1. WHAT IS A VULNERABILITY ASSESSMENT

As the climate continues to change, communities across the U.S. and the world are asking, "How are these changes already affecting my community?" and "What local impacts might we experience from future changes in climate?" To help answer these questions, communities are using a tool called a vulnerability assessment. A vulnerability assessment helps stakeholders identify:

1. What changes in climate are projected to happen and what those changes could mean in terms of local **impacts**,
2. The level of **exposure** the community has to potential changes,
3. How **sensitive** the various city and community systems are to projected changes in climate, and
4. What **capacity** those systems have to adapt.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2014).

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2014).

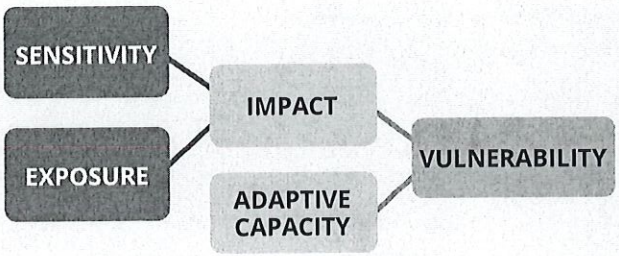
Impact: Effects on natural and human systems such as lives, livelihoods, health, ecosystems, economics, societies, cultures, services, and infrastructure (IPCC, 2014).

Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Figure 1 provides a graphical depiction of how exposure, sensitivity, impacts, and adaptive capacity all combine to create vulnerability.

Figure 1: Graphical depiction of the various elements of vulnerability

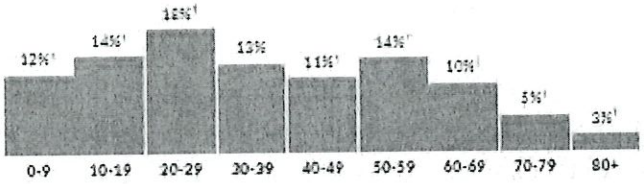


Once completed, the results of a vulnerability assessment can be used to inform the types of actions a community should take to reduce vulnerabilities or seize on potential opportunities.

Currently, most existing vulnerability assessment guidance and tools have either limited or no discussion regarding the important role that a community's social and economic characteristics play in determining local vulnerability. Because of the critical importance social dynamics play in shaping our local community, the City of Dayton partnered with fellow Midwestern cities, the Huron River Watershed Council, the Great Lakes Integrated Sciences and Assessment (GLISA), and Headwaters Economics to develop a revised vulnerability assessment template that assesses our community's social, physical, cultural, economic, and environmental vulnerability to climate change. The document you are currently reading is a spinoff of this work, focused explicitly on understanding the vulnerability of Dayton's stormwater system to climate change, socio-economic considerations, and local landscape features. We will use this document to help ensure that all our residents are safe, resilient, and thriving both today and in a climate-altered future.

2. SOCIO-ECONOMIC PROFILE OF DAYTON

Table 1: Section Summary[1]

Population by age range	Age	Income	
	33.4 Median age	$18,964 Per capita income	$30,643 Median household income

Dayton is a unique and diverse city. It is this diversity that makes us great. In 2017, 39.3% identified as Black or African American, 0.3% identified as American Indian, and 5.0% identified as "Other Races". Dayton is also home to immigrants from more than 100 countries.

In order to fully understand how the City of Dayton is resilient or vulnerable to climate change, we need to take a deep look at the social characteristics that make up our community. Using the Socio-Economic Data Mapper (Data Mapper) tool from Headwaters Economics, we analyzed ten characteristics that help explain our local vulnerability:

A. Percent of population over 65

B. Percent of population under 5

C. Percent of community in poverty

D. Percent of population with limited English proficiency

E. Percent of non-white population

F. Percent of households receiving public assistance

G. Percent of households where mortgage is greater than 30% of household income

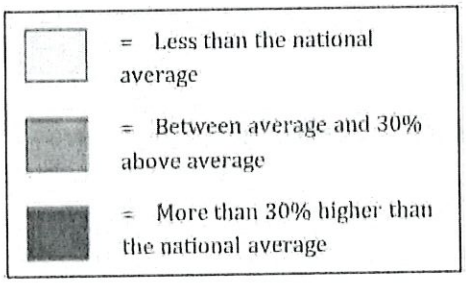
H. Percent of disabled

I. Percent of renters

J. Percent of population without a high school diploma

Note for this section

For all maps in this section, tract color is relative to the national average and a 30% increase from average.



A. Percent of population over 65

As of 2017, the City of Dayton had 140,939 residents, 12.6% (17,699) of which were 65 years or older.[2] This is lower than the U.S. national average for residents over 65, which is 14.9%. Of this population, approximately 2,136 (1.5%) are 80 years or older. This figure is important because elderly populations are at increased risk of compromised health related to environmental hazards and climate change. In fact, age is the single greatest risk factor related to illness and death from extreme heat[3] and the elderly are more likely to have pre-existing medical conditions or compromised mobility, which reduces their ability to respond to extreme heat and extreme weather events[4] - which are both likely to become more frequent due to climate change. Finally, the increased likelihood of chronic disease,[5] combined with the fact that older adults are more susceptible to air pollution, which is expected to become worse due to climate change, makes them a uniquely vulnerable population.[6]

All of these factors combined mean that the elderly require unique and/or additional services compared to younger residents. As such, understanding our community's age profile helps us determine the appropriate types of services and resources needed to ensure all of Dayton's residents are able to survive and thrive in a climate-altered future.

B. Percent of population under 5

As of 2017, 6.4% (9,080) of the City of Dayton's population was under 5 years of age. This is slightly higher than the national average (6.2%).[7] Knowing what percentage of our residents are under the age of five and where they reside, is important because children's developing bodies are particularly sensitive to health problems and environmental stresses,[8] including those associated with climate change. Children also spend more time outside and have faster breathing rates than adults, so they are more at risk for respiratory problems related to things such as ground level ozone, airborne particulates, and allergens:[9] all of which can be exacerbated by climate change. Moreover, because their immune systems are not fully developed, children are more susceptible to infectious diseases,[10] including those that spread during natural disasters.

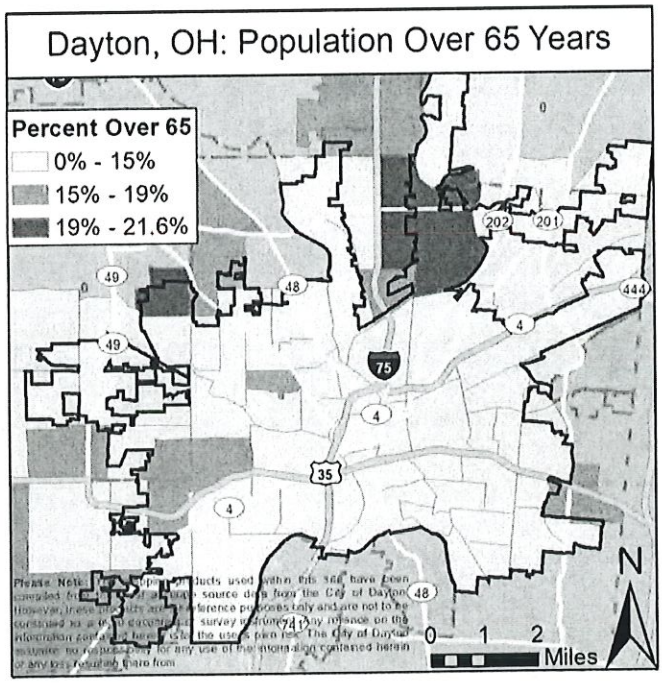


Figure 2: Census Tracts in Dayton where the population 65 years of age or older is higher than the national average (14.9% is the national average). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

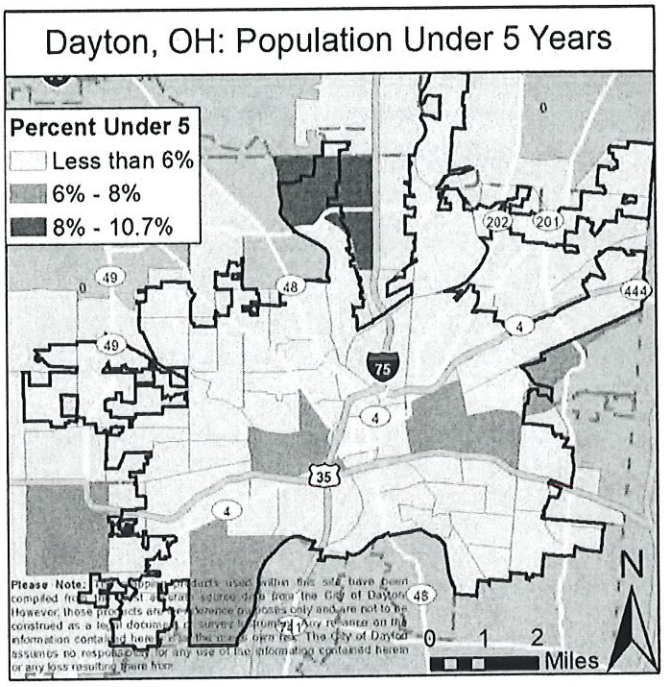


Figure 3: Census Tracts in Dayton where the population under 5 years of age is higher than the national average (6.2% is the national average). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

Focusing our efforts on reducing youth vulnerability makes sense for a number of reasons, including the fact that childhood lays the foundation for lifelong health, meaning that poor health during childhood can significantly increase the likelihood of problems throughout adulthood.[11] With the rising cost of health care in the U.S., ensuring that we have a healthy, productive community is pivotal to not only our wellbeing, but also our social structure and our economy.

As we seek to ensure our youth are resilient to climate change, we need to pay particular attention to youth that are living in poverty, as children living in poverty are less likely to receive high-quality health care, meaning that they may be especially sensitive to changes in climate and the ensuing health impacts.[12] Children living in poverty are also more likely to live in vulnerable areas, including areas that have poor air quality, limited transit options, and homes that are less resilient to changing weather patterns. As we move forward with building community-wide resilience, care must be taken to ensure that children, especially those in poverty, are prioritized.

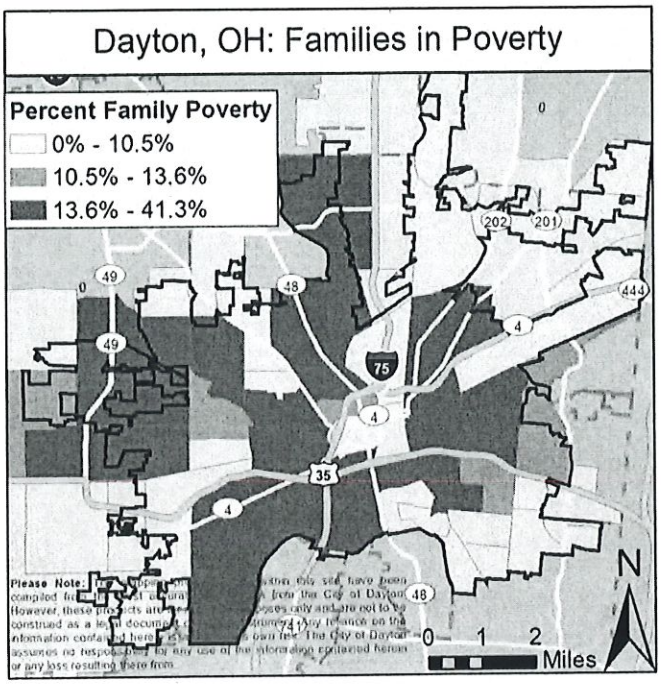


Figure 4: Census Tracts in Dayton where the number of families living in poverty is higher than the national average (10.5% is the national average). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

C. Percent of community in poverty

As of 2017, 42,382 City of Dayton residents were living in poverty; 21,110 were classified as living in deep poverty (meaning they earn less than ½ of the federal poverty level). This represents 32.7% of the City's population that is living in poverty and 16.3% that is living in deep poverty. In addition, data shows that 1.8% of the City's residents (2,395) are both living in poverty and over the age of 65. All of these numbers are significantly above US national averages.[13]

The above information focuses on the number of individuals living in poverty. In addition, we also analyzed the number of families living in poverty. As of 2017, 8,455 families (28.5%) in Dayton lived in poverty. Of these, 6,804 had at least one child residing in their household, and 5,014 were households with a single mother (16.9% of all households). This rate of family poverty is higher than the national average (10.5% for families in poverty and 4.8% for single mother families in poverty).

Understanding the percent and location of those living in poverty is critical because low income is one of the strongest predictors of compromised health as well as an individual's ability to recover from disasters.[14] Moreover, we know that natural disasters disproportionately impact low-income people because of things such as inadequate housing, social exclusion, a diminished ability to evacuate, lack of property insurance, and more acute emotional stress.[15] In addition, research has shown that low-income people are more likely to be overlooked during the emergency response period following a disaster.[16] Low-income populations are also more likely to live or work in areas with greater exposure to environmental hazards, including working in jobs that require outdoor labor.[17]

Income inequality within a community is also associated with poor health outcomes. Residents in low-income neighborhoods tend to have higher incidences of asthma, depression, diabetes, heart conditions, and emotional stress compared to higher-income neighborhoods.[18] Low-income households also have to make lifestyle compromises in order to make ends meet, such as choosing unhealthy foods, less food, substandard housing, or delayed medical care.[19] Having limited income may also mean that it is simply too expensive to run fans, air conditioners, or heaters to manage

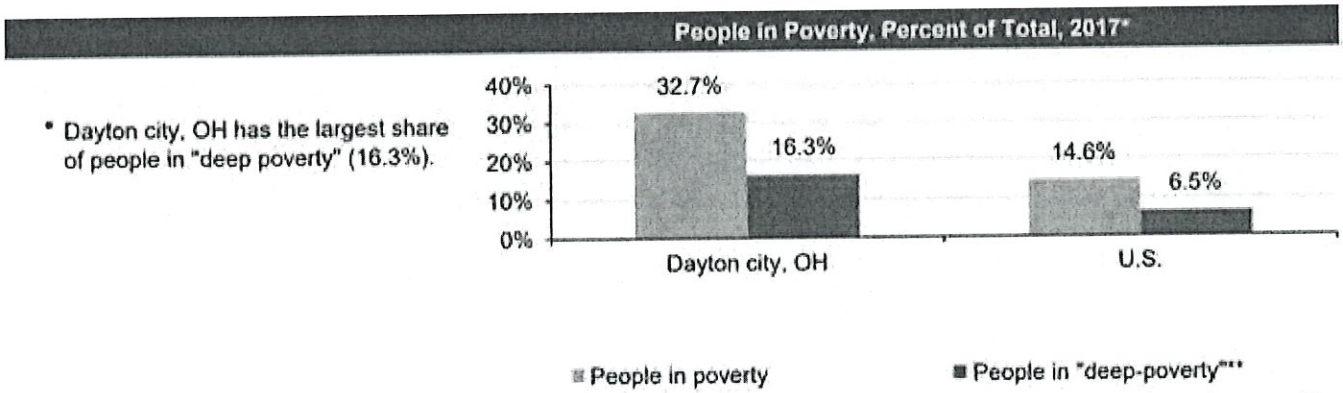


Figure 5: Percentage of residents living in poverty. This table was taken from the Populations at Risk Tool created by Headwaters Economics (accessible here).

indoor living temperatures, not to mention that many low-income residences are located in high crime areas, meaning that residents may feel unsafe opening their windows.[20] Finally, low-income individuals are least likely to have health insurance, which further exacerbates their vulnerability to the negative health impacts associated with climate change such as deteriorating air quality, higher incidences of asthma, and increased allergens.[21]

D. Percent of population with limited English proficiency

According to the US Census Bureau, in 2017, 1.4% of the Dayton community did not speak English well (1,909 people). This is lower than the national average (4.5%).[22] Understanding the percentage and location of people with limited English proficiency is important because many, if not most, aspects of life in the US require basic proficiency in English. For example, knowing about and then accessing emergency services, learning about poverty reduction programs, or accessing health care all necessitate basic English proficiency. Research has found that limited English proficiency can:

- Limit a person's ability to effectively act during emergencies;[23]
- Make it harder to follow directions and interact with agencies, thereby limiting the amount of support available to respond to and recover from disasters of all types;[24]
- Make it harder for people to get higher wage jobs;[25] and
- Result in isolation from other segments of the US population, and social isolation can be a serious health risk.[26]

Because of these factors, it is important that we identify who within our population has limited English proficiency and work with trusted partners to ensure these populations have access to the information, tools, and resources they need to build resilience.

E. Percent of non-white population

As of 2017, 44.6% of the population in Dayton (62,842) identified as non-white. This is higher than the national average (27.0%). Of the total population of Dayton, 39.3% (55,410) identified as Black or African American, 3.9% (5,563) identified as Hispanic,[27] 0.3% (444) identified as

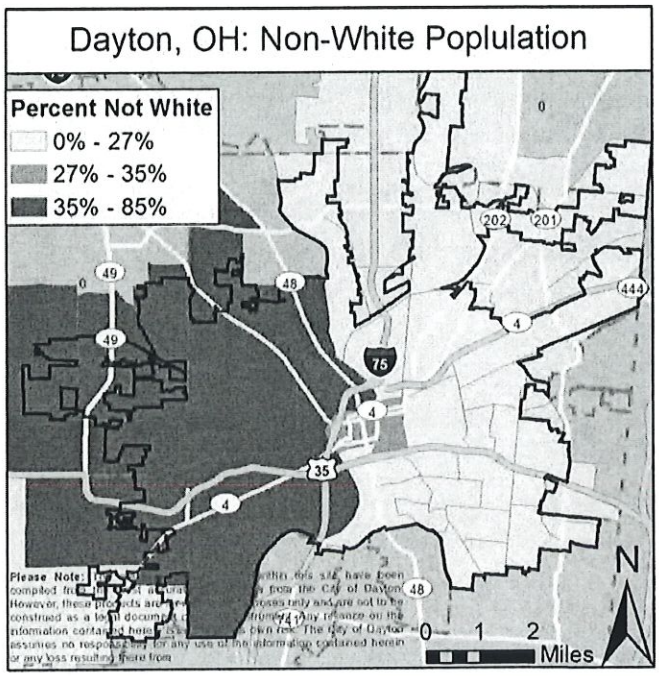


Figure 6: Census Tracts in Dayton where the population that identifies as non-white is greater than the national average (27%). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

American Indian, and 5.0% (6,988) identified as "Other Races".[28]

This information is important because race and ethnicity strongly correlate with disparities in health, exposure to environmental pollution, and vulnerability to natural hazards, including climate-related natural hazards.[29] More specifically:

- Research consistently finds race-based environmental inequities across many variables, including the tendency for minority populations to live closer to noxious facilities and Superfund sites, and to be exposed to pollution at greater rates than whites. [30]
- Across races, the rates of preventable hospitalizations are highest among black and Hispanic populations. Preventable hospital visits often reflect inadequate access to primary care. These types of hospital visits are also costly and inefficient for the health care system.[31] Relative to other ethnicities and races, Hispanics and Blacks/African Americans are less likely to have health insurance, but rates of uninsured are dropping for both groups.[32]
- Compared to other races, Blacks/African Americans have higher rates of infant mortality, homicide, heart

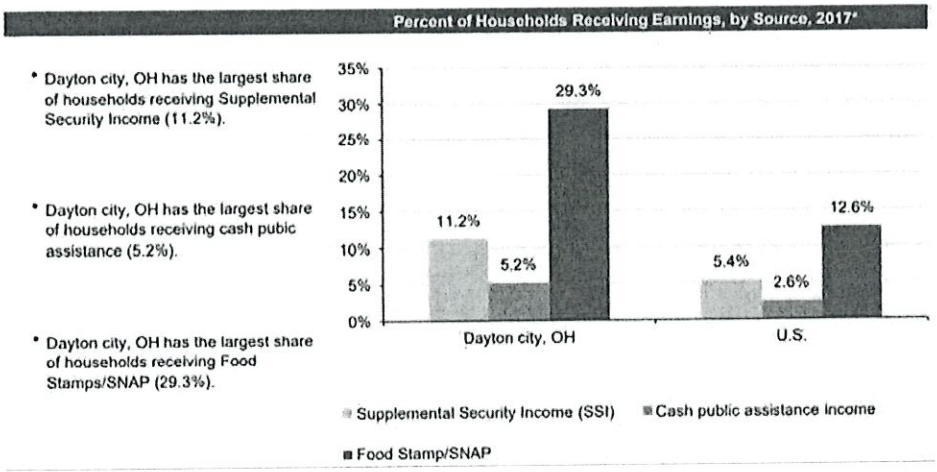


Figure 7: Percentage of households in Dayton and in the U.S. that receive three types of public assistance.

disease, stroke, and heat-related deaths.[33]

- Hispanics have higher rates of diabetes and asthma, compared to other ethnicities.[34]
- Minority communities often have less access to parks and nutritious food, and are more likely to live in substandard housing, all of which can negatively impact health outcomes.[35]
- Minorities tend to be particularly vulnerable to disasters and extreme heat events. This is due to language differences, housing patterns, variations in the quality of housing, community isolation, and cultural barriers.[36]
- Blacks/African Americans and Hispanics, two segments of the population that are currently experiencing poorer health outcomes, are an increasing percentage of the U.S. population and our local community.[37]

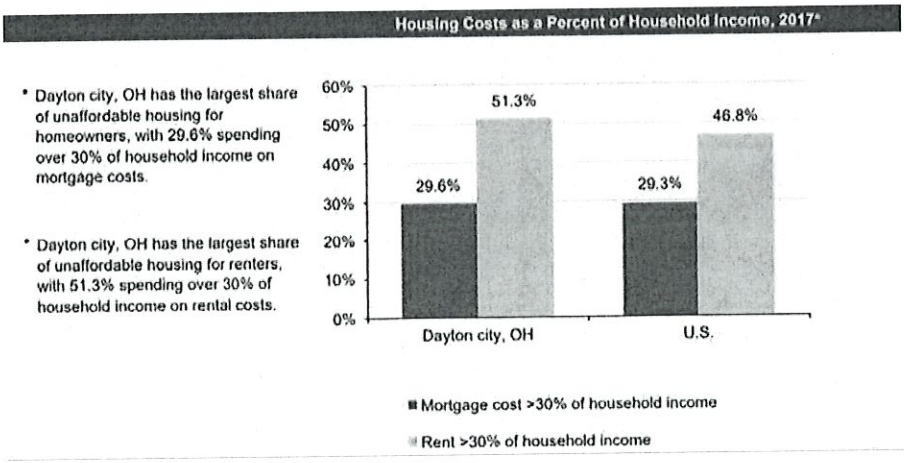
Given these realities, it is important that the City of Dayton ensures that we effectively integrate the needs, perspectives, and lived realities of our population into our efforts to enhance resilience.

F. Percent of households receiving public assistance

As of 2017, 16,910 households within Dayton (29.3%) received Food Stamps/SNAP assistance. This rate of Food Stamp/SNAP assistance is significantly higher than the national average, which is 12.6% of all U.S. households.[38] While this isn't the only form of public assistance, we have chosen Food Stamps/SNAP assistance as our indicator of public assistance because it is more widely known than the other types of assistance and, as such, there is a higher likelihood that at-need households are getting this assistance compared to the more obscure forms of public assistance.

Understanding the percentage and location of residents receiving public assistance is important because this information is indicative of households living in poverty or households with insufficient resources. For example, in 2011, families receiving public assistance spent, on average, 77% of their household budget to meet the basic

Figure 8: Comparison of the percentage of households in Dayton and the U.S. that spend more than 30% of their income on rental fees or their mortgage.



necessities of housing, food, and transportation,[39] leaving little to accommodate other important needs including disaster preparedness, response, and recovery.

G. Percent of households where mortgage is greater than 30% of household income

As of 2017, 4,807 households (29.6%) in Dayton were paying more than the sustainable 30% of household income towards their mortgage and 15,426 households (51.3%) were paying more than the sustainable 30% of household income towards their rent. Rental costs are slightly above the national average and point to a troubling sign regarding the affordability of housing in Dayton compared to the income being earned. The reason this is important is because the federal government considers families with housing costs that exceed 30% of their income to be "housing-cost burdened"[40] and therefore have less disposable income to spend on other necessities such as food, heating/cooling, transportation, healthcare, etc. Research also shows that those households living in affordable housing (those spending less than 30% of household income on housing) are more stable and less likely to move frequently. This can enhance community vitality and cohesion, an important element of creating a more resilient Dayton. In addition, this stability is linked to several positive health outcomes in children and young adults, such as improved emotional and behavioral problems, fewer unplanned pregnancies, reduced drug use, and a lower risk for depression.[41]

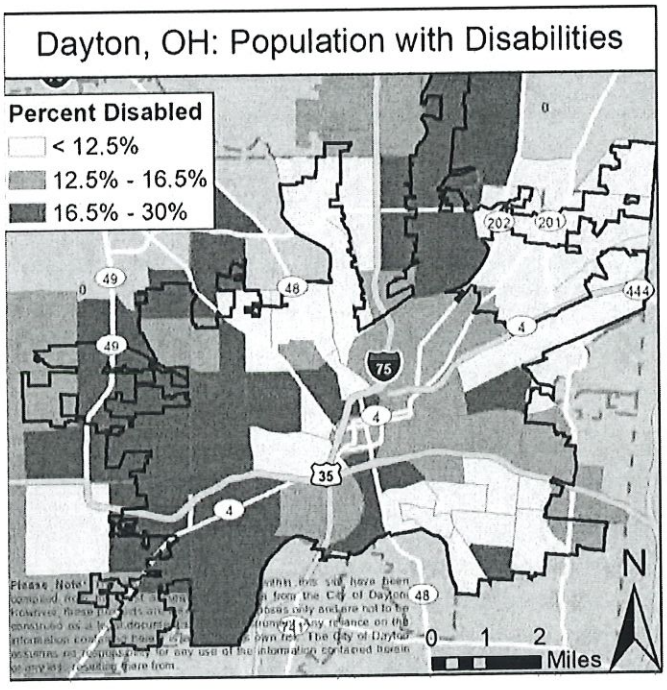


Figure 9: Census Tracts in Dayton where the population that has a disability is higher than the national average (12.5%). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

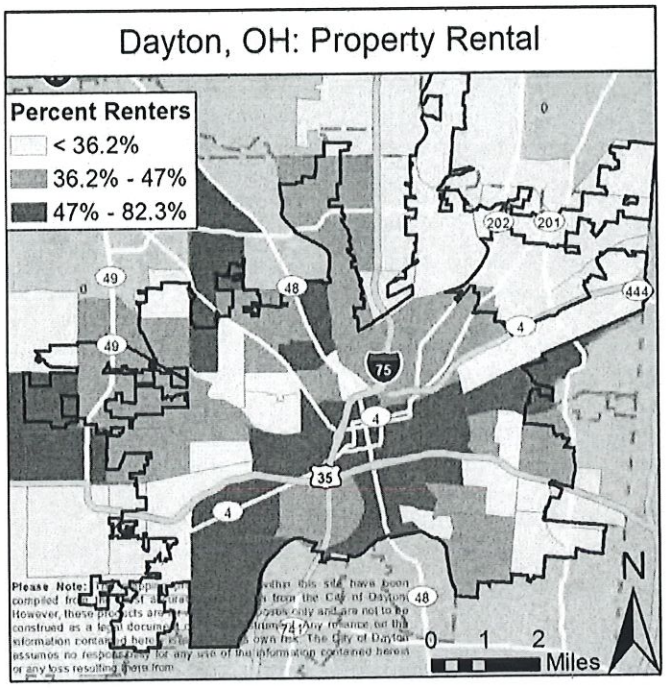


Figure 10: Census Tracts in Dayton where 36.2% or more of the housing units were rentals (36.2% is the national average). Light red indicates an increase from the national average. Darker red indicates areas more than 30% higher than the national average.

As we work to ensure that Dayton is building resilience, we must be aware of the needs of all residents, including those with limited economic resources.

H. Percent of those with disabilities

As of 2017, 25,348 residents of Dayton were living with disabilities. This represents 18.4% of our total population; a figure higher than the national average of 12.6%.[42]

People with disabilities are subject to a series of health complications that are often significantly heightened due to environmental conditions. For example, limited mobility and/or being bed ridden raises heat mortality,[43] limited mobility can significantly delay and/or prevent effective evacuation during times of disaster, and extreme weather events can disrupt one's ability to get medical treatment, which can be disastrous for those with compromised health. These are only some of the heightened vulnerabilities faced by people with disabilities. Because of

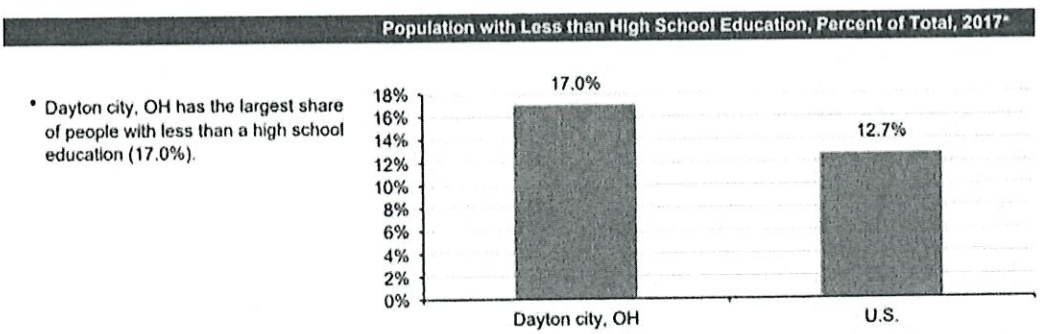


Figure 11: Comparison of individuals in Dayton and the U.S. that have less than a high school education.

this, Dayton is determined to incorporate the needs of this population in our attempts to create a more resilient community.

I. Percent of renters

As of 2017, 52.1% of housing units in Dayton were rentals; an additional 1.4% were mobile homes.[44] This rate is significantly higher than the national average of 36.2% for rentals, but lower than the national average of 5.7% for mobile home residences.

The median home value in Dayton is currently $67,897. This figure represents a decrease in home value of $21,011 based on average home values in 2010.

Understanding what percentage of our population owns a home is important because home ownership contributes to well-being and stability. Home ownership also improves mental health, including increasing self-esteem, creating a heightened sense of control over one's living situation and financial security.[45] On the flip side, the financial stress associated with losing one's home is heightened by people's attachment to place and their neighborhoods.[46]

In terms of renters, studies have repeatedly shown that renters pay a larger proportion of their income in rent. Rental rates have increased over the past 25 years with no sign of abatement.[47] This financial burden is exacerbated by the fact that rental homes are typically not well maintained with conditions such as dampness, mold, and exposure to toxic substances or allergens heightened for those residing in rental units.[48] Because of this, renters may pay even more to heat, cool, or make their rentals more accommodating, further exacerbating the financial impact associated with renting.

J. Percent of population without a high school diploma

As of 2017, 14,954 people in Dayton did not have a high school diploma (17.0%). This is higher than the national average (12.7%),[49] a troubling statistic because high school completion is a common proxy for overall socio-economic circumstances. In particular, lack of education is strongly correlated with poverty and poor health. For example:

- People without a high school degree are more than twice as likely to live in inadequate housing compared to those with some college education.[50]
- Thirty-eight percent of Americans without a high school degree do not have health insurance, compared to 10 percent with a college degree.[51]
- The rate of diabetes is much greater for those without a high school degree. Incidence of this disease is more than double the rate of those who have education beyond high school.[52]

Cumulative Socio-Economic Vulnerability

Combining the findings from each of the previous sections, we were able to create a map denoting some of our most socio-economically vulnerable neighborhoods (Figure 12). This figure identifies all the Census Tracts where the City of Dayton has higher than the national average for all of the following variables: percentage of families in poverty; percentage of people with disabilities; percentage of households that rent; percentage of population under the age of five; percentage of population over the age of 65; and percentage of population that is non-white. To estimate vulnerability we assigned vulnerability numbers to each factor based on the increase from the national average as follows: if it was higher than average but less than 15% above average it was assigned 1; if it was between 15% and 30% higher than average it was assigned 2; and if it was more than 30% higher than average it was assigned 3. Vulnerability scores were calculated in each tract for each of the socio-economic factors, then the scores for all factors were added together in each tract to provide the total socio-

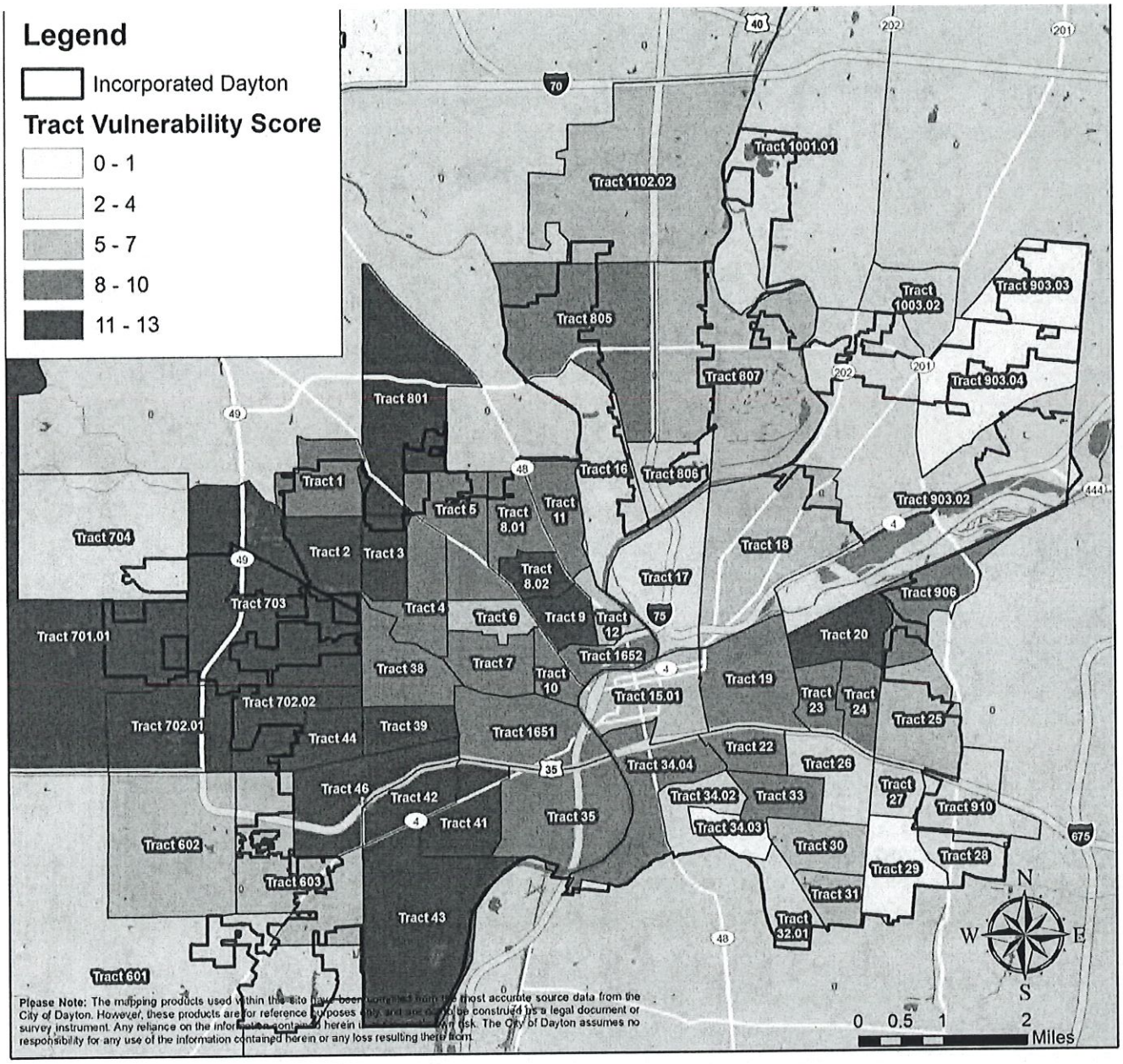


Figure 12: Census Tracts within the City of Dayton that have the highest overall socioeconomic vulnerability. The map highlights all of the Census Tracts with high averages relative to the rest of the City for: percentage of families in poverty; percentage of people with disabilities; and percentage of population that is non-white.

economic vulnerability score for that tract.

This analysis shows a notable pattern, with areas of higher socio-economic vulnerability located in the western portion of the city, with several other vulnerable tracts in the eastern portion of the city, along the Mad River. This pattern is driven by strong spatial trends in non-white population, percent of families in poverty, and populations with disabilities.

In the next section we highlight our exposure to historic, current, and projected futures changes in weather and climate.

3. CLIMATE CHANGE IN THE GREAT LAKES REGION AND DAYTON

In the next section we highlight our exposure to historic, current, and projected future changes in weather and climate.

Great Lakes Regional Summary

- Average air temperature in the Great Lakes region has increased by 2.3°F
- Average air temperature is projected to rise 3°F to 6°F by the mid-21st century.
- Total annual precipitation has increased by 14% in the region with significant intra-regional variation.
- The total volume of rain falling in the most extreme 1% of events has increased 35%.
- Total annual precipitation will likely increase in the future, though types of precipitation will vary (i.e., more winter precipitation in the form of rain).

A. Climate Change Profile for the Great Lakes Region

The climate of cities throughout the Great Lakes region is already changing. Rising temperatures are leading to more storm activity in our atmosphere, helping to fuel extreme weather and increased precipitation. While heat, drought, and other changes associated with climate change remain a concern for the future, many areas of the region are already facing challenges associated with more total precipitation and more frequent downpours.

Temperature

Average annual temperatures in the Great Lakes region have increased by 2.3°F since 1951, faster than the global and national rates. Most of this warming has been observed during the late spring and early winter, and in overnight low temperatures. The average temperature for the Great Lakes region is projected to increase in the future (3°F to 6°F by 2050), and many of the northern parts of the region will likely experience the most change. The region is projected to see increases in the number of hot and very hot days by the end of the 21st century, with projections indicating the region will see 17 to 42 more days over 90°F in an average year compared to the late 20th century.

Precipitation

The Great Lakes region has experienced changes in the frequency, amount, and form of precipitation. Total precipitation has increased by 14% since 1951 across the region, though this change varies within the region. Therefore, more local data should be used where available. In addition, heavy precipitation (over 1.25" of rainfall in 24hrs) has increased rapidly throughout the region. The amount of rain falling in the most extreme events (heaviest 1% of storms) has increased by 35% and these events have generally become more frequent since 1951. Much of the region is projected to experience more average annual precipitation with total amounts ranging from an additional 2 to 6 inches per year by the end of the 21st century. In addition, the Great Lakes themselves are projected to contribute more water vapor to the air. This increase in moisture combined with rising temperatures, which are necessary for storm formation, will likely produce more intense storms in the future.

Climate change will likely accelerate in the future.

The observed trends in temperature, precipitation, and seasonality are projected to continue or accelerate into the future. The rate of warming has been fastest during the winter, with some locations experiencing twice the annual warming rate of the Great Lakes region. Temperatures will continue to warm at a pace near or faster than the current rate, and precipitation will likely continue to increase, though variability and multi-year dry periods should still be anticipated. By mid-century, summer and spring temperatures may have greater increases compared to fall and winter.

Preparing for the next normal, not a new normal.

The climate system is dynamic and will continue to change rapidly due to greenhouse gas emissions and inherent feedback systems. The challenges, priorities, and risks of the current or next generation climate will continually

change and will affect all sectors. Importantly, climate and weather conditions will not change to a new set of static conditions. This means long-term planning efforts in all departments should regularly evaluate climate and be as flexible and adaptable as possible. Assessing vulnerabilities of a city's assets is a first step toward this goal.

The following table summarizes how various climate risk factors in the Great Lakes region are expected to change in the future. The number and direction of arrows indicate the relative projected trend for mid-century and end of century. A single arrow indicates a projected moderate increase or decrease by mid-century, and two arrows indicate a substantial increase or decrease by end of century.

Table 2: Climate Change in the Great Lakes Region

Risk	By Mid Century	By End of Century	Summary
Convective Weather (Severe Winds, Lightning, Tornadoes, Hail)	**Uncertain***	**Uncertain***	While extreme precipitation has increased in the region, specific severe weather types (e.g., tornadoes and hail) have remained relatively stable over time.
Severe Winter Weather (Ice/Sleet Storms, Snow Storms)	**Uncertain***	^	Warmer, shorter winters will reduce the length of winter and winter-related impacts. However, some areas may see more ice, sleet, freezing rain, and wet snow with slightly warmer winter temperatures.
Extreme Heat	^	^^	The number of extremely hot days, those over 95°F and 100°F, will likely increase, though not as fast as in areas farther south. Overnight lows have warmed faster than daytime highs, which may lessen opportunities for relief during heat waves.
Extreme Cold	v	vv	The number of extremely cold days (i.e., days below 10°F) have decreased in the region and are projected to decrease even more in the future.
Dam Failures	^	^^	Stronger and more extreme precipitation events coupled with aging dam infrastructure will increase the probability of dam failure, if appropriate measures are not taken.
Flood Hazards	^	^^	Stronger and more extreme precipitation events will be more likely to overwhelm stormwater infrastructure without appropriate adaptation efforts.
Wildfires	**Uncertain***	^	Summer drought and the number of consecutive dry days may increase in the future, despite more precipitation annually, increasing the risk of wildfires.
Drought	**Uncertain***	^	Summer drought and the number of consecutive dry days may increase in the future.
Infestation	^	^	With shorter winters and longer growing seasons, conditions may become more suitable for invasive species and pests currently found elsewhere and distribute vector-borne illnesses.

**Boxes labeled uncertain reflect either a lack of available data to discern a trend or no apparent trend from existing data.*

The arrows in this table reflect a qualitative assessment made by the project team based on the best available data for the Great Lakes region. While these trends hold true for projections for most of the region, they should not be assumed to hold true for any particular location. Data used to make this assessment is provided by the NOAA Technical Report NESDIS 142-3 and the Third National Climate Assessment.