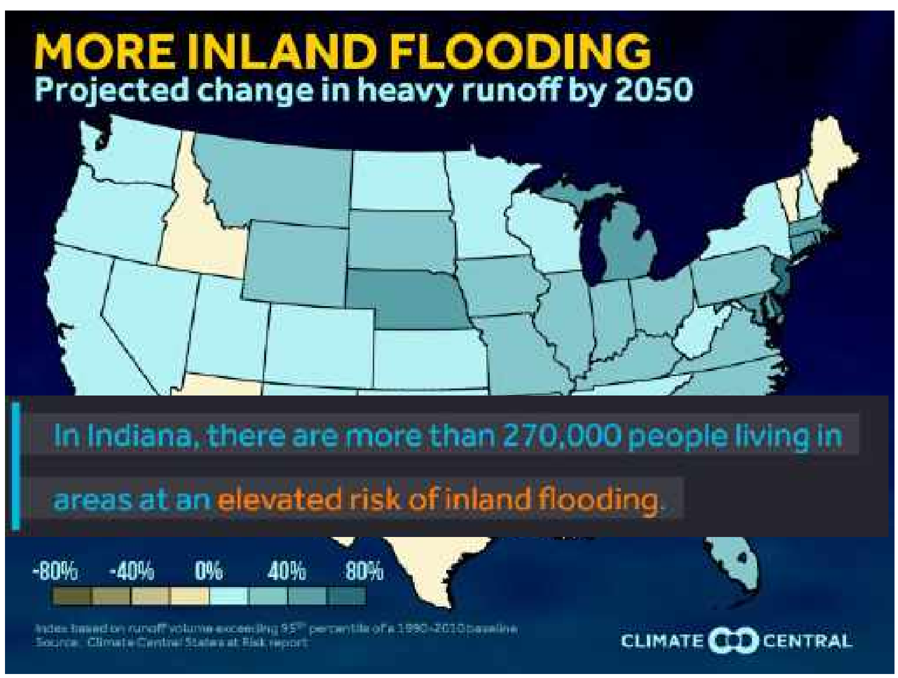
> The increased frequency and severity of precipitation, as well as the timing in the spring and winter, considerably increase the risk of flooding, especially in low-lying areas throughout the state. These flood events will be responsible for fatal and non-fatal injuries and waterborne disease. Heavy storms can cause storm drains and sewage pipes to overflow and residential stormwater management systems (e.g., sump pumps) to fail. Contact with stormwater/wastewater has been correlated with increased rates of gastrointestinal illnesses. Dampness in homes, schools and other buildings caused by flooding can increase mold growth and lead to higher rates of asthma and allergies.

By 2050, Indiana is projected to see:

An increase of flood risk by more than **25%**

As well as a **200%** increase in its index of the severity of widespread drought.

(Source: US Climate Resilience Toolkit, Climate Central)



Primary Climate Risks to Bloomington

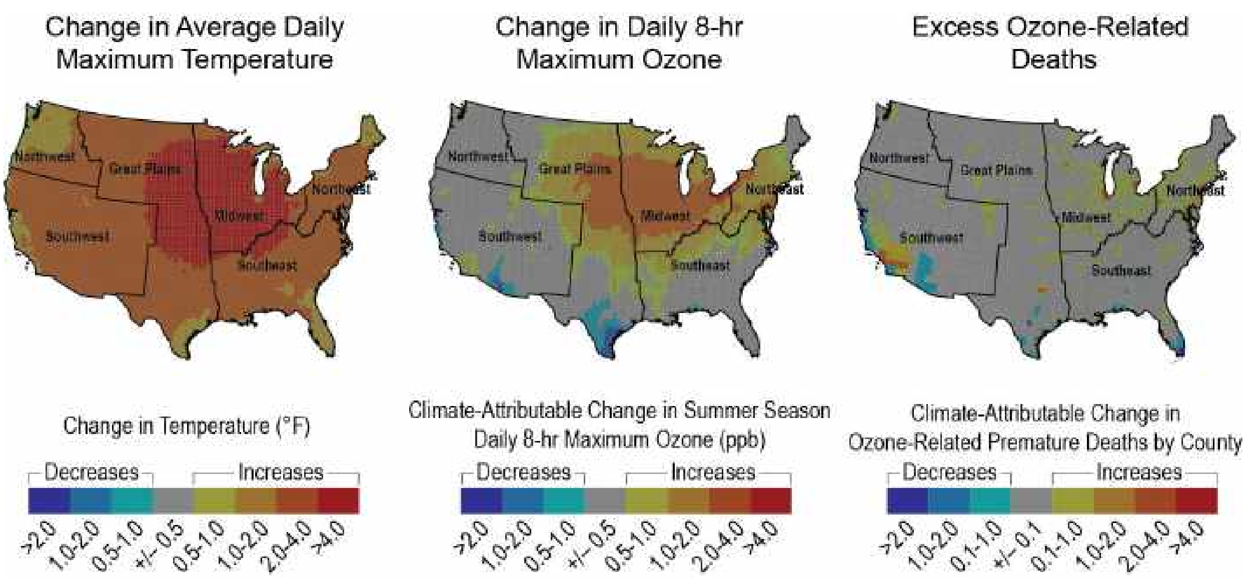
Air Quality Impacts

According to the published literature, air pollution is associated with premature death, increased rates of hospitalization for respiratory and cardiovascular conditions, adverse birth outcomes, and lung cancer. Air quality is indexed (AQI) by the U.S. Environmental Protection Agency (EPA) and Indiana Pollution Control Agency to provide a simple, uniform way to report daily air quality conditions. Indiana AQI numbers are determined by hourly measurements of five pollutants: fine particles (PM2.5), ground-level ozone (O3), sulfur dioxide (SO2), nitrogen dioxide (NO2), and carbon monoxide (CO). The levels of all of these pollutants can be effected by climate impacts as well as the greenhouse gas emissions which are driving Indiana's changing climate impacts.

These pollutants have a range of potential health impacts. Ozone exposure may lead to a number of adverse health effects such as shortness of breath, chest pain when inhaling deeply, wheezing and coughing, temporary decreases in lung function, and lower respiratory tract infections. Long-term exposure to fine particulate matter (also known as $PM_{2.5}$) is correlated with a number of adverse health effects. In fact, each 10 $\mu g/m^3$ elevation in $PM_{2.5}$ is associated with an 8% increase in lung cancer mortality, a 6% increase in cardiopulmonary mortality, and a 4% increase in death from general causes. The annual average of $PM_{2.5}$ provides an indication of the long-term trends in overall burden, relevant to the long-term health effects. Increased surface temperatures are known to increase ground level ozone levels. The projected Indiana climate change impacts of extreme heat, changes in precipitation, drought and wild fires can all cause increases in fine particulate matter, which in turn, can contribute to respiratory illness particularly in populations vulnerable to them.

The US EPA designates counties with unhealthy levels of air pollution as "Non attainment" areas and areas which are on the edge of unhealthy levels "maintenance" areas. The State of Indiana has had multiple jurisdictions designated as "non attainment" areas, however, as of May 2020, Monroe County is not included in the "non attainment" county list. Air quality issues currently being addressed in State of Indiana implementation plans include Carbon Monoxide, Sulfur Dioxide, and Particulate Matter. For current and forecasted air quality throughout the state visit the Indiana State DNR: https://www.in.gov/idem/airquality/ You can also download Plume Lab's free mobile phone air quality monitoring app: https://plumelabs.com/en/air/

Climate change is expected to affect air quality through several pathways, including production and potency of allergens and increase regional concentrations of ozone, fine particles, and dust. Some of these pollutants can directly cause respiratory disease or exacerbate existing conditions in susceptible populations, such as children or the elderly. Other air quality issues with health considerations include allergens, pollen, and smoke from wildfires (traces sufficient to cause respiratory impacts are capable of traveling great distances). Each of these are anticipated to be increased with climate change.



Projected Change in Temperature, Ozone, and Ozone-Related Premature Deaths in 2030
Projected changes in average daily maximum temperature (degrees Fahrenheit), summer average maximum daily 8-hour ozone (parts per billion), and excess ozone-related deaths (incidences per year by county) in the year 2030 relative to the year 2000.

(Source: US Climate Resilience Toolkit)

Primary Climate Risks to Bloomington

Air Quality Impacts (Continued)

Allergens

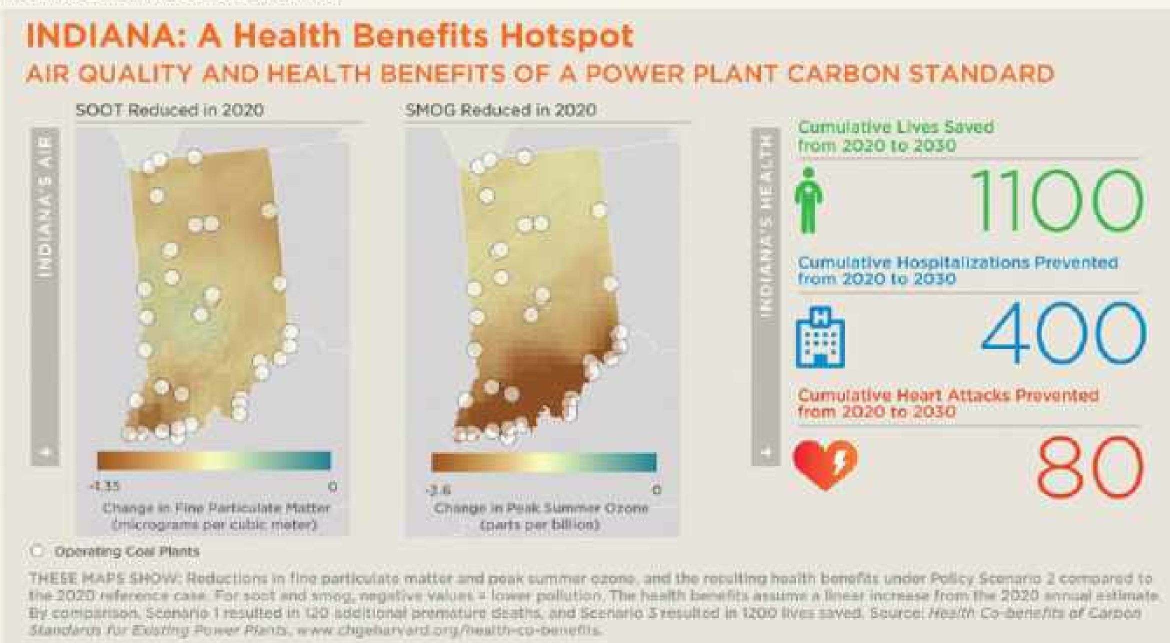
According to "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*" by Purdue University:

> Climate change is extending and amplifying the growing season for plants in Indiana. This is the case not only for crops, but for allergen-producing plants as well. This, too, negatively affects air quality across the state. Indiana's frost-free season — in which the temperature continuously stays above 32°F —has lengthened by an average of nine days beyond what it was in 1915 (Widhalm et al., 2018b). Eight of those have come in the spring and one in the fall. Under a high-emissions6 scenario, by mid-century2 Indiana's growing season is projected to lengthen by 35 days, 33 days, and 30 days in the northern, central, and southern areas of the state respectively. This allows allergy-causing plants such as ragweed to produce pollen for longer periods, extending the seasonal allergy season, and to produce more pollen, which can increase the onset, frequency and severity of allergic reactions (Ziska et al., 2011). Pollen is also a trigger for asthma attacks, inflammation, coughing and wheezing (Darrow et al., 2012)

Did you know that some plants, like ragweed and poison ivy, thrive with higher concentrations of carbon dioxide (CO_2) in the atmosphere? Researchers have found that poison ivy plants, for example, grow faster and produce more toxic oil per plant in high-CO_2 environments. Poison ivy toxicity could double by the year 2050 if CO_2 emissions continue unabated. Ragweed has also been shown to grow faster, with increased pollen production, when grown in warmer conditions with higher levels of CO_2. Grass pollen also grows in abundance as CO_2 concentrations rise. With more than 50 million Americans suffering from seasonal allergies, at a cost of $18 billion annually, these changes threaten to reduce the health and well-being of many Hoosiers. (Sources: Ziska et al. (2007), Ziska and Caulfield (2000), Albertine et al. (2014))

Health Benefits of Cleaner Air

Reducing carbon emissions from power plants can slow the planet's rate of warming. At the same time, reduced power plant emissions would provide measurable and meaningful benefits to our health, including fewer hospital admissions and premature deaths from air pollution. One study found that reducing carbon pollution by the amount proposed in the 2014 EPA Clean Power Plan would also eliminate the emission of other pollutants that would otherwise cause 3,500 premature deaths per year in the U.S. and result in 1,000 hospitalizations (Schwartz et al., 2014). Indiana ranks in the top 12 states with the highest potential number of lives saved if emissions were reduced.



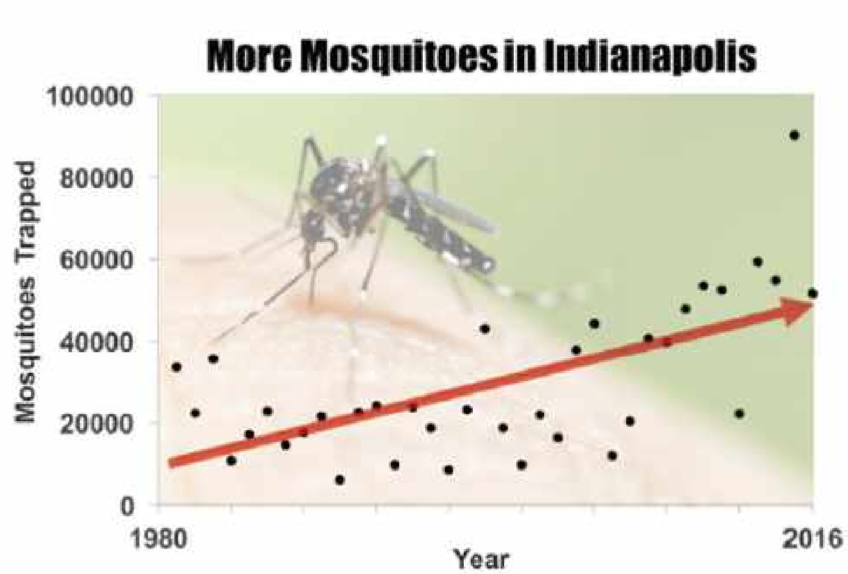
Above: *With stringent reductions in carbon pollution from power plants, Indiana would see fewer deaths and injuries due to air pollution. Source:* [Harvard School of Public Health](#) *and Schwartz et al. (2014).*

(Graphic Source: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*")

Primary Climate Risks to Bloomington

Vector-Borne Diseases

Vector-Borne diseases are diseases spread by agents such as ticks and mosquitoes. The projected climate change impacts in this region are anticipated to increase the spread of vector borne diseases such as West Nile virus, and Lyme disease by altering conditions that affect the development and dynamics of the disease vectors and the pathogens they carry. Rising global temperatures can increase the geographic range of disease-carrying insects, while increased rainfall, flooding and humidity creates more viable areas for vector breeding and allows breeding to occur more quickly. In addition, Indiana's lengthening growing season and warming winters will increase the population of vector carrying insects as well as open the region up to new species.



Above: Mosquitoes trapped in 20 light traps in Marion County, Indiana from 1981 to 2016. Source: Marion County Public Health Department

(Graphic Source: Indiana Climate Change Impacts Assessment, Purdue University, "Hoosier Health in A Changing Climate")

IN CCIA
Indiana Climate Change Impacts Assessment

Primary Climate Risks to Bloomington

Food Insecurity and Food-borne Diseases

According to former U.S. agriculture secretary Tom Vilsack, climate change is likely to destabilize cropping systems, interrupt transportation networks and trigger food shortages and spikes in food cost. According to the US National Climate Assessment for the Midwestern states: "In the next few decades, longer growing seasons and rising carbon dioxide levels will increase yields of some crops, though those benefits will be progressively offset by extreme weather events. Though adaptation options can reduce some of the detrimental effects, in the long term, the combined stresses associated with climate change are expected to decrease agricultural productivity."

Nutritious food is a basic necessity of life, and failure to obtain sufficient calories, macronutrients (fats, proteins, carbohydrates), and micronutrients (vitamins, minerals) can result in illness and death. While malnutrition and hunger are typically problems in the developing world, Indiana still has significant populations affected by insufficient food resources and under-nutrition. Food can be a source of food-borne illnesses, resulting from eating spoiled food or food contaminated with microbes, chemical residues or toxic substances. The potential effects of climate change on food-borne illness, nutrition, and security are mostly indirect but represent risks, especially for vulnerable populations. Some of the climate impacts which may increase food insecurity and food-borne diseases in Indiana include:

- Extreme weather events and changes in temperature and precipitation can damage or destroy crops and interrupt the transportation and delivery of food
- Changes in agricultural ranges, practices and changing environmental conditions can reduce the availability and nutritional content of food supplies. For example, an increase in the use of pesticides leads to a decrease in nutritional content of food.
- Extreme weather events, such as flooding, drought, and wildfires can contaminate crops and fisheries with metals, chemicals, and toxicants released into the environment.
- Degraded soil health and soil erosion, exacerbated by increasing drought/flood cycles and increasing storm intensities.

According to "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*":

> Rising temperatures will extend the length of the growing season throughout the state, offering opportunities to grow different types of crops or to double-crop in some places. But those temperature increases will come with more plant heat stress days, and reduced summer precipitation and increased water demand are projected to reduce soil moisture and lead to drought or drought-like conditions that will further stress and damage crops.

Water Quality/Quantity

Water risks consist of both water quality as well as water quantity issues. Water quantity issues are clearly linked to precipitation levels and timing, water variability, as well as changes in water demand. Water demand itself can be increased not only by population changes but also as a result of climate changes such as increased temperatures and time frames between rain events which increase demands on water consumption. In addition, water withdraw from ground water sources deplete aquifer capacities. Indirectly, the lack of water can cause pressure on agricultural productivity, increase crop failure, and cause reductions in food supply and increases in food prices and food insecurity. As a highly precious resource, all communities should look to increase water conservation regardless of the projected water stress levels of their immediate region, while communities in regions with a projected increase in water stress should view water conservation as a major long-term priority.

Water quality issues can be affected by climate impacts in a number of ways:

- Increased precipitation and rapid snow melt can result in flooding, which in turn increases the likelihood of water contamination from sources such as sewage as well as contaminants such as chloride, gasoline, oil, chemicals, fertilizers, and pesticides.
- Increased air and water temperatures can increase toxic algae blooms, decrease water oxygen levels, and cause changes in fish populations as well as increases in mercury concentrations in fish.
- Increased heavy rain events can result in increases in sediment, diminishing water quality.
- Impacts on water accessibility and affordability as demand and infrastructure needs increase costs.

Primary Climate Risks to Bloomington

Waterborne Illness

Waterborne diseases are caused by a variety of microorganisms, biotoxins, and toxic contaminants, which lead to devastating illnesses such as cholera, schistosomiasis and other gastrointestinal problems. Outbreaks of waterborne diseases often occur after a severe precipitation event (rainfall, snowfall). Because climate change increases the severity and frequency of some major precipitation events, communities could be faced with elevated disease burden from waterborne diseases. Increased frequency of intense extreme weather events can cause flooding of water and sewage treatment facilities, increasing the risk of waterborne diseases. According to "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*" by Purdue University:

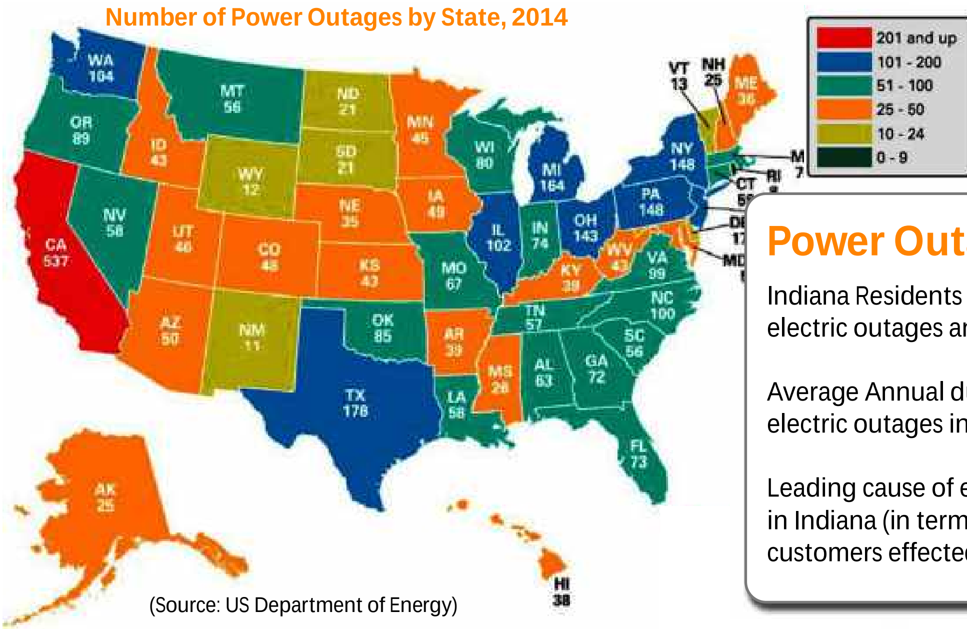
> Floods also bring other problems that will impact Hoosiers' health. For instance, the increased rain, along with higher temperatures, is expected to increase the growth of harmful algae, which can lead to dangerous algal blooms. The Indiana Department of Environmental Management has data from Brookville Lake17 from 2012 that show climate-related trends in algae cell counts and harmful algal blooms. Blue-green algae blooms are more likely in warmer water. Nutrients from farm fields, carried by runoff, also contribute to their formation.
>
> The algae forms scum on the surface of water and creates cyanotoxins. These can be ingested through fish caught in the water, by drinking or touching infected water, and even breathing air near the water. Depending on the type of algae, the toxins can cause vomiting, diarrhea, confusion, seizures, liver damage, or even paralysis and death18. This hyper-production of algae can also cause fish kills, leading to negative economic impacts, and can degrade water quality from drinking water sources to such a level that replacement sources need be brought in, at great expense (as happened in Toledo, Ohio, in 2014).

Infrastructure Failure

Extreme weather events, flooding and flash flooding, as well as increasing daily stresses caused by increasing climate variability all represent potential causes of failure of our aging infrastructure. Power outages, road damage, bridge collapse, water infrastructure failure - each of these represent significant physical climate risks to the community, especially individuals who are climate vulnerable or especially vulnerable to loss of utilities like those with medically vulnerability such as those on ventilators. As noted in "*Climate Change and Indiana's Energy Sector: A Report from the Indiana Climate Change Impacts Assessment*", a study by the University of Purdue, Climate Change may have other direct impacts on our electrical infrastructure, including:

- Higher average and extreme temperatures, including higher nighttime temperatures, would reduce the capacity of energy transmission lines and substations, potentially causing energy disruptions.
- Higher extreme temperatures may shorten the lifetimes of transformers and their overloading capacity.
- Electricity outages often result from high winds, severe storms, and icing events. Only recently have scientists begun using climate models to estimate changes in storm activity. Early projections suggest an increase in the frequency and intensity of storms, which would affect the reliability of electric grids, but considerable uncertainty remains (Gensini and Mote 2014; Hoogewind et al., 2017).

Number of Power Outages by State, 2014



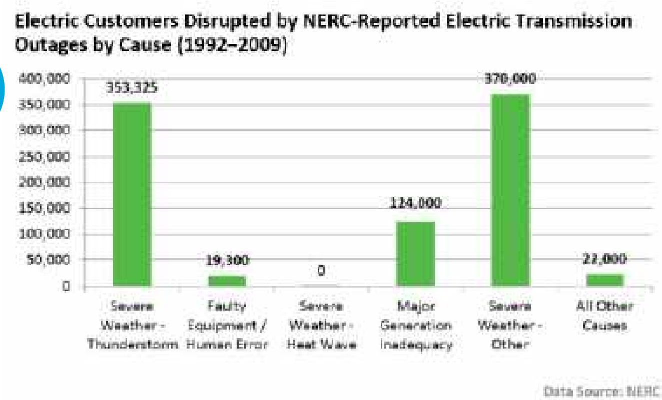
(Source: US Department of Energy)

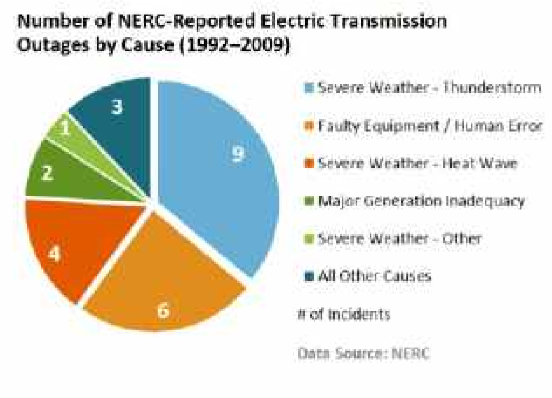
Power Outages

Indiana Residents effected by electric outages annually:	288,830
Average Annual duration of electric outages in Indiana:	85 hrs/yr
Leading cause of electric outages in Indiana (in terms of number of customers effected):	Weather/ falling trees

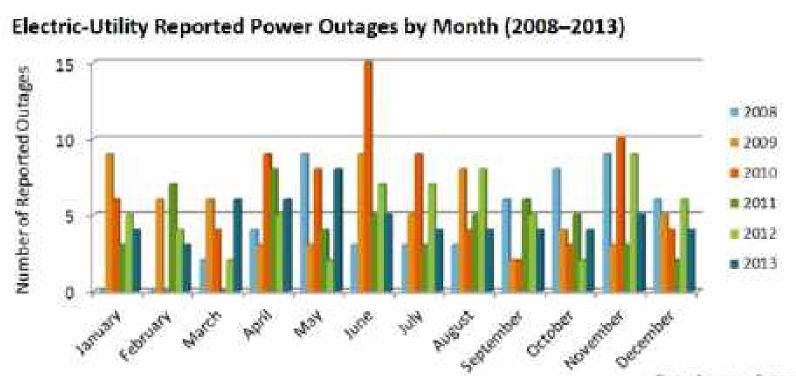
Primary Climate Risks to Bloomington

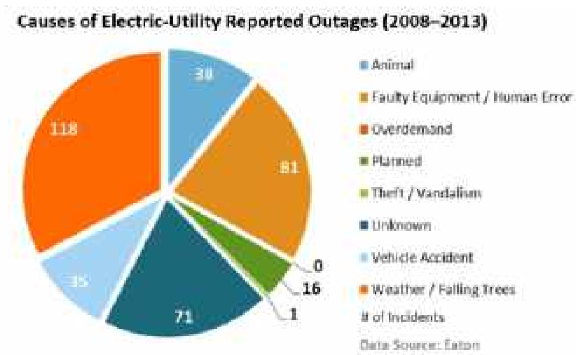
Infrastructure Failure (continued)





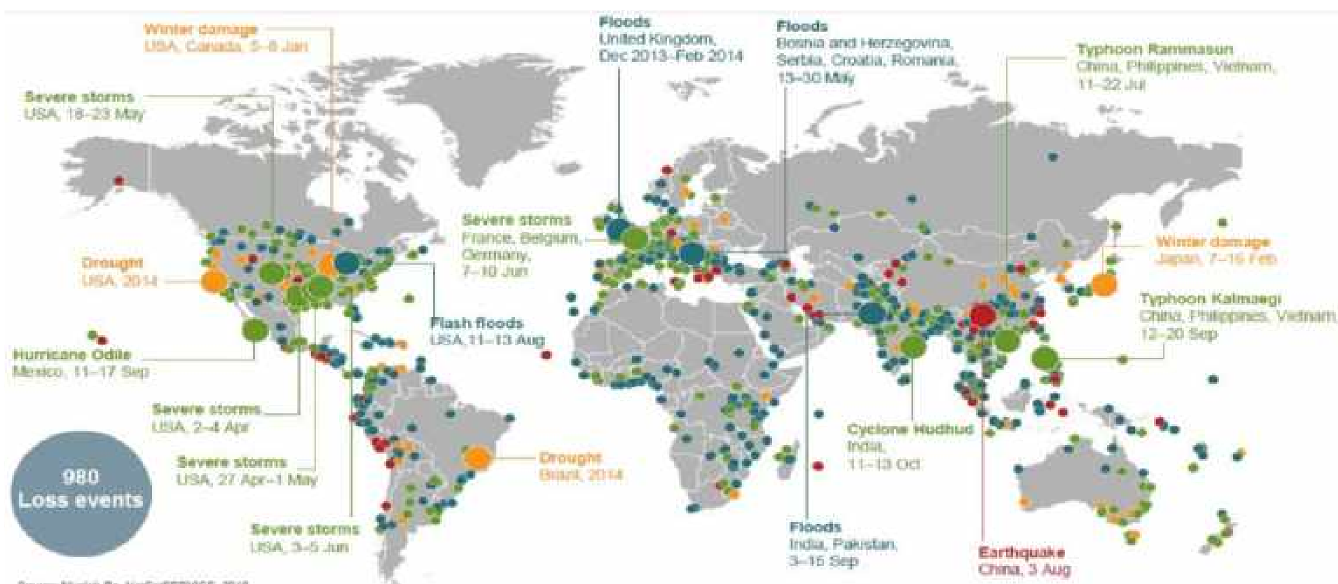
(Source: US Department of Energy)



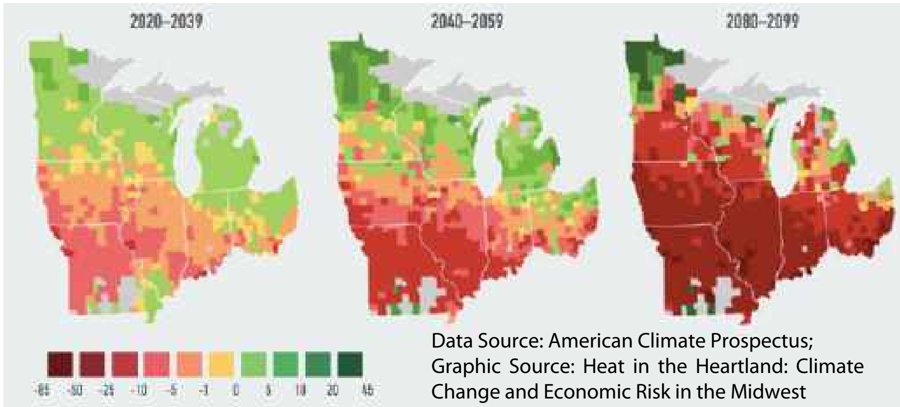


Data Source: Eaton
(Source: US Department of Energy)

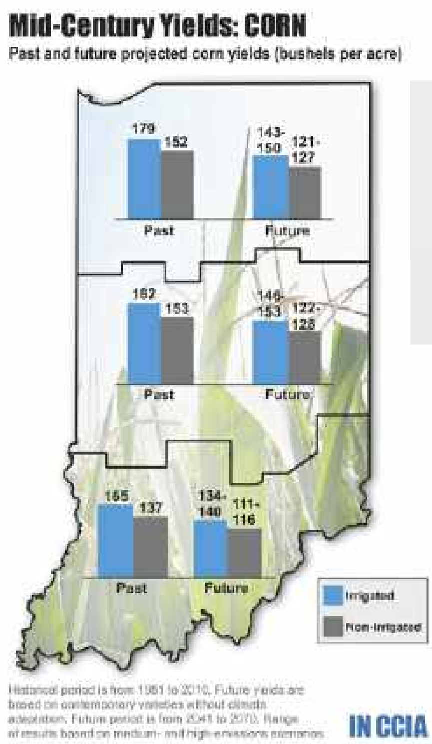
Global Loss Events, 2014



Projected Change in Corn, Soybeans, and Wheat Yields.



Data Source: American Climate Prospectus;
Graphic Source: Heat in the Heartland: Climate Change and Economic Risk in the Midwest



More frequent heat stress and a doubling of water deficits will **reduce corn yields, for current varieties, by 16-20%.**

- Indiana Climate Change Impacts Assessment

Above: *Historical (1981 to 2010) and future (2041 to 2070) corn yields across Indiana for irrigated (blue) and non-irrigated (gray) production systems. Future yields are based on contemporary varieties without any changes in management or technology. The range of future yields represents projections for medium- and high-emissions scenarios. Maps for soybean and wheat yields are also available. Source: Bowling et al. (in review).*

(Graphic Source: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*")

Economic Climate Risks to Bloomington

Incidents of severe weather in the United States, such as significant flooding in the Midwest or extreme forest fire events in California, are tangible examples of the types of economic impacts of projected climate trends. Future economic and social impacts of climate change include impacts to agriculture, energy costs, labor impacts, death rates, and crime impacts among others. "Estimating Economic Damage from Climate Change in the United States", a study by Solomon Hsiang et al from the Goldman School of Public Policy at the University of California Berkeley was a comprehensive effort at quantifying the economic impacts for every county within the United States. As described in the journal Science;

> The study collected national data documenting the responses in six economic sectors to short-term weather fluctuations. These data were integrated with probabilistic distributions from a set of global climate models and used to estimate future costs during the remainder of this century across a range of scenarios. In terms of overall effects on gross domestic product, the authors predict negative impacts in the southern United States and positive impacts in some parts of the Pacific Northwest and New England.

The sectors assessed, and the findings for Monroe County Indiana and the City of Bloomington are below:

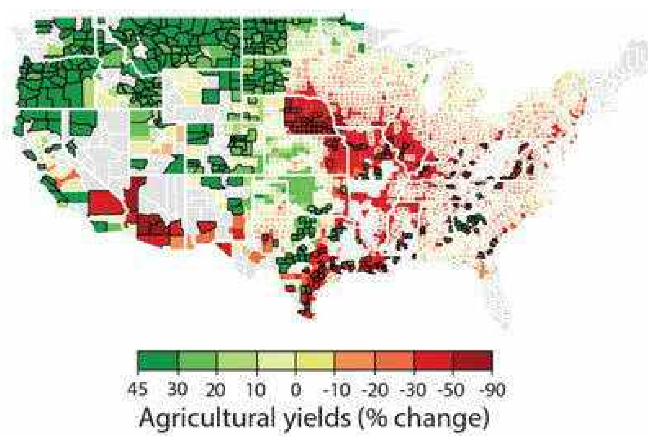
Agricultural Yields

Agricultural Yields Through 2100

Agricultural yields are projected to decline with th increase of Global Mean Surface Temperature in addition to impacts related to precipitation change Although increased CO_2 levels are anticipated to offset a portion of these yield loses, the impact for much of the United States will be a net negative. Local projections:

Monroe County and City of Bloomington:

-35.6%



In addition to economic impacts related to crop los and productivity, projected reductions in crop yield (see on previous page) are likely to bring cost increases and food price volatility, impacting vulnerable communities the most, and increasing food insecurity.

Energy Costs

Energy Expenditures Through 2100

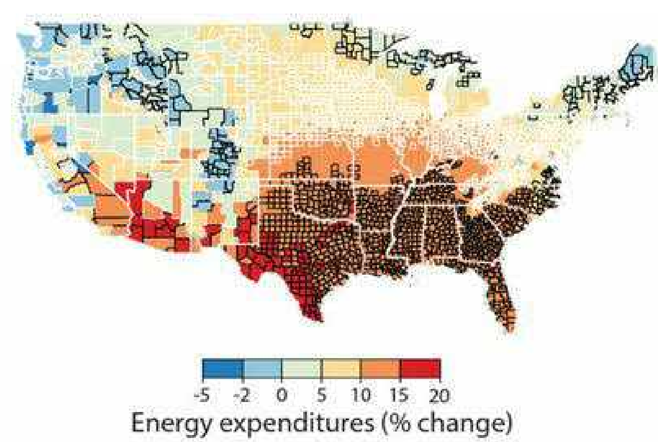
As average annual temperatures increase, demand for energy will increase, resulting in increased energy expenditures. Local projections:

Monroe County and City of Bloomington:

+11.7%

Estimated Average Annual Cost to Bloomington Families (2020 dollars):

$260



Economic Climate Risks to Bloomington

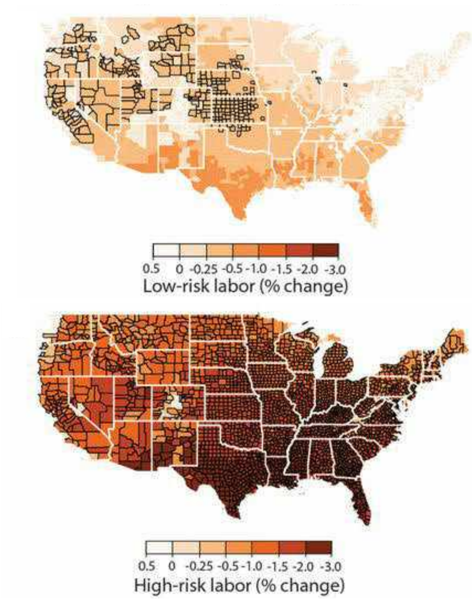
Labor Losses

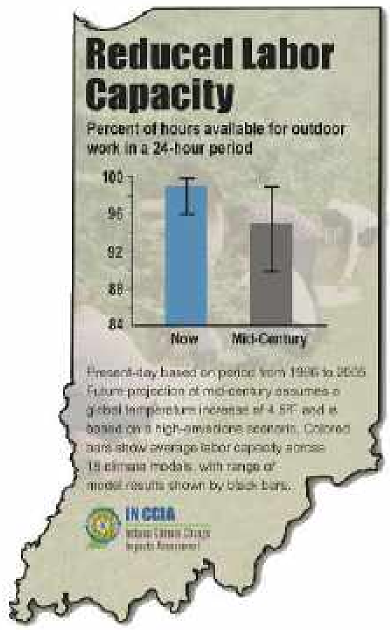
Reduced Labor Productivity Through 2100

Worker health and well-being can be impacted significantly with increases in temperature or extreme weather. Associated with these impacts, labor productivity declines with the instance of increased temperature. Rates vary for "low-risk" workers who are predominantly not exposed to exterior conditions and for "high-risk" workers (those identified as "At Risk Workers" in Section 9). Local projections:

Low-Risk Labor Loss for Monroe County and City of Bloomington: **-0.21%**

High-Risk Labor Loss for Monroe County and City of Bloomington*: **-5%–11%**





(*Graphic Source: "*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*")

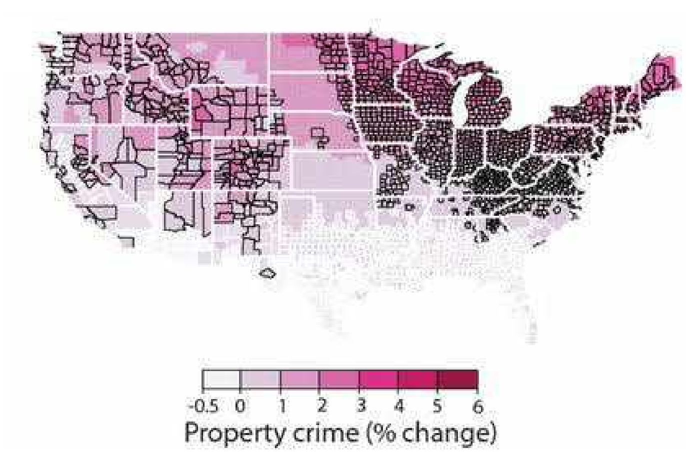
Crime

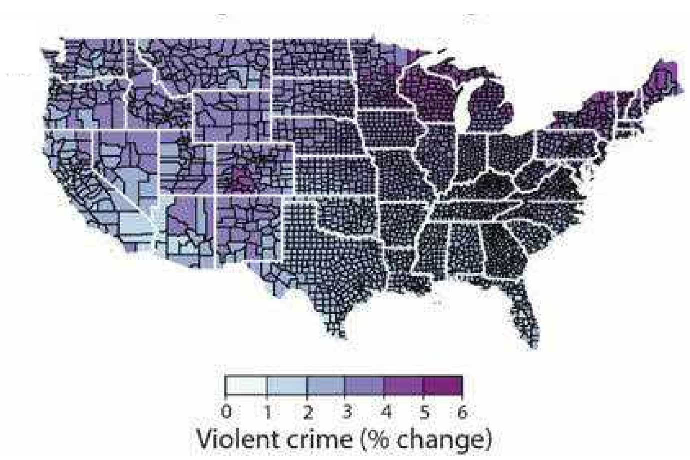
Increases in Crime Rates Through 2100

Studies indicate property crime increases as the number of cold days decrease due to the property crime suppression effect cold days have. Violent crime rates have been shown to increase linearly at a relatively precise 0.88% per 1°C. Local projections:

Property Crime Increase for Monroe County and City of Bloomington: **+0.97%**

Violent Crime Increase for Monroe County and City of Bloomington: **+3.46%**



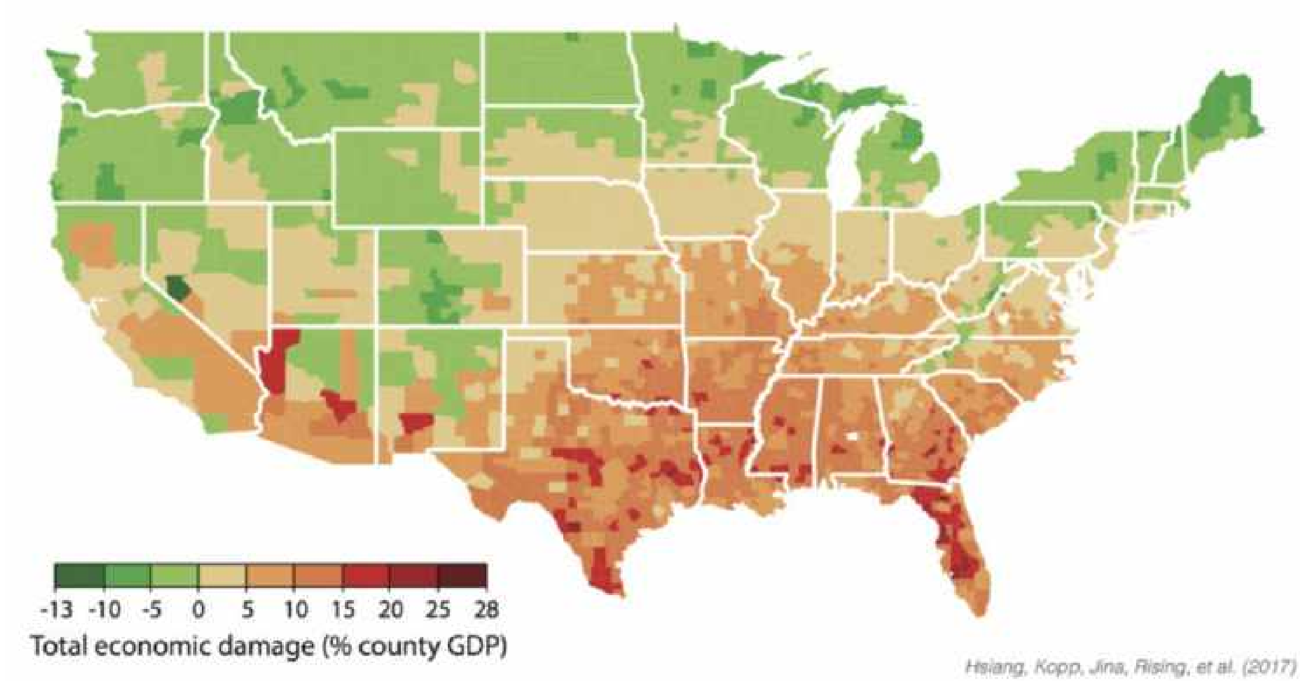


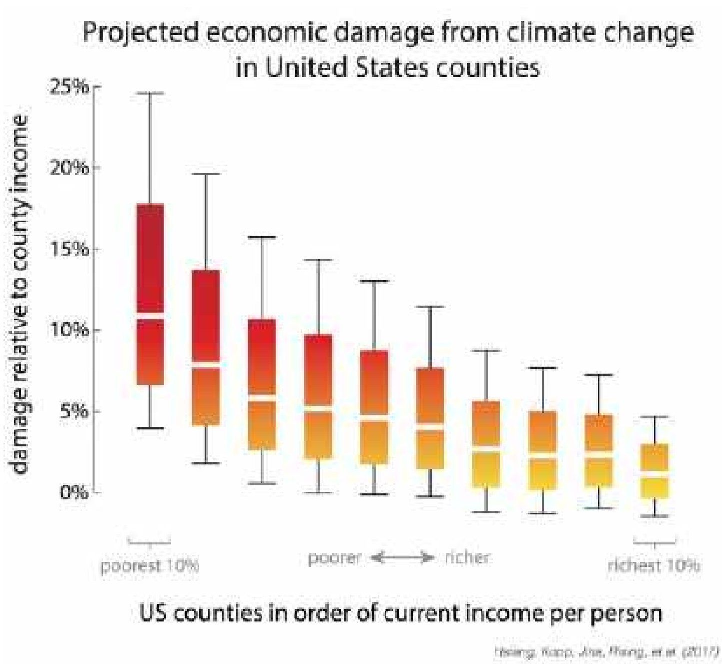
Economic Climate Risks to Bloomington

Total Projected Economic Impacts Through 2100

According to research completed for "Estimating economic damage from climate change in the United States", a 2017 study completed by Solomon Hsiang and others from the University of California at Berkeley the total annual economic impact for Monroe County Indiana by 2100 will be: **$258,537,929 annually (2018 dollars)**

Estimating the total annual economic impact for the City of Bloomington on a Pro Rata share results in: **$150,518,657 annually (2018 dollars)**





Inequity of Economic Impacts Through 2100

According to the study "Estimating economic damage from climate change in the United States", climate change economic impacts will increase the unpredictability and inequity of future economic outcomes. The projected economic effects are unequally borne. As the graphic to the left illustrates, the poorest 10% are likely to receive 5 to 10 times the negative economic impacts of the wealthiest 10% in the community.

Sources: "Estimating economic damage from climate change in the United States" Muir-Wood, Paul Wilson, Michael Oppenheimer, Kate Larsen and Trevor Houser Solomon Hsiang, Robert Kopp, Amir Jina, James Rising, Michael Delgado, Shashank Mohan, D. J. Rasmussen, Robert
DOI: 10.1126/science.aal4369
Science 356 (6345), 1362-1369.
http://www.impactlab.org/research/estimating-economic-damage-from-climate-change-in-the-united-states/
"*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*"

Section 07

Climate Impact Multipliers

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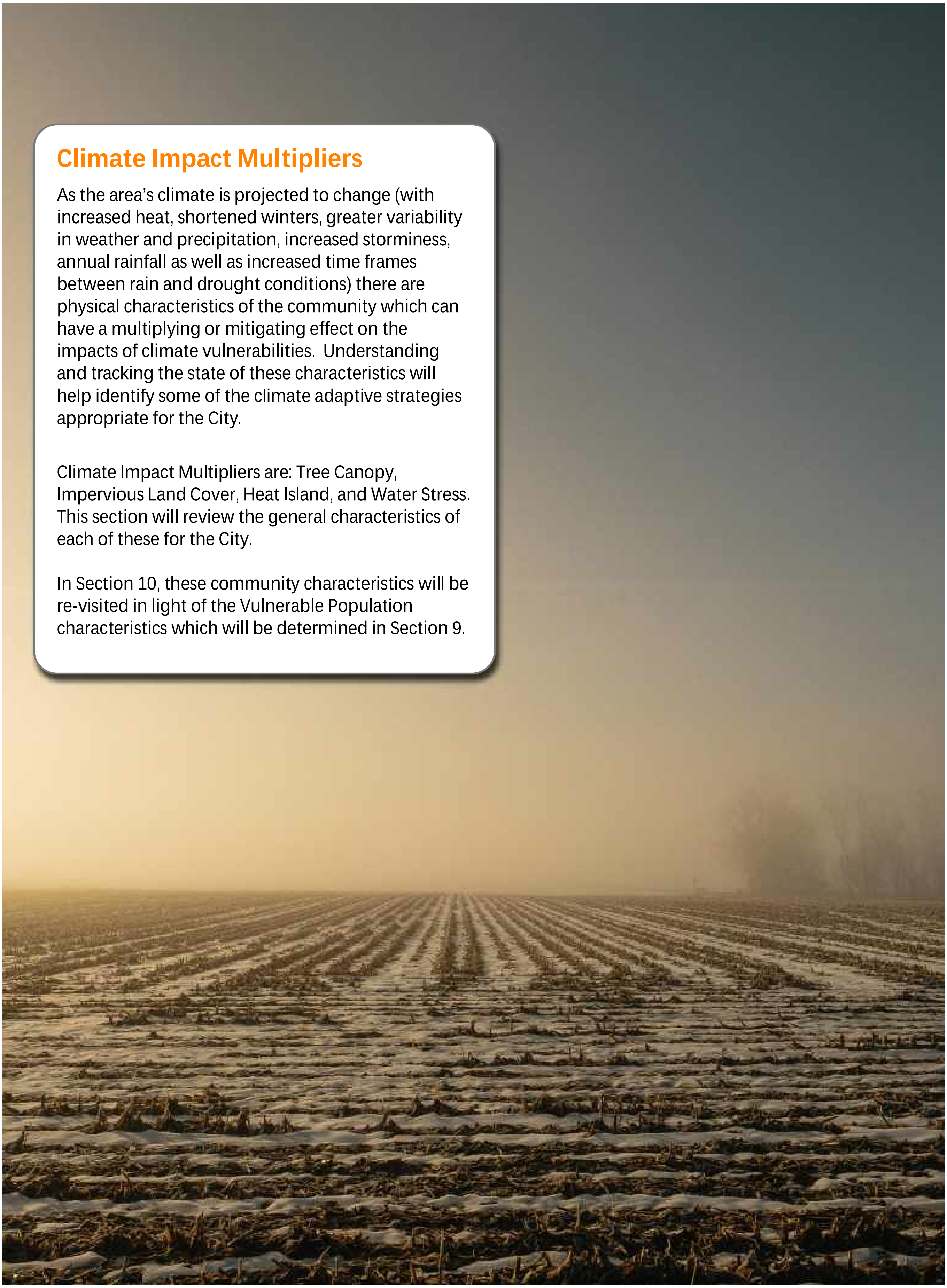


Climate Impact Multipliers

As the area's climate is projected to change (with increased heat, shortened winters, greater variability in weather and precipitation, increased storminess, annual rainfall as well as increased time frames between rain and drought conditions) there are physical characteristics of the community which can have a multiplying or mitigating effect on the impacts of climate vulnerabilities. Understanding and tracking the state of these characteristics will help identify some of the climate adaptive strategies appropriate for the City.

Climate Impact Multipliers are: Tree Canopy, Impervious Land Cover, Heat Island, and Water Stress. This section will review the general characteristics of each of these for the City.

In Section 10, these community characteristics will be re-visited in light of the Vulnerable Population characteristics which will be determined in Section 9.

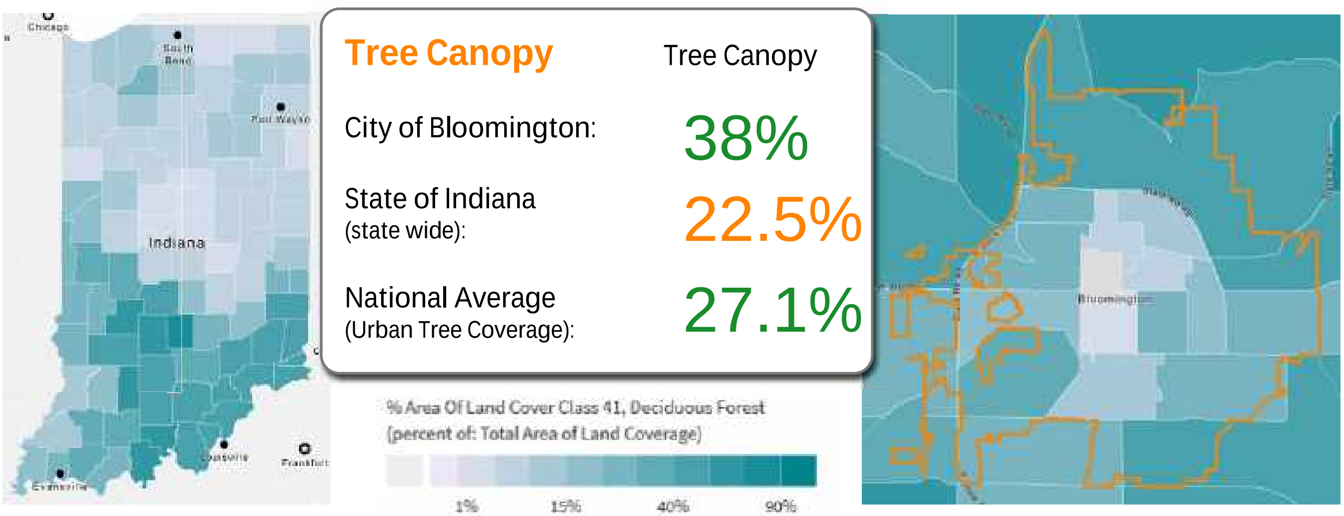
Climate Impact Multiplier - Tree Canopy

A healthy and extensive tree canopy within developed areas can mitigate the impacts of heat stress, water impacts, increased levels of precipitation and drought, and air quality impacts. "Urban forests" deliver a range of environmental, health, and social benefits. Shaded surfaces can be anywhere from 25°F to 45°F cooler than the peak temperatures of unshaded surfaces. Trees cool communities, reduce heating and cooling costs, capture and remove air pollutants including CO_2 from the air; strengthen quality of place and local economies, improve the quality of storm water entering rivers and streams, reduce storm water infrastructure costs, improve social connections, positively contribute to property value, improve pedestrian/recreation experiences, reduce mental fatigue, improve overall quality of life for residents, and provide habitat to support biodiversity.

A healthy tree canopy mitigates heat stress in developed areas by providing direct shading on buildings and through transpiration cooling. Neighborhoods well shaded by street and yard trees can be up to 6-10 degrees cooler than neighborhoods without, reducing overall energy needs. Just three trees properly placed around a house can save up to 30% of energy use.

City of Bloomington Tree Canopy

The City of Bloomington 2019 Urban Tree Canopy Assessment Summary Report provides citywide estimates for tree canopy, impervious surface, pervious surface, and open soil land area coverages. Below is a comparison of the reported tree canopy coverage against the State and National averages.



City of Bloomington Priority Tree Tree Planting Area

The City of Bloomington's 2019 Urban Tree Canopy Assessment included a determination of recommended priority areas for tree planting in support of advancing the city's urban tree canopy. According to the report:

> The plantable area analysis found 3,338 acres of public and private land with the potential for 61,702 plantable areas in Bloomington. To be categorized for purpose or returned benefit, plantable Very High, High, Moderate, Low, and Very Low Levels further define areas. Very High and High plantable areas total 532 acres and an estimated 24,670 tree planting sites. Figure 13 presents an illustrated view of the resulting distribution of prioritized plantable tree area in Bloomington.

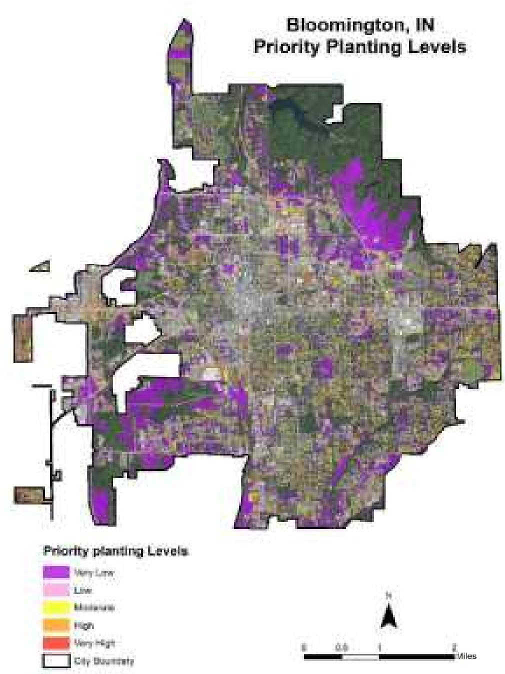


Figure 13 from City of Bloomington's 2019 Urban Tree Canopy Assessment

Climate Impact Multiplier - Tree Canopy (continued)

Planting Climate Adaptive Trees

Tree canopies in Indiana also have some vulnerabilities associated with the current and projected impacts of climate change. Trees have a degree of vulnerability to changes in temperature ranges, precipitation patterns, soil temperature and moisture levels, and changes to winter processes and growing season length. According to the US Forest service, urban forests are very susceptible to a number of climate change factors including species invasion, and insect and pathogen attack. These stressors will make it more difficult to preserve or increase canopy cover in Indiana communities. Conducting tree canopy studies and creating climate adaptive tree canopy policies will help Indiana communities in adapting to these stressors.

Species projected to have negative stressors in the Bloomington region include Basswood, Aspen, and Black Cherry. Extended drought conditions and warming winters may also negatively impact other species such as Sugar Maple, and Yellow Birch. Finally, increased growing seasons will result in taller trees which may be more susceptible to damage in extreme weather events. Boulevard, streetscape, and parking lot trees are particularly vulnerable due to decreased snow cover, increased freeze/thaw cycles, salt exposure, and increased chemical exposure.

(Graphic Source: "*Maintaining Indiana's Urban Green Spaces: A Report from the Indiana Climate Change Impacts Assessment*")

INDIANA: Tree Habitat Suitability in 2100

Trees commonly found in urban areas

Central Till Plains

Decrease	No change	Increase
Black maple	American hornbeam	Black oak
Eastern white pine	Bur oak	Common persimmon
Northern red oak	Ohio buckeye	Eastern hophornbeam
Sugar maple	Red maple	Eastern redbud
Yellow-poplar	Serviceberry	Eastern redcedar
	Swamp white oak	Green ash*
	White ash*	Hackberry
	White oak	Honeylocust
	Wild plum	River birch
		Silver maple
		Sweetgum
		Sycamore

Southern Hills

Decrease	No change	Increase
Black maple	Red maple	American hornbeam
Bur oak	River birch	Black oak
Eastern white pine	White ash*	Common persimmon
Northern red oak	White oak	Eastern hophornbeam
Ohio buckeye	Wild plum	Eastern redbud
Serviceberry		Eastern redcedar
Sugar maple		Green ash*
Swamp white oak		Hackberry
Yellow-poplar		Honeylocust
		Silver maple
		Sweetgum
		Sycamore

* declining due to emerald ash borer

Shown above are the projected changes in tree habitat suitability for three physiographic regions in Indiana (regions based on Indiana Geological Survey special report 81). Projections are based on the average future climate in the year 2100 from three climate models using a high-emissions scenario. A projected species decline of >20% is classified as **Decrease**. A projected species increase of >20% is classified as **Increase**. Species with projected changes (increase or decrease) of < 20% are classified as **No Change**. Species are classified as **New** if not currently found in Indiana.

Source: Prasad et al. (2014) and Phillips et al. (in review)

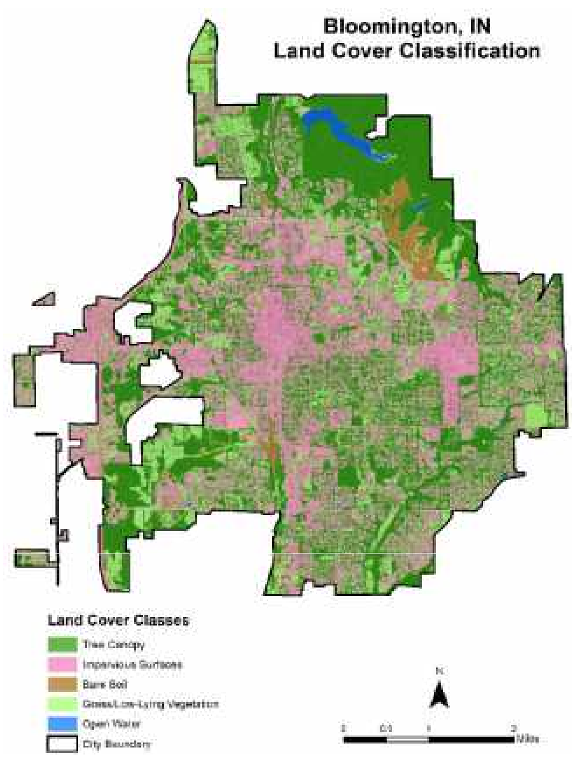
Climate Impact Multiplier - Impervious Land Cover

Impervious surfaces, including building and pavement surfaces, typically absorb solar radiation faster than pervious land coverings (grass, trees). This absorbed energy is typically retained throughout the day and then released slowly during the night. Consequently, ambient temperatures near building and paved areas are higher than grasslands and forest areas. The effects of higher levels of impervious surfaces impact not only large cities, but smaller cities and towns as well.

Increases in impervious cover can also dramatically increase the impact of so-called 100-year flood events. Typically, floods in areas of high impervious surfaces are short-lived, but extended flooding can stress trees, leading to leaf yellowing, defoliation, and crown dieback. If damage is severe, mortality can occur. In addition, flooding can lead to secondary attacks to trees by insect pests and diseases . Higher impervious surface coverage also increase the likelihood of flooding of surrounding homes and businesses and the potential of increased standing water and insect infestation following heavy rain events.

Impervious Surface Area in Bloomington

The City of Bloomington's 2019 Urban Tree Canopy Assessment mapped ground cover characteristics in the city. Areas with high impervious surface coverage, as shown on the map to the right, could benefit from strategies to decrease impervious surface area and increase pervious and green space coverage

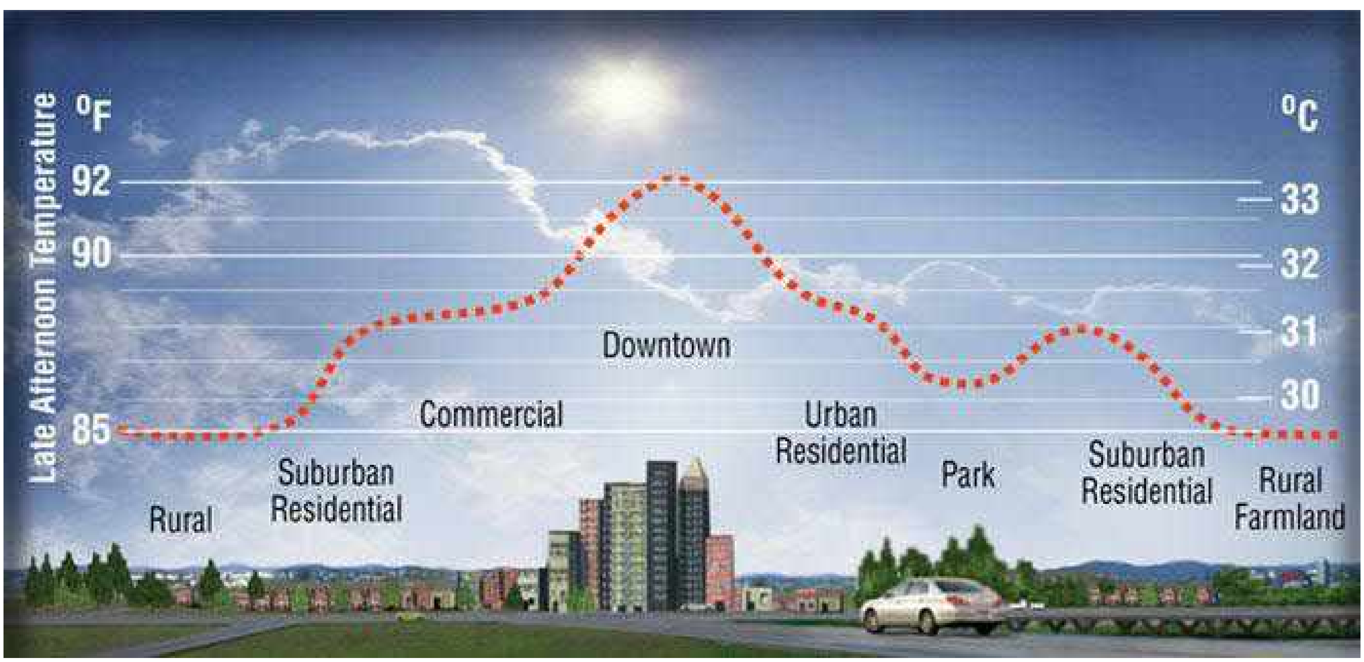


Climate Impact Multiplier - Heat Island

Residents of cities and town centers are more at risk for heat-related illnesses than rural dwellers. The radiant heat trapped by impervious surfaces and buildings as well as heat generated by building mechanical systems, motorized equipment, and vehicles is known as the "Heat Island Effect" . In larger cities, heat island effects create a micro-climate throughout the metro area while occupants of smaller cities and towns can still experience higher temperatures and decreased air movement due to the effects of surrounding buildings and impervious surfaces. This heat island effect serves to increase the impact of climate change effects in developed areas of all size populations, especially those with low or intermittent tree canopy coverage. A developed area's impervious surface characteristics, and tree canopy conditions combine to exacerbate or mitigate the community's heat island impacts.

Due to the heat island effect, developed areas are usually hotter and cool off less at night than non developed areas. Heat islands can increase health risks from extreme heat by increasing the potential maximum temperatures residents are exposed to and the length of time that they are exposed to elevated temperatures. The heat island effect can make developed areas one hardiness zone warmer than the surrounding undeveloped area, allowing some more southern species to be planted. In addition to milder winters, however, heat island effects can also make summer temperatures higher, especially near dark pavements and buildings. Thus, some native plants that are becoming marginal for the area because of increased heat could experience negative effects.

The heat index is a measure of how hot weather feels. Much like wind chills combine temperature and wind to provide a figure about how cold it is in winter, heat indices measure temperature and humidity. Research indicates that in rural areas or regions with significant agriculture, crops can impact heat island effect. Unlike many plants, corn transpires, or sweats, both day and night. Keeping humidity and heat high at night means there is little chance for relief. A University of Minnesota study released in 2016 shows farm crops can increase dew points and heat indices by as much as 5 degrees, while a Northern Illinois University climatologist David Changnon released a study in 2002 showing that modern-day heat waves probably are worse than a century ago because of crops.

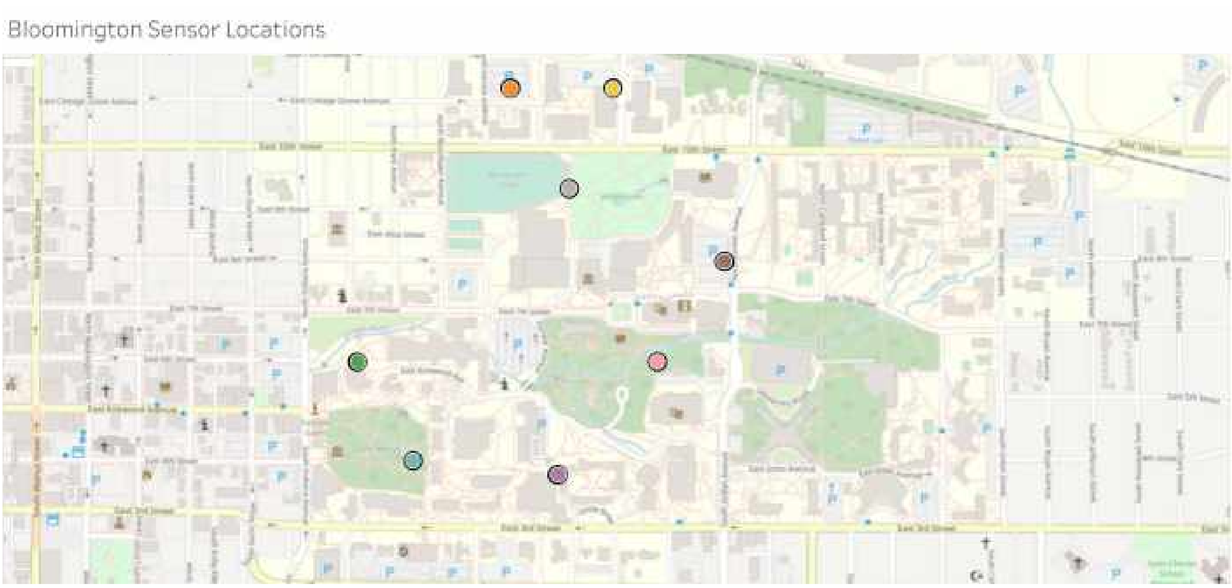


Source: Lawrence Berkeley National Laboratory

Climate Impact Multiplier - Heat Island (continued)

Evidence of Heat Island Impact in Bloomington

In 2018, a study by the Healthy City's Lab of the Indiana University's School of Informatics, Computing, and Engineering deployed heat sensors around the City of Bloomington to study the temperature differences experienced due to micro and macro heat island characteristics. Data collected from the sensors through the summer of 2018 indicated temperature differences as much as 9 degrees during daytime hours and 4 degrees during nighttime hours.



(Source: Healthy City's Lab of the Indiana University's School of Informatics, Computing, and Engineering)

Climate Impact Multiplier - Water Stress

Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). Overall water risks are impacted by projected changes in precipitation levels, seasonal and annual variability, flood and drought vulnerabilities, increased air and water temperature, and water use demand and supply.

Though most of these water stress influences are direct climate impacts, we call Water Stress a climate multiplier because the existence of water stress can greatly increase the overall impact of climate conditions such as extreme heat and overall population vulnerability. It has economic ramifications for individuals as well as the community as a whole which decrease resilience. Water stress affects recreational tourism, industrial productions, jobs, and income.

Water stress in developed areas is directly affected by a community's impervious surface, tree canopy/ground cover, and heat island characteristics. Higher temperatures and impervious surface run-off lead to increases in toxic algae blooms, more rapid evaporation, reduced water retention within the water table, increased demand for irrigation, and decreased lake/river levels. A review of a community's water stress includes the overall water stress, overall water risk, and flood vulnerability.

Overall water stress measures the ratio of total annual water withdrawals to total available annual renewable supply. This number accounts for upstream consumptive use. Higher values indicate more competition among users. Increases in projected water stress into the future indicate a potential for water shortage, conflict, or management challenge.

Overall water risk identifies areas with higher exposure to water-related risks and is an aggregated measure of physical risks related to quantity (flooding, drought, etc), physical risks related to water quality that may impact water availability (such as the percentage of available water that has been previously used and discharged upstream as wastewater where higher values indicate higher dependency on treatment plants and potentially poor water quality in areas that lack sufficient treatment infrastructure), and water regulatory and conflict risks.

As indicated by the inclusion of upstream conditions in the overall water risk calculation, it is extremely important to note that upstream communities can impact the water risk and stress of downstream communities. Failure to implement appropriate storm water management, flood management, and water conservation policies in one community can greatly impact the water stress of communities down stream. As a highly precious resource, all communities should look to increase water conservation regardless of the projected water stress levels of their immediate region, while communities in regions with a projected increase in water stress should view water conservation as a major long-term priority.

Bloomington Water Stress (current)

Baseline water stress measures the ratio of total annual water withdrawals to total available annual renewable supply, accounting for upstream consumptive use. Higher values indicate more competition among users.

The current water stress in Bloomington is "Medium-High" (Source: World Resources Institute)

Water Stress

Low	Low-medium	Medium-high	High	Extremely high
(<10%)	(10-20%)	(20-40%)	(40-80%)	(>80%)

Bloomington Overall Water Risk Quantity (current)

Physical risks quantity measures risk related to too little or too much water, by aggregating all selected indicators from the Physical Risk Quantity category. Higher values indicate higher water quantity risks.

The current water risk in Bloomington is "Medium-High" (Source: World Resources Institute)

Physical Risks Quantity

Low	Low - Medium	Medium-high	High	Extremely high
(0-1)	(1-2)	(2-3)	(3-4)	(4-5)

Bloomington Overall Water Risk Quality (current)

Physical risks quality measures risk related to water that is unfit for use, by aggregating all selected indicators from the Physical Risk Quality category. Higher values indicate higher water quality risks.

The current water risk in Bloomington is "Low-Medium" (Source: World Resources Institute)

Physical Risks Quality

Low	Low - Medium	Medium-high	High	Extremely high
(0-1)	(1-2)	(2-3)	(3-4)	(4-5)

Bloomington Drought Risk (current)

Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate higher risk of drought.

The current water risk in Bloomington is "Medium" (Source: World Resources Institute)

Drought Risk

Low	Low-medium	Medium	Medium-high	High
(0.0-0.2)	(0.2-0.4)	(0.4-0.6)	(0.6-0.8)	(0.8-1.0)

Bloomington Projected Water Stress (through 2040)

Water stress is an indicator of competition for water resources and is defined informally as the ratio of demand for water by human society divided by available water.

The projected water stress in Bloomington is "1.4 - 2.0 Increase" (Source: World Resources Institute)

Water Stress

2.8x or greater decrease	2x decrease	1.4x decrease	Near normal	1.4x increase	2x increase	2.8x or greater increase

Bloomington Projected Seasonal Variability (Through 2040)

Seasonal variability (SV) is an indicator of the variability between months of the year. Increasing SV may indicate wetter wet months and drier dry months, and higher likelihood of droughts or wet periods. We used the within-year coefficient of variance between monthly total blue water as our indicator of seasonal variability of water supply.

Seasonal Variability

1.3x or greater decrease	1.2x decrease	1.1x decrease	Near normal	1.1x increase	1.2x increase	1.3x or greater increase

Bloomington Projected Water Supply (Through 2040)

Total blue water (renewable surface water) was our indicator of water supply. Projected change in total blue water is equal to the 21-year mean around the target year divided by the baseline period of 1950–2010.

The current water risk in Bloomington is "Near Normal" (Source: World Resources Institute)

Water Supply

1.7x or greater decrease	1.4x decrease	1.2x decrease	Near normal	1.2x increase	1.4x increase	1.7x or greater increase

Bloomington Projected Water Demand (Through 2040)

Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate higher risk of drought.

The projected waster demand in Bloomington is "1.2 to 1.4x Increase" (Source: World Resources Institute)

Water Demand

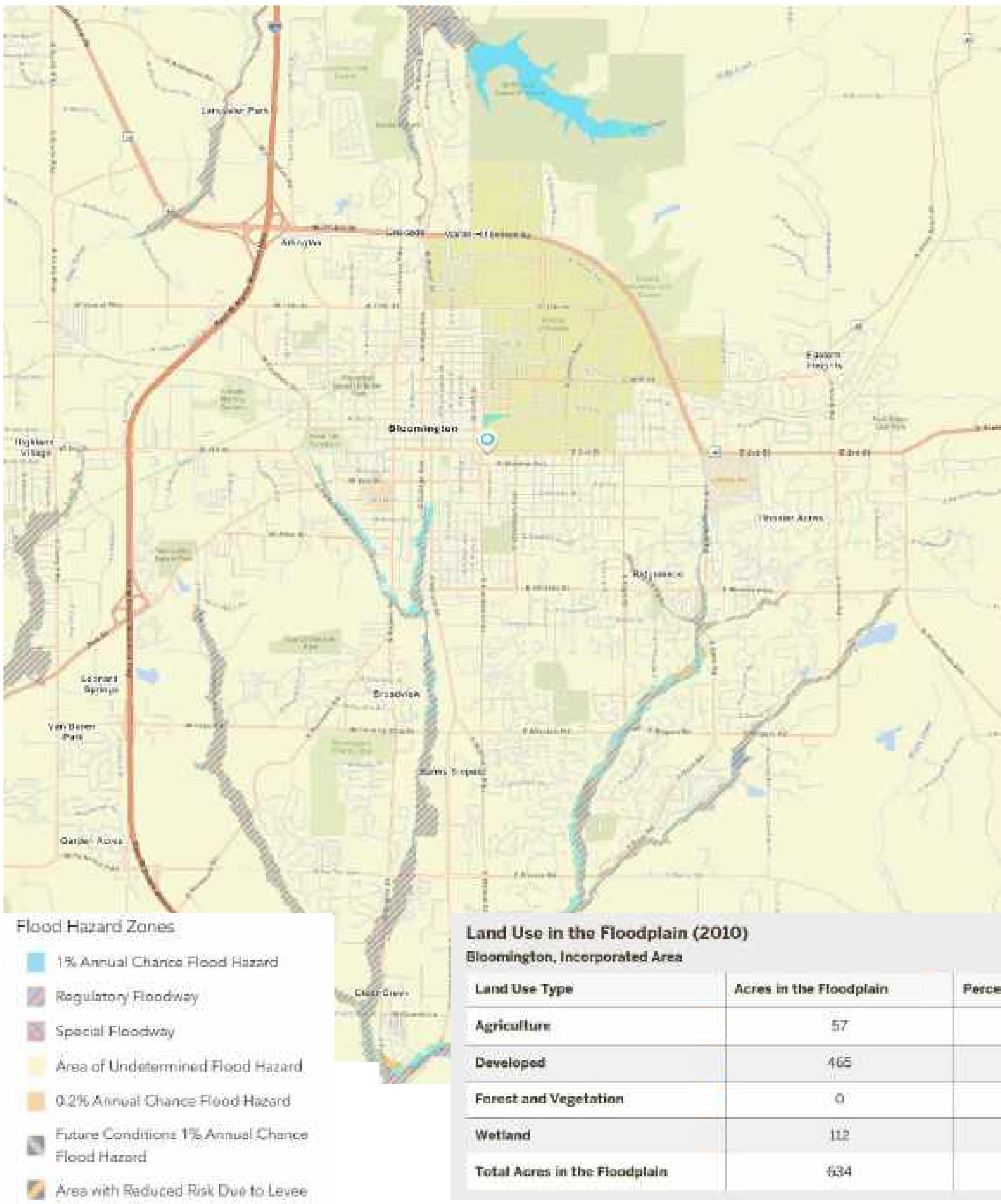
1.7x or greater decrease	1.4x decrease	1.2x decrease	Near normal	1.2x increase	1.4x increase	1.7x or greater increase

Bloomington Flood Vulnerability

According to the US National Climate Assessment, the ten rainiest days can contribute up to 40% of the annual precipitation in the Indiana region. By 2070, the Bloomington area can anticipate an increase of 10-20% in the total annual precipitation, while the amount of precipitation in summer months may actually decline. In addition, the timeframe between rains is expected to continue to increase, (source US National Climate Assessment). Under this scenario, it is likely that certain periods of the year, like spring, may be significantly wetter with storms producing heavier rains. In anticipation of that, it is appropriate to review the areas of the City with flood risk and to review current storm water management capacity against future extreme rainfall event projections.

The map shows the flood risk areas throughout the City as defined by FEMA . Flood risks illustrated relate to water surface elevations for 1% chance annual floods ("100 year flood event"). Areas shown relate to existing bodies of water as well as potential "flash flood" zones in low-lying areas.

*NOTE: 100 year and 500 year flood zones may not reflect current status due to climate change already experienced.
(Source: FEMA, FM Global, National Flood Services, University of Indiana Hoosier Resilience Index)



Land Use in the Floodplain (2010)
Bloomington, Incorporated Area

Land Use Type	Acres in the Floodplain	Percent of Total Acres in the Floodplain
Agriculture	57	9%
Developed	465	73%
Forest and Vegetation	0	0%
Wetland	112	18%
Total Acres in the Floodplain	634	100%

$ 162.50 K
Total Flood Losses In The Community

95
Total Current Policies In The Community

$ 6,250
Total Average Claim Amount In The Community

Section 08

Climate Resilience Indicators

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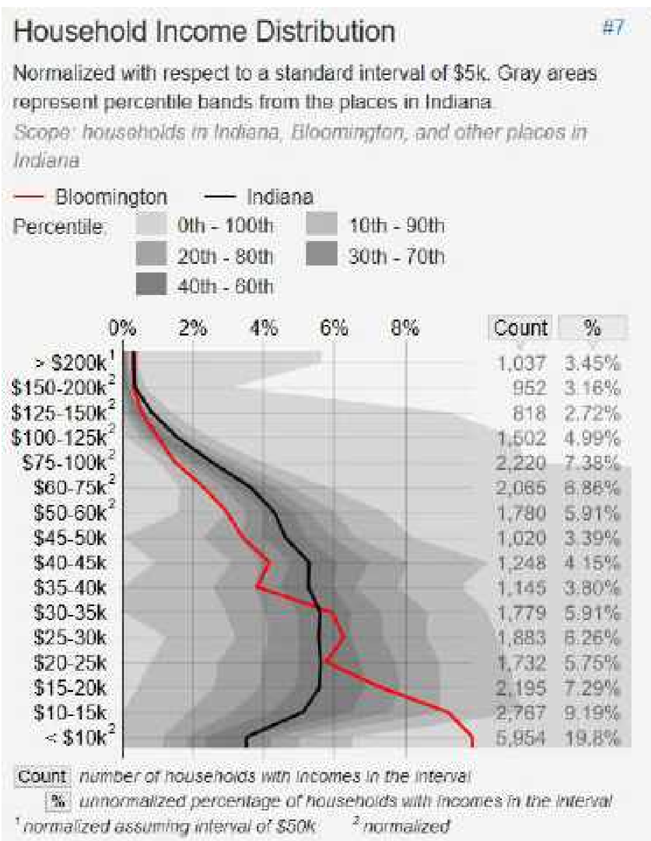
Climate Resilience Indicators

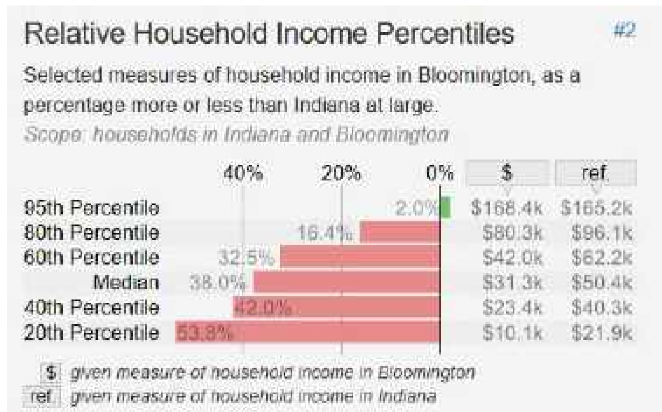
Similar to Climate Impact Multipliers, a community's overall resilience can have a multiplying or a mitigating affect on the population's ability to adapt to climate risks and rapidly recover from extreme weather events. Understanding and tracking the state of these Resilience Indicators will help identify some of the climate adaptive strategies appropriate for the City.

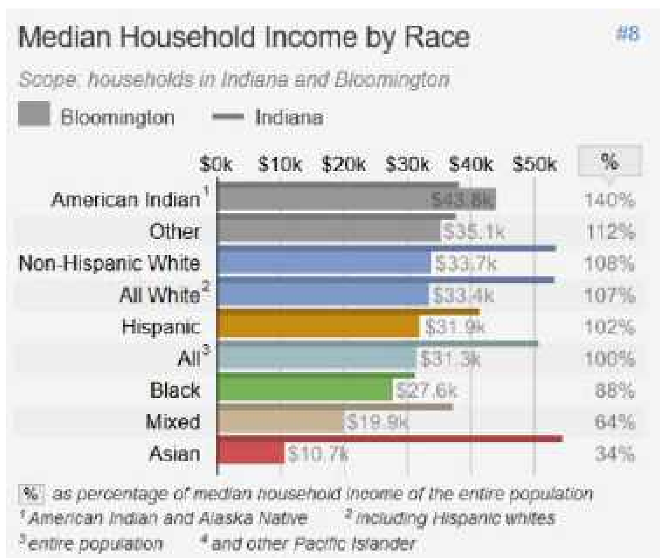
Resilience Indicators include: Economic Stress, Health Indicators, EPA Environmental Justice Screen, EPA Social Vulnerability Index, Housing Burden.

Bloomington Resilience Indicators - Economic Stress

Economic stress within communities function as an impact multiplier. The issue is not limited to individuals – communities with large lower incomes or low tax bases, or low tax rates, can have a lag in infrastructure planning, maintenance, and redevelopment. These stressors on a city's planning capacity or activity decrease the ability for a community to prepare for and respond to climate stresses and vulnerabilities. In addition, a report by the World Health Organization points out that disadvantaged communities are likely to shoulder a disproportionate share of the burden of climate change because of their increased exposure and vulnerability to health threats.







(Source: US Census, Statistical Atlas)

paleBLUEdot LLC

Bloomington Resilience Indicators - Health

The potential magnitude of the population climate risks outlined in section 6 “Local Climate Risks” can be anticipated by understanding current community resilience indicators. Resilience indicators which are higher locally than State or National averages may imply a potential weakness which could be exacerbated by the risks posed by projected climate change.

On the other hand, it should be understood that these community resilience indicators are usually only available at the granularity of County level. This means that the City should carefully consider potential implications for any community resilience indicator even if the local demographic appears "stronger" (lower percentage/value/percentile) than State levels.

	State	County
Poor/Fair Health	18%	**17%**
Uninsured	9%	**9%**
Asthma emergency department visits (per 10,000)	40.6	**22.9**
Pulmonary Disease Deaths (COPD per 100,000)	55.2	**25.4**
Heart Disease Death Rate (per 100,000)	351.9	**328**

(Source: County Health Rankings & Roadmaps program, Centers for Disease Control and Prevention)

Health and Heavy Traffic

Vehicles are a significant and widespread source of air and noise pollution in Indiana communities. Heavy traffic and busy roads increase the relative health risks caused by all air pollutants coming from cars, trucks, and buses. When it gets hot outside, the impacts of pollution on health are even worse. Hotter summers influenced by climate change may mean more health problems for people living, working, or going to school in communities near major roadways. People who live, work, or attend schools near high-traffic roadways are more exposed to traffic-associated air pollutants. Even people passing through these areas while commuting, walking, or biking are more at risk.

The map to the right shows concentrations of on-road vehicle noise and particulate pollution in the city. Darker areas indicate higher air pollution and, subsequently, those locations pose greater risk to human health.
(Source: US Department of Transportation)

Bloomington Resilience Indicators - EPA Environmental Justice Screen

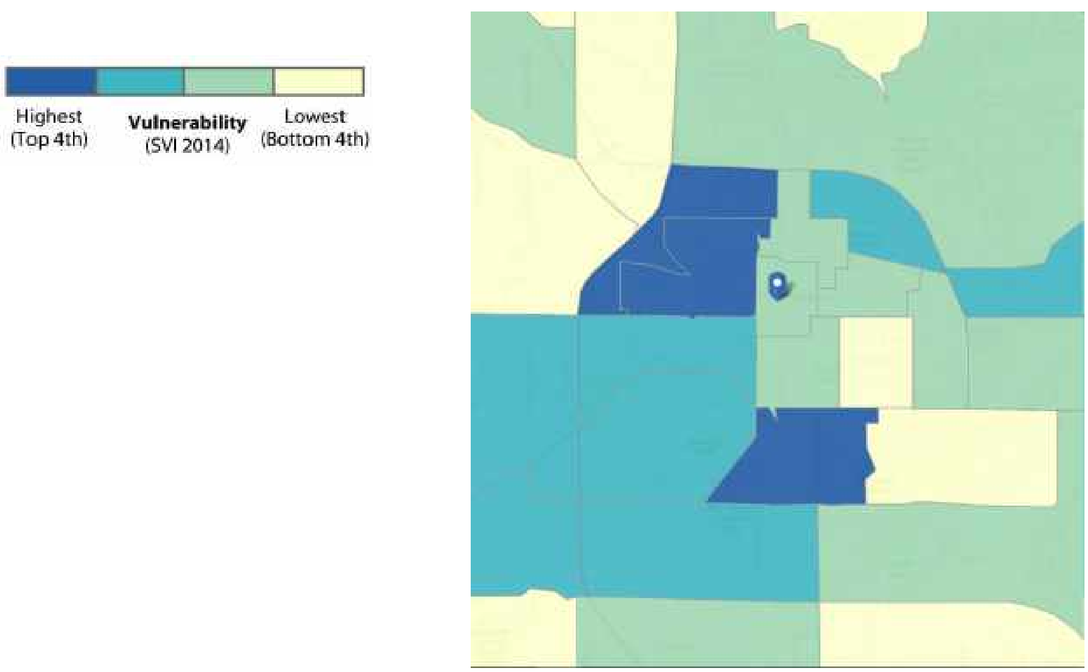
EJSCREEN is an environmental justice mapping and screening tool that provides EPA with a nationally consistent data set and approach for combining environmental and demographic indicators. All of the EJSCREEN indicators are publicly-available data. EJSCREEN simply provides a way to display this information and includes a method for combining environmental and demographic indicators into EJ indexes. Below are the EJSCREEN results for the City. All values circled in orange are values in the upper 35 percentile for the State, representing areas of potential focus for the City.

Selected Variables	Value	State Avg.	%ile in State	EPA Region Avg.	%ile in EPA Region	USA Avg.	%ile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in $\mu g/m^3$)	7.6	9	0	8.63	16	8.3	29
Ozone (ppb)	42.8	43.9	8	43.4	25	43	44
NATA* Diesel PM ($\mu g/m^3$)	0.393	0.449	48	0.446	50-60th	0.479	50-60th
NATA* Cancer Risk (lifetime risk per million)	29	26	76	26	70-80th	32	<50th
NATA* Respiratory Hazard Index	0.36	0.34	66	0.34	60-70th	0.44	<50th
Traffic Proximity and Volume (daily traffic count/distance to road)	290	380	65	530	61	750	56
Lead Paint Indicator (% Pre-1960 Housing)	0.17	0.34	38	0.38	32	0.28	49
Superfund Proximity (site count/km distance)	0.47	0.17	92	0.13	94	0.13	94
RMP Proximity (facility count/km distance)	0.21	0.82	34	0.82	37	0.74	40
Hazardous Waste Proximity (facility count/km distance)	2.4	1.1	85	1.5	80	4	80
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	1.7E-05	0.45	35	0.82	37	14	47

Bloomington Resilience Indicators - EPA Social Vulnerability Index

Social vulnerability refers to the resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss.

The Social Vulnerability Index (SVI) compares and ranks every community in the United States at the Census Tract level. Factors include poverty, lack of car access, and crowded housing. The SVI is developed by the Centers for Disease Control. The City of Bloomington has areas in all four levels of vulnerability (lowest quartile through to highest quartile)

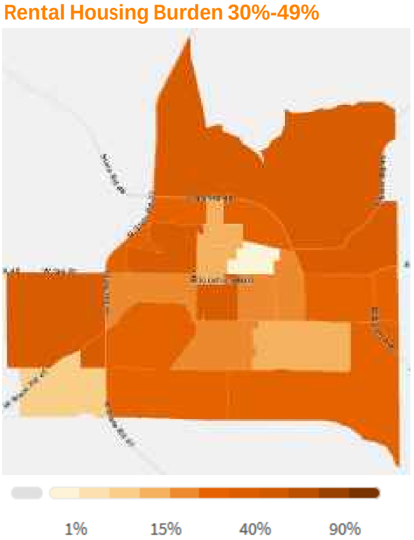


Bloomington Resilience Indicators - Housing Burden

Housing burden can be understood as a household living with any of four housing problems: overcrowding, high housing cost, no kitchen, no plumbing. Households with housing burden can occur at any income level, though they may be more common in middle to lower income brackets. Housing burden factors, like other economic stress indicators, can challenge a household's capacity to respond to emergencies increasing that household's climate vulnerability. Though there are a number of housing burden types as indicated above, the charts and data that follow focus on economic housing burden due to availability of data.

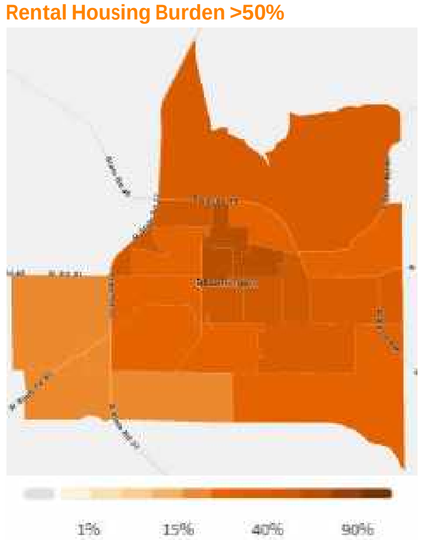
According to the US Census, the City of Bloomington has a total of 30,897 households with 20,220 renters and 10,677 homeowners. Within the City, 58.91% of rental property residents and 16.49% of homeowners are paying 30% or more of their total income on housing costs.

Rental Housing Burden 30%-49%



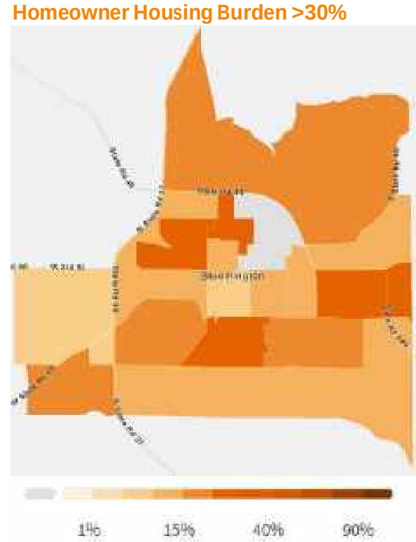
Renter-Occupied Housing Units: 30 to 49 Percent	21.26% 4,298
Percent base: Renter-Occupied Housing Units	20,220

Rental Housing Burden >50%



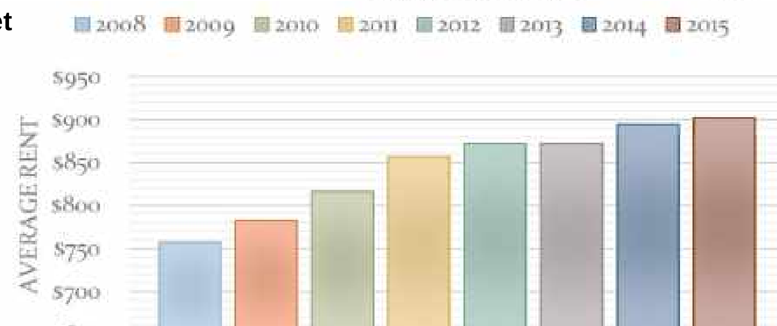
Renter-Occupied Housing Units: 50 Percent or More	37.65% 7,612
Percent base: Renter-Occupied Housing Units	20,220

Homeowner Housing Burden >30%



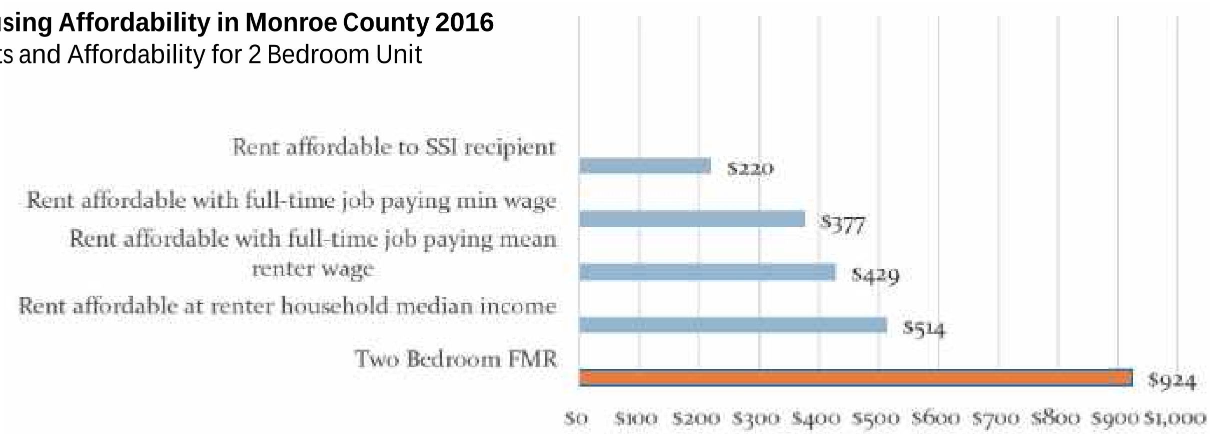
Owner-Occupied Housing Units: Homeowners Who are Paying at Least 30% of Income for Ownership Costs	16.49% 1,761
Percent base: Owner-Occupied	10,677

Bloomington Overall Market Average Rent 2009-2014



Source: South Central Indiana Housing Opportunities

Housing Affordability in Monroe County 2016
Costs and Affordability for 2 Bedroom Unit



Bloomington Resilience Indicators - Housing Bur(Continued)

Housing Type Impacts on Housing Burden

The type of structure a resident lives in can impact the level of housing burden experienced by community members. According to a 2005 study by the US Housing and Urban Development Agency, renters, on average, have 10% more of their monthly income going to utility costs. Those who live in mobile home type constructions often pay even more.

The Environmental and Energy Study Institute, indicates that mobile homes built before 1980 consume an average of 84,316 BTUs per square foot, 53 percent more than other types of homes. A study by the energy consultant group Frontier Associates found that residents in older manufactured homes may pay up to $500 a month for electricity, or over 24% of average monthly income. Mobile homes are also less resilient to extreme temperatures, extreme weather, high winds, and tornado events.

Bloomington Housing by Type and Occupancy

Housing Type	Housing Units			Owner-Occupied			Renter-Occupied		
	Number	% of Total	State Ave	Number	% of Total	State Ave	Number	% of Total	State Ave
1, detached	10,974	35.90%	74.40%	8,061	76.50%	91.40%	2,925	14.60%	36.70%
1, attached	2,935	9.60%	3.70%	1,317	12.50%	2.90%	1,603	8.00%	5.60%
2 apartments	642	2.10%	2.30%	84	0.80%	0.40%	541	2.70%	6.30%
3 or 4 apartments	2,507	8.20%	3.30%	148	1.40%	0.30%	2,344	11.70%	9.90%
5 to 9 apartments	4,341	14.20%	4.50%	74	0.70%	0.20%	4,267	21.30%	13.80%
10 or more apartments	8,131	26.60%	7.50%	84	0.80%	0.30%	8,053	40.20%	23.40%
Mobile home	1,039	3.40%	4.40%	759	7.20%	4.50%	280	1.40%	4.20%
Total Occupied Units	30,569			10,537	34.5%	68.9%	20,032	65.5%	31.1%

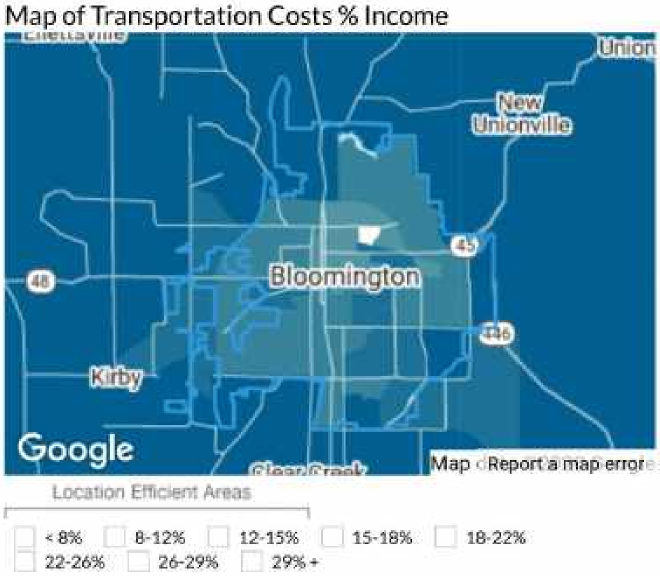
(Source: US Census Bureau)

Housing And Transit Affordability

Traditional measures of housing affordability ignore transportation costs. Typically a household's second-largest expenditure, transportation costs are largely a function of the characteristics of the neighborhood in which a household chooses to live. Location Matters. Compact and dynamic neighborhoods with walkable streets and high access to jobs, transit, and a wide variety of businesses are more efficient, affordable, and sustainable.

The statistics below are modeled for the Regional Typical Household. Income: $42,725 Commuters: 1.07 Household Size: 2.37 (Bloomington, IN)

Map of Transportation Costs % Income



Location Efficiency Metrics

Places that are compact, close to jobs and services, with a variety of transportation choices, allow people to spend less time, energy, and money on transportation.

0% Percent of location efficient neighborhoods

Neighborhood Characteristic Scores (1-10)

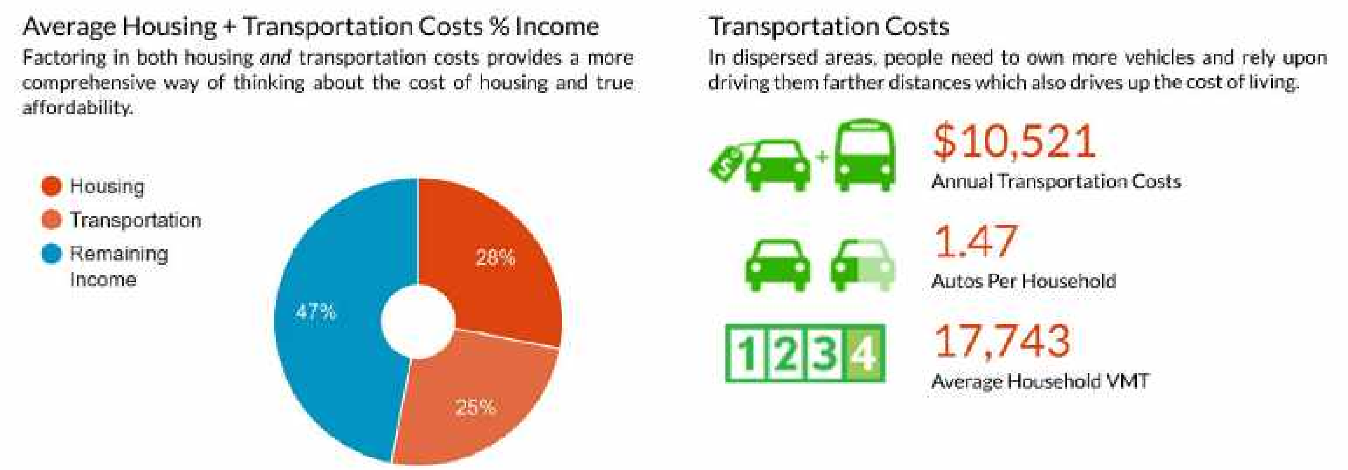
As compared to neighborhoods in all 955 U.S. regions in the Index

Job Access	AllTransit Performance Score	Compact Neighborhood
5.9	5.1	6.7
Moderate access to jobs	Moderate access to public transportation	High density and walkable

(Source: Center for Neighborhood Technology H+T Index)

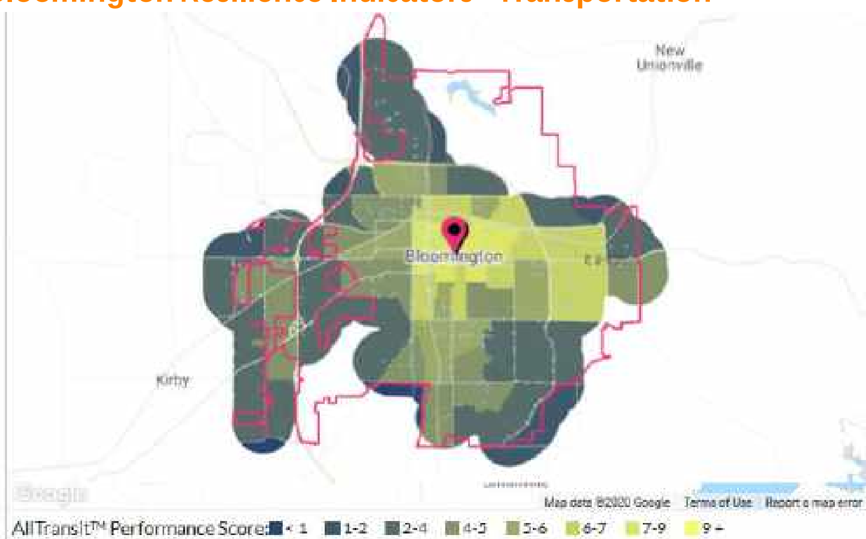
Bloomington Resilience Indicators - Housing Burden (Continued)

Housing And Transit Affordability (continued)



(Source: Center for Neighborhood Technology H+T Index)

Bloomington Resilience Indicators - Transportation



AllTransit ™ Performance Score

4.9

Low combination of trips per week and number of jobs accessible enabling few people to take transit to work

On Average Households have:

- 787 Transit Trips per Week within ½ Mile
- 8 Transit Routes within ½ Mile
- 42,311 Jobs Accessible in 30-minute trip
- 6.86% Commuters Who Use Transit

JOBS

Jobs Near Transit: Percent of jobs that are located within ½ mile of transit.

96.1%

42,997 jobs are near transit

ECONOMY

Transit Access to Customers: Customer households accessible to a business within a 30 minute transit commute.

19,113

Households within a 30 minute transit commute.

HEALTH

Healthy Commuters: Workers who commute by walking or biking and live within ½ mile of transit.

14.75% Walk

4.11% Bike

EQUITY

Low-income Households Near Transit: Percent of households making under $50,000 within a ½ mile of high frequency full day transit.

0%

0 Households

TRANSIT QUALITY

High Frequency Transit: Households within ½ mile of high frequency transit.

0% Around the Clock

0% Full Day

24% Rush Hour

MOBILITY

Transit Routes: Transit routes available within ½ mile of a block group on average.

8

Transit Routes

(Source: Center for Neighborhood Technology AllTransit)

Walk and Bike-Ability

Improved levels of walk and bike-ability of a community can improve equity and mobility among vulnerable populations. According to Jeff Speck, author of Walkable City: How Downtown Can Save America, One Step at a Time, “There are powerful equity reasons to invest in walkability.” Car-centered cities cater only to those residents who can drive—excluding the elderly, the vision-impaired, and people who cannot afford to have a vehicle. Cities with more transit choices demonstrate less income inequality and less overspending on rent. Communities with better sidewalks increase “livability” and safety for wheelchair users, seniors, youth, and others.

Active transportation networks can provide not only a cost savings to the users but immediate and long-term benefits to the local economy as well.

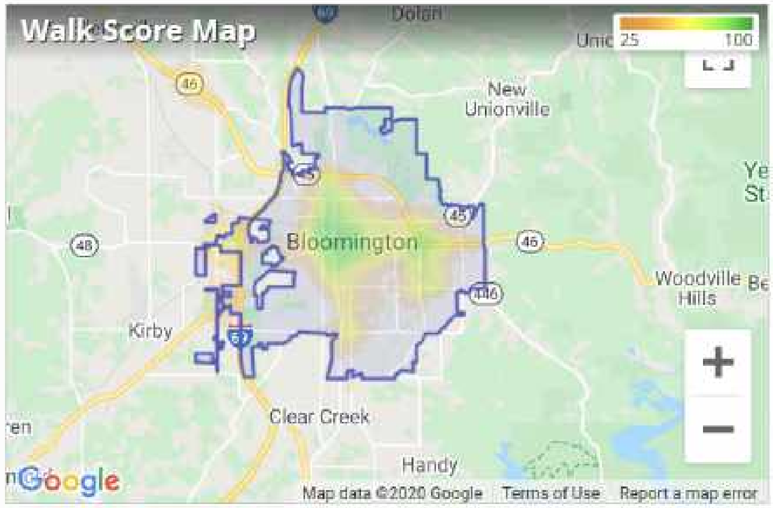
Annual Cost of Transportation

Figure source: Transit for Livable Communities, Minnesota

Walk Score 43

Bloomington is a Car-Dependent city

Most errands require a car.



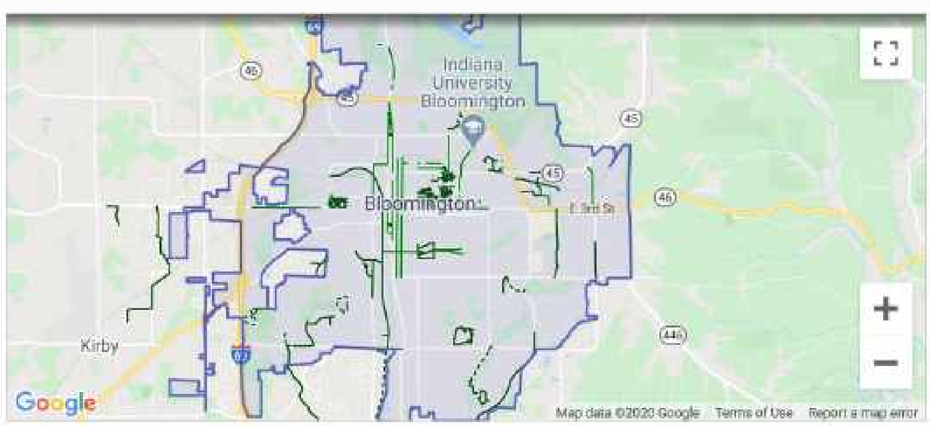
Bloomington Neighborhoods

Rank	Name	Walk Score	Transit Score	Bike Score	Population
1	Downtown	88	38	78	1,907
2	High Point	83	37	70	522
3	Old Northeast	79	37	64	3,194
4	Elm Heights	77	37	71	4,709
5	Prospect Hill	76	36	80	999
6	Maple Heights	70	30	66	687
7	Near West Side	69	33	81	661
8	Garden Hill	69	32	58	1,205
9	Green Acres	65	33	85	1,145
10	Bryan Park	63	31	75	1,681
11	Eastside	53	32	68	615
12	Indiana University	52	30	65	13,338
13	Park Ridge	47	30	71	604
14	Barclay Gardens	31	24	54	912
15	SoMax	29	29	56	539
16	Park Ridge East	25	27	45	850
17	Sycamore Knolls	22	25	40	619
18	Broadview	18	23	62	1,344

Bike Score 57

Bloomington is Bikeable

Some bike infrastructure.



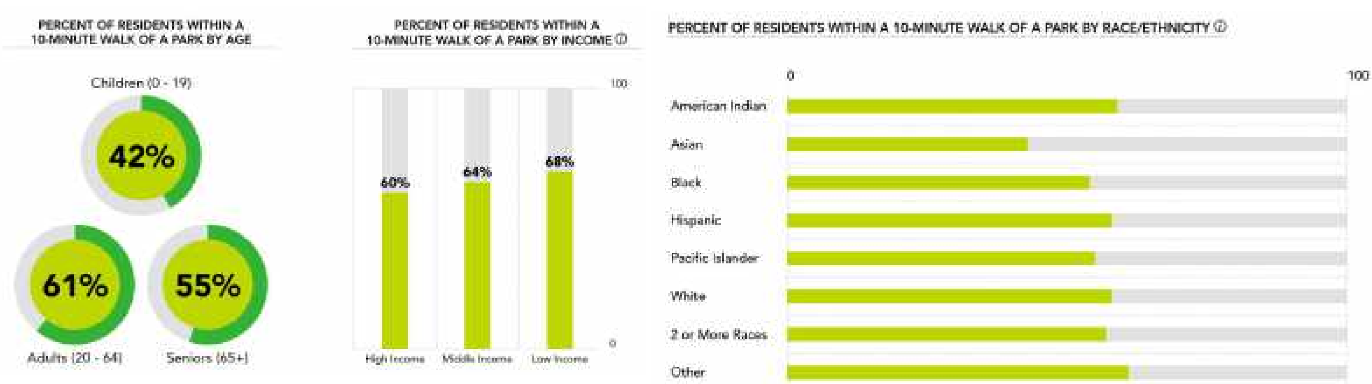
(Source: Walkscore.com)

Bloomington Resilience Indicators - Access To Greenspace

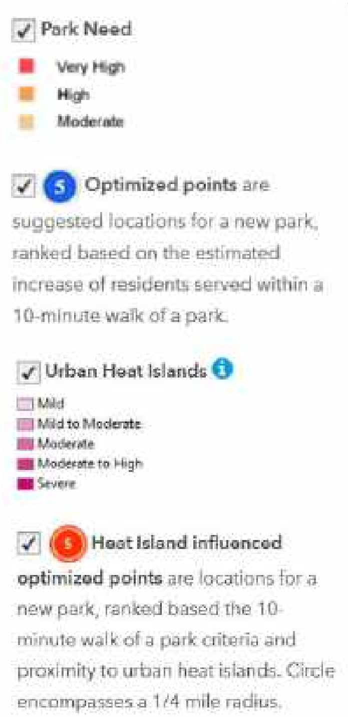
Access to greenspace like public parks can be a meaningful indicator of community resilience. As noted by the National Recreation and Park Association "Marginalized areas often have poor access to quality parks. This limited access to green space can negatively impact public health and well-being, especially in communities already facing numerous challenges to success. The term "health disparities" refers to major gaps in health between different groups."

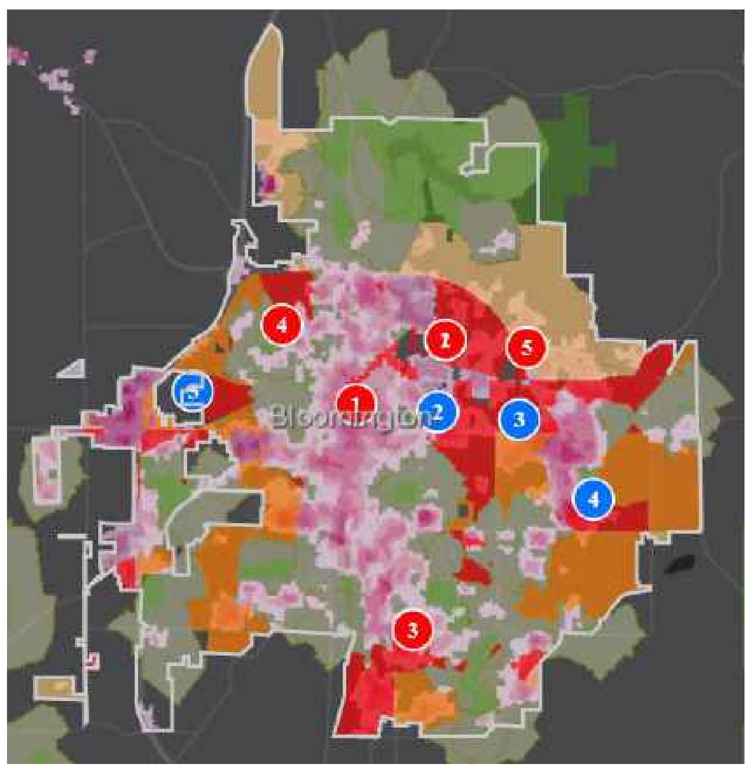
Beyond livability and health equity considerations of park space, assuring quality park space and access for all residents, particularly the most vulnerable, is a meaningful strategy to address climate change impacts in a community. From a mitigation perspective, parks reduce CO2 emissions as well as other forms of pollution like ozone and particulate matter. Parks increase a neighborhood's resilience in the face of extreme weather and flooding, extreme heat, and droughts.

City of Bloomington Park Characteristics

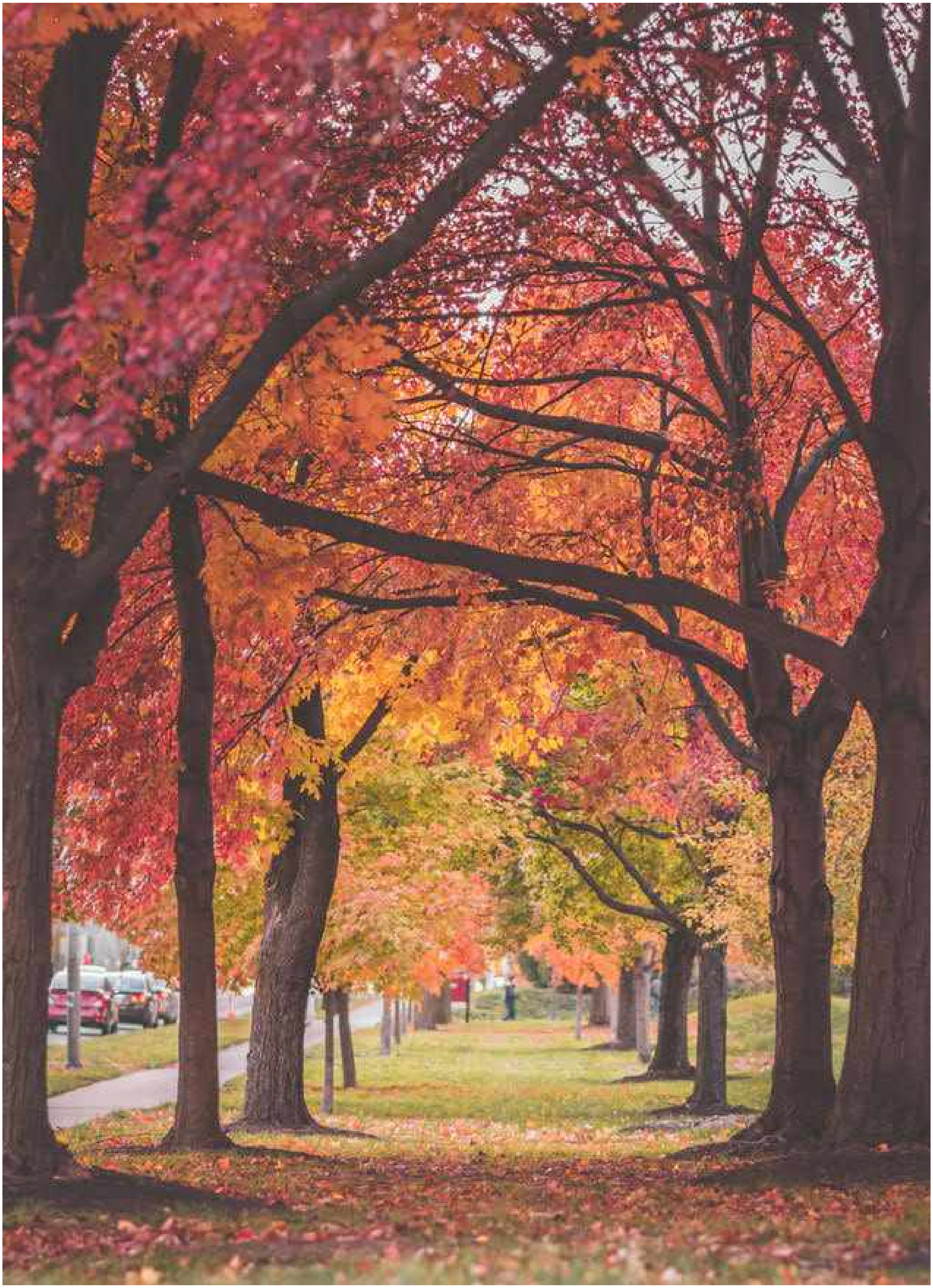


City of Bloomington Park Recommendations for Equity and Heat Island





(Source: The Trust For Public Land)



Section 09

Vulnerable Populations

Click to
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Vulnerable Populations in Bloomington

Some groups face a number of stressors related to both climate and non-climate factors. For example, people living in impoverished urban or isolated rural areas, floodplains, and other at-risk locations such as areas of current or historically high levels of toxic chemical pollution are more vulnerable not only to extreme weather and persistent climate change but also to social and economic stressors. Many of these stressors can occur simultaneously or consecutively.

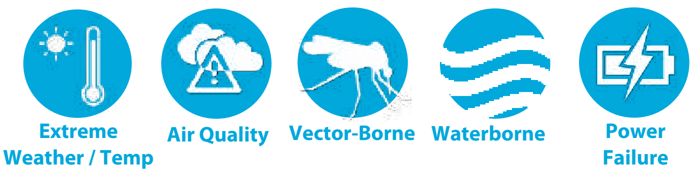
People or communities can have greater or lesser vulnerability to health risks depending on age, social, political, and economic factors that are collectively known as social determinants of health. Some groups are disproportionately disadvantaged by social determinants of health that limit resources and opportunities for health-promoting behaviors and conditions of daily life, such as living/working circumstances and access to healthcare services. Populations of concern are particularly vulnerable to climate change impacts. Heightened vulnerability to existing and projected climate impacts can be due to a sector of the population's exposure, sensitivity, or adaptive capacity to a climate impact.

The following pages map the populations particularly vulnerable to the risks of climate change impacts within the City of Bloomington.

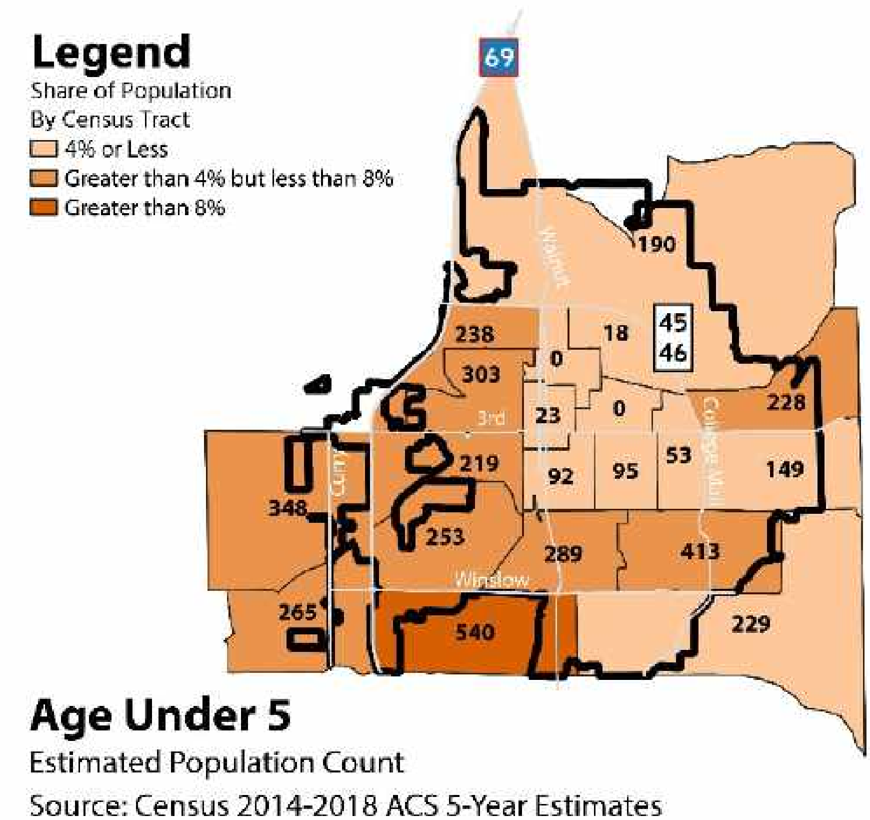
Children

According to the US Global Change Research Program “Children are vulnerable to adverse health effects associated with environmental exposures due to factors related to their immature physiology and metabolism, their unique exposure pathways, their biological sensitivities, and limits to their adaptive capacity. Children have a proportionately higher intake of air, food, and water relative to their body weight compared to adults. They also share unique behaviors and interactions with their environment that may increase their exposure to environmental contaminants such as dust and other contaminants, such as pesticides, mold spores, and allergens.”

Children are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):



Map of Vulnerable Population Distribution Within Community



Children Under 5 Summary

Total Estimated Population:	**3,945**
Estimated Share of Total Vulnerable Population:	**6-9%**
Estimated Share of Total City Population:	**4.0%**

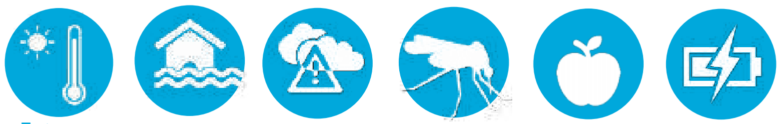
Observations for Bloomington

The estimated total child population under five for Bloomington is 3,945. This vulnerable population makes up 4% of the City’s total population. Children under five are most concentrated in the Western and Southern sections of the City. These sections represent both the highest estimated population as well as the highest share of the total population of these tracts - ranging from 4% to over 8% of the total population of those neighborhoods.

Older Adults (65 and over)

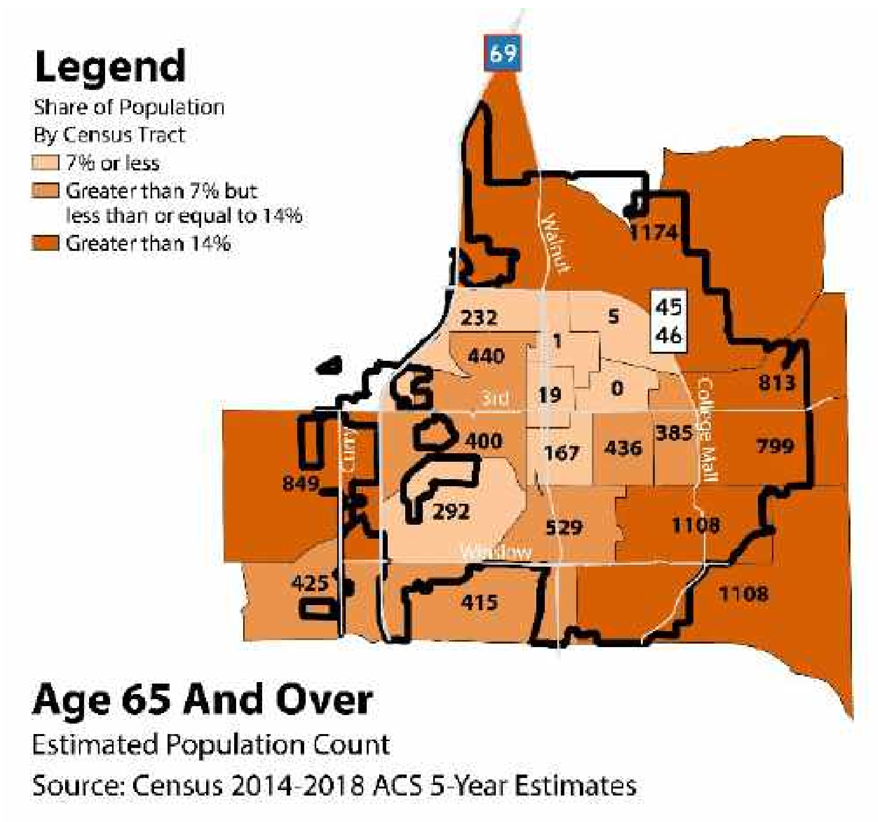
Older adults are also vulnerable to the health impacts associated with climate change and weather extremes. Vulnerabilities within older adults are not uniform due to the fact that this demographic is a diverse group with distinct sub-populations that can be identified not only by age but also by race, educational attainment, socioeconomic status, social support networks, overall physical and mental health, and disability status. According to the US Global Change Research Program "the potential climate change related health impacts for older adults include rising temperatures and heat waves; increased risk of more intense floods, droughts, and wildfires; degraded air quality; exposure to infectious diseases; and other climate-related hazards."

Older Adults are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):



Extreme Weather / Temp | **Flood** | **Air Quality** | **Vector-Borne** | **Food Insecurity** | **Power Failure**

Map of Vulnerable Population Distribution Within Community



Older Adults Summary

Total Estimated Population: **9,597**

Estimated Share of Total Vulnerable Population: **13-18%**

Estimated Share of Total City Population: **9.74%**

Observations for Bloomington

The estimated total older adult population for Bloomington is 9,597. This vulnerable population makes up 9.74% of the City's total population. Older adults make up at least 13% of the climate vulnerable individuals in Bloomington . Older adults are most concentrated in the Northern, Eastern, and West Central sections of the City. These sections represent the highest share of the total population of these tracts - making up 20% or more of the total population of those neighborhoods.

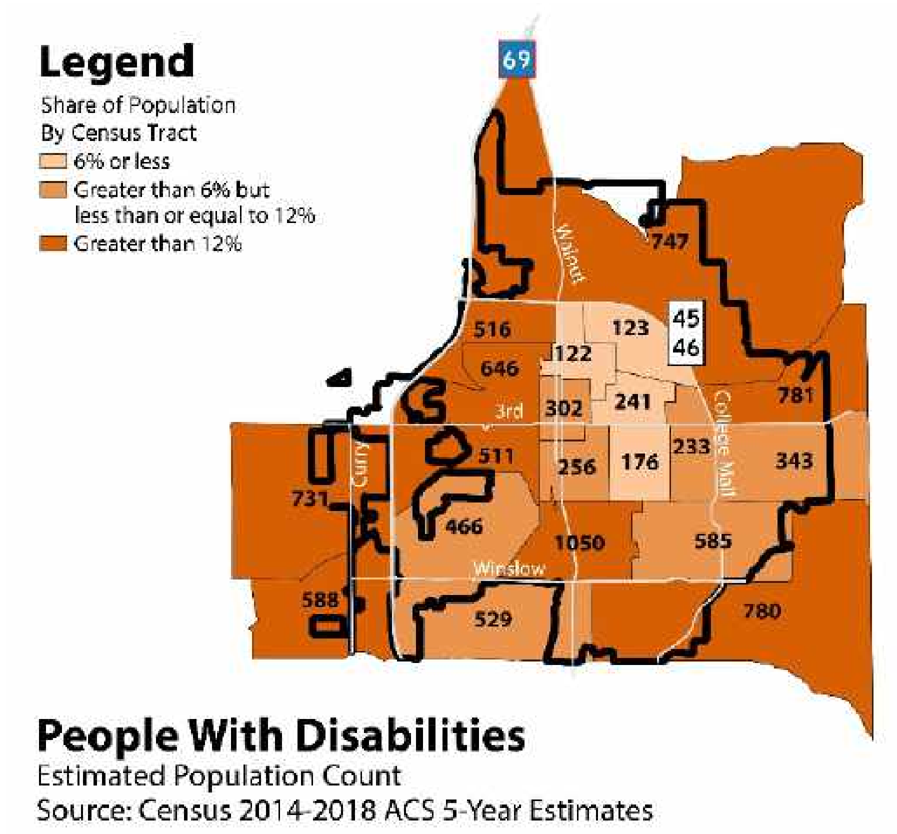
Individuals with Disabilities

People with disabilities experience disproportionately higher rates of social risk factors, such as poverty and lower educational attainment, that contribute to poorer health outcomes during extreme events or climate-related emergencies. These factors compound the risks posed by functional impairments and disrupt planning and emergency response. Of the climate-related health risks experienced by people with disabilities, perhaps the most fundamental is their “invisibility” to decision-makers and planners. Disability refers to any condition or impairment of the body or mind that limits a person’s ability to do certain activities or restricts a person’s participation in normal life activities, such as school, work, or recreation.

Individuals with disabilities are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):

Extreme Weather / Temp | Flood | Air Quality | Food Insecurity | Power Failure

Map of Vulnerable Population Distribution Within Community



Individuals with Disabilities Summary

Total Estimated Population: **9,726**

Estimated Share of Total Vulnerable Population: **14-19%**

Estimated Share of Total City Population: **9.9%**

Observations for Bloomington

The estimated total population of individuals with disabilities for Bloomington is 9,726.   This vulnerable population makes up 9.9% of the City’s total population. Individuals with disabilities make up at least 1 in every 7 climate vulnerable individuals in Bloomington . Individuals with disabilities are fairly evenly distributed throughout the City. This population makes from 6 to over 12% of the total population of most sections of the City.

Individuals Under Economic Stress

Individuals and families living under economic stress, defined here as “low income” individuals (200% poverty level), are frequently the most adaptive demographic group in our communities. Those living under economic stress exhibit on-going adaptation capabilities simply navigating day-to-day challenges with less than needed resources. This adaptive capacity, however, is overwhelmed in times of emergency as lack of sufficient economic resources greatly reduce the range of options available in response to crisis. For those in poverty, weather-related disasters or family members falling ill can facilitate crippling economic shocks.

With limited economic adaptive capacity, this portion of our population is especially vulnerable to every projected climate impact. Frequently the most effective measures in avoiding extreme heat such as efficiently functioning air conditioning or high performing building enclosures are simply not available to those in poverty while many work in outdoor or industrial jobs which are particularly vulnerable to climate conditions. Diseases which may result from exposure to vector-borne, water-borne, and air-borne pathways may go untreated due to lack of medical access or ability to pay and may increase the level of economic stress due to missed work days or even loss of employment. Those living under economic stress usually carry a heavy housing cost burden, including higher utility costs. This burden can be exacerbated from damaged sustained by their home in extreme weather or flooding events.

Those in economic stress are also frequently food insecure. In Indiana, food insecurity affects 1 in 8 people. Many of the projected climate change impacts are likely to effect agricultural production and distribution, which in turn, may cause spikes in food costs and increase food and nutrition insecurity among those in economic stress.

Individuals experiencing economic stress, defined as those at 200% poverty level (the common definition of “Low Income”) are particularly sensitive to the following Climate Risks:

Map of Vulnerable Population Distribution Within Community

See maps on next page.

Observations for Bloomington

The estimated total population in economic stress for Bloomington is 38,058 with 34% being individuals and 66% being families. Those living in economic stress make up over 48% climate vulnerable individuals in Bloomington.

Families living in economic stress are most concentrated in the East Central and West Central sections of the City while individuals living in economic stress are most concentrated in the Central sections of the City. These sections represent both the highest estimated economically stressed population as well as the highest share of the total population of these tracts - ranging from 30% to >60% of the total population of those neighborhoods.

Economic Stress Summary

Total Estimated Population: 38,058

Estimated Share of Total Vulnerable Population: 48-55%

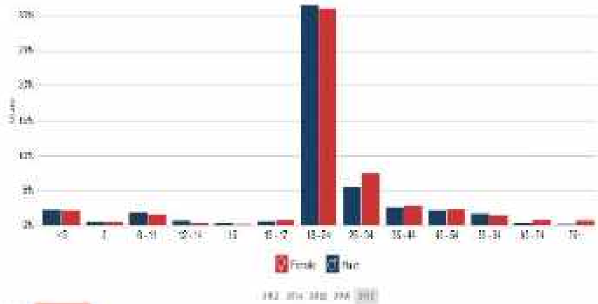
Estimated Share of Total City Population: 38.6%

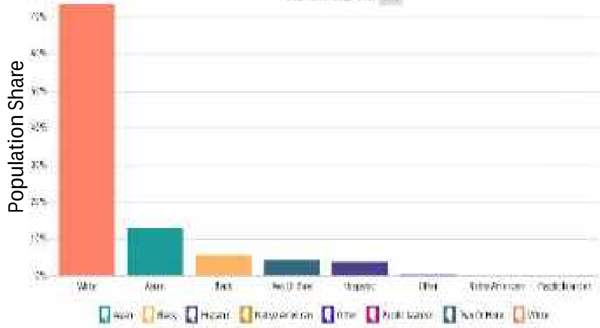
Note: University students living within low income levels may experience hardships, however, the full range of climate change vulnerabilities that are associated with low income individuals are not necessarily experienced equally among full time college students. Due to the significant number of students within the City of Bloomington, the data available for low income individuals and families may be skewed somewhat by the student population. To adjust for the high student population, this study has also mapped the total “Non-Student Residents in Poverty”. This map indicates that the highest concentrations of non-student poverty are located in the Central sections of the City, making from 25% to over 50% of the populations in these neighborhoods.

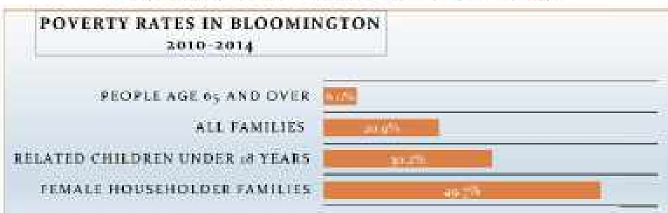
Poverty by Age and Gender

37.5% of the population in Bloomington live below the poverty line. The largest demographic living in poverty is male 18-24, followed by Female 25-34 and then Male 25-34. Likely, these numbers are impacted significantly by the City's total university population.

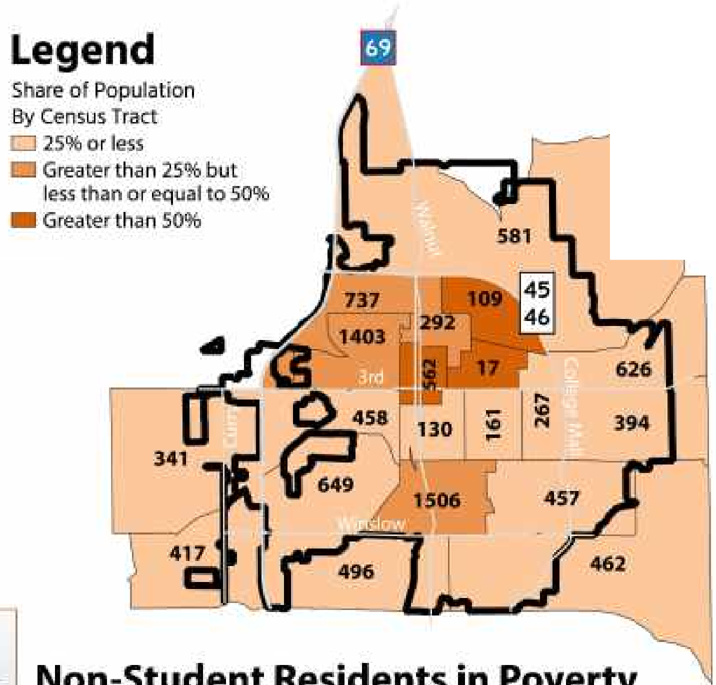
The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who classifies is impoverished. If a family's total income is less than the family's threshold than that family and every individual in it is considered to be living in poverty.







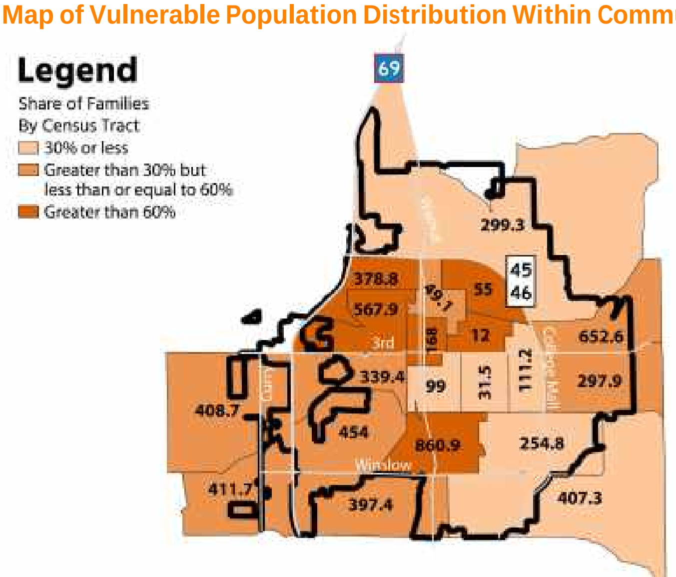
Source: South Central Indiana Housing Opportunities



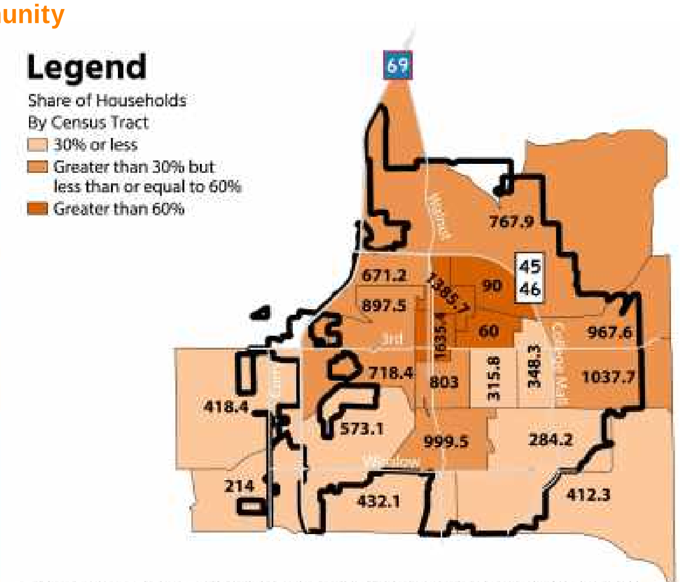
Non-Student Residents in Poverty
Estimated Population Count
Source: Census 2014-2018 ACS 5-Year Estimates

"Student" referrs to full time college student as defined by Census

Map of Vulnerable Population Distribution Within Community



Income At Or Below 200% Poverty (Family of Four)
Estimated Family Count
Source: Census 2014-2018 ACS 5-Year Estimates



Income At Or Below 200% Poverty (1-Person Household)
Estimated Household Count
Source: Census 2014-2018 ACS 5-Year Estimates

People of Color and Limited English Populations

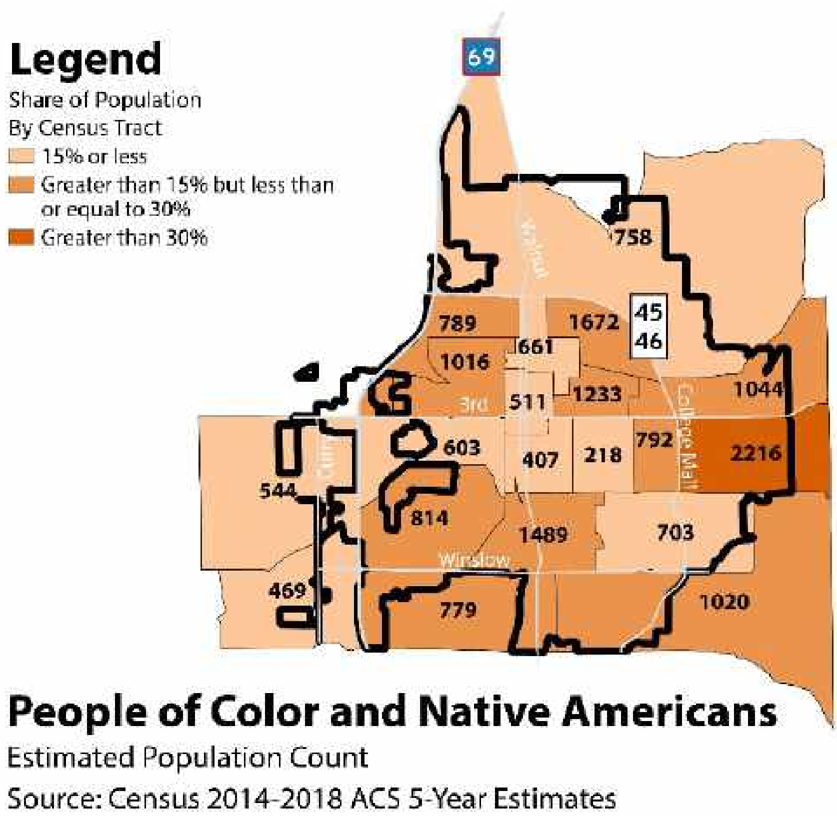
These populations are at increased risk of exposure given their higher likelihood of living in risk-prone areas, areas with older or poorly maintained infrastructure, or areas with an increased burden of air pollution. In addition, according to the Center for Disease Control and the National Health Interview Survey these portions of our population also experience higher incidence of chronic medical conditions which can be exacerbated by climate change impacts. These populations may also be impeded from preparing, responding, and coping with climate related health risks due to socioeconomic and education factors, limited transportation, limited access to health education, and social isolation related to language barriers.

Though not specifically a “person of color” category, individuals with limited English frequently overlap with populations of color. Individuals with limited English language skills may be more socially isolated. Their limited English also likely limits their access to public information and notifications, potentially resulting in a knowledge gap related to community resources, programs, or education which may be relevant in preparing for and recovering from climate impacts. In addition, communication barriers may create challenges for limited English speakers in understanding critical information or instructions given in public address during an extreme weather event.

People of Color may be particularly sensitive to the following Climate Risks:

Extreme Weather / Temp | Flood | Air Quality | Vector-Borne | Food Insecurity | Waterborne | Power Failure

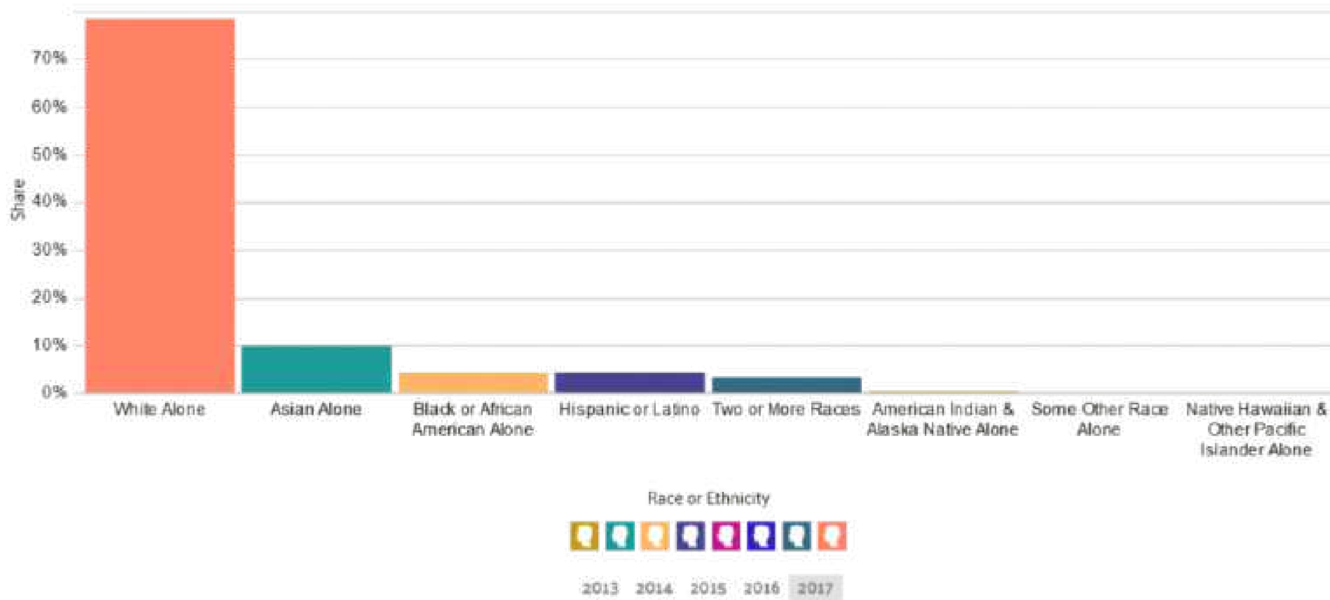
Map of Vulnerable Population Distribution Within Community



People of Color Summary

Total Estimated Population:	17,738
Estimated Share of Total Vulnerable Population:	25-30%
Estimated Share of Total City Population:	18.0%

Breakdown of Race and Ethnicity



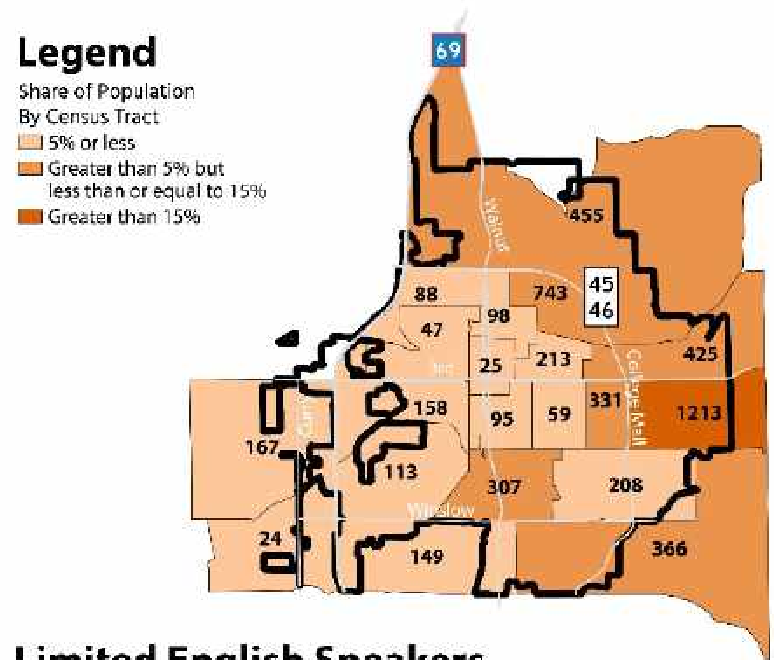
Observations for Bloomington

The estimated total population of people of color in Bloomington is 17,738 with approximately 54% being Asian, 22% Hispanic or Latino, 22% African-American, and the balance Native American, Pacific Islander, or two or more races. This vulnerable population makes up 18% of the City's total population and approximately 1 in 3 of all climate vulnerable individuals in Bloomington.

Populations of color are most concentrated in the East, South, and Central sections of the City. These sections represent both the highest estimated population of color as well as the highest share of the total population of these tracts - ranging from 15% to over 30% of the total population of those neighborhoods

There are an estimated 5,284 limited English speakers in the Bloomington. For limited English speakers, the most common languages spoken at home are Spanish (26.9%), Korean (12.5%), German (10.1%), French (8.18%), Chinese (7.5%), and Japanese (5.12%).

Assuring key communications related to community resources, safety, emergency, and extreme weather preparedness is equally accessible to community residents with limited English is important for overall community resilience. The City should review its current and future communications for translation opportunities targeting the city's non-English primary languages to the greatest extent feasible.



Limited English Speakers
Estimated Population Count
Source: Census 2014-2018 ACS 5-Year Estimates

At-Risk Workers

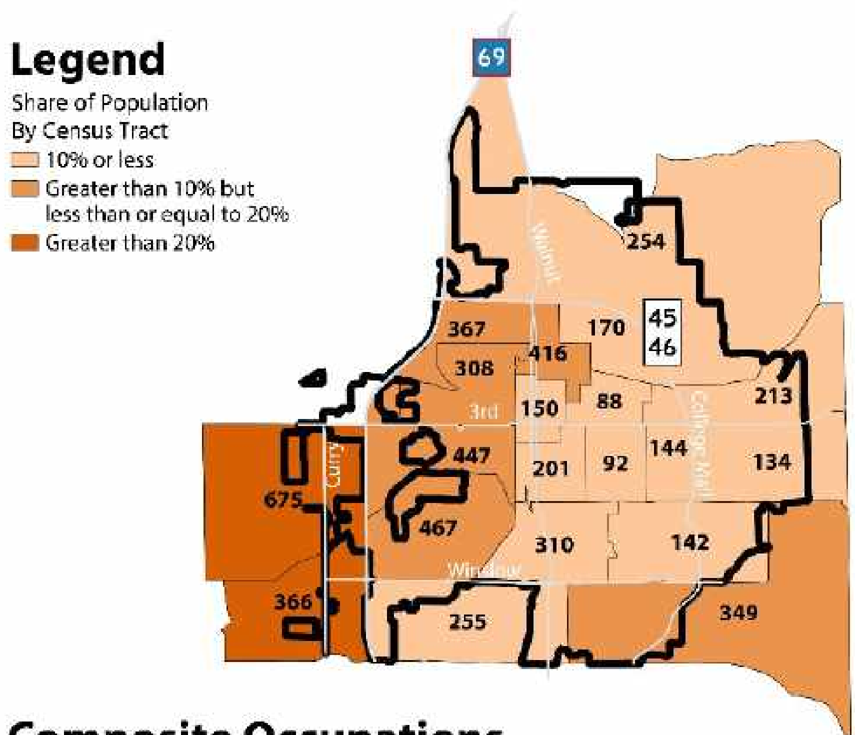
Climate change will increase the prevalence and severity of occupational hazards related to environmental exposure. As our climate changes, we may also experience the emergence of new work related risks. Climate change can be expected to affect the health of outdoor workers through increases in ambient temperature, more prevalent and longer-lasting heat waves, degraded air quality, extreme weather, vector-borne diseases, and industrial exposures. Workers affected by climate change include farmers, ranchers, and other agricultural workers; laborers exposed to hot indoor work environments; construction workers; paramedics, firefighters and other first responders; and transportation workers.

For individuals employed in climate vulnerable jobs who also fall within other vulnerable population categories, the health effects of climate change can be cumulative. For these individuals, the risks experienced in their work can be exacerbated by exposures associated with poorly insulated housing and lack of air conditioning. Workers may also be exposed to adverse occupational and climate-related conditions that the general public may be more able to avoid, such as direct exposure to extreme heat, extreme weather events, low air quality, or wildfires.

Individuals employed in at-risk occupations may be particularly sensitive to the following Climate Risks:

Extreme Weather / Temp | Flood | Air Quality | Vector-Borne | Waterborne

Map of Vulnerable Population Distribution Within Community



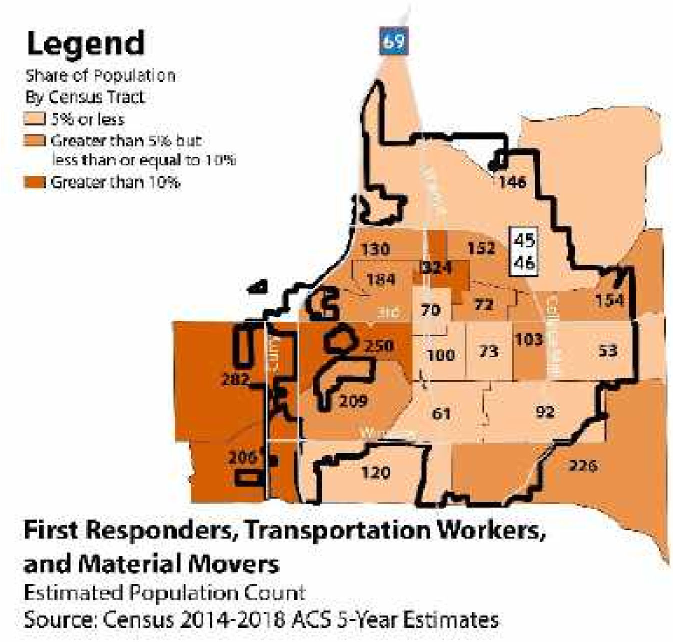
Composite Occupations
Estimated Population Count
Source: Census 2014-2018 ACS 5-Year Estimates

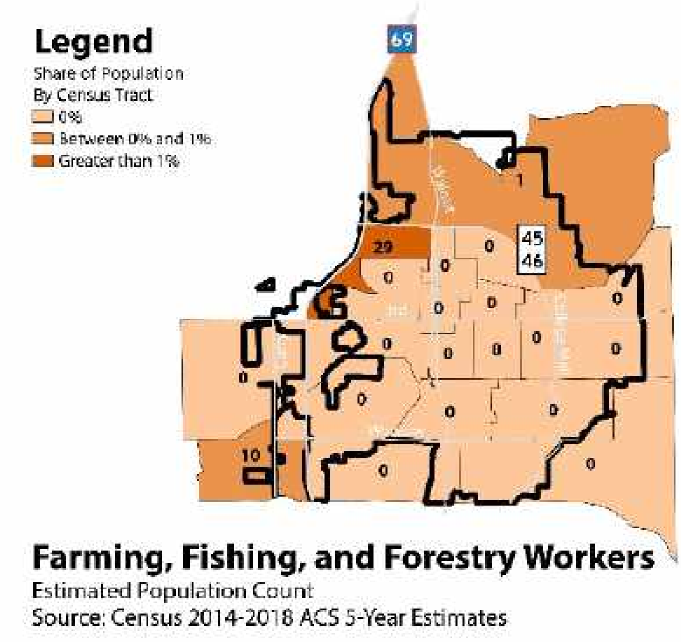
At- Risk Employment Summary

Total Estimated Population:	5,548
Estimated Share of Total Vulnerable Population:	8-12%
Estimated Share of Total City Employment:	10.9%
Estimated Share of Total City Population:	5.6%

Observations for Bloomington

The estimated total Bloomington residents employed in at-risk occupations is 5,548, nearly 11% of all residents who are employed, and over 5.5% of the City's total population. At-risk workers make up approximately 1 in every 10 climate vulnerable individuals in the City . At-risk workers are most concentrated in the West and Southeast sections of the City, making up 10% to over 20% of the total population of those neighborhoods. The largest at-risk worker categories are employed in First Responder, Transportation, Material Mover, Construction, Extraction, and Production jobs.





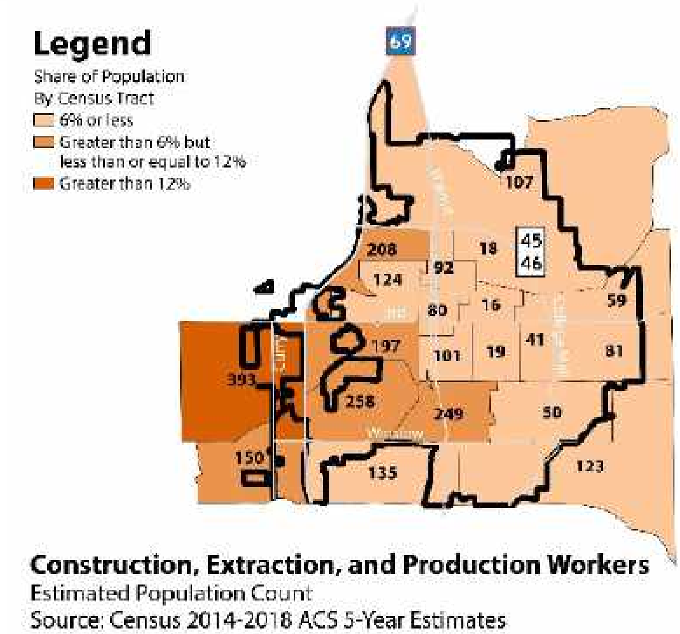
At-Risk Occupations Breakdown

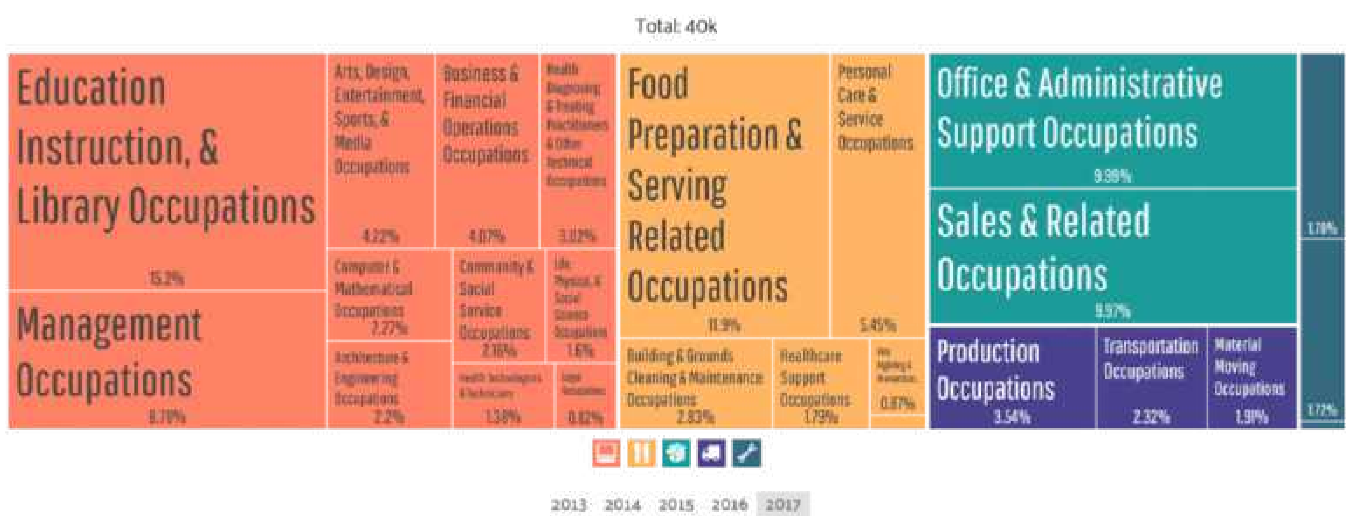
This series of maps illustrates the breakdown of workers employed in the primary at-risk occupation categories.

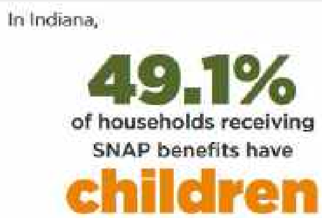
Total Employment by Occupation

From 2016 to 2017, employment in Bloomington, IN grew at a rate of 1.51%, from 39.4k employees to 40k employees. The chart below shows the share breakdown of the primary jobs held by residents of Bloomington.

(Source: USAData, US Census Bureau)







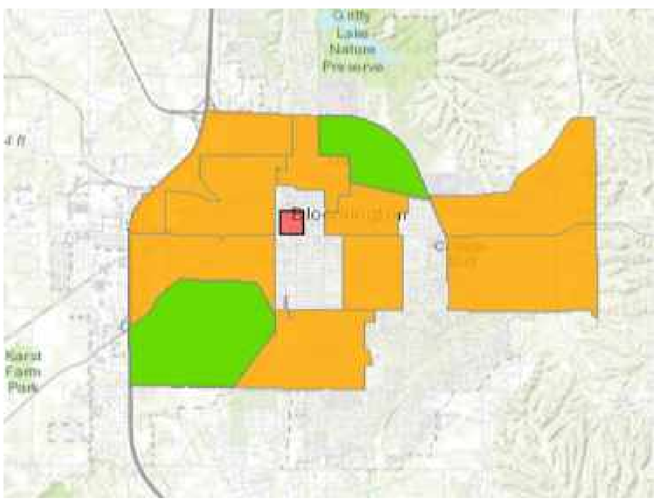
(Source: Feed America)

Individuals with Possible Food Insecurity

Climate change affects agriculture in a number of ways, including through changes in average temperatures, rainfall, and extreme weather events and heat; changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations. These effects can be anticipated regionally as well as worldwide to become more pronounced by mid-century.

As the food distribution system becomes more stressed, individuals with less readily available access are more likely to be negatively impacted by the resulting cycles of food shortages and food price increases.

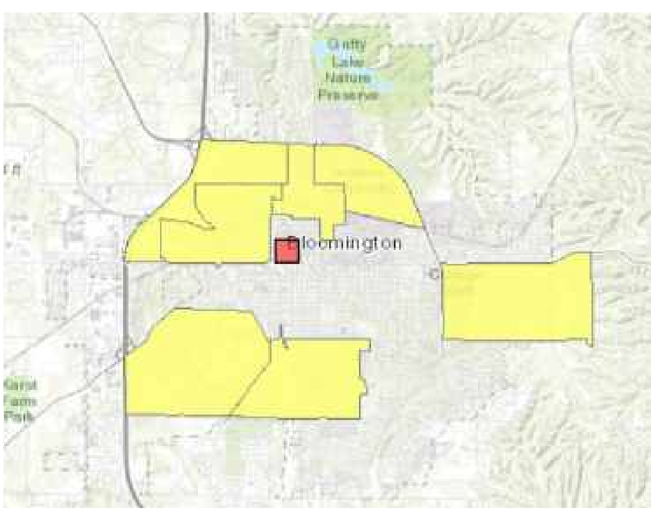
Individuals experiencing food insecurity may be particularly sensitive to the following Climate Risks:



Food Access

On the map to the left, highlighted sections represent low-income census tracts (tracts where 20% or more of the population is at or below poverty, or where family median incomes are 80% or less of State median) where a significant number (at least 500 people) or share (at least 33 percent) of residents are distant from the nearest supermarket. In sections which are green, residents are more than 1 mile (urban) or 10 miles (rural), while in orange sections residents are more than ½ mile (urban) or 10 miles (rural) from nearest supermarket.

(Source: USDA Economic Research Service Food Atlas)



Vehicle Access

On the map to the left, highlighted sections represent Low-income census tract where more than 100 housing units do not have a vehicle and are more than ½ mile from the nearest supermarket in urban/suburban areas, or a significant number (at least 500 people) or share (at least 33 percent) of residents are more than 20 miles from the nearest supermarket in rural areas.

As outlined in Section 8, a regional typical household can spend 25% of their income on transportation in Bloomington, IN, high above the recommended threshold f 15%.

(Source: USDA Economic Research Service Food Atlas, CNT's H+T Affordability Index)

Climate Migrant Populations

In the United States alone, within just a few decades, hundreds of thousands of homes on US coasts will be chronically flooded. According to a study by the Union of Concerned Scientists, over 170 communities in the United States will be chronically inundated from sea level rise by the end of this decade. More than half of these 170 communities are currently home to socioeconomically vulnerable neighborhoods.

By 2060 the number may more than double to 360 communities and by 2100 double yet again to over 670 communities chronically inundated. By that time more than 50 heavily populated areas—including Oakland, California; Miami and St. Petersburg, Florida; and four of the five boroughs of New York City—will face chronic inundation. These effects of sea level rise could displace 13,000,000 people within the United States by the end of this century.

In addition to these internal-US climate migrants, the UN forecasts estimate that there could be anywhere between 25 million and 1 billion environmental migrants by 2050.

Human migration is a natural response to these climate change pressures, and is one of many adaptation measures that people will take in response to climate change. Understating how human migration will be affected by climate change is therefore a critical input in the decision making process of many governments and organizations. In particular, it is important to understand how climate change driven migration will differ from "business as usual" forms and motivations humans have to migrate, increasing the volume rate of migration brining with it indirect impacts on the communities likely to receive migrants.

The impacts of climate migration will cause accelerated changes for inland areas, particularly urban areas, that will observe much higher levels of incoming migrants than they would have without climate impacts. It is projected that 86% of all communities with populations of over 10,000 will be impacted with climate migration this century. These changes can in turn take the form of tighter labor markets and increased housing prices, and impacts on income inequality. This climate migration can also have positive impacts such as improved productivity, broadened skillsets within the labor force, and expanded human capital.

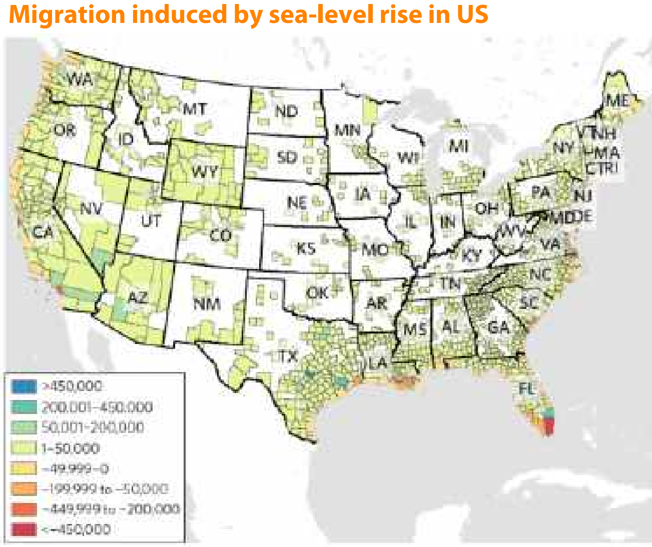
Projected Potential Climate Migrant Population by 2100

Monroe County: **20-50,000**

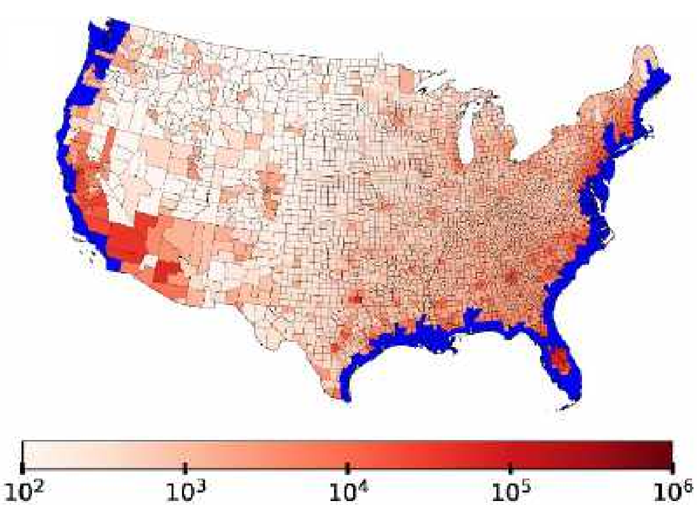
City of Bloomington: **12-29,000**
(Pro rata share)

Below are two modeled projections for US climate migration induced by sea level rise only through 2100:

Hauer Projection
Migration induced by sea-level rise in US



Robinson Projection
Migration induced by sea-level rise in US



(Sources: United Nations International Organization on Migration
Hauer, M. Migration induced by sea-level rise could reshape the US population landscape. Nature Clim Change 7, 321–325 (2017). https://doi.org/10.1038/nclimate3271
Robinson C, Dilkina B, Moreno-Cruz J (2020) Modeling migration patterns in the USA under sea level rise. PLoS ONE 15(1): e0227436. https://doi.org/10.1371/journal.pone.0227436)

Section 10

Findings

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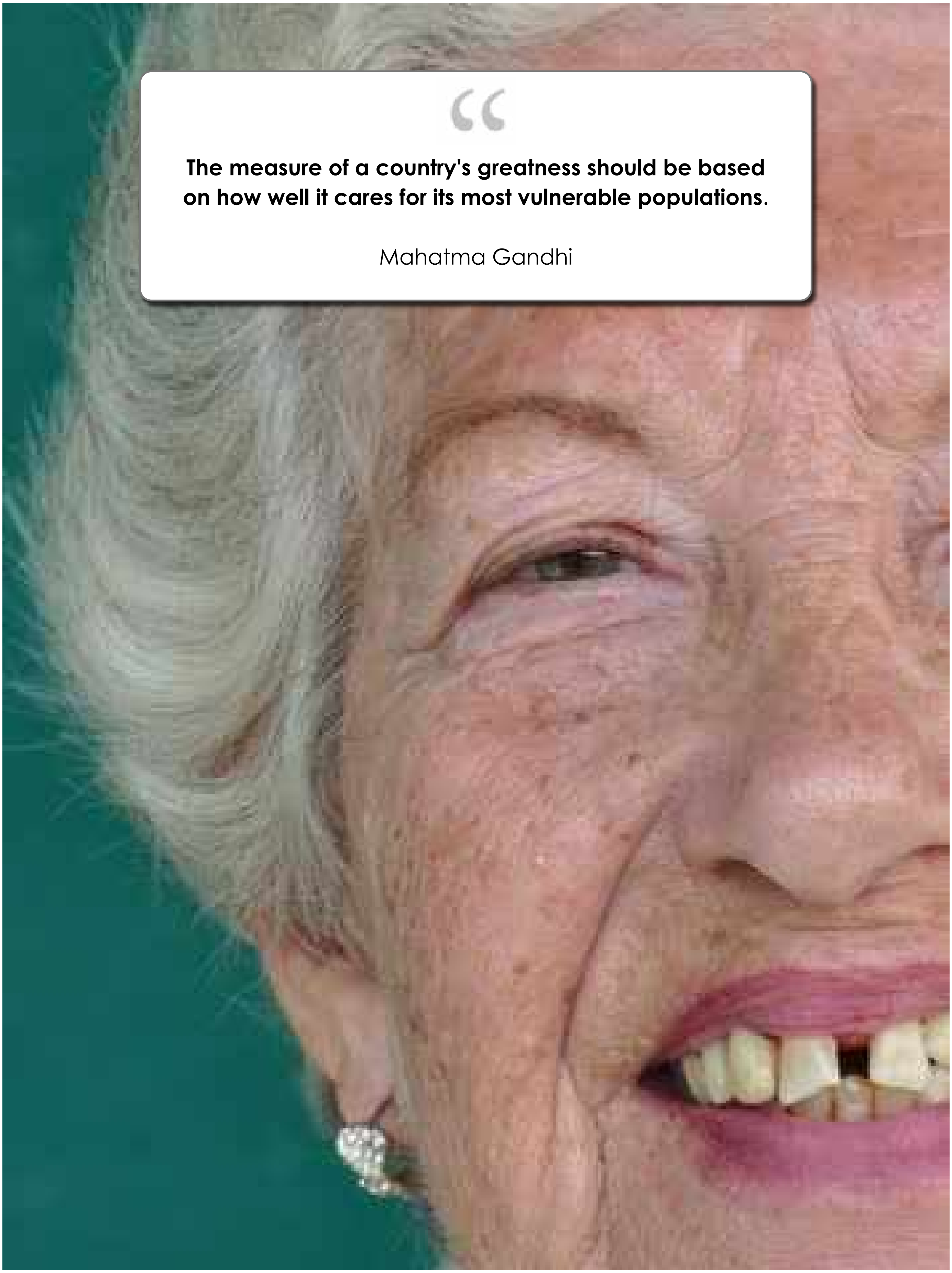


The measure of a country's greatness should be based on how well it cares for its most vulnerable populations.

Mahatma Gandhi

Findings

Summary of Vulnerabilities

The chart below summarizes the vulnerable population demographics by category for each census tract in the City. The tracts with the highest quartile of each demographic are highlighted in blue. The "Composite (instances of vulnerabilities)" line shows the total instances of vulnerabilities for each census tract. It should be noted that it is possible for individuals to be members of more than one vulnerable population. For example, an individual may be both an adult over age 65 as well as an individual living below 200% of poverty level. Consequently, the "Composite" total instances of vulnerabilities does not necessarily represent the numbers of vulnerable individuals. The "Vulnerability Coefficient" represents the total "Composite (instances of vulnerabilities)" divided by the total population of the census tract ("Total pop/tract") and is a representation of the proportion of total climate vulnerabilities within the population of the census tract. The "Rank Based on Coefficient" identifies each Census Tract's vulnerability rank based on the "Vulnerability Coefficient", with higher numbers representing a higher number of instances of vulnerability per capita. The Census Tracts in the highest quartile of Vulnerability Coefficient rankings are highlighted in red.

Lastly, the chart includes a calculation of the "Share of Total Vulnerability" which indicates the percentage of all citywide instances of vulnerability which occur within each Census Tract. This number represents the raw total instances of vulnerabilities without consideration to the size of the overall population of the Census Tract. The "Rank Based on Share of Total" then shows the rank of each census tract based on their share of the total instances of vulnerability within the City. The Census Tracts in the highest quartile of share of total vulnerability are highlighted in green.

Summary Chart of Vulnerabilities

Tract	1	2.01	2.02	3.01	3.02	4.01	4.02	5.01	5.02	6.01	6.02	8	9.01	9.03	9.04	10.01	10.02	11.01	11.02	16
children	23	18	0	92	95	219	253	348	265	303	238	190	53	228	149	413	229	289	540	0
seniors	19	5	0	167	436	400	292	849	425	440	232	1174	385	813	799	1108	1108	529	415	1
disabled	302	123	241	256	176	511	466	731	588	646	516	747	233	781	343	585	780	1050	529	122
Low Income Individuals	1635	90	60	803	316	718	573	418	214	898	671	768	348	968	1038	284	412	999	432	1386
Low Income Families	168	55	12	99	32	339	454	409	412	568	379	299	111	653	298	255	407	861	397	49
POC	511	1672	1233	407	218	603	814	544	469	1016	789	758	792	1044	2216	703	1020	1489	779	661
Limited English	25	743	213	95	59	158	113	167	24	47	88	455	331	425	1213	208	366	307	149	98
At Risk Workers	150	170	88	201	92	447	467	675	366	308	367	254	144	213	134	142	349	310	255	416
Composite (Instances of Vulnerability)	2833	2876	1847	2120	1423	3396	3432	4141	2763	4225	3280	4645	2397	5124	6190	3698	4672	5834	3497	2733
Percentage of Population (Instances of Vulnerability)	59%	43%	29%	51%	46%	81%	68%	84%	83%	107%	89%	80%	73%	97%	112%	65%	76%	97%	73%	47%
Total pop/tract	4827	6639	6427	4141	3109	4182	5024	4927	3332	3946	3687	5806	3265	5306	5507	5651	6140	6007	4812	5803
Vulnerability Coefficient	**0.59**	**0.43**	**0.29**	**0.51**	**0.46**	**0.81**	**0.68**	**0.84**	**0.83**	**1.07**	**0.89**	**0.80**	**0.73**	**0.97**	**1.12**	**0.65**	**0.76**	**0.97**	**0.73**	**0.47**
Rank Based on Coefficient	**15**	**19**	**20**	**16**	**18**	**8**	**13**	**6**	**7**	**2**	**5**	**9**	**12**	**4**	**1**	**14**	**10**	**3**	**11**	**17**
Share of Total Vulnerability	3.98%	4.04%	2.60%	2.98%	2.00%	4.77%	4.83%	5.82%	3.88%	5.94%	4.61%	6.53%	3.37%	7.20%	8.70%	5.20%	6.57%	8.20%	4.92%	3.84%
Rank Based on Share of Total	14	13	19	18	20	11	10	7	15	6	12	5	17	3	1	8	4	2	9	16

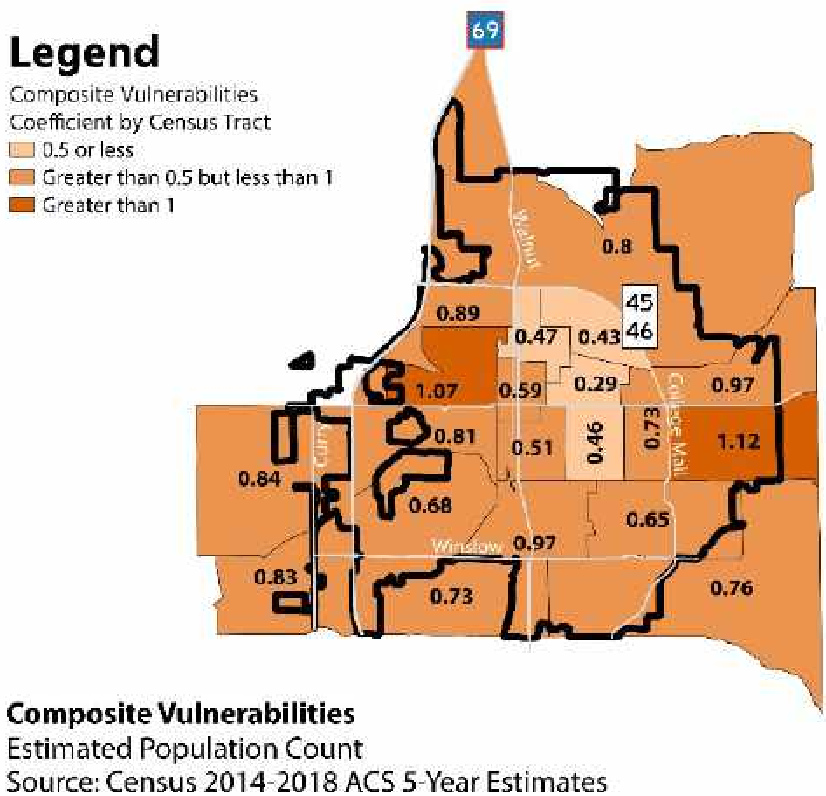
Composite Vulnerabilities

The map to the right illustrates the Vulnerability Coefficient for each Census Tract based on the charted information above. As outlined above, the Vulnerability Coefficient represents the ratio of total instances of population vulnerabilities to the total population within the census tract. The intent of this Vulnerability Coefficient is to identify the proportion of instances of vulnerability within their populations. Neighborhoods with high proportions of vulnerability are likely to have greater adaptation need than neighborhoods with low proportions of vulnerability.

For the City of Bloomington, the Census Tracts in the highest quartile are:

9.04, 6.01, 11.01, 9.03, and 6.02

Map of Total Vulnerable Population Distribution Within Community



Vulnerable Population Risk Sensitivity Chart

	Primary Climate Risks to Population								Economic Climate Risks to Population				
	Extreme Heat	Flooding	Air Quality	Vectorborne Disease	Food Insecurity	Water Quality Impacts	Waterborne Disease	Power Failure	Crop Yield Impacts	Mortality Impacts	Energy Costs	Property Crime	Violent Crime
children	3,945		3,945	3,945			3,945	3,945	3,945	3,945	3,945		
seniors	9,597	9,597	9,597	9,597	9,597			9,597	9,597	9,597	9,597	9,597	
disabled	9,726	9,726	9,726		9,726			9,726		9,726	9,726	9,726	
Low Income Individuals	13,032	13,032	13,032	13,032	13,032	13,032	13,032	13,032	13,032		13,032	13,032	13,032
Low Income Families	6,256	6,256	6,256	6,256	6,256	6,256	6,256	6,256	6,256		6,256	6,256	6,256
POC	17,738	17,738	17,738	17,738	17,738		17,738	17,738			17,738	17,738	17,738
Limited English	5,284	5,284	5,284	5,284	5,284		5,284	5,284	5,284		5,284	5,284	5,284
At Risk Workers	5,548	5,548	5,548	5,548			5,548						5,548
No Car	3,577	3,577	3,577			3,577	3,577		3,577				
Total by category	74,704	70,759	74,704	61,401	61,634	22,866	55,381	65,579	41,692	23,268	65,579	61,634	47,859
Percentage of Vuln pop	105%	99%	105%	86%	87%	32%	78%	92%	59%	33%	92%	87%	67%
Rank by Vuln	2	3	1	6	5	11	7	4	9	10	4	5	8
Percentage of Total Pop	76%	72%	76%	62%	63%	23%	56%	67%	42%	24%	67%	63%	49%

Based on the total estimated population count for each vulnerable population and considering the risks each demographic is most sensitive to, the population vulnerabilities can be considered from highest sensitivity (more vulnerable individuals) to lowest (fewer vulnerable individuals) sensitivity. It should be noted that risks which appear to have lower sensitivity levels should not be considered irrelevant for the community.

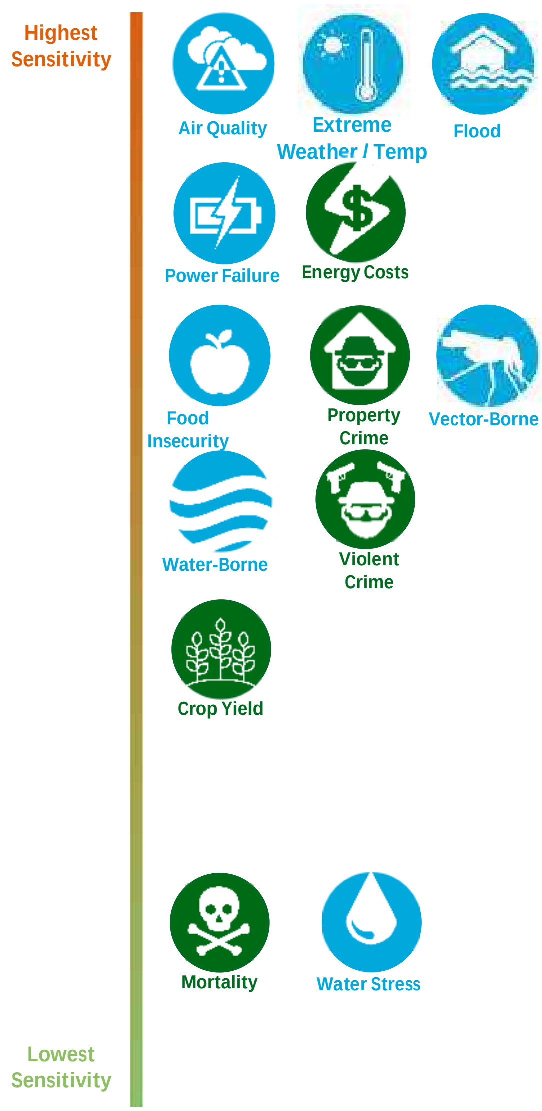
The Vulnerable Population Risk Sensitivity Chart above tabulates the instances of vulnerable population which are particularly sensitive to each of the Climate Risks to the Population as outlined in Section 6 and mapped/calculated in Section 9. The left side of the chart includes all of the primary climate risks while the right side includes the economic climate risks. At the bottom of the chart, the risks are ranked and the top five risk scores are highlighted in shades of red.

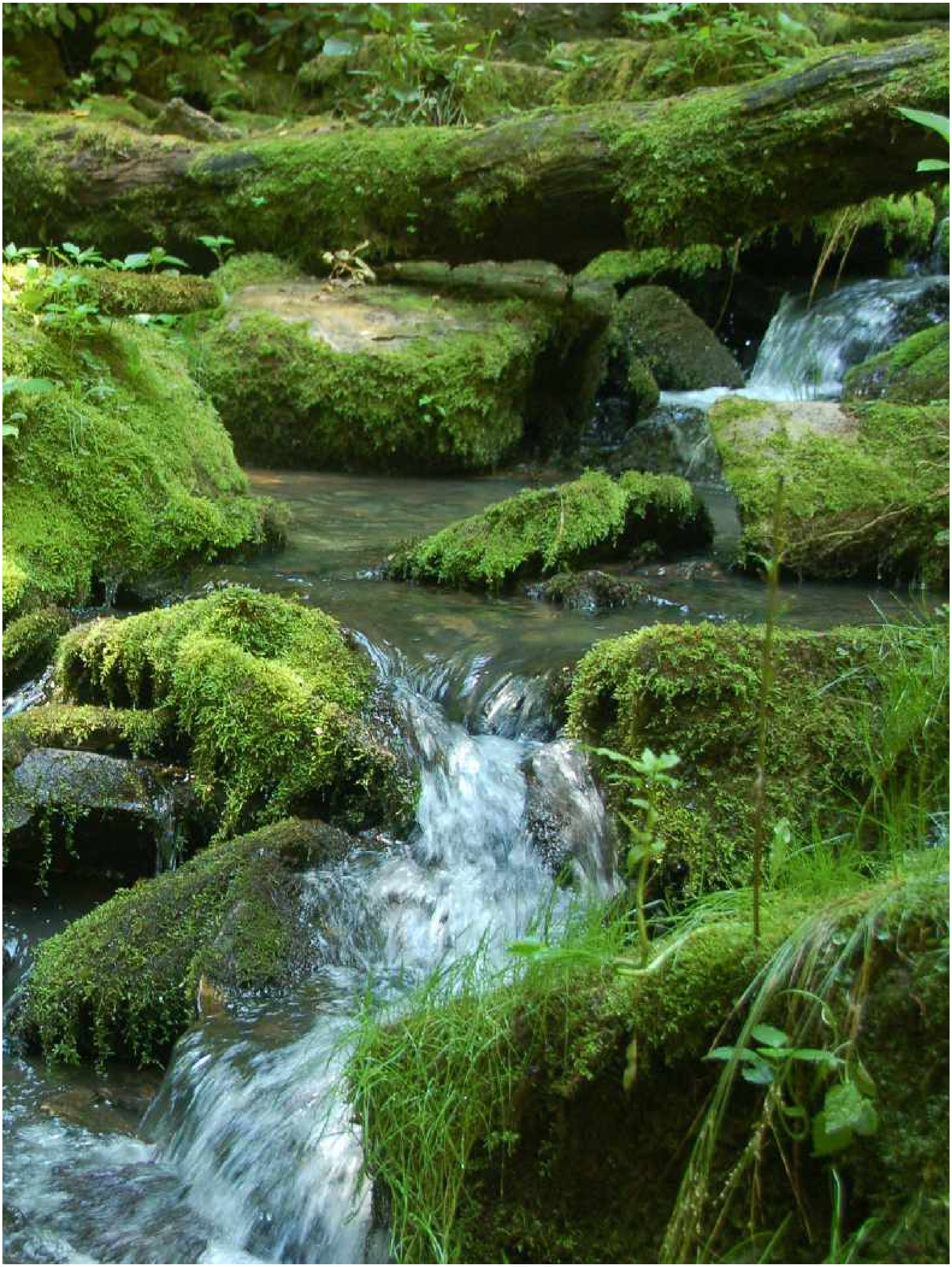
Ranking of vulnerable population ranking of sensitivity to climate risks for the City are summarized to the right.

Prioritizing Risk and Vulnerable

Climate change impacts will affect everyone and City policies and actions should consider climate adaptive needs of the entire community. As with all planning efforts climate adaptation benefits from analysis in order to assist in establishing priorities for initial efforts. An effort to structure a prioritization should not be seen as an attempt to discard the need to address climate impacts for any population within the City - whether or not it is defined as one of the “vulnerable” populations . Prioritization, however, is necessary to ensure the greatest impact and effectiveness of limited City resources.
Based on the above review the City’s adaptive efforts may be most effective by prioritizing strategies which address the climate risks of Air Quality, Extreme Heat, Flooding, Power/Infrastructure Failure, Energy Costs, Food Insecurity, and Property Crime. Particular attention should be paid to strategies which are most effective for those in Economic Stress, People of Color, Individuals with Disabilities, and Seniors over 65.

Bloomington Climate Risk Sensitivity Ranking Summary





Findings

City's Climate Impact Multipliers

Based on the summary of vulnerable population findings from the previous page, it is appropriate to re-visit some of the City's Climate Impact Multiplier characteristics defined in Section 7 to determine which, if any, of those characteristics should be addressed in the City's prioritized Adaptation and Resilience Goals and Strategies. A review of these characteristics in light of the vulnerable population findings will enable a prioritization of strategies and geographic focus for addressing the combination of anticipated climate impacts and the community's climate impact multiplier and vulnerable population characteristics.

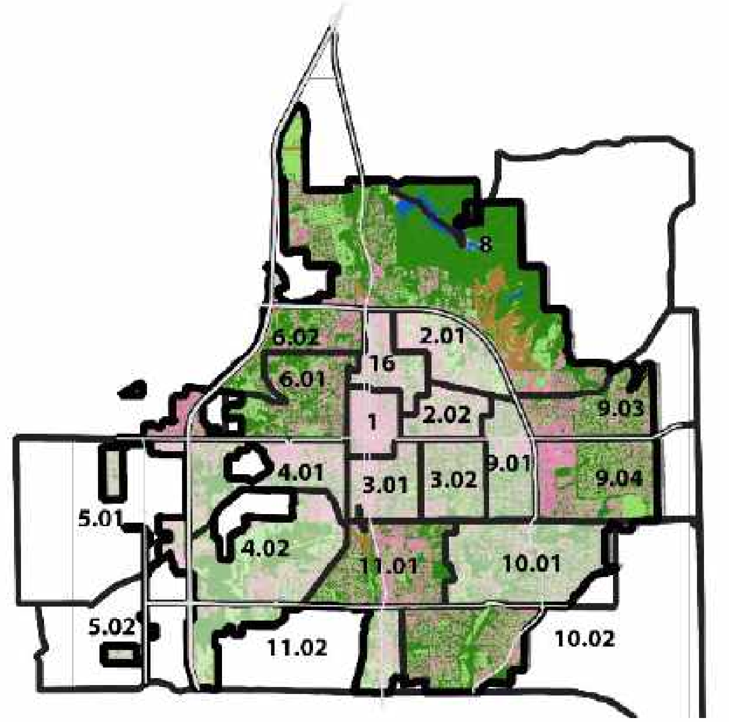
Based on the City's vulnerable population findings, a review of the City's Climate Impact Multiplier characteristics provides:

Impervious Surface, Tree Canopy, and Heat Island

The City's average existing Tree Canopy coverage of 38% is above the national average, however, there are likely portions of the City which could benefit from increased tree canopy.

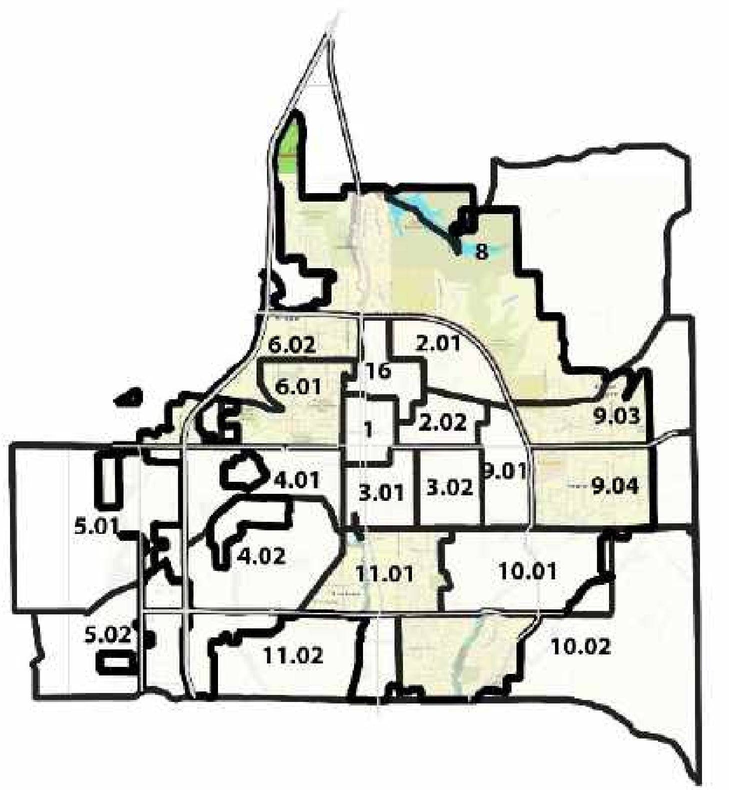
The graphic to the right from the City's Urban Tree Canopy Assessment Summary Report illustrates the impervious land cover (pink) within the City. To highlight concentrations of vulnerable populations, the census tracts with the highest vulnerabilities (see Summary Chart of Vulnerabilities page 10-3) are shown with full color while all other census tracts have masked colors.

Areas which have higher concentrations of impervious surfaces are areas likely to experience micro climate heat island effects and would benefit from anti-heat island strategies particularly those in the tracts with the highest impact sensitivities.



Findings - Flood Vulnerability

The graphic to the right illustrates FEMA flood vulnerable areas (see page 7-8). The Census Tracts with the highest impact sensitivities are highlighted. This graphic indicates that many of areas of higher flood risk appear in the tracts with the highest impact sensitivities. These sections may benefit from flood mitigation strategies. Those which overlap with the higher exposure areas illustrated in the Impervious Surface, Tree Canopy, and Heat Island graphic would likely also benefit from strategies which increase tree canopy and pervious land cover.



Findings

Climate Resilience Indicators

Based on the City's increased risk sensitivity of Air Quality the EPA Environmental Indicators of particular concern are Diesel Particulate Matter in which Bloomington ranks in the 50th-60th percentile in the nation, Respiratory Hazard Index in which Bloomington ranks in the 66th percentile in the State, Traffic Proximity and Volume in which Bloomington ranks in the 65th percentile in the State, and Hazardous Waste Proximity in which Bloomington ranks in the 85th percentile in the State. Breathing in particles causes inflammation in our respiratory and circulatory system. These pollutants can make it harder to breathe; it can cause asthma-like symptoms - of concern even with Monroe County's lower than State average instance of asthma emergency department visits. High rates of particulate matter pollution have been linked to higher rates of cancer, heart disease, stroke, and early on-set dementia.

Potential health effects of PM exposure, increased risk of:
impaired respiratory function
chronic cough
bronchitis
chest illness
chronic obstructive pulmonary disease (COPD)
pneumonia
cardiovascular diseases
allergic disease and asthma
cardiopulmonary diseases
cancer

The primary source for particulate matter pollution is vehicle emissions and incomplete fossil fuel combustion for heating, cooling, and energy generation. The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). Bloomington's proximity to high traffic volumes is in the 65th percentile for the State and the 56th percentile nationally.

Summary of Climate Impact Multiplier and Climate Resilience Findings

In addition to the strategy priorities outlined in the Summary of Vulnerable Population Findings, the City should look to prioritize strategies which address the City's Climate Impact Multiplier characteristics and opportunities. These community characteristics will benefit from strategies which: increase pervious surfaces, tree canopy cover, and greenscaping; mitigate flood hazards; and increase Air Quality, particularly from stationary and mobile fossil fuel use.

Photo: SVR Design

Review of Climate Hazards for the City of Bloomington

A "Climate Hazard" is a physical process or event (hydro-meteorological or oceanographic variables or phenomena) that can harm human health, livelihoods, or natural resources. Climate Hazards are reviewed based on current hazard level, anticipated change over time, and projected future hazard level.

The chart below reviews the current, future, and timeline of change for each of the primary Climate Hazards for the city. In addition, the columns on the right illustrate the reported number of events, % change, and annualized economic impact of each of these hazards over the last 20 years. Note, the number of events and annualized property losses are based solely on the number of events reported by NOAA, the actual number is likely to vary.

Climate Hazards

Climate Hazard Type	Current hazard risk level	Expected change in intensity	Expected change in frequency	Timeframe	Number of Reported Events 1999-2009 vs 2009-2019 (NOAA)	% Change	Countywide Annualized Property Loss Value (NOAA)
Extreme Heat	Low	Increase	Increase	Medium-term	0 events to 0 events	N/A	$0K
Extreme Cold	Low	Increase	Decrease	Medium-term	0 events to 0 events	N/A	$0K
Extreme Precipitation	Not Known	Increase	Increase	Short-term	48 events to 41 events	86%	$100K
Floods	High	Increase	Increase	Short-term	26 events to 15 events	58%	$80K
Droughts	Moderate	Increase	Increase	Medium-term	0 events to 10 events	N/A	$0K
Storms	High	Increase	Increase	Short-term	104 events to 105 events	101%	$630K
Forest/Wild Fires	Low	Not known	Not known	Not known	0 events to 0 events	N/A	N/A
Air Quality Impacts	Moderate	Increase	Increase	Long-term	N/A	N/A	N/A

Review of Climate Risks for the City of Bloomington

A "Climate Risk" is the potential for negative consequences and outcomes for human health, systems, or communities. The most common way of evaluating the level of risk associated is "likelihood of Occurrence" x "Impact Level" or vulnerability.

Two charts are provided below. The first reviews the expected impacts, likelihood of occurrence, impact level based on Population vulnerability reviewed in Section 9 and earlier in Section 10, potential timeframe, and resulting overall risk level for Climate Risks to Population (Health Impacts). The second reviews the infrastructural and institutional Climate Risks to the Community. Each chart includes a brief review of the expected impacts and indicators.

Climate Risks to Population

Health Impacts	Expected Impact(s)	Likelihood of Occurrence	Impact Level (Population Vulnerability)	Timeframe	Risk (Likelihood x Impact)	Impact-related indicators
Extreme Heat	Increased demand for cooling; heat stress and emergency visits, heat related health	Likely	High	Medium-term	Very High	Cooling Degree Days, days above 95
Flooding	damage to property; flood related health impacts; infrastructure impacts	Possible	High	Short-term	High	Flood events, flash flood occurances, wettest 5-day periods, number of heavy rain events, disaster declarations, change in NOAA storm
Drought	Damage to crop/tree/ecosystem, reduced drinking water source, increased flash flood potential due to decreased soil permeability	Likely	Moderate	Medium-term	Moderate	Consecutive days without rain, acquafer level, surface water condition, river flow
Air Quality Impacts	Increased particulate matter, increased ozone impacts, increased instances of asthma	Likely	High	Medium-term	High	Air quality index
Vector-Borne Diseases	Increased instances of lyme disease, encephalitis, heart worm, malaria, zika virus,	Likely	Moderate	Long-term	Moderate	Disease records
Nutrition Insecurity	Food price volitility/change, fluctuation in availability	Possible	High	Medium-term	High	Food price index, Foodshelf demand, % of school children qualifying for free and reduced lunch
Water Quanity/Quality Impacts	Water shortage, surface water quality impacts due to heat and stormwater runoff	Likely	Low	Long-term	Moderate	Acquafer health; Water quality test results
Water Borne Disease	Bacteria exposusure at infected surface water locations, contamination of drinking water due to flood	Unlikely	Moderate	Medium-term	Low	flood events; algea blooms

Climate Risks to Infrastructure and Institutions

Impacted Policy Sector	Expected Impact(s)	Likelihood of Occurrence	Potential Impact Level	Timeframe	Risk (Likelihood x Impact)	Impact-related indicators
Buildings	Increased demand for cooling, need for weatherization	Likely	Moderate	Short-term	High	Low income housing units, % of residents with housing burden, housing stock age, % of units without weatherization improvements
Transport / Roads	Increased freeze/thaw damage, increased salt/sand use and maintenance budgets	Likely	High	Short-term	Very High	% of flooded or flood damaged roads and bridges, City road maintenance budget
Energy	Increased power outages, increased demand and cost expediture	Likely	High	Medium-term	High	Energy outage occurances, number of customers without power, cooling degree day increases
Water	Increased scarcity, water quality impacts	Possible	High	Long-term	Moderate	Water infrastructure damage, acquafer health, flood contamination
Waste	Damage to waste infrastructure and processing, particularly wastewater	Unlikely	Moderate	Long-term	Low	Flood impacts at wastewater facilities, sewage release, flooding at landfill/RDF sites
Land Use Planning	Stormwater management impacts, heat island impacts, flood management,	Likely	High	Short-term	Very High	Heat Island co-efficient; stormwater runoff projections, citywide tree canopy coverage, citywide impervious surface coverage, % of complete streets
Agriculture & Forestry	Reduction in crop yield, forest + tree species loss due to changes in hardiness zone and pests	Likely	Moderate	Medium-term	High	% change in crop yeild, impacts to crop planting and harvesting; tree canopy loss to pests, tree canopy loss to hardiness zone changes
Environment & Biodiversity	Insect infestation, increased disease vectors, ecosystem degradation	Likely	Moderate	Long-term	Low	% of habitat loss, invasive species
Law Enforcement and Emergency Response	Increased property and violent crime, increased emergency response demand and mortality rate	Likely	High	Long-term	Moderate	Property and violent crime statistics (particularly during extreme heat), instances of mental health need, calls for emergency response (particularly during extreme heat and weather)
Tourism	Decline in tourism demand	Not known	Not Known	Not known	Not Known	Tourism statistics, hotel occupancy levels
Economic Impact	Impacts on regional Ag business, energy expenditures, labor impacts	Likely	High	Medium-term	Moderate	Disaster declarations, economic indicators, employment rates

Priority Climate Risks for the City of Bloomington

The priority climate risks to the population of Bloomington include Flooding, Extreme Heat, and Air Quality Impacts while the priority climate risks to infrastructure/institutions include Roads, Land Use Planning, Buildings, Energy, and Agriculture and Forestry.

Section 11

Recommendations

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Recommendations

Recommended Adaptation and Resilience Goals

The following are recommended overall goals for increasing the climate resilience for the City of Bloomington. These goals are based on the anticipated climate impacts for the City as well as the vulnerable populations present in the City. Some of the goals and strategies identified in this report will require new City policies or program development. Many others have some existing City, County, and State policies already underway which relate to them. A detailed review of all existing policies against the goals and the strategies recommended in this report should be conducted and policy modifications integrated.

In prioritizing the implementation of the goals and strategies which follow, the City of Bloomington should:

- Consider available resources and opportunities to leverage new resources.
- When budget, staff, or schedule restrictions limit strategy implementation capacity, apply strategies with a priority towards vulnerable populations and tracts/areas with higher vulnerable populations (see Section 10, page 10-3 for further information)
- Consider the associated carbon emission reduction opportunities and other co-benefits of strategies.
- Study the anticipated equity impacts of strategies.
- Consider the urgency and window of opportunity.
- Conduct appropriate outreach and engagement efforts with community residents and businesses for community feedback and buy-in.
- Identify departments / staff capable of taking the lead for strategy implementation. Integrate implementation plans into a routine working plan that is reviewed and revised regularly (every 2 to 5 years recommended).
- Whenever possible select strategies that provide everyday benefits in addition to climate risk reduction. These forms of strategies are known as “no regrets strategies” and they can be justified from economic, social, and environmental perspectives whether natural hazard events or climate change hazards take place or not.
- Explore possible use and effectiveness of existing City owned facilities and properties to meet emergency shelter and cooling center functions.

Climate Adaptation and Resilience Goals

The following are potential Climate Adaptation Goals for the City of Bloomington provided for consideration. The goals are organized based on the primary anticipated climate change impacts they address.

Priority

C Goals To Build Capacity For Individuals/Institutions/Businesses Preparing For And Responding To Population Risks Of Climate Change Impacts

Goal C1 - Incorporate climate change preparedness activities into existing local government plans and programs as a means to increase resilience while minimizing costs.

Goal C2 - Improve effectiveness of on-going adaptation measures.

Goal C3 - Strengthen emergency management capacity to respond to weather-related emergencies.

Goal C4 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to climate impacts.

Goal C5 - Enhance resilience of critical city operations.

Goal C6 - Enhance city's capacity for adaptation implementation.

Goal C7 - Secure funding to support City's adaptation efforts.

Priority

H Goals Responding to Heat Stress And Extreme Weather

Goal H1 - Strengthen emergency management capacity to respond to heat stress and extreme weather.

Goal H2 - Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.

Goal H3 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to high heat and extreme weather.

Goal H4 - Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.

Goal H5 - Enhance resilience of community tree canopy and park/forest land

Goal H6 - Enhance the resilience of buildings within the community to extreme heat, weather, and energy and fuel disruptions.

Goal H7 - Improve the energy efficiency and weatherization of homes and businesses to reduce energy costs and carbon pollution.

Goal H8 - Expand access to distributed solar energy in low-income communities in order to lower energy bills, increase access to air conditioning, and decrease carbon pollution levels.

Goal H9 - Enhance resilience of local businesses to extreme weather.

Goal H10 - Strengthen social cohesion and networks to increase support during extreme weather events.

Goal H11 - Increase the resilience of natural and built systems to adapt to increased timeframes between precipitation and increased drought conditions.

Goal H12 - Enhance the reliability of the grid during high heat events to minimize fires, brownouts and blackouts.

Priority

A Goals Responding to Air Quality Impacts

Goal A1 - Reduce auto-generated particulate matter, tailpipe pollutants, waste heat, and ozone formation.

Goal A2 - Increase and maintain air quality for residents and businesses.

Priority

F Goals Responding To Flood Vulnerability

Goal F1 - Strengthen emergency management capacity to respond to flood-related emergencies.

Goal F2 - Increase the resilience of the natural and built environment to more intense rain events and associated flooding.

Goal F3 - Enhance resilience to fuel disruptions in transportation and mobility.

V Goals Responding To Vector-Borne Disease Risks

Goal V1 - Manage the increased risk of disease due to changes in vector populations.

Priority

FI Goals Responding To Food Insecurity And Food-borne Disease Risks

Goal FI-1 - Increase food security for residents, especially those most vulnerable to food environment.

(Rural communities) Goal A3 - Increase resilience of croplands, farms, and farmers within community.

W Goals Responding To Water Quality and Quantity Risks

Goal W1 - Increase the resilience of City's water supply in drier summers.

WB Goals Responding To Waterborne Illness Risks

Goal WB1 - Enhance protection of surface water quality damage from severe storms

Goal WB2 - Enhance public protection from exposure to surface water pathogen contamination

Priority

E Goals Enhancing Economic Resilience In Support of Climate Resilience

Goal E1 - Leverage the economic development opportunities of the Green Economy

Goal E2 - Enhance community resilience through economic resilience

Goal E3 - Including Economic Resilience in Emergency Response Planning

Section 12

Possible Funding

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Possible Funding

Many of the strategies for increasing climate resilience can be done for little to no costs. Some strategies, however, come with a cost which may be more than the City can cover within the desired implementation timeframe. Increasingly, funding for local climate adaptation and resilience projects must draw on a range of public and private financing. For instance, groups may apply for federal grant funding, work through public/private partnerships, and/or fund projects through local taxes.

In the United States, a range of government entities and private foundations offer financial and technical resources to advance local adaptation and mitigation efforts. For your convenience, we've listed some of them here.

EPA Smart Growth Grants and Other Funding
The U.S. Environmental Protection Agency's Office of Sustainable Communities occasionally offers grants to support activities that improve the quality of development and protect human health and the environment.
https://www.epa.gov/smartgrowth/epa-smart-growth-grants-and-other-funding

Partnership for Sustainable Communities
The U.S. Department of Housing and Urban Development (HUD), U.S. Department of Transportation (DOT), and the U.S. Environmental Protection Agency (EPA) work together to help communities nationwide improve access to affordable housing, increase transportation options, and lower transportation costs while protecting the environment. The site's map of grants shows information on awards already made through Partnership programs.
https://www.sustainablecommunities.gov/partnership-resources
https://www.sustainablecommunities.gov/content/grants-your-community

FEMA (Federal Emergency Management Agency) Preparedness (Non-Disaster) Grants
FEMA provides state and local governments with preparedness program funding to enhance the capacity of their emergency responders to prevent, respond to, and recover from a range of hazards.
https://www.fema.gov/preparedness-non-disaster-grants

FEMA Hazard Mitigation Assistance
FEMA's Hazard Mitigation Assistance grant programs provide funding to protect life and property from future natural disasters. https://www.fema.gov/hazard-mitigation-assistance

- Hazard Mitigation Grant Program (HMGP) assists in implementing long-term hazard mitigation measures following a major disaster. https://www.fema.gov/hazard-mitigation-grant-program
- Pre-Disaster Mitigation (PDM) provides funds for hazard mitigation planning and projects on an annual basis. https://www.fema.gov/pre-disaster-mitigation-grant-program https://www.fema.gov/pre-disaster-mitigation-grant-program
- **Flood Mitigation Assistance (FMA)** provides funds for projects to reduce or eliminate risk of flood damage to buildings that are insured under the National Flood Insurance Program (NFIP) on an annual basis. https://www.fema.gov/flood-mitigation-assistance-grant-program

Drought Recovery Information
This page from the National Integrated Drought Information System describes support that may be available through federal agencies for both short- and long-term impacts of drought. Links lead to information regarding financial and technical assistance, disaster assistance programs, economic injury loans, and assistance in implementing conservation practices. https://www.drought.gov/drought/search/site/resources%20OR%20recovery

Clean Diesel Program
The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). https://www.epa.gov/cleandiesel

USDA Natural Resources Conservation Service
NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources in a sustainable manner.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/
Programs include:

- The **Agricultural Management Assistance Program** helps agricultural producers use conservation to manage risk and address natural resource issues through natural resources conservation.
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/ama/?cid=stelprdb1242818
- **Conservation Innovation Grants** offer funding opportunities at the state level to stimulate the development and adoption of innovative conservation approaches and technologies that leverage federal investment in environmental enhancement and protection.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/
- The **Conservation Stewardship Program** helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/csp/?cid=stelprdb1242683
- The **Environmental Quality Incentives Program** provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits, such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation, or improved or created wildlife habitat.
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1242633

Federal Funding Compendium for Urban Heat Adaptation
The Georgetown Climate Center produced an in-depth document that collected and analyzed information relating to 44 separate federal programs that could support cities and states in reducing the impacts of urban heat. While federal funding sources are often dependent on appropriations, this list may be useful for finding federal funding opportunities for climate-related work.
http://www.georgetownclimate.org/files/report/Federal%20Funding%20Compendium%20for%20Urban%20Heat%20Adaptation.pdf

Tribal Climate Change Guide to Funding, Science, Programs and Adaptation Plans
This sortable spreadsheet can help tribes find potential funding sources and other resources. Maintained by University of Oregon. http://tribalclimateguide.uoregon.edu/

Kresge Environment Program
The Kresge Foundation Environment Program seeks to help communities build resilience in the face of climate change. They invest in climate resilience through two primary strategies:
1. Accelerating place-based innovation through support to efforts that are anchored in cities and have a strong potential to serve as models.
2. Building the climate-resilience field by supporting activities to disseminate and bring to scale promising climate-resilience approaches. http://kresge.org/programs/environment

Quadratec Cares 'Energize The Environment' Grant Program
This program offers two $3,500 grants per year, one each in the spring and fall, to an individual or group implementing a program designed to benefit the environment. Examples of projects the program may fund include trail building or restoration, community environmental educational projects, and youth educational engagement events. Proposers write and submit a 1000-1600 word essay to apply for the grants. Entries for the fall grant are due on June 30th; entries for the spring grant are due October 30th. https://www.quadratec.com/page/quadratec-cares-grant-program

Wildlife Conservation Society's Climate Adaptation Fund
This fund supports projects that demonstrate effective interventions for wildlife adaptation to climate change. http://wcsclimateadaptationfund.org/

Climate Solutions University
The Climate Solutions University aids rural communities by offering training, expertise, and support in climate adaptation planning through a peer-learning network. In the past, the organization has offered two distance-learning programs: the Climate Adaptation Plan Development Program focuses on forest and water resource resilience, and the Climate Adaptation Plan Implementation Program supports participants in moving the plan into action.
http://www.mfpp.org/csu/

Open Space Institute Resilient Landscape Initiative
The Resilient Landscapes Initiative, supported by the Doris Duke Charitable Foundation, offers two types of grants for specified locations in the eastern United States. The group's Capital Grants help land trusts and public agencies increase the conservation of resilient landscapes in areas that represent critical climate priorities. The group's Catalyst Grants help land trusts and public agencies build the knowledge base of key audiences and advance the practical application of climate science. https://www.openspaceinstitute.org/funds/resilient-landscapes-funds

Section A1

Appendix 1
Local Climate Risks to the Environment

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Climate change projections for the City represent potential risks. The types of risks can be organized into risks to the environment and ecosystems and risks to the population. The following is an overview of the potential risks posed by climate change for the region:

Climate Risks to the Environment

Warmer summers

Pollution control risks:
Wildfires may lead to soil erosion

Habitat risks:
Greater evaporation
Lower groundwater tables
Switching public water supply between surface and groundwater sources may affect the integrity of water bodies

Fish Wildlife and Plant risks:
Species that won't tolerate warmer summers may die/migrate
Biota at the southern limit of their range may disappear from ecosystems
Species may be weakened by heat and become out-competed
Essential food sources may die off or disappear, affecting the food web
Species may need to consume more water as temperature rises

Recreation and Public Water Supply Risks:
More people using water for recreation may raise the potential for pathogen exposure
Warmer temperatures may drive greater water demand
Evaporation losses from reservoirs and groundwater may increase

Warmer winters

Pollution Control risks:
Increased fertilizer and pesticide use due to longer growing season.
Warmer winters result in more ice and freeze thaw resulting in greater chloride application and more permanent damage to local water bodies due to increased salt concentrations.

Habitat risks:
Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change
Changing spring runoff with varying snow.

Fish Wildlife and Plant risks:
Species that used to migrate away may stay all winter and species that once migrated through may stop and stay
Pests may survive winters that used to kill them and invasive species may move into places that used to be too cold
Some plants need a "setting" cold temperature and may not receive it consistently
A longer growing season may lead to an extra reproductive cycle
Food supplies and bird migrations may be mistimed

Recreation and Public Water Supply Risks:
Summer water supplies that depend on winter snow pack may be reduced or disappear
Cold places may see more freeze/thaw cycles that can affect infrastructure

Warmer water

Pollution Control risks:
Temperature criteria for discharges may be exceeded (thermal pollution)
Warmer temperatures may increase toxicity of pollutants
Higher solubility may lead to higher concentration of pollutants
Water may hold less dissolved oxygen
Higher surface temperatures may lead to stratification
Greater algae growth may occur
Parasites, bacteria may have greater survival or transmission

Habitat risks:
Warmer water may lead to greater likelihood of stratification
Desired fish may no longer be present
Warmer water may promote invasive species or disease

Fish Wildlife and Plant risks:
Newly invasive species may appear
Habitat may become unsuitably warm, for a species or its food
Heat may stress immobile biota
Oxygen capacity of water may drop

Climate Risks to the Environment

Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature
Parasites and diseases are enhanced by warmer water

Fish resource food harvesting, Recreation, and Public Water Supply Risks:
Harmful algal blooms may be more likely
Fishing seasons and fish may become misaligned
Desired recreational fish may no longer be present
Invasive plants may clog creeks and waterways
Changes in treatment processes may be required
Increased growth of algae and microbes may affect drinking water quality

Increased drought

Pollution Control risks:
Critical-low-flow criteria for discharging may not be met
Pollutant concentrations may increase if sources stay the same and flow diminishes
Pollution sources may build up on land, followed by high-intensity flushes

Habitat risks:
Groundwater tables may drop
Base flow in streams may decrease
Stream water may become warmer
Increased human use of groundwater during drought may reduce stream baseflow
New water supply reservoirs may affect the integrity of freshwater streams

Fish Wildlife and Plant risks:
Species may not tolerate a new drought regime (birch family)
Native habitat may be affected if freshwater flow in streams is diminished or eliminated

Recreation and Public Water Supply Risks:
Freshwater flows in streams may not support recreational uses
Groundwater tables may drop
Maintaining passing flows at diversions may be difficult

Increased storminess

Pollution Control risks:
Combined sewer overflows may increase
Treatment plants may go offline during intense floods
Streams may see greater erosion and scour
Urban areas may be subject to more floods
Flood control facilities (e.g., detention basins, manure management) may be inadequate
High rainfall may cause septic systems to fail

Habitat risks:
The number of storms reaching an intensity that causes significant problems may increase
Stronger storms may cause more intense flooding and runoff
Turbidity of surface waters may increase
Increased intensity of precipitation may yield less infiltration
Stream erosion may lead to high turbidity and greater sedimentation
Lower pH from NPS pollution may affect target species

Fish Wildlife and Plant risks:
Greater soil erosion may increase turbidity and decrease water clarity
Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species

Recreation and Public Water Supply Risks:
More frequent or more intense storms may decrease recreational opportunities
Greater nonpoint source pollution may impair recreation
Water infrastructure may be vulnerable to flooding
Flood waters may raise downstream turbidity and affect water quality

(Source: USEPA "Being Prepared for Climate Change A Workbook for Developing Risk-Based Adaptation Plans")

Section A2

Appendix 2
Climate Adaptive Tree Species (A document by the National Institute of Applied Climate Science of the USDA Forest Service)

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

INDIANA

The region's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Central Hardwoods region (Brandt et al. 2014). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full assessment.

TREE SPECIES INFORMATION:

This assessment uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with one forest impact model (Tree Atlas) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the assessment. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
Black cherry	Limited drought tolerance and susceptible to some insect pests
MAY DECREASE	
White ash	Susceptible to emerald ash borer
NO CHANGE	
Red maple	Competitive colonizer tolerant of disturbance and diverse sites
Black oak	Drought tolerant, but susceptible to pest and disease
Pignut hickory	Susceptible to insects and inteolerant of drought
MAY INCREASE	
Hackberry	Drought tolerant
Eastern redbud	Tolerant of a wide range of site conditions
Boxelder	Disperses and regenerates easily
Sweetgum	Susceptible to drought and fire topkill
Eastern cottonwood	Susceptible to insects, disease, and fire topkill
Bitternut hickory	Drought tolerant
Pin oak	Susceptible to insects, disease, and fire topkill

NIACS
Northern Institute of Applied Climate Science

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Remember that models are just tools, and they're not perfect. Model projections don't account for some factors that could be modified by climate change, like droughts, wildfire activity , and invasive species. If a species is rare or confined to a small area, Tree Atlas results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS
MIXED MODEL RESULTS	
American beech	Extremely shade tolerant, but affected by beech bark disease
American elm	Needs a particular type of habitat, affected by Dutch elm disease
American hornbeam	Regenerates easily, but drought-intolerant
Black locust	Susceptible to some insect pests
Black walnut	Susceple to thousand cankers disease
Eastern redcedar	Drought tolerant but susceptible to firetopkill
Flowering dogwood	Shade-tolerant
Green ash	Susceptible to emerald ash borer
Northern red oak	Susceptible to some insect pests
Sassafras	Susceptible to fire topkill
Shagbark hickory	Susceptible to insects and fire topkill
Silver maple	Disperses and regenerates easily but drought-intolerant
Slippery elm	Susceptible to fire topkill
Sugar maple	Shade-tolerant
Sycamore	Susceptible to anthracnose
White oak	Tolerant of fire
Yellow-poplar	Disperses and regenerates easily but drought-intolerant

FUTURE PROJECTIONS

Data for the end of the century are summarized for the Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) under two climate change scenarios. Tree Atlas models future suitable habitat; additional data are available in the assessment.

▲ **INCREASE**
Projected increase of >20% by 2100

● **NO CHANGE**
Little change (<20%) projected by 2100

▼ **DECREASE**
Projected decrease of >20% by 2100

★ **NEW HABITAT**
Tree Atlas projects new habitat for species not currently present

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors.

\+ high
Species may perform better than modeled

· medium

– low
Species may perform worse than modeled

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
American basswood	▼	▼	·
American beech	●	▼	·
American elm	●	▼	·
American hornbeam	●	▲	·
Baldcypress	●	●	·
Bigtooth aspen	▼	▼	·
Bitternut hickory	▲	▲	+
Black cherry	▼	▼	–
Black hickory	▲	▲	·
Black locust	●	▼	·
Black maple	●	▼	+
Black oak	●	●	·
Black walnut	▲	▼	·
Black willow	▲	▲	–
Blackgum	▲	●	+
Blackjack oak	▲	▲	+
Blue ash	●	●	–
Boxelder	▲	▲	+
Bur oak	▲	▲	+
Butternut	▼	▼	–
Cedar elm	★	★	–
Cherrybark oak	▲	●	·
Chestnut oak	●	▼	+
Chinkapin oak	▲	▼	·
Common persimmon	▲	▲	+
Eastern cottonwood	▲	▲	·
Eastern hophornbeam	●	▲	+
Eastern red cedar	●	▼	·
Eastern redbud	▲	▲	·
Eastern white pine	●	▼	–
Flowering dogwood	●	▼	·
Green ash	▲	▲	·
Hackberry	▲	●	+
Honeylocust	▲	▲	+
Jack pine	▼	●	·
Kentucky coffeetree	▼	▼	·
Loblolly pine	★	★	·
Mockernut hickory	●	▲	+
Northern catalpa	●	●	·
Northern pin oak	▼	●	+
Northern red oak	●	▼	+

SOURCE: Brandt, L.; He, H.; Iverson, L.; Thompson, F.R., III; Butler, P.; Handler, S.; Janowiak, M.; Shannon, P.D.; Swanston, C.; Albrecht, M.; Blume-Weaver, R.; Deizman, P.; DePuy, J.; Dijak, W.D.; Dinkel, G.; Fei, S.; Jones-Farrand, D.T. Leahy, M.; Matthews, S.; Nelson, P. Oberle, B.; Perez, J.; Peters, M.; Prasad, A.; Schneiderman, J.E.; Shuey, J.; Smith, A.B.; Studyvin, C.; Tirpak, J.M.; Walk, J.W.; Wang, W.J.; Watts, L.; Weigel, D.; Westin, S. 2014. Central Hardwoods ecosystem vulnerability assessment and synthesis: a report from the Central Hardwoods Climate Change Response Framework project. Gen. Tech. Rep. NRS-124. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 254 p. https://www.nrs.fs.fed.us/pubs/45430

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
Ohio buckeye	●	▼	·
Osage-orange	▲	▲	+
Overcup oak	●	▲	–
Pawpaw	▲	▼	·
Pecan	▼	●	–
Pignut hickory	●	●	·
Pin oak	▲	▲	–
Post oak	▲	▲	+
Red maple	●	●	+
Red mulberry	▲	▲	·
River birch	▲	▲	·
Rock elm	▲	▼	–
Sassafras	●	▼	·
Scarlet oak	▲	▼	·
Shagbark hickory	●	▼	·
Shellbark hickory	▲	●	·
Shingle oak	●	▲	·
Shortleaf pine	▲	▲	·
Shumard oak	▼	▲	+
Silver maple	●	▲	+
Slash pine	★	★	·
Slippery elm	●	▼	·
Sourwood	▲	●	+
Southern red oak	▲	▲	+
Sugar maple	●	▼	+
Sugarberry	▲	▲	·
Swamp chestnut oak	▼	▼	·
Swamp tupelo	●	▼	–
Swamp white oak	▲	▼	·
Sweetgum	▲	▲	·
Sycamore	●	▼	·
Virginia pine	▲	●	·
Water oak	★	★	·
White ash	●	▼	–
White oak	●	▼	+
Wild plum	●	●	·
Willow oak	★	★	·
Winged elm	▲	▲	·
Yellow birch	▼	▼	·
Yellow buckeye	●	▼	–
Yellow-poplar	●	▼	+

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Section A3

Appendix 3
Data References and Resources

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Section 1 Introduction

State of Minnesota, Department of Natural Resources
https://www.dnr.state.mn.us/climate/climate_change_info/index.html
http://glisa.umich.edu/media/files/Minn-StPaulMN_Climatology.pdf
US Climate Resilience Toolkit
https://toolkit.climate.gov/
Metropolitan Council, Local Planning Handbook
https://lphonline.metc.state.mn.us/commportal
Intergovernmental Panel on Climate Change
http://www.ipcc.ch/
NOAA National Centers for Environmental Information
https://www.ngdc.noaa.gov/
NASA
https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Section 2 Climate Change in the Midwest

US Climate Resilience Toolkit
https://toolkit.climate.gov/
US National Climate Assessment
https://nca2014.globalchange.gov/

Section 3 Climate Change in Indiana

Midwest Economic Policy Institute "*Climate Change and Its Impact on Infrastructure Systems in Indiana*"
https://midwestepi.files.wordpress.com/2018/06/indiana-infrastructure-and-climate-change-final.pdf
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"*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*"
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University of Indiana Hoosier Resilience Index
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The Indiana Climate Change Impacts Assessment, Purdue University
https://ag.purdue.edu/indianaclimate/
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Indiana Climate Change Assessment: for Policymakers
https://ag.purdue.edu/indianaclimate/wp-content/uploads/2019/10/Issue-brief_INCCIA_1019.pdf

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"*Hoosiers' Health in a Changing Climate: A Report from the Indiana Climate Change Impacts Assessment*"
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https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=27%2CMINNESOTA
University of Michigan, Climate Center
http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml
US Climate Resilience Toolkit, Climate Explorer
https://toolkit.climate.gov/climate-explorer2/
Minnesota Public Radio:
https://www.mprnews.org/story/2015/02/02/climate-change-primer
US Climate Resilience Toolkit
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Environment Minnesota Research and Policy Center
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http://www.asicontrols.com/wp-content/uploads/2014/05/11.jpg

Section 5 City on The Move

University of Michigan, Climate Center
http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml
Indiana's Past and Future Climate: A Report from the Indiana Climate Change Impacts Assessment
https://ag.purdue.edu/indianaclimate/indiana-climate-report/

Section 6 Climate Risk to The Population

National Climate Assessment
https://nca2014.globalchange.gov/highlights/report-findings/human-health
US Global Change Research Program
https://health2016.globalchange.gov/populations-concern

Centers for Disease Control and Prevention
https://www.cdc.gov/climateandhealth/brace.htm
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Hoosier Health in a Changing Climate
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Section 7 Climate Impact Multipliers

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https://heatisland.lbl.gov/
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http://healthycities.sice.indiana.edu/sensor/index.html
World Resources Institute, Aqueduct Water Risk Atlas
http://www.wri.org/applications/maps/aqueduct-atlas/#x=8.00&y=0.44&s=ws!20!28!c&t=waterrisk&w=def&g=0&i=BWS-16!WSV-4!SV-2!HFO-4!DRO-4!STOR-8!GW-8!WRI-4!ECOS-2!MC-4!WCG-8!ECOV-2!&tr=ind-1!prj-1&l=3&b=terrain&m=group
FEMA
https://msc.fema.gov/portal/search
National Flood Services
http://www.floodtools.com/Map.aspx

Section 8 Climate Resilience Indicators

United States Census Bureau
https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Data USA
https://datausa.io/
County Health Rankings & Roadmaps Program
http://www.countyhealthrankings.org/app/minnesota/2017/overview
US EPA Environmental Justice Screen
https://ejscreen.epa.gov/mapper/
Centers for Disease Control
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South Central Indiana Housing Opportunities
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Center for Neighborhood Technology H+T Index
https://htaindex.cnt.org/
Center for Neighborhood Technology AllTransit
https://www.cnt.org/tools/alltransitWalkscore
https://www.walkscore.com/
The Trust For Public Land
https://www.tpl.org/parkscore

Section 9 Vulnerable Populations

United States Census Bureau
Census 2011-2015 American Community Survey 5-Year Estimates
https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
United States Census Bureau, Quick Facts Table
https://www.census.gov/quickfacts/fact/table/US/PST045217
Data USA
https://datausa.io/
USDA Economic Research Service, Food Atlas
https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/
Center for Neighborhood Technology H+T Index
https://htaindex.cnt.org/
See also references and resources for Section 6 Climate Risk to The Population

Section 10 Findings

Deep Root, Fiona Watt and Bram Gunther, New York City Department of Parks
http://www.deeproot.com/blog/blog-entries/tree-cover-how-does-your-city-measure-up
Project Sunroof
https://www.google.com/get/sunroof/data-explorer/
NOAA National Centers for Environmental Information
https://www.ncdc.noaa.gov/stormevents/

See also references and resources for Section 6 Climate Risk to The Population
See also references and resources for Section 7 Climate Impact Multipliers
See also references and resources for Section 8 Climate Resilience Indicators
See also references and resources for Section 9 Vulnerable Populations

Section A4

Appendix 4
Glossary of Climate Adaptation and Vulnerability Terms

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A

Activity Data
Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arisings are examples of activity data. (IPCC)

Aerosols
A collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 micrometer that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in several ways: directly through scattering and absorbing radiation, and indirectly by acting as cloud condensation nuclei or modifying the optical properties and lifetime of clouds. (IPCC2)

Afforestation
Planting of new forests on lands that historically have not contained forests. (IPCC2)

Air Pollutant
Any man-made and/or natural substance occurring in the atmosphere that may result in adverse effects to humans, animals, vegetation, and/or materials. (CARB)

Anthropogenic
The term "anthropogenic", in the context of greenhouse gas inventories, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities. (USEPA2)

Atmosphere
The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapor, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols. (IPCC2)

B

Baseline Emissions
A baseline is a measurement, calculation, or time used as a basis for comparison. Baseline emissions are the level of emissions that would occur without policy intervention or without implementation of a project. Baseline estimates are needed to determine the effectiveness of emission reduction programs (also called mitigation strategies).

Base Year
The starting year for the inventory. Targets for reducing GHG emissions are often defined in relation to the base year.

Biogenic
Produced by the biological processes of living organisms. Note that we use the term "biogenic" to refer only to recently produced (that is non-fossil) material of biological origin. IPCC guidelines recommend that peat be treated as a fossil carbon because it takes a long time to replace harvested peat.

Biogeochemical Cycle
Movements through the Earth system of key chemical constituents essential to life, such as carbon, nitrogen, oxygen, and phosphorus. (NASA)

Biomass
Either (1) the total mass of living organisms in a given area or of a given species usually expressed as dry weight; or (2) Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material. (IPCC1)

Biomass Waste
Organic non-fossil material of biological origin that is a byproduct or a discarded product. "Biomass waste" includes municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural crop byproducts, straw, and other biomass solids, liquids, and gases; but excludes wood and wood-derived fuels (including black liquor), biofuels feedstock, biodiesel, and fuel ethanol. Note: EIA "biomass waste" data also include energy crops grown specifically for energy production, which would not normally constitute waste. (EIA)

Black Carbon
Operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability; consists of soot, charcoal and/or possible light absorbing refractory organic matter (Charlson and Heintzenberg, 1995, p. 401). (IPCC2)

C

Carbon Cycle
All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere. (NASA)

Carbon Dioxide (CO_2)
A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1. (IPCC2)\

Carbon Dioxide Equivalent (CO_2e)
A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

Carbon Disclosure Project (CDP)
An international organization that administers a platform for organizations and cities to publicly disclose their environmental impacts, such as climate risk. CDP is one of the approved disclosure platforms utilized by GCoM.

Carbon Emissions
The release of carbon dioxide into the atmosphere. Primary human sources of the release of carbon dioxide occur from burning oil, coal, and gas for energy use.

Carbon Equivalent (CE)
A metric measure used to compare the emissions of the different greenhouse gases based upon their global warming potential. Carbon equivalents can be calculated from to carbon dioxide equivalents by multiplying the carbon dioxide equivalents by 12/44 (the ratio of the molecular weight of carbon to that of carbon dioxide). The use of carbon equivalent is declining in GHG inventories.

Carbon Intensity
The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels. (EIA)

Carbon Neutrality
For the purposes of the Plan, Carbon Neutrality refers to the point at which the organization / organization's net greenhouse gas emissions reach 0. This will likely be achieved through a combination of reducing emission sources and offsetting and sequestering any remaining emissions.

Carbon Sinks
A forest, ocean, or other natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere.

Carbon Sequestration
This refers to the capture of CO_2 from the atmosphere and its long term storage in oceans (oceanic carbon sequestration), in biomass and soils (terrestrial carbon sequestration) or in underground reservoirs (geologic carbon sequestration).

Chlorofluorocarbons (CFCs)
Greenhouse gases covered under the 1987 Montreal Protocol and used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. Because they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone. These gases are being replaced by other compounds, including hydrochlorofluorocarbons and hydrofluorocarbons, which are greenhouse gases covered under the Kyoto Protocol. (IPCC3)

Circular Economy
An alternative to a traditional linear economy (make, use, dispose) in which an economy is a regenerative system where resource input and waste are minimized. This is achieved through long-lasting product design, repair, reuse, remanufacturing, and recycling. Circular economy strategies are often cited as systems level approaches to reducing waste generation through product and system design.

Climate
Climate in a narrow sense is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (IPCC2)

Climate Adaptation or Resilience
The capacity of a natural environment to prevent, withstand, respond to, and recover from a disruption. The process of adjusting to new climate conditions in order to reduce risks to valued assets.

Climate Change
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC2)

Climate Hazard
An extreme climate event or condition that can harm human health, livelihoods, or natural resources. It can include abrupt changes to the climate system such as extreme precipitation, storms, droughts, and heat waves.

Climate Vulnerability Assessment
A report used to identify and define the risks posed by climate change and inform adaptation measures needed to combat climate change. Reports can be about a wide range of fields including food security, poverty analysis, and extreme weather events.

Cogeneration
Cogeneration is an industrial structure, installation, plant, building, or self-generating facility that has sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. (CARB)

Combined Heat and Power (CHP)
Combined heat and power is the simultaneous production of both electricity and useful heat for application by the producer or to be sold to other users with the aim of better utilisation of the energy used. Public utilities may utilise part of the heat produced in power plants and sell it for public heating purposes. Industries as auto-producers may sell part of the excess electricity produced to other industries or to electric utilities. (IPCC)

Community Solar
Solar facilities shared by multiple community subscribers who receive credit on their electricity bills for their share of the power produced. Community solar allows members of a community to share the benefits of solar power on their property without installing it on their own property. Electricity generated by the community solar farm typically costs less than the price from utility companies.

Consistency
Consistency means that an inventory should be internally consistent in all its elements over a period of years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. (IPCC)

Continuous Emission Monitor (CEM)
A type of air emission monitoring system installed to operate continuously inside of a smokestack or other emission source. (CARB)

Criteria Air Pollutant
An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include: ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA must describe the characteristics and potential health and welfare effects of these pollutants. The U.S. EPA and CARB periodically review new scientific data and may propose revisions to the standards as a result. (CARB)

D

Deforestation
Those practices or processes that result in the change of forested lands to non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: 1) the burning or decomposition of the wood releases carbon dioxide; and 2) trees that once removed carbon dioxide from the atmosphere in the process of photosynthesis are no longer present and contributing to carbon storage. (UNFCC)

Distillate Fuel Oil
A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation. (EIA)

E

Emissions
The release of a substance (usually a gas when referring to the subject of climate change) into the atmosphere. (USEPA1)

Emission Factor
A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions. (IPCC)

Emission Inventory
An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year. (CARB)

Emission Rate
The weight of a pollutant emitted per unit of time (e.g., tons / year). (CARB)

Environmental Justice
The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies

Estimation
Estimation is the assessment of the value of an unmeasurable quantity using available data and knowledge within stated computational formulas or mathematical models.

F

Fluorocarbons
Carbon-fluorine compounds that often contain other elements such as hydrogen, chlorine, or bromine. Common fluorocarbons include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). (UNFCC)

Flux
Either (1) Raw materials, such as limestone, dolomite, lime, and silica sand, which are used to reduce the heat or other energy requirements of thermal processing of minerals (such as the smelting of metals). Fluxes also may serve a dual function as a slagging agent. (2) The rate of flow of any liquid or gas, across a given area; the amount of this crossing a given area in a given time. (e.g., "Flux of CO2 absorbed by forests"). (IPCC)

Fossil Fuel
Geologic deposits of hydrocarbons from ancient biological origin, such as coal, petroleum and natural gas.

Fuel Combustion
Fuel combustion is the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus. (IPCC)

Fugitive Emissions
Emissions that are not emitted through an intentional release through stack or vent. This can include leaks from industrial plant and pipelines. (IPCC)

G

Geologic Farbon Sequestration
It is the process of injecting CO_2 from a source, such as coal-fired electric generating power plant, through a well into the deep subsurface. With proper site selection and management, geologic sequestration could play a major role in reducing emissions of CO_2. Research efforts to evaluate the technical aspects of CO_2 geologic sequestration are underway. (USEPA4)

Global Warming
Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities. Also see Climate Change (USEPA1)

Global Warming Potential (GWP)
An index, based upon radiative properties of well-mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame. (IPCC2)

GCOM Global Covenant of Mayors:
GCoM is the largest global alliance for city climate leadership, built upon the commitment of over 10,000 cities and local governments. The alliance's mission is to mobilize and support climate and energy action in communities across the world.

Greenhouse Effect
Trapping and build-up of heat in the atmosphere (troposphere) near the earth's surface. Some of the heat flowing back toward space from the earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase. (UNFCC)

Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories:
A robust, transparent and globally-accepted framework that cities and local governments can use to consistently identify, calculate and report on city greenhouse gas emissions.

Greenhouse Gas
Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). (UNFCC)

Green Infrastructure
An approach to managing precipitation by reducing and treating stormwater at its source while delivering environmental, social, and economic benefits. Stormwater runoff can carry trash, bacteria, and other pollutants and is a major cause of water pollution in urban areas.

Gross Domestic Product (GDP)
The sum of gross value added, at purchasers' prices, by all resident and non-resident producers in the economy, plus any taxes and minus any subsidies not included in the value of the products in a country or a geographic region for a given period, normally one year. It is calculated without deducting for depreciation of fabricated assets or depletion and degradation of natural resources. (IPCC3)

H

Halocarbons
A collective term for the group of partially halogenated organic species, including the chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), halons, methyl chloride, methyl bromide, etc. Many of the halocarbons have large Global Warming Potentials. The chlorine and bromine-containing halocarbons are also involved in the depletion of the ozone layer. (IPCC2)

Hydrocarbons
Strictly defined as molecules containing only hydrogen and carbon. The term is often used more broadly to include any molecules in petroleum which also contains molecules with S, N, or O An unsaturated hydrocarbon is any hydrocarbon containing olefinic or aromatic structures. (IPCC)

Hydrofluorocarbons (HFCs)
Compounds containing only hydrogen, fluorine, and carbon atoms. They were introduced as alternatives to ozone depleting substances in serving many industrial, commercial, and personal needs. HFCs are emitted as by-products of industrial processes and are also used in manufacturing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases with global warming potentials ranging from 140 (HFC-152a) to 11,700 (HFC-23). (USEPA1)

I

ICLEI Local Governments for Sustainability:
A membership organization for local governments to pursue reductions in carbon pollution and improvements in advancing sustainable urban development. ICLEI's members and team of experts work together through peer exchange, partnerships and capacity building to create systemic change for urban sustainability.

Intergovernmental Panel on Climate Change
The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories. (USEPA1)

K

Kilowatt Hour (kWh):
A measure of electrical energy equivalent to a power consumption of 1,000 watts for one hour.

Kyoto Protocol
The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol

(most Organisation for Economic Cooperation and Development countries and countries with economies in transition) agreed to reduce their anthropogenic greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) by at least 5% below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005. (IPCC2)

L

Land Use and Land Use Change

Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have a radiative forcing and/or other impacts on climate, locally or globally. (IPCC2)

LULUCF

Acronym for "Land Use, Land Use Change and Forestry", a category of activities in GHG inventories.

M

Megawatt Hour (MWH):

A measure of electrical energy equivalent to a power consumption of 1,000,000 watts for one hour.

Methane (CH_4)

A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 25 times that of carbon dioxide (CO_2). Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, flooded rice fields, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion. The GWP is from the IPCC's Fourth Assessment Report (AR4).

Metric Ton

The tonne (t) or metric ton, sometimes referred to as a metric tonne, is an international unit of mass. A metric ton is equal to a Megagram (Mg), 1000 kilograms, 2204.6 pounds, or 1.1023 short tons.

Million Metric Tons (MMT)

Common measurement used in GHG inventories. It is equal to a Teragram (Tg).

Mitigation:

Actions taken to limit the magnitude or rate of long-term global warming and its related effects. Climate change mitigation generally involves reductions in human emissions of greenhouse gases.

Mobile Sources

Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes. (CARB)

Mode Share

The percentage of travelers using a particular type of transportation. Modal share is an important component in developing sustainable transport within a city or region because it reveals the level of utilization of various transportation methods. The percentage reflects how well infrastructure, policies, investments, and land-use patterns support different types of travel.

Model
A model is a quantitatively-based abstraction of a real-world situation which may simplify or neglect certain features to better focus on its more important elements. (IPCC)

Municipal Solid Waste (MSW)
Residential solid waste and some non-hazardous commercial, institutional, and industrial wastes. This material is generally sent to municipal landfills for disposal. (USEPA1)

N

Natural Sources
Non-manmade emission sources, including biological and geological sources, wildfires, and windblown dust. (CARB)

Net-zero Emissions (NZE)
Building A building or property that generates or offsets all energy consumed. If the City develops a NZE building code, this definition will have to be refined to provide additional guidance on calculating emissions and offsets to achieve net-zero emissions.

Nitrogen Fixation
Conversion of atmospheric nitrogen gas into forms useful to plants and other organisms by lightning, bacteria, and blue-green algae; it is part of the nitrogen cycle. (UNFCC)

Nitrogen Oxides (NO_x)
Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced in the emissions of vehicle exhausts and from power stations. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants. (NASA)

Nitrous Oxide (N_2O)
A powerful greenhouse gas with a global warming potential of 298 times that of carbon dioxide (CO_2). Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, manure management, fossil fuel combustion, nitric acid production, and biomass burning. The GWP is from the IPCC's Fourth Assessment Report (AR4).

O

Ozone (O_3)
Ozone, the triatomic form of oxygen (O_3), is a gaseous atmospheric constituent. In the troposphere, it is created both naturally and by photochemical reactions involving gases resulting from human activities (smog). Tropospheric ozone acts as a greenhouse gas. In the stratosphere, it is created by the interaction between solar ultraviolet radiation and molecular oxygen (O_2). Stratospheric ozone plays a dominant role in the stratospheric radiative balance. Its concentration is highest in the ozone layer. (IPCC2)

Ozone Depleting Substances (ODS)
A compound that contributes to stratospheric ozone depletion. Ozone-depleting substances (ODS) include CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride, and methyl chloroform. ODS are generally very stable in the troposphere and only degrade under intense ultraviolet light in the stratosphere. When they break down, they release chlorine or bromine atoms, which then deplete ozone. (IPCC)

P

Perfluorocarbons (PFCs)
A group of human-made chemicals composed of carbon and fluorine only. These chemicals (predominantly CF_4 and

C_2F_6) were introduced as alternatives, along with hydrofluorocarbons, to the ozone depleting substances. In addition, PFCs are emitted as by-products of industrial processes and are also used in manufacturing. PFCs do not harm the stratospheric ozone layer, but they are powerful greenhouse gases: CF_4 has a global warming potential (GWP) of 7,390 and C_2F_6 has a GWP of 12,200. The GWP is from the IPCC's Fourth Assessment Report (AR4).

Photosynthesis
The process by which plants take carbon dioxide from the air (or bicarbonate in water) to build carbohydrates, releasing oxygen in the process. There are several pathways of photosynthesis with different responses to atmospheric carbon dioxide concentrations. (IPCC2)

Point Sources
Specific points of origin where pollutants are emitted into the atmosphere such as factory smokestacks. (CARB)

Power Purchase Agreement (PPA)
A power purchase agreement (PPA), or electricity power agreement, is a contract between two parties; one party generates electricity (the seller) and the other party looks to purchase electricity (the buyer). Individual customers and organizations may enter into PPAs with individual developers or may join together to seek better prices as a group. PPAs can allow longer term commitments to renewable energy as well as a form of “direct” investing in new renewable energy generation.

Property-Assessed Clean Energy (PACE)
A program created for financing energy efficiency and renewable improvements on private property. Private property can include residential, commercial or industrial properties. Improvements can include energy efficiency, renewable energy and water conservation upgrades to a building.

Process Emissions
Emissions from industrial processes involving chemical transformations other than combustion. (IPCC)

R

Radiative Forcing
A change in the balance between incoming solar radiation and outgoing infrared (i.e., thermal) radiation. Without any radiative forcing, solar radiation coming to the Earth would continue to be approximately equal to the infrared radiation emitted from the Earth. The addition of greenhouse gases to the atmosphere traps an increased fraction of the infrared radiation, reradiating it back toward the surface of the Earth and thereby creates a warming influence. (UNFCC)

Reforestation
Planting of forests on lands that have previously contained forests but that have been converted to some other use. (IPCC2)

Regeneration
The act of renewing tree cover by establishing young trees, naturally or artificially - note regeneration usually maintains the same forest type and is done promptly after the previous stand or forest was removed. (CSU)

Renewable Energy
Energy resources that are naturally replenishing such as solar, wind, hydro and geothermal energy.

Renewable Energy Credits (RECs)
A market-based instrument that represents the property rights to the environmental, social and other non-power attributes of renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource. The single largest category of

reductions in Evanston's emissions has been through the purchase of RECs.

Residence Time
Average time spent in a reservoir by an individual atom or molecule. Also, this term is used to define the age of a molecule when it leaves the reservoir. With respect to greenhouse gases, residence time usually refers to how long a particular molecule remains in the atmosphere. (UNFCC)

Reservoir
Either (1) a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored; or (2) Water bodies regulated for human activities (energy production, irrigation, navigation, recreation etc.) where substantial changes in water area due to water level regulation may occur. (IPCC)

Respiration
The process whereby living organisms convert organic matter to carbon dioxide, releasing energy and consuming molecular oxygen. (IPCC2)

Retro-commissioning
The systematic process to improve an existing building's performance ensuring the building controls are running efficiently and balancing the designed use and the actual use of the building.

Ride-share
The practice of sharing transportation in the form of carpooling or vanpooling. It is typically an arrangement made through a ride-matching service that connects drivers with riders.

S

Scope 1:
Scope 1 includes emissions being released within the city limits resulting from combustion of fossil fuels and from waste decomposition in the landfill and wastewater treatment plant.

Scope 2:
Scope 2 includes emissions produced outside the city that are induced by consumption of electrical energy within the city limits.

Scope 3:
Scope 3 includes emissions of potential policy relevance to local government operations that can be measured and reported but do not qualify as Scope 1 or 2. This includes, but is not limited to, outsourced operations and employee commute.

Short Ton
Common measurement for a ton in the United States. A short ton is equal to 2,000 lbs or 0.907 metric tons. (USEPA1)

Sink
Any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere. (IPCC2)

Solar Radiation
Electromagnetic radiation emitted by the Sun. It is also referred to as shortwave radiation. Solar radiation has a distinctive range of wavelengths (spectrum) determined by the temperature of the Sun, peaking in visible wavelengths. (IPCC2)

Source
Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere. (IPCC2)

Stationary Sources
Non-mobile sources such as power plants, refineries, and manufacturing facilities which emit air pollutants. (CARB)

Sulfur Dioxide (SO_2)
A compound composed of one sulfur and two oxygen molecules. Sulfur dioxide emitted into the atmosphere through natural and anthropogenic processes is changed in a complex series of chemical reactions in the atmosphere to sulfate aerosols. These aerosols are believed to result in negative radiative forcing (i.e., tending to cool the Earth's surface) and do result in acid deposition (e.g., acid rain). (UNFCC)

Sulfur Hexafluoride (SF_6)
A colorless gas soluble in alcohol and ether, slightly soluble in water. A very powerful greenhouse gas with a global warming potential most recently estimated at 22,800 times that of carbon dioxide (CO_2). SF_6 is used primarily in electrical transmission and distribution systems and as a dielectric in electronics. This GWP is from the IPCC's Fourth Assessment Report (AR4).

T

Terrestrial Carbon Sequestration
It is the process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The term "sinks" is also used to refer to forests, croplands, and grazing lands, and their ability to sequester carbon. Agriculture and forestry activities can also release CO_2 to the atmosphere. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period. (USEPA3)

Therm:
A unit of measure for energy that is equivalent to 100,000 British Thermal units, or roughly the energy in 100 cubic feet of natural gas. Often used for measuring natural gas usage for billing purposes.

Total Organic Gases (TOG)
Gaseous organic compounds, including reactive organic gases and the relatively unreactive organic gases such as methane. (CARB)

Transparency
Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information. (IPCC)

Trend
The trend of a quantity measures its change over a time period, with a positive trend value indicating growth in the quantity, and a negative value indicating a decrease. It is defined as the ratio of the change in the quantity over the time period, divided by the initial value of the quantity, and is usually expressed either as a percentage or a fraction. (IPCC)

U

Urban Tree Canopy
Describes the makeup and characteristics of trees within the urban environment.

V

VMT Vehicle Miles Traveled:
A unit used to measure vehicle travel made by private vehicles, including passenger vehicles, truck, vans and motorcycles. Each mile traveled is counted as one vehicle mile regardless of the number of persons in the vehicle.

W

Water Vapor
The most abundant greenhouse gas; it is the water present in the atmosphere in gaseous form. Water vapor is an important part of the natural greenhouse effect. While humans are not significantly increasing its concentration, it contributes to the enhanced greenhouse effect because the warming influence of greenhouse gases leads to a positive water vapor feedback. In addition to its role as a natural greenhouse gas, water vapor plays an important role in regulating the temperature of the planet because clouds form when excess water vapor in the atmosphere condenses to form ice and water droplets and precipitation. (UNFCC)

Weather
Atmospheric condition at any given time or place. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. A simple way of remembering the difference is that climate is what you expect (e.g. cold winters) and 'weather' is what you get (e.g. a blizzard). (USEPA1)

Z

Zero Emission Vehicles (ZEV)
A vehicle that does not emit harmful emissions during operation. Harmful emissions can have a negative impact on human health and the environment. Electric (battery-powered) cars, electric trains, hydrogen-fueled vehicles, bicycles, and carriages are considered to produce zero emissions.

Zero Waste
A cyclical system in which products are designed for reuse, which creates no waste. A zero waste system eliminates the volume and toxicity of waste and materials and conserves current resources through reuse.

Photo: spablab via Flickr

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