PREPARED FOR ENVIRONMENTAL CHANGE GRAND CHALLENGE INITIATIVE

ENVIRONMENTAL RESILIENCE INSTITUTE

INDIANA UNIVERSITY

Hoosier Resilience Index Technical Document

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PREPARED FOR ENVIRONMENTAL CHANGE GRAND CHALLENGE INITIATIVE

ENVIRONMENTAL RESILIENCE INSTITUTE

The Hoosier Resilience Index

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The Hoosier Resilience Index was developed by researchers at Indiana University with experience in a wide range of disciplines related to climate science, data analytics, and resilience and mitigation policies and programs. The Environmental Resilience Institute eagerly sought and gratefully received input from local government officials and staff, and many other external parties along the way. Two counties and two municipalities participated in a beta test of the Index and provided invaluable feedback.

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I. Introduction

Scientific evidence shows that the climate is changing in the Midwest. In Indiana, average annual temperatures have increased 1.2°F since 1895 and by the late 21st century are projected to increase an additional 6-10°F. Precipitation is becoming heavier and more damaging in the winter and spring, and water is becoming less plentiful in the summer and fall, with implications for agriculture, ecosystems, and flood frequency and severity. To help the state of Indiana prepare for these impacts, Indiana University's Environmental Resilience Institute developed the Hoosier Resilience Index.

Designed to help local decision makers understand the path to making their communities more resilient to climate change, the Hoosier Resilience Index provides:

- Current data and future projections for extreme heat and extreme precipitation events;
- A platform local government officials and employees can work through to evaluate how sensitive their residents and developed, natural, and agricultural areas may be to increasing heat and precipitation; and
- A series of self-evaluation worksheets and scores to help local governments understand their current preparedness and identify and prioritize new initiatives and policies to increase resilience.

Climate change will not impact every city, town, and county in the same way, or to the same extent. To lower community risk, local governments have a responsibility to ensure that critical community structures and services are prepared, and that preparedness is equitably addressed across neighborhoods and households.

The Environmental Resilience Institute intends for the Hoosier Resilience Index to be easy to use and understand, informative, objective, inspiring, and accessible to the diverse array of cities, towns, and counties within the state and beyond. It uses Indiana-specific data about future environmental conditions. Although the tool will initially be designed for an Indiana audience (and the data are Indiana specific), the Index is intended to be relevant across a range of community sizes in the Midwest. The Index helps communities understand where to focus their attention and provides a methodology for measuring progress towards resilience. The Index is intended to complement, not duplicate, existing tools for climate-related vulnerability assessments.

Being resilient means we will be able to deal with change in ways that equitably protect the health, welfare, and economic vitality of our human and ecological communities. Being resilient is not about running away from our way of life or waiting for the worst to happen, but growing toward stronger, cleaner, healthier, safer, and more vibrant communities. Communities in the Midwest want to become more resilient. This tool helps users understand the gravity of climate change, that adaptation and mitigation are important, and preparedness is necessary, feasible, and unique to each community. The Index also allows communities to understand their specific risks, strengths, and weaknesses to help them set priorities.

The purpose of this Technical Document is to explain the process used to develop the Hoosier Resilience Index, identify specific data sources, and provide additional information so that users and prospective replicators may understand the intricacies of the tool. As with any tool, the Index will improve as people use it and provide feedback to staff at the IU Environmental Resilience Institute. Please send any comments or feedback to resindex@iu.edu.

II. Climate Vulnerability

The Indiana Climate Change Impacts Assessment (Widhalm *et al*., 2018) identifies rising average annual temperatures and rising average annual precipitation as the most significant climate change impacts in the state. To understand how these impacts will affect communities in Indiana, the Hoosier Resilience Index provides data on four key vulnerability indicators for every county and incorporated city and town in Indiana:

- Extreme heat
- Extreme precipitation
- Floodplain land use
- Social vulnerability

The sections below provide the methodologies and sources used for each indicator.

Extreme Heat

The average number of days per year with extreme heat is calculated for each Indiana county, for two time periods: current (1971-2000), and the 2050s (2041-2070) under two scenarios, resulting in three extreme heat event totals overall. The current data are based on observational weather data, and the data for the 2050s are based on climate projection data for "medium" and "high" greenhouse gas emission scenarios, also referred to as the Representative Concentration Pathways 4.5 and 8.5 scenarios ($RCP_{4.5}$ and $RCP_{8.5}$, respectively; Van Vuuren, *et al.*, 2011).

> $RCP_{4.5}$ assumes that countries around the globe will simultaneously and effectively reduce greenhouse gas emissions (Thomson *et al*., 2011).
>
> $RCP_{8.5}$ assumes that countries around the globe do not try to achieve greenhouse gas reductions, resulting in a high level of greenhouse gas emissions (Riahi *et al*., 2011).

The Hoosier Resilience Index defines extreme heat events as days with highs 90°F or greater and nights with lows 68°F or greater. Increasing daytime and nighttime temperatures are hazardous to human health, especially for sensitive populations (e.g. children, the elderly, low-income households, outdoor workers; Filippelli, *et al*., 2018). The *Extreme Heat* data provided only account for the frequency of extreme temperatures and do not explicitly include humidity. Nighttime low temperatures, however, provide a close approximation of the dewpoint temperature (and, therefore, humidity). Increased humidity exacerbates the health implications of extreme heat, as illustrated in the National Weather Service's Heat Index (See Figure 1).

NWS Heat Index — Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 1. Heat Index (National Oceanic and Atmospheric Administration and National Weather Service, 2019).

The total number of extreme heat events is the sum of *High Heat Days*, *High Heat Nights*, and *High Heat Days with High Heat Nights*.

High Heat Days (HD): Number of days, on average per year, where daily high temperature (T) is 90°F or greater and daily low temperature is less than 68°F.

$$Tmax \geq 90°F \; AND \; Tmin < 68°F$$

High Heat Nights (HN): Number of days, on average per year, where daily high temperature (T) is less than 90°F and daily low temperature is 68°F or greater.

$$Tmax < 90°F \; AND \; Tmin \geq 68°F$$

High Heat Days with High Heat Nights (HDHN): Number of days, on average per year, where the daily high temperature (T) is 90°F or greater and daily low temperature is 68°F or greater.

$$Tmax \geq 90°F \; AND \; Tmin \geq 68°F$$

Three *Extreme Heat data* points are calculated per county in Indiana.

Current Extreme Heat: The 30-year (1971-2000, i.e. current period) average number of observed days with temperature highs 90°F or greater (i.e. *High Heat Days*), the 30-year average number of observed days with temperature lows 68°F or greater (i.e. *High Heat Nights*), and the 30-year average number of observed days with temperature highs 90°F or greater and lows 68°F or greater (i.e. *High Heat Days with High Heat Nights*).

2050s Extreme Heat, Medium Emissions Scenario: The 30-year (2041-2070, i.e. 2050s period) average projected number of days identified as *High Heat Days*, *High Heat*

Nights, and *High Heat Days with High Heat Nights*, as calculated with the Representative Concentration Pathway 4.5.

2050s Extreme Heat, High Emissions Scenario: The 30-year (2041-2070, i.e. 2050s period) average projected number of days identified as *High Heat Days*, *High Heat Nights*, and *High Heat Days with High Heat Nights*, as calculated with the Representative Concentration Pathway 8.5.

Data Sources

The input observation data used to generate the current *Extreme Heat* data were provided by Alan Hamlet (University of Notre Dame) and the Purdue Climate Change Research Center, which coordinated the Indiana Climate Change Impacts Assessment (Hamlet *et al*., 2018; Byun and Hamlet, 2018).

The input projected data used to generate both 2050s *Extreme Heat* scenario data were also provided by Alan Hamlet (University of Notre Dame) and the Purdue Climate Change Research Center using an ensemble of 10 statistically downscaled global climate model simulations (Hamlet *et al*., 2018; Byun and Hamlet, 2018).

Both datasets were processed by Scott Robeson (Indiana University) to obtain the combination of high and low temperatures.

Data Scale

Extreme Heat data are calculated for each county in Indiana.

Calculation – Current Data

Current High Heat Days (HD_C): 30-year average number of observed days with temperature highs 90°F and greater and temperature lows less than 68°F.

$\frac{1}{n}\sum_{i=1}^{n} HD_{C,L,i}$: sum (Σ) of number of *High Heat Days* (HD) for period, *C*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

C = 1971-2000

L = Each Indiana county

i = 1971, 1972, 1973…2000

n = 30

Current High Heat Nights (HN_C): 30-year average number of observed days with temperature highs less than 90°F and temperature lows 68°F or greater.

$\frac{1}{n}\sum_{i=1}^{n} HN_{C,L,i}$: sum (Σ) of number of *High Heat Nights* (HN) for period, *C*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

C = 1971-2000

L = Each Indiana county

i = 1971, 1972, 1973…2000

n = 30

Current High Heat Days with High Heat Nights ($HDHN_C$): 30-year average number of observed days with temperature highs 90°F or greater with temperature lows 68°F or greater.

$\frac{1}{n}\sum_{i=1}^{n} HDHN_{C,L,i}$: sum (Σ) of number of *High Heat Days with High Heat Nights* (HDHN) for period, *C*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

C = 1971-2000

L = Each Indiana county

i = 1971, 1972, 1973…2000

n = 30

Temperatures: All temperatures were calculated and are displayed in degrees Fahrenheit.

Tmax: daily high temperature

Tmin: daily low temperature

$Tmax_{L,Y}$: daily high temperature for location, *L*, and year, *Y*

$Tmin_{L,Y}$: daily low temperature for location, *L*, and year, *Y*

$$Current\ Extreme\ Heat$$
$$= Current\ High\ Heat\ Days + Current\ High\ Heat\ Nights + Current\ High\ Heat\ Days\ with\ High\ Heat\ Nights$$
$$= HD_C + HN_C + HDHN_C$$

$$Where\ Tmax_{L,Y}\ and\ Tmin_{L,Y} = observed\ daily\ temperature\ high\ and\ low\ (respectively)\ for\ location, L, and\ year, Y$$

$$HD_C = Current\ High\ Heat\ Days$$
$$= \frac{1}{n}\sum_{i=1}^{n} HD_{C,L,i} = \frac{HD_{C,L,1} + HD_{C,L,2} + \cdots + HD_{C,L,n}}{n}$$

$$HD = High\ Heat\ Days\ ;\ Tmax_{L,Y} \geq 90°\text{F}\ AND\ Tmin_{L,Y} < 68°\text{F}$$

$$HN_C = Current\ High\ Heat\ Nights$$
$$= \frac{1}{n}\sum_{i=1}^{n} HN_{C,L,i} = \frac{HN_{C,L,1} + HN_{C,L,2} + \cdots + HN_{C,L,n}}{n}$$
$$HN = High\ Heat\ Nights;\ Tmax_{L,Y} < \ 90°\text{F}\ AND\ Tmin_{L,Y} \geq 68°\text{F}$$

$$HDHN_C = Current\ High\ Heat\ Days\ with\ High\ Heat\ Nights$$
$$= \frac{1}{n}\sum_{i=1}^{n} HDHN_{C,L,i} = \frac{HDHN_{C,L,1} + HDHN_{C,L,2} + \cdots + HDHN_{C,L,n}}{n}$$
$$HDHN = High\ Heat\ Days\ with\ High\ Heat\ Nights;$$
$$Tmax_{L,Y} < \ 90°\text{F}\ AND\ Tmin_{L,Y} \geq 68°\text{F}$$

Calculation – 2050s Data

Projected High Heat Days (HD_P): 30-year average projected number of days with temperature highs 90°F or greater and temperature lows less than 68°F.

$\frac{1}{n}\sum_{i=1}^{n} HD_{P,L,i}$: sum (Σ) of number of *High Heat Days* (HD) for period, *P*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

P = 2041-2070

L = Each Indiana county

i = 2041, 2042, 2043,…2070

n = 30

Projected High Heat Nights (HN_P): 30-year average projected number of days with temperature highs less than 90°F and temperature lows 68°F or greater.

$\frac{1}{n}\sum_{i=1}^{n} HN_{P,L,i}$: sum (Σ) of number of *High Heat Nights* (HN) for period, *P*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

P = 2041-2070

L = Each Indiana county

i = 2041, 2042, 2043,…2070

n = 30

Projected High Heat Days with High Heat Nights ($HDHN_P$): 30-year average projected number of days with temperature highs 90°F or greater with temperature lows 68°F or greater.

$\frac{1}{n}\sum_{i=1}^{n} HDHN_{P,L,i}$: sum (Σ) of number of *High Heat Days with High Heat Nights* (HDHN) for period, *P*, location, *L*, during year, *i*, divided by the total numbers of years, *n*.

P = 2041-2070

L = Each Indiana county

i = 2041, 2042, 2043,…2070

n = 30

Temperatures: All temperatures were calculated and are displayed in degrees Fahrenheit.

Tmax: daily high temperature

Tmin: daily low temperature

$Tmax_{L,Y}$: daily high temperature for location, L, and year, Y

$Tmin_{L,Y}$: daily low temperature for location, L, and year, Y

$$2050s\ Extreme\ Heat$$
$$= Projected\ High\ Heat\ Days + Projected\ High\ Heat\ Nights + High\ Heat\ Days\ with\ High\ Heat\ Nights$$
$$= HD_P + HN_P + HDHN_P$$

$$Where\ Tmax_{L,Y}\ and\ Tmin_{L,Y} = observed\ daily\ temperature\ high\ and\ low\ (respectively)\ for\ location, L, and\ year, Y$$

$$HD_P = Projected\ High\ Heat\ Days$$
$$= \frac{1}{n}\sum_{i=1}^{n} HD_{P,L,i} = \frac{HD_{P,L,1} + HD_{P,L,2} + \cdots + HD_{P,L,n}}{n}$$
$$HD = High\ Heat\ Days\ ;\ Tmax_{L,Y}\ \geq\ 90°\text{F}\ AND\ Tmin_{L,Y} < 68°\text{F}$$

$$HN_P = Projected\ High\ Heat\ Nights$$
$$= \frac{1}{n}\sum_{i=1}^{n} HN_{P,L,i} = \frac{HN_{P,L,1} + HN_{P,L,2} + \cdots + HN_{P,L,n}}{n}$$
$$UN = High\ Heat\ Nights;\ Tmax_{L,Y} <\ 90°\text{F}\ AND\ Tmin_{L,Y} \geq 68°\text{F}$$

$$HDHN_P = Projected\ High\ Heat\ Days\ with\ High\ Heat\ Nights$$

$$= \frac{1}{n}\sum_{i=1}^{n} HDHN_{P,L,i} = \frac{HDHN_{P,L,1} + HDHN_{P,L,2} + \cdots + HDHN_{P,L,n}}{n}$$

$$HDHN = High\ Heat\ Days\ with\ High\ Heat\ Nights;$$

$$Tmax_{L,Y} < \ 90°\text{F}\ AND\ Tmin_{L,Y} \geq 68°\text{F}$$

Extreme Precipitation

The average number of days per decade with an extreme precipitation event is calculated for each Indiana county for two time periods: current (1971-2000) and the 2050s (2041-2070) under two scenarios, resulting in three extreme precipitation event totals overall. The current data are based on observational weather data, and the 2050s projected data are based on climate projection data for “medium” and “high” greenhouse gas emission scenarios, also referred to as the Representative Concentration Pathways 4.5 and 8.5 scenarios ($RCP_{4.5}$ and $RCP_{8.5}$, respectively; Van Vuuren, *et al.*, 2011).

> $RCP_{4.5}$ assumes that countries around the globe will simultaneously and effectively reduce greenhouse gas emissions (Thomson *et al*., 2011).
>
> $RCP_{8.5}$ assumes that countries around the globe do not try to achieve greenhouse gas reductions, resulting in a high level of greenhouse gas emissions (Riahi *et al*., 2011).

The Hoosier Resilience Index defines extreme precipitation events as days with precipitation of 2 inches or greater. Extreme precipitation events, especially rain, increase flooding risk, which can endanger lives, damage property, and wash fertilizer and sediment from agricultural fields (Widhalm *et al*., 2018). The *Extreme Precipitation* data only account for how many days per decade an extreme precipitation event occurs and do not explicitly address the intensity of those events. For example, a 2 inch storm on one day is counted as one event, and a 4 inch storm on another day is also counted as one event. The severity of extreme precipitation impacts is dependent on many other factors, such as soil moisture, topography, land cover, and groundwater hydrology (Hoegh-Guldberg *et al*., 2018).

The number of extreme precipitation events is given in terms of the number of days per decade with precipitation of 2 inches or greater.

> **Extreme Precipitation Days (PD_{Ext})**: Number of days, on average per decade, when daily precipitation (P) is 2 inches or greater.
>
> $$P \geq 2\ inches$$

Three *Extreme Precipitation* values are calculated per county in Indiana.

Current Extreme Precipitation: The 30-year (1971-2000, i.e. current period) average number of observed days per decade with precipitation of 2 inches or greater (i.e. Extreme Precipitation Days).

2050s Extreme Precipitation, Medium Emissions Scenario: The 30-year (2041-2070, i.e. 2050s period) average projected number of days identified as an Extreme Precipitation Day, as calculated with the Representative Concentration Pathway 4.5.

2050s Extreme Precipitation, High Emissions Scenario: The 30-year (2041-2070, i.e. 2050s period) average projected number of days identified as an Extreme Precipitation Day, as calculated with the Representative Concentration Pathway 8.5.

Data Sources

The input observation data used to generate the Current Extreme Precipitation data were provided by Alan Hamlet (University of Notre Dame) and the Purdue Climate Change Research Center, which coordinated the Indiana Climate Change Impacts Assessment (Hamlet *et al*., 2018; Byun and Hamlet, 2018).

The input projected data used to generate the projected Extreme Precipitation data were also provided by Alan Hamlet (University of Notre Dame) and the Purdue Climate Change Research Center using an ensemble of 10 statistically downscaled global climate model simulations (Hamlet *et al*., 2018; Byun and Hamlet, 2018).

Both datasets were processed by Scott Robeson (Indiana University) to obtain the number of 2 inch storms per decade, on average.

Data Scale

Extreme Precipitation data are calculated for each county in Indiana.

Calculation – Current Data

Current Extreme Precipitation Days ($PD_{Ext,C}$): 30-year average number of observed days, multiplied by 10 to get a per-decade value, with daily precipitation at or above 2 inches.

$\frac{10}{n}\sum_{i=1}^{n} PD_{Ext,C,L,i}$: sum (Σ) of number of *Extreme Precipitation Days* (PD_{Ext}) for period, *C*, location, *L*, during year, *i*, divided by the total numbers of years, *n*, multiplied by 10 to achieve a per decade value.

C = 1971-2000

L = Each Indiana county

i = 1971, 1972, 1973…2000

n = 30

$$Current\ Extreme\ Precipitation\ Score$$
$$= Current\ Extreme\ Precipitation\ Days$$
$$= PD_{Ext,C}$$

$$Where\ P_{L,Y} = observed\ daily\ precipitation\ for\ location, L, and\ year, Y$$

$$PD_{Ext,C} = Current\ Extreme\ Precipitation\ Days$$
$$= \frac{10}{n}\sum_{i=1}^{n} PD_{Ext,C,L,i} = \frac{PD_{Ext,C,L,1} + PD_{Ext,C,L,2} + \cdots + PD_{Ext,C,L,n}}{n}$$

$$PD_{Ext} = Extreme\ Precipitation\ Day;\ 2.0\ inches \leq P_{L,Y}$$

Calculation – 2050s Data

Projected Extreme Precipitation Days ($PD_{Ext,P}$): 30-year average projected number of days, multiplied by 10 to get a per-decade value, with daily precipitation at or above 2 inches.

$\frac{10}{n}\sum_{i=1}^{n} PD_{Ext,P,L,i}$: sum (Σ) of number of *Extreme Precipitation Days* (PD_{Ext}) for period, *P*, location, *L*, during year, *i*, divided by the total numbers of years, *n*, multiplied by 10 to achieve a per decade value.

P = 2041-2070

L = Each Indiana county

i = 2041, 2042, 2043,…2070

n = 30

$$Projected\ Extreme\ Precipitation\ Score$$
$$= Projected\ Extreme\ Precipitation\ Days$$
$$= PD_{Ext,P}$$
$$Where\ P_{L,Y} = observed\ daily\ precipitation\ for\ location, L, and\ year, Y$$

$$PD_{Ext,P} = Current\ Extreme\ Precipitation\ Days$$
$$= \frac{10}{n}\sum_{i=1}^{n} PD_{Ext,P,L,i} = \frac{PD_{Ext,P,L,1} + PD_{Ext,P,L,2} + \cdots + PD_{Ext,P,L,n}}{n}$$

$$PD_{Ext} = Extreme\ Precipitation\ Day;\ 2\ inches \leq P_{L,Y}$$

Floodplain Land Use

The Floodplain Land Use data are calculated for each Indiana county and incorporated city and town using 2010 observation-based land use data from the U.S. Environmental Protection Agency's Integrated Climate and Land Use Scenarios (ICLUS) tool and the floodplain dataset from the "Best Available" Floodplain Mapping dataset of the Indiana Department of Natural Resources (IN DNR, 2018).

The Hoosier Resilience Index defines floodplain land as land within the 100-year and 500-year floodplains. The Floodplain Land Use component presents the amount and percent of floodplain acres per land use group and type. Although the USEPA dataset does model the projected land use change for 2050 based on population growth, migration, development, and climatic influences, only the 2010 observation-based land use data are used in the Hoosier Resilience Index.

Data Sources

Counties

Dataset Title	Census Counties (2000)
URL	https://maps.indiana.edu/previewMaps/Demographics/Census_Counties.html
Author	U.S. Census Bureau
Publication Date	10/2002
Data Date	2000
Scale/Resolution	Vector with 1:24,000
Key Features	Shows counties and contains 2000 U.S. Census data regarding race, gender, age, families, and households. Data are from Census 2000 SF1 tables.
Layer Name(s)	Census_County_TIGER00_IN.shp
Notes	Only the geographic boundaries were used from this shapefile.

Cities and Towns

Dataset Title	2018 TIGER/Line® Shapefiles: Places, Indiana, Current Place State-based
URL	https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2018&layergroup=Places (Place > Indiana)
Author	U.S. Census Bureau

Publication Date	05/2019
Data Date	2018
Scale/Resolution	Vector with 1:500,000
Key Features	Boundaries, roads, address information, water features, and more.
Layer Name(s)	tl_2018_18_place.shp
Notes	Designed for use with GIS (geographic information systems).

Floodplains

Dataset Title	Best Available Flood Hazard
URL	https://www.in.gov/dnr/water/9846.htm
Author	Indiana Department of Natural Resources, Division of Water
Publication Date	2018
Data Date	2018
Scale/Resolution	Vector with maximum (zoomed in) 1:5,000 and minimum (zoomed out) 1:625,000
Key Features	"Best available" floodplains within Indiana
Layer Name(s)	[County_Name]_FloodHazard_BestAvai_DNR_Water.shp
Notes	92 shapes files, one for each county. "The data layer "Best Available Flood Hazard Area" ("Best Available") is the Effective [Special Flood Hazard Area] with additional studies that have been reviewed and approved by the Division of Water. While this data has not yet been submitted to FEMA for inclusion in the FIRMs or NFHL (DFIRMs), this data can be used for general planning, construction, and development purposes." From https://dnrmaps.dnr.in.gov/appsphp/fdms/.

Land Use

Dataset Title	ICLUS v2.1.1 land use projections for SSP2 and RCP4.5 pathways
URL	https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7BC009CEAD-8841-4268-B13E-7D01C51F6010%7D
Author	U.S. Environmental Protection Agency, Office of Research and Development-National Center for Environmental Assessment
Publication Date	07/27/2016 (Last Revised: 03/27/2017)
Data Date	2000-2100
Scale/Resolution	Contiguous U.S. with 90 m x 90 m pixels

Key Features	Primary land use for each location (i.e. pixel)
Layer Name(s)	ICLUS_v2_1_1_land_use_conus_2010.tif, ICLUS_v2_1_1_land_use_conus_2050_ssp2_rcp45_giss_e2_r.tif
Notes	Only the ICLUS_v2_1_1_land_use_conus_2010.tif was used from dataset. Methodology documentation: Environmental Protection Agency (US EPA). (2017). Updates to the Demographic and Spatial Allocation Models to Produce Integrated Climate and Land-Use Scenarios (ICLUS) (Final Report, Version 2). DOI: EPA/600/R-16/366F. Available at: [https://cfpub.epa.gov/ncea/iclus/recordisplay.cfm?deid=322479.](https://cfpub.epa.gov/ncea/iclus/recordisplay.cfm?deid=322479)

Data Scale

Floodplain Land Use data are calculated for every county and incorporated city and town in Indiana.

Calculation

Select 100-year and 500-year Floodplains

Using ArcMap 10.6, the analysis outlined below was performed to retain only the 100-year and 500-year floodplains from the Indiana Department of Natural Resources (IDNR) "Best Available Flood Hazard" shapefiles. The analysis was performed on each of the 92 county files provided by the IDNR. These data were also used for the analysis of Indiana's incorporated cities and towns.

ArcToolbox > Analysis Tools > Extract > Select

Input Features: [County name]_FloodHazard_BestAvai_DNR_Water.shp

Output Feature Class: Select_Floodplains_County_Pct.gdb/[County name]_Select_FloodHazard_BestAvai_DNR_Water.shp

Expression: "ZONE_SUBTY" <> 'AREA OF MINIMAL FLOOD HAZARD'

Notes: Select the floodplains that are not zoned as "area of minimal flood hazard." Selection results in shapefile of A and AE floodplains (100-year) and X floodplains with "0.2 PCT ANNUAL CHANCE FLOOD HAZARD" (500-year).

Select Extent of 2010 ICLUS Land Use Raster

Using ArcMap 10.6, the below analysis was performed to retain a raster of land use for the state of Indiana.

ArcToolbox > Data Management Tools > Raster > Raster Processing > Clip

Input Raster: ICLUS_v2_1_1_land_use_conus_2010.tif

Output Extent: IN_State.shp (Census_County_TIGER00_IN.shp with dissolved boundaries leaving only the outline of Indiana)

Rectangle: Self populates from "Output Extent"

Use Input Features for Clipping Geometry: Checked

Output Raster Dataset: year_2010.tif

NoData Value: Self populates

Maintain Clipping Extent: Unchecked

Notes: Process one input raster file at a time. Creates raster file of Indiana.

Calculate Area and Percent of Land Use per County and Incorporated Area

Using ArcMap 10.6, the below analysis was performed to tabulate the type of land use within Indiana counties and incorporated areas.

ArcToolbox > Conversion Tools > From Raster > Raster to Polygon

Input rater: year_2010.tif

Field (optional): Value

Output polygon features: Polygon_ICLUS.gdb/year_2010.shp

Simplify polygons: Checked

Create multipart features: Unchecked

Maximum vertices per polygon feature: Blank

Notes: Creates polygon shapefile from land use raster file for use as Tabulate Intersection input.

ArcToolbox > Analysis Tools > Statistics > Tabulate Intersection

Input Zone Features: Census_County_TIGER00_IN.shp

Zone Fields: GEOID, NAME_L

Input Class Features: year_2010.shp

Output Table: Counties_2018_ICLUS_2010

Class Fields: Gridcode

Sum Fields: Blank

XY Tolerance: [leave field blank]

Output Units: SQUARE METERS

Notes: Creates table with the number of square meters per land use class/type per Indiana County.

ArcToolbox > Conversion Tools > Excel > Table to Excel

Input table: Counties_2018_ICLUS_2010

Output Excel File: Counties_2018_ICLUS_2010.xls

Notes: In Excel, the file was processed to calculate the acres and percent of county for each land use type/class and group.

ArcToolbox > Analysis Tools > Statistics > Tabulate Intersection

Input Zone Features: tl_2018_18_place.shp

Zone Fields: GEOID, NAME_L

Input Class Features: year_2010.shp

Output Table: Incorp_2018_ICLUS_2010

Class Fields: Gridcode

Sum Fields: Blank

XY Tolerance: [leave field blank]

Output Units: SQUARE METERS

Notes: Creates table with the number of square meters per land use class/type per Indiana incorporated area.

ArcToolbox > Conversion Tools > Excel > Table to Excel

Input table: Counties_2018_ICLUS_2010

Output Excel File: Counties_2018_ICLUS_2010.xls

Notes: In Excel, the file was processed to calculate the acres and percent of incorporated area for each land use type/class and group.

Calculate Area and Percent of Land Use with County's 100-year and 500-year Floodplains

Using ArcMap 10.6, the below analysis was performed to tabulate the type of land use within Indiana counties' 100-year and 500-year floodplains.

ArcToolbox > Analysis Tools > Statistics > Tabulate Intersection

Input Zone Features: [County name]_Select_FloodHazard_BestAvai_DNR_Water.shp

Zone Fields: GEOID, NAME_L

Input Class Features: year_2010.shp

Output Table: Counties_Floodplains_2018_ICLUS_2010

Class Fields: Gridcode

Sum Fields: Blank

XY Tolerance: [leave field blank]

Output Units: SQUARE METERS

Notes: Creates table with the number of square meters per land use class/type for the 100-year and 500-year floodplains within each Indiana county. Batch "Tabulate Intersection" was perform to analyze all 92 [County name]_Select_FloodHazard_BestAvai_DNR_Water.shp shapefiles.

ArcToolbox > Conversion Tools > Excel > Table to Excel

Input table: [County name]_Floodplains_2018_ICLUS_2010

Output Excel File: [County name]_Floodplains_2018_ICLUS_2010.xls

Notes: In Excel, the 92 Excel files were appended together and processed to calculate the acres and percent of county for each land use type/class and group within the county's 100-year and 500-year floodplains.

Calculate Area and Percent of Land Use with Incorporated Area's 100-year and 500-year Floodplains

Using ArcMap 10.6, the below analysis was performed to tabulate the type of land use within Indiana incorporated areas' 100-year and 500-year floodplains.

ArcToolbox > Analysis Tools > Extract > Clip

Input Features: [County name]_Select_FloodHazard_BestAvai_DNR_Water.shp

Clip Features: tl_2018_18_place.shp

Output Feature Class: Select_Floodplains_Places_[County name].shp

XY Tolerance (optional): Blank

Notes: Batch "Clip" was perform to analyze all 92 [County name]_Select_FloodHazard_BestAvai_ DNR_Water.shp shapefiles.

ArcToolbox > Data Management Tools > General > Merge

Input Datasets: all 92 Select_Floodplains_Places_[County name].shp

Output Dataset: Select_Floodplains_Places_Merged_Counties.shp

Field Map (optional): Left as is

Notes: This creates a shapefile with an attribute table that contains all of the floodplains within Indiana incorporated areas.

ArcToolbox > Analysis Tools > Extract > Split

Input Features: Select_Floodplains_Places_Merged_Counties.shp

Split Features: tl_2018_18_place.shp

Split Field: GEOID

Target Workspace: Select_Floodplains_PlacesSplit_Merged_Counties.shp

XY Tolerance (optional): Blank

Notes: Creates a shapefile of floodplains such that floodplains that cross incorporated area boundaries are split into representative pieces according to the intersected incorporated area boundary. This allows for only the portion of floodplains within a specific incorporated area to be used during Tabulate Intersection.

ArcToolbox > Analysis Tools > Overlay > Spatial Join

Target Features: Select_Floodplains_PlacesSplit_Merged_Counties.shp

Join Features: tl_2018_18_place.shp

Output Feature Class: Select_Floodplains_NamedPlacesSplit_Merged_Counties.shp

Field Map of Join Features (optional): Keep all of the target features and join features

Match Option (optional): WITHIN

Search Radius (optional): Blank

Notes: Creates a shapefile with incorporated area attributes joins to the spatially relevant 100-year and 500-year floodplains.

ArcToolbox > Analysis Tools > Statistics > Tabulate Intersection

Input Zone Features: Select_Floodplains_NamedPlacesSplit_Merged_Counties.shp

Zone Fields: GEOID, NAME_L

Input Class Features: year_2010.shp

Output Table: Incorp_Floodplains_2018_ICLUS_2010

Class Fields: Gridcode

Sum Fields: Blank

XY Tolerance: [leave field blank]

Output Units: SQUARE METERS

Notes: Creates table with the number of square meters per land use class/type for the 100-year and 500-year floodplains within each Indiana county. Batch "Tabulate Intersection" was performed to analyze all 92 [County name]. Select_FloodHazard_BestAvai_DNR_Water.shp shapefiles.

ArcToolbox > Conversion Tools > Excel > Table to Excel

Input table: Incorp_Floodplains_2018_ICLUS_2010Count_2018_ICLUS_2010

Output Excel File: Incorp_Floodplains_2018_ICLUS_2010.xls

Notes: In Excel, the file was processed to calculate the acres and percent of incorporated area for each land use type/class and group within the incorporated area's 100-year and 500-year floodplain.

Social Vulnerability

When climate change impacts occur, the most vulnerable populations within a community are hit first and hardest (Oxfam America, 2019). The inclusion of the Centers for Disease Control and Prevention's Social Vulnerability Index (CDC, SVI) and its data in the Hoosier Resilience Index allows Indiana communities to overlay social vulnerability data with climate impacts to understand the resilience of their residents to hazardous events such as extreme heat and floods.

A social vulnerability score is calculated for each census tract in the state of Indiana using the CDC's Social Vulnerability Index methodology, as described in the CDC's SVI 2016 Documentation (CDC, 2019), and the Census' 2013-2017 American Community Survey data. While the CDC uses their SVI to rank census tracts across the United States, the Hoosier Resilience Index has scaled the SVI methodology to the state of Indiana. Social vulnerability rankings within the Hoosier Resilience Index compare each Indiana census tract to all of the other census tracts within the state.

The Hoosier Resilience Index defines social vulnerability using the same definition as the CDC.

What is social vulnerability?

Every community must prepare for and respond to hazardous events, whether a natural disaster like a tornado or a disease outbreak, or an anthropogenic event such as a harmful chemical spill. The degree to which a community exhibits certain social conditions, including high poverty, low percentage of vehicle access, or crowded households, may affect that community's ability to prevent human suffering and financial loss in the event of disaster. These factors describe a community's social vulnerability (CDC, 2019).

What is CDC's Social Vulnerability Index?

The Agency for Toxic Substances and Disease Registry's (ATSDR) Geospatial Research, Analysis & Services Program (GRASP) created the CDC's Social Vulnerability Index to help public health officials and emergency response planners identify and map the communities that will most likely need support before, during, and after a hazardous event.

CDC's SVI indicates the relative vulnerability of every U.S. Census tract. Census tracts are subdivisions of counties for which the Census collects statistical data. The SVI ranks the tracts on 15 social factors, including unemployment, minority status, and disability, and further groups them into four related themes. Thus each tract receives a ranking for each Census variable and for each of the four themes, as well as an overall ranking (CDC, 2019). See the SVI Introduction Video and the SVI Methods Video for more information.

The CDC's SVI organizes vulnerability into three tiers (see Figure 2):

Tier I includes 15 census variables considered to be the indicators of social vulnerability.

Tier II groups Tier I variables into four related themes.

- Socioeconomic Status (The Hoosier Resilience Index refers to this theme as "Socioeconomic vulnerability" to alleviate confusion with the data's interpretation)
- Household Composition & Disability
- Minority Status & Language
- Housing & Transportation

Tier III provides an aggregation of the four themes, creating an "Overall Vulnerability" score.

The SVI methodology produces three ranking options for each census tract: by vulnerability variable, by vulnerability theme, and by overall vulnerability (Figure 2).

- Rankings are calculated using a percentile ranking method.
- Percentile rank of 0 means least vulnerable; percentile rank of 1 means most vulnerable.
- For example, a census tract with a percentile rank of 0.8 is more vulnerable than 80% of census tracts across Indiana.

How can CDC's SVI help communities be better prepared for hazardous events?

The SVI provides specific socially and spatially relevant information to help public health officials and local planners better prepare communities to respond to emergency events such as severe weather, floods, disease outbreaks, or chemical exposure (CDC, 2019).

The SVI can be used to:

- Allocate emergency preparedness funding by community need.
- Estimate the amount and type of needed supplies like food, water, medicine, and bedding.
- Decide how many emergency personnel are required to assist people.
- Identify areas in need of emergency shelters.
- Create a plan to evacuate people, accounting for those who have special needs, such as those without vehicles, the elderly, or people who do not understand English well.
- Identify communities that will need continued support to recover following an emergency or natural disaster. Estimate the amount of needed supplies like food, water, medicine, and bedding (CDC, 2019).

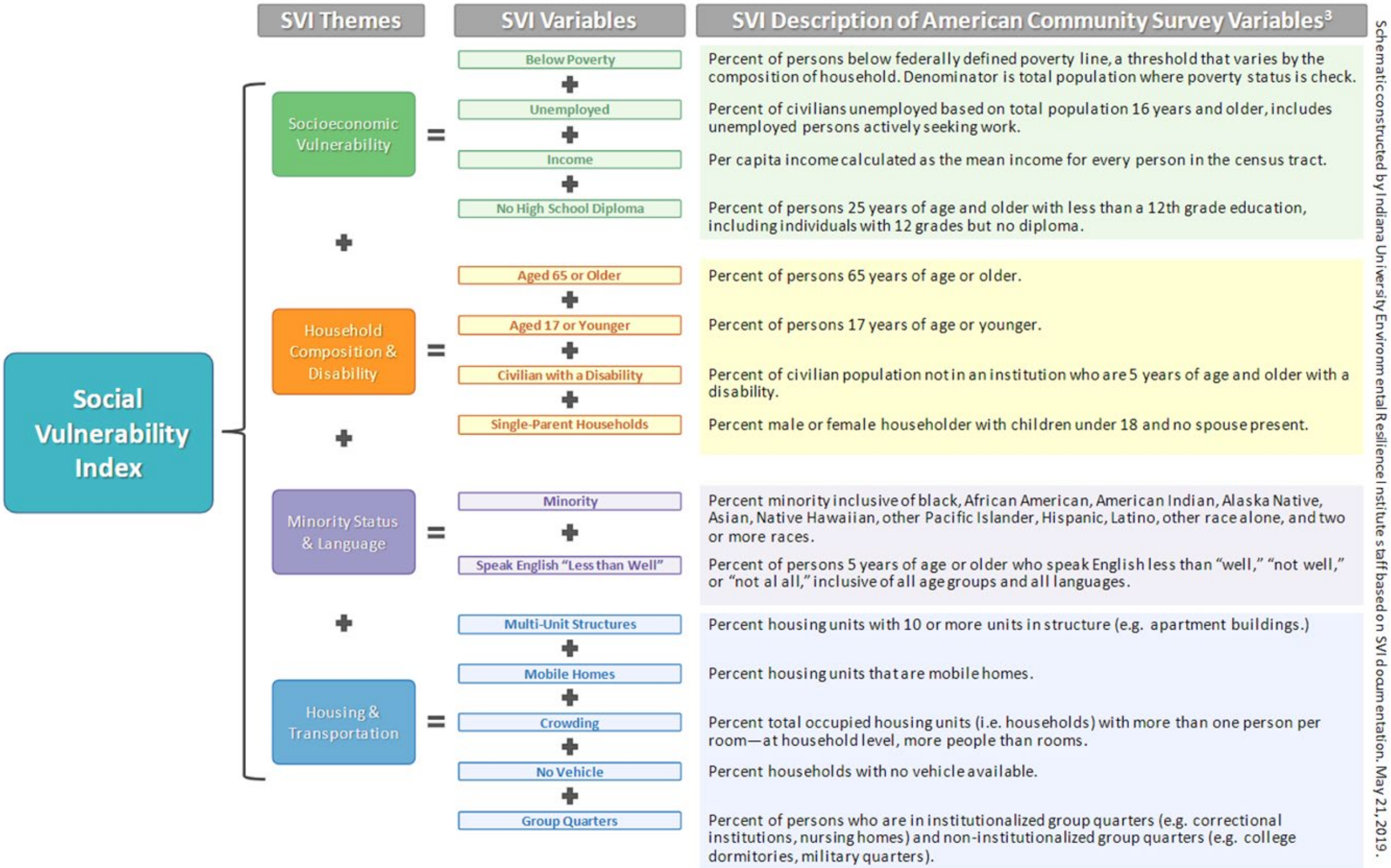

Figure 2. Breakdown of the tiered structure of CDC's Social Vulnerability Index (SVI; CDC, 2019; Flanagan, et al., 2011). The index is comprised of four themes (Socioeconomic Vulnerability, Household Composition and Disability, Minority Status and Language, and Housing and Transportation) and each theme comprises thematically relevant census variables. (Schematic reconstructed and slightly modified by ERI staff for clarity.)

Data Sources

The input data were pulled from the U.S. Census 2013-2017 American Community Survey**.**

Data Scale

The Hoosier Resilience Index's version of the CDC's Social Vulnerability Index provides data and rankings for each census tract in Indiana, and calculates rankings for each Indiana census tract. Rankings are based on a comparison to the census tracts within Indiana.

Score Calculation

Data Collection

Socioeconomic Vulnerability **(THEME1):** SVI theme comprising poverty, employment, income, and education variables.

> **Below Poverty (EP_POV):** Percent of persons, per census tract, below federally defined poverty line, a threshold that varies by the composition of household. Denominator is total population where poverty status is checked.
>
> **Unemployed (EP_UNEMP)**: Percent of civilians, per census tract, unemployed based on total population 16 years and older, includes unemployed persons actively seeking work.
>
> **Income (EP_PCI):** Per capita income calculated as the mean income for every person in the census tract.
>
> **No High School Diploma (EP_NOHSDP):** Percent of persons, per census tract, 25 years of age and older with less than a 12th grade education, including individuals with 12 grades but no diploma.

Household Composition and Disability **(THEME2):** SVI theme comprising age, disability, and single parenting variables.

> **Aged 65 or Older (EP_AGE65):** Percent of persons, per census tract, 65 years of age or older.
>
> **Aged 17 or Younger (EP_AGE17):** Percent of persons, per census tract, 17 years of age or younger.
>
> **Civilian with a Disability (EP_DISABL):** Percent of civilian population, per census tract, not in an institution who are 5 years of age and older with a disability.
>
> **Single-Parent Households (EP_SNGPNT):** Percent male- or female-led households, per census tract, with children under 18 and no spouse present.

Minority Status and Language **(THEME3):** SVI theme comprising race, ethnicity, and English-language proficiency variables.

Minority (EP_MINRTY): Percent minority, per census tract, inclusive of black, African American, American Indian, Alaska Native, Asian, Native Hawaiian, other Pacific Islander, Hispanic, Latino, other race alone, and two or more races.

Speak English "Less than Well" (EP_LIMENG): Percent of persons 5 years of age or older, per census tract, who speak English "less than well," "not well," or "not at all," inclusive of all age groups and all languages.

Housing and Transportation **(THEME4):** SVI theme comprising house structure, crowding, and vehicle access variables.

Multi-Unit Structures (EP_MUNIT): Percent housing units, per census tract, with 10 or more units in structure (e.g. apartment buildings.)

Mobile Homes (EP_MOBILE): Percent housing units, per census tract, that are mobile homes.

Crowding (EP_CROWD): Percent total occupied housing units (i.e. households), per census tract, with more than one person per room—at household level, more people than rooms.

No Vehicle (EP_NOVEH): Percent households with no vehicle available.

Group Quarters (EP_GROUPQ): Percent of persons, per census tract, who are in institutionalized group quarters (e.g. correctional institutions, nursing homes) and non-institutionalized group quarters (e.g. college dormitories, military quarters).

Overall Vulnerability **(THEMES):** social vulnerability, at the census tract level, comprising of socioeconomic status, household composition and disability, minority status and language, and housing and transportation.

Ranking

Vulnerability Variables Percentile Ranks, Tier 1 (Flanagan *et al*., 2011; CDC, 2019)**:** Percentile rank was performed on all vulnerability variables in Excel using the function PERCENTRANK.INC with four significant digits:

Percentile ranks for each variable, except for Percentile Income, were calculated as:

Percentile *XXXX* (EPL_XXXX) = PERCENTRANK.INC([*array of census tracts for variable*], [*individual census tract*], 4)

Percentile ranks for Percentile Income, were calculated as:

Percentile Income (EPL_PCI) = 1 - PERCENTRANK.INC([*array of census tracts for variable*], [*individual census tract*], 4)

Socioeconomic Vulnerability Sum (SPL_THEME1): Sum of variable percentiles for Socioeconomic Status theme.

$$SPL\_THEME1 = EPL\_POV + EPL\_UNEMP + EPL\_PCI + EPL\_NOHSDP$$

Percentile Below Poverty (EPL_POV): Percentile percentage of persons below poverty estimate.

Percentile Unemployed (EPL_UNEMP): Percentile percentage of civilians (age 16+) unemployed estimate

Percentile Income (EPL_PCI): Percentile per capita income estimate.

No High School Diploma (EPL_NOHSDP): Percentile percentage of persons with no high school diploma (age 25+) estimate.

Household Composition and Disability Sum (SPL_THEME2): Sum of variable percentiles for Household Composition and Disability theme.

$$SPL\_THEME2 = EPL\_AGE65 + EPL\_AGE17 + EPL\_DISABL + EPL\_SNGPNT$$

Percentile Aged 65 or Older (EPL_AGE65): Percentile percentage of persons aged 65 and older estimate.

Percentile Aged 17 or Younger (EPL_AGE17): Percentile percentage of persons aged 17 years and younger estimate.

Percentile Civilian with a Disability (EPL_DISABL): Percentile percentage of civilian noninstitutionalized population with a disability.

Percentile Single-Parent Households (EPL_SNGPNT): Percentile percentage of single parent households with children under 18 estimate.

Minority Status and Language Sum (SPL_THEME3): Sum of variable percentiles for Minority Status and Language theme.

$$SPL\_THEME3 = EPL\_MINTRY + EPL\_LIMENG$$

Percentile Minority (EPL_MINRTY): Percentile percentage minority (all persons except white, non-Hispanic) estimate.

Percentile Speak English "Less than Well" (EPL_LIMENG): Percentile percentage of persons (age 5+) who speak English "less than well" estimate.

Housing and Transportation Sum (SPL_THEME4): Sum of variable percentiles for Housing and Transportation theme.

$$SPL\_THEME4 = EPL\_MUNIT + EPL\_MOBILE + EPL\_CROWD + EPL\_NOVEH + EPL\_GROUPQ$$

Percentile Multi-Unit Structures (EPL_MUNIT): Percentile percentage housing in structures with 10 or more units estimate.

Percentile Mobile Homes (EPL_MOBILE): Percentile percentage mobile homes estimate.

Percentile Crowding (EPL_CROWD): Percentile percentage households with more people than rooms estimate.

Percentile No Vehicle (EPL_NOVEH): Percentile percentage households with no vehicle available estimate.

Percentile Group Quarters (EPL_GROUPQ): Percentile percentage of persons institutionalized) and non-institutionalized group quarters.

Themes Percentile Ranks; Tier 2 *(*Flanagan *et al*., 2011; CDC, 2019)**:** Percentile rank was performed on all theme sums in Excel using the function PERCENTRANK.INC with four significant digits. Percentile ranks for each theme sum were calculated as:

Percentile Ranking *XXXX* (RPL_THEME*X*) = PERCENTRANK.INC([*array of census tracts for theme*], [*individual census tract*], 4)

Percentile Ranking for Socioeconomic Vulnerability Theme (RPL_THEME1):

RPL_THEME1 = PERCENTRANK.INC([array of census tracts for **SPL_THEME1**], [individual census tract], 4)

Percentile Ranking for Household Composition and Disability Theme (RPL_THEME2):

RPL_THEME2 = PERCENTRANK.INC([array of census tracts for **SPL_THEME2**], [individual census tract], 4)

Percentile Ranking for Minority Status and Language Theme (RPL_THEME3):

RPL_THEME3 = PERCENTRANK.INC([array of census tracts for **SPL_THEME3**], [individual census tract], 4)

Percentile Ranking for Housing and Transportation Theme (RPL_THEME4):

RPL_THEME4 = PERCENTRANK.INC([array of census tracts for **SPL_THEME4**], [individual census tract], 4)

Overall Vulnerability Percentile Rank; Tier 3 (Flanagan *et al*., 2011; CDC, 2019)**:** Percentile rank was performed on the sum of all theme's percentile ranking sums (e.g. RPL_THEME*X*) in Microsoft Excel using the function PERCENTRANK.INC with four significant digits.

Overall Sum of Themes (SPL_THEMES): Sum of theme percentile ranking.

$$SPL\_THEMES = SPL\_THEME1 + SPL\_THEME2 + SPL\_THEME3 + SPL\_THEME4$$

Overall Percentile Ranking (RPL_THEMES):

RPL_THEMES = PERCENTRANK.INC([array of census tracts for **SPL_THEMES**], [individual census tract], 4)

Flags

***Note - Flags are not presented in the Index's online platform. Flagging data are, however, included in the downloadable dataset at https://services.arcgis.com/tKsJAIiLjd90D5q2/arcgis/rest/services/RPL_THEMES/FeatureServer.*

Flags identify the census tracts where the variables, themes, and overall vulnerability percentiles are greater than 90, i.e. tracts that are more vulnerable than 90% of the census tracts in Indiana (Flanagan *et al*., 2011; CDC, 2019). Flagging was performed on each variable percentile rank (EPL_XXXX) in Excel. The flag count was then aggregated for each theme and then overall.

F_*XXXX* = EPL_*XXXX* >= 0.90; returns TRUE (1) or FALSE (0)

F_THEME*X* = F_*XXXX* + F_*XXXX* + … + F_*XXXX*

F_TOTAL = F_THEME1 + F_THEME2 + F_THEME3 + F_THEME4

Sum of Flags for Socioeconomic Status Theme (F_THEME1):

$$F\_THEME1 = F\_POV + F\_UNEMP + F\_PCI + F\_NOHSDP$$

Flag Below Poverty (F_POV): Flag if the percentage of persons in poverty is in the 90th percentile.

Flag Unemployed (F _UNEMP): Flag if the percentage of civilian unemployed is in the 90th percentile.

Flag Income (F _PCI): Flag if the per capita income is in the 90th percentile.

90th percentile for per capita income includes the census tracts that fall within the bottom 10 percent of per capita income across the state. See page 30 for the definition.

Flag No High School Diploma (F _NOHSDP): Flag if the percentage of persons with no high school diploma is in the 90th percentile.

Sum of Flags for Household Composition and Disability Theme (F_THEME2):

$$F\_THEME2 = F\_AGE65 + F\_AGE17 + F\_DISABL + F\_SNGPNT$$

Flag Aged 65 or Older (F _AGE65): Flag if the percentage of persons aged 65 and older is in the 90th percentile.

Flag Aged 17 or Younger (F _AGE17): Flag if the percentage of persons aged 17 years or younger is in the 90th percentile.

Flag Civilian with a Disability (F _DISABL): Flag if the percentage of persons with a disability is in the 90th percentile.

Flag Single-Parent Households (F _SNGPNT): Flag if the percentage of single parent households is in the 90^{th} percentile.

Sum of Flags for Minority Status and Language Theme (F_THEME3): SVI theme comprising race, ethnicity, and English-language proficiency variables.

$$F\_THEME3 = F\_MINTRY + F\_LIMENG$$

Flag Minority (F _MINRTY): Flag if the percentage of minority is in the 90^{th} percentile.

Flag Speak English "Less than Well" (F _LIMENG): Flag if the percentage those with limited English is in the 90^{th} percentile.

Sum of Flags for Housing and Transportation Theme (F_THEME4):

$$F\_THEME4 = F\_MUNIT + F\_MOBILE + F\_CROWD + F\_NOVEH + F\_GROUPQ$$

Flag Multi-Unit Structures (F _MUNIT): Flag if the percentage households in multi-unit housing is in the 90^{th} percentile.

Flag Mobile Homes (F _MOBILE): Flag if the percentage of mobile homes in the 90^{th} percentile.

Flag Crowding (F _CROWD): Flag if the percentage of crowded households is in the 90^{th} percentile.

Flag No Vehicle (F _NOVEH): Flag if the percentage of households with no vehicles is in the 90^{th} percentile.

Flag Group Quarters (F _GROUPQ): Flag if the percentage of persons in group quarters is in the 90^{th} percentile.

Sum of Flags for All Four Themes (F_TOTAL):

$$F\_TOTAL = F\_THEME1 + F\_THEME2 + F\_THEME3 + F\_THEME4$$

Sum of flags for Socioeconomic Status theme (F_THEME1).

Sum of flags for Household Composition and Disability theme (F_THEME2).

Sum of flags for Minority Status and Language theme (F_THEME3).

Sum of flags for Housing and Transportation theme (F_THEME4).

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III. Readiness Assessment

The Readiness Assessment questions outline actions local governments can take to prepare their communities for climate change impacts specific to Indiana. The Assessment does not provide *every* action that could be taken to prevent or alleviate climate change impacts; instead, the Assessment includes actions that have been identified as the most useful based on feasibility, relevance in the state of Indiana, the technologies available, and the ability of an action to address cascading impacts. All of the actions included have been implemented by one or more local governments in the Midwest and are considered first order responses. The sections below describe the process used for developing the actions and questions in the Readiness Assessment.

Readiness Questions

The readiness questions were developed by identifying the climate change impacts relevant in the state of Indiana, conducting a risk pathway assessment of the state's climate change impacts, using the risk pathway assessment to conduct a network analysis and identify the highest order climate change impacts, conducting a literature review of adaptation and mitigation strategies to draft the list of actions and responses, and working with local government beta testers and community and academic experts to refine the action list and responses.

The Indiana Climate Change Impacts Assessment (INCCIA) was used to identify the ways in which Indiana is and will be impacted by climate change. Risk pathways were pulled from the INCCIA reports (Bowling *et al*., 2018; Day *et al*., 2018; Filippelli *et al*., 2018; Höök *et al*., 2018; Phillips *et al.*, 2018; Raymond *et al*., 2018; Reynolds *et al*., 2018; Widhalm *et al*., 2018) and parsed into primary, secondary, and tertiary impacts.

> <u>Example Risk Pathway</u>
> Increased precipitation > Increased human-derived nutrients entering Indiana waterways > Increased total runoff > More algal blooms

The network analysis was performed using Gephi (Bastian *et al*., 2009) on the identified risk pathways to visualize the relationships between the climate change impacts and identify the most significant impacts for Indiana; see Figure 3. The nodes (i.e. circles) of the network represent the climate change impact; the edges (i.e. arrowed lines) connect subsequent impacts, with the arrow signifying the direction of the impact. The size of the impact node is proportional to the number of subsequent impact nodes. The larger the node, the more subsequent impacts. The colors of the nodes represent subnetworks within the greater network, i.e. impacts more densely connected to each other than other impacts (Blondel *et al*., 2008).

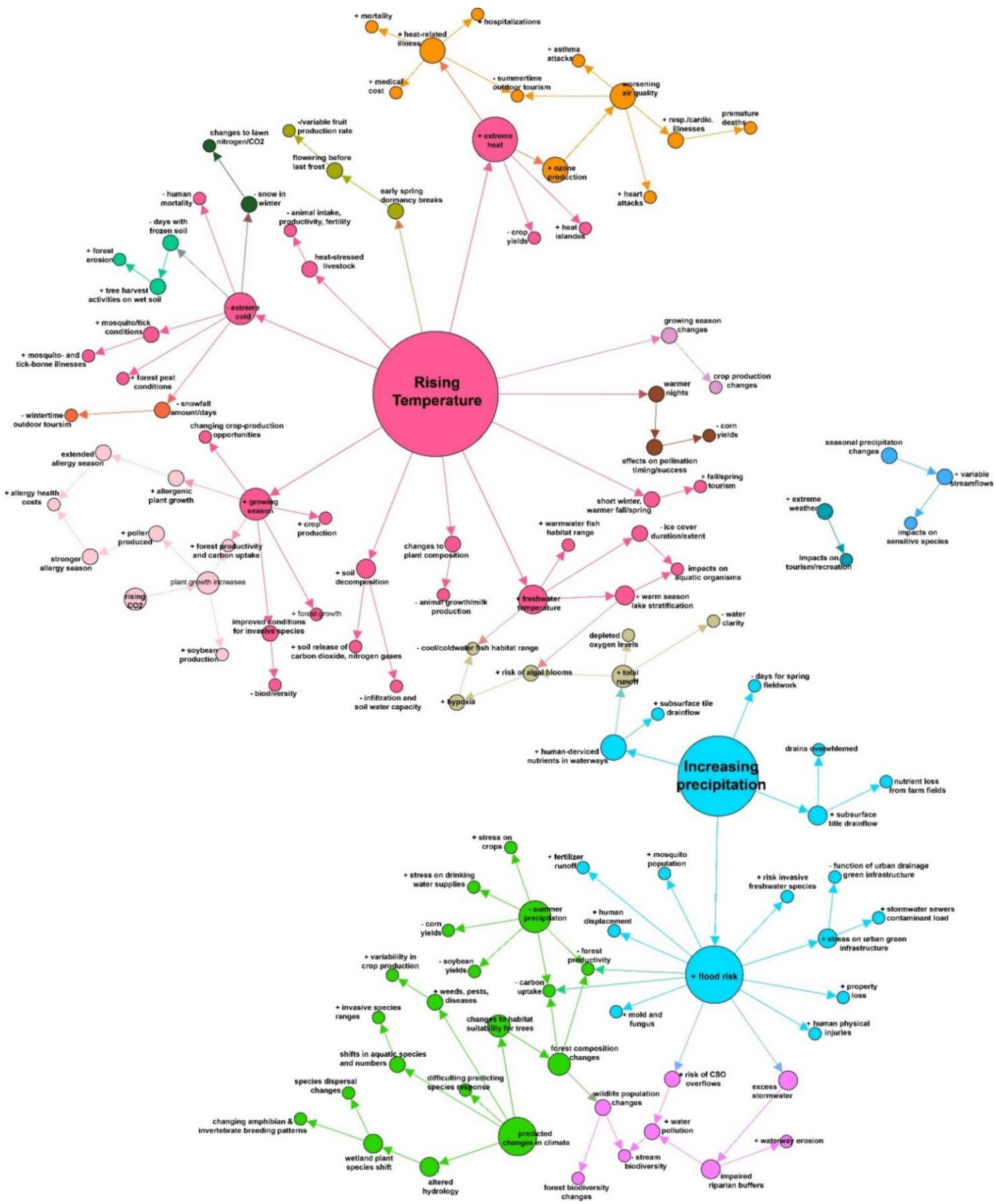

Figure 3. Risk Pathway Analysis of the Indiana Climate Change Impacts Assessment reports that had been released by December 2018. Nodes are climate change impacts, edges connect subsequent impacts, arrows signify direction of impact, and the node color represents more highly connected impacts.

Following the network analysis, higher order impacts (i.e. impacts that lead to cascading impacts, represented by the larger nodes in Figure 3) were narrowed down to those that are able to be addressed by a local government in Indiana and have a clear negative climate impact. Some climate impacts may have beneficial impacts, or both positive and negative impacts. The analysis used to develop the Hoosier Resilience Index includes only climate impacts with clearly negative impacts. To fill in the gaps, this list of impacts was supplemented and refined through a review of impacts in other documents (Indiana Department of Homeland Security, 2019; Midwest Economic Policy Institute, 2018; U.S. Global Change Research Program, 2018) and using input from academic, government agency, nonprofit, and general public focus groups.

Following the development of the list of impacts included in the Readiness Assessment, adaption and mitigation actions were identified through a review of best practice literature (See the Readiness Assessment References section below) and individual expertise from academics and practitioners. The questions were drafted by staff at the Environmental Resilience Institute, using the references listed in the previous sentence. Feedback on the initial set of Readiness Assessment questions was incorporated from local government employees in Indiana, and by experts in academia and the nonprofit sector.

See a full list of all Readiness Assessment questions.

Readiness Scores

Three scores are calculated for each county, incorporated city, and incorporated town that completes the Readiness Assessment: extreme heat readiness score, extreme precipitation readiness score, and a floodplain readiness score.

Score Calculation

Scores are calculated for each community based on:

- A community's responses to the questions in their tailored Readiness Assessment. Each unique Assessment includes questions that are relevant to the responding community based on size, type of government, and location in relation to the floodplain.
- An action's relevance to lessening the impact of the corresponding vulnerability – extreme heat, extreme precipitation, and floodplain management. For example, the action, "Identify housing and businesses most susceptible to river flooding and minimize or eliminate the impact" helps lessen the impact of extreme precipitation and river flooding, which takes place in floodplains. This action is relevant to extreme precipitation and floodplain management, but not to extreme heat.

Extreme Heat Readiness Score (S_{EH}): Score between 1 and 10 that conveys a community's readiness for extreme heat events based on responses to the questions in the Readiness Assessment.

$10\left(\frac{1}{n_{EH}*5}\sum_{i=1}^{n_{EH}} R_{L,EH,i}\right)$: sum (Σ) of readiness responses (R) for location, *L*, extreme heat, *EH*, for question, *i*, divided by the number of applicable questions relevant to extreme heat, n_{EH}, times the best possible question score (5), multiplied by 10 to achieve a score between 1 and 10.

L = Each Indiana community

EH = Extreme heat

i = Question 1,2,3…79

n_{EH} = Number of applicable questions relevant to extreme heat readiness.

$$S_{EH} = \text{Extreme Heat Readiness Score}$$
$$= 10\left(\frac{1}{n_{EH}*5}\sum_{i=1}^{n_{EH}} R_{L,EH,i}\right) = 10\left(\frac{R_{L,EH,1}+R_{L,EH,2}+\cdots+R_{L,EH,n}}{n_{EH}*5}\right)$$
$$R = \text{Readiness Question Response}$$

Extreme Precipitation Readiness Score (S_{EP}): Score between 1 and 10 that conveys a community's readiness for extreme precipitation based on responses to the questions in the Readiness Assessment.

$10\left(\frac{1}{n_{EP}*5}\sum_{i=1}^{n_{EP}} R_{L,EP,i}\right)$: sum (Σ) of readiness question responses (R) for location, *L*, extreme precipitation, *EP*, for question, *i*, divided by the number of applicable questions relevant to extreme precipitation, n_{EP}, times the best possible action question score (5), multiplied by 10 to achieve a score between 1 and 10.

L = Each Indiana community

EP = Extreme precipitation

i = Question 1,2,3…79

n_{EP} = Number of applicable questions relevant to extreme precipitation readiness.

$$S_{EP} = \text{Extreme Precipitation Readiness Score}$$
$$= 10\left(\frac{1}{n_{EP}*5}\sum_{i=1}^{n_{EP}} R_{L,EP,i}\right) = 10\left(\frac{R_{L,EP,1}+R_{L,EP,2}+\cdots+R_{L,EP,n}}{n_{EP}*5}\right)$$
$$R = \text{Readiness Question Response}$$

Floodplain Land Use Readiness Score (S_{FL}): Score between 1 and 10 that conveys a community's readiness for river flooding based on responses to the questions in the Readiness Assessment.

$10\left(\frac{1}{n_{FL}*5}\sum_{i=1}^{n_{FL}} R_{L,FL,i}\right)$: sum (Σ) of readiness responses (R) for location, *L*, floodplain land use, *FL,* for question, *i*, divided by the number of applicable questions relevant to floodplain land use, n_{FL}, times the best possible action question score (5) , multiplied by 10 to achieve a score between 1 and 10.

L = Each Indiana community

FL= Floodplain land use

i = Question 1,2,3…79

n_{FL} = Number of applicable questions relevant to river flooding readiness.

$$S_{FL} = \ Floodplain\ Land\ Use\ Readiness\ Score$$

$$= 10\left(\frac{1}{n_{FL}*5}\sum_{i=1}^{n_{FL}} R_{L,FL,i}\right) = 10\left(\frac{R_{L,RL,1}+R_{L,FL,2}+\cdots+R_{L,FL,n}}{n_{FL}*5}\right)$$

$$R = Readiness\ Question\ Response$$

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IV. Data Links and Data References

Hoosier Resilience Index Data Links

The Index's excel files, shapefiles, and metadata are publicly available. Detailed information on attributes, variable names, and definitions can be found in the *Entity_and_Attribute_Information* sections in the metadata linked below.

Base Map, Indiana Counties and Incorporated Areas Boundaries

Extreme Heat

- Extreme Heat Events, Current
- Extreme Heat Events, Medium Emissions Scenario ($RCP_{4.5}$)
- Extreme Heat Events, High Emissions Scenario ($RCP_{8.5}$)

Extreme Precipitation

- Extreme Precipitation Events, Current
- Extreme Precipitation Events, Medium Emissions Scenario ($RCP_{4.5}$)
- Extreme Precipitation Events, High Emissions Scenario ($RCP_{8.5}$)

Floodplain Land Use

- Developed Land within the Floodplain by County, 2010
- Land Use Coverage, Groups
- Land Use Coverage, Sub-groups (Classes)
- 100-Year Floodplain
- 500-Year Floodplain

Social Vulnerability

- Overall Social Vulnerability
- Household Composition and Disability Vulnerability
- Housing and Transportation Vulnerability
- Minority Status and Language Vulnerability
- Socioeconomic Vulnerability

Climate Vulnerability Data Source References

Extreme Heat and Precipitation

The projected data used to calculate *Extreme Heat* and *Extreme Precipitation* were provided by Alan Hamlet (University of Notre Dame) and the Purdue Climate Change Research Center, which coordinated the Indiana Climate Change Impacts Assessment, using an ensemble of 10 statistically downscaled global climate model simulations.

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