City of Ames
Climate Vulnerability Assessment

July 2020
Revised August 2020

Prepared by:

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Section 01

Introduction

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Introduction

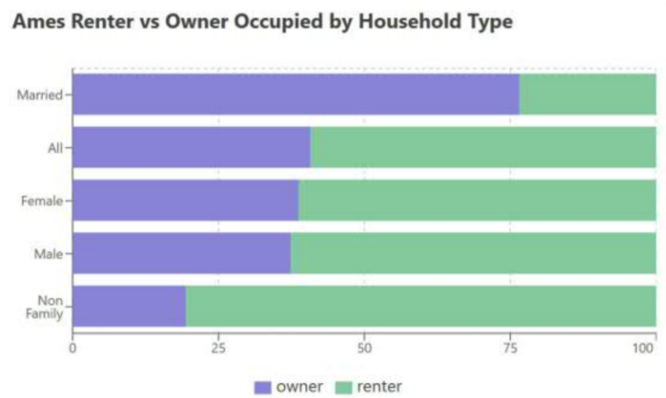
Climate change is a global phenomenon that creates local impacts. Two changes to Iowa's climate are occurring already: shorter winters with fewer cold extremes, and more heavy and extreme precipitation. In the future, there is relatively high confidence that those two changes will continue to increase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

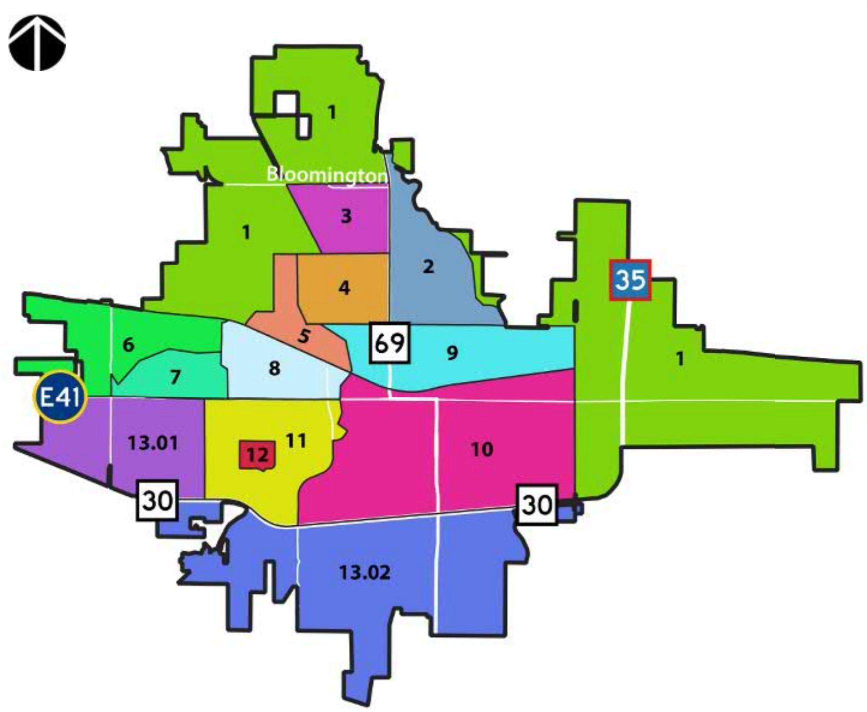
While the science behind climate change is complex, many of the solutions to reducing impacts are already a part of Ames municipal government expertise. In many instances, responding to climate change does not require large scale changes to municipal operations, but simply requires adapting exiting plans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

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

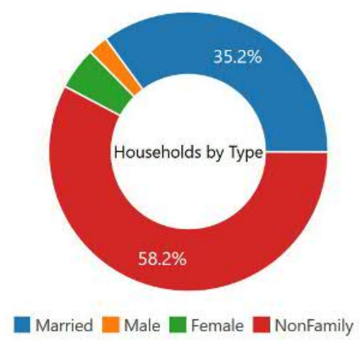
City of Ames

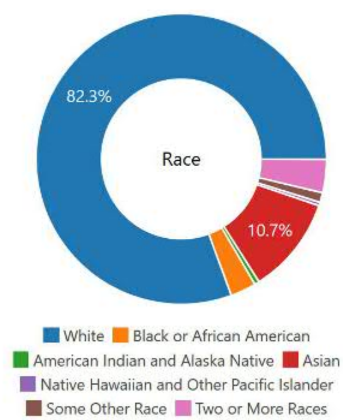
Area	24.3 sq miles 15,532 Acres
Parks, Recreation & Preserves (1997)	1,230 Acres
Population (2018)	66,498
Households (2017)	25,123
Employment (2017)	36,233





Overview Of Census Tracts





What is Climate Change Vulnerability?

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

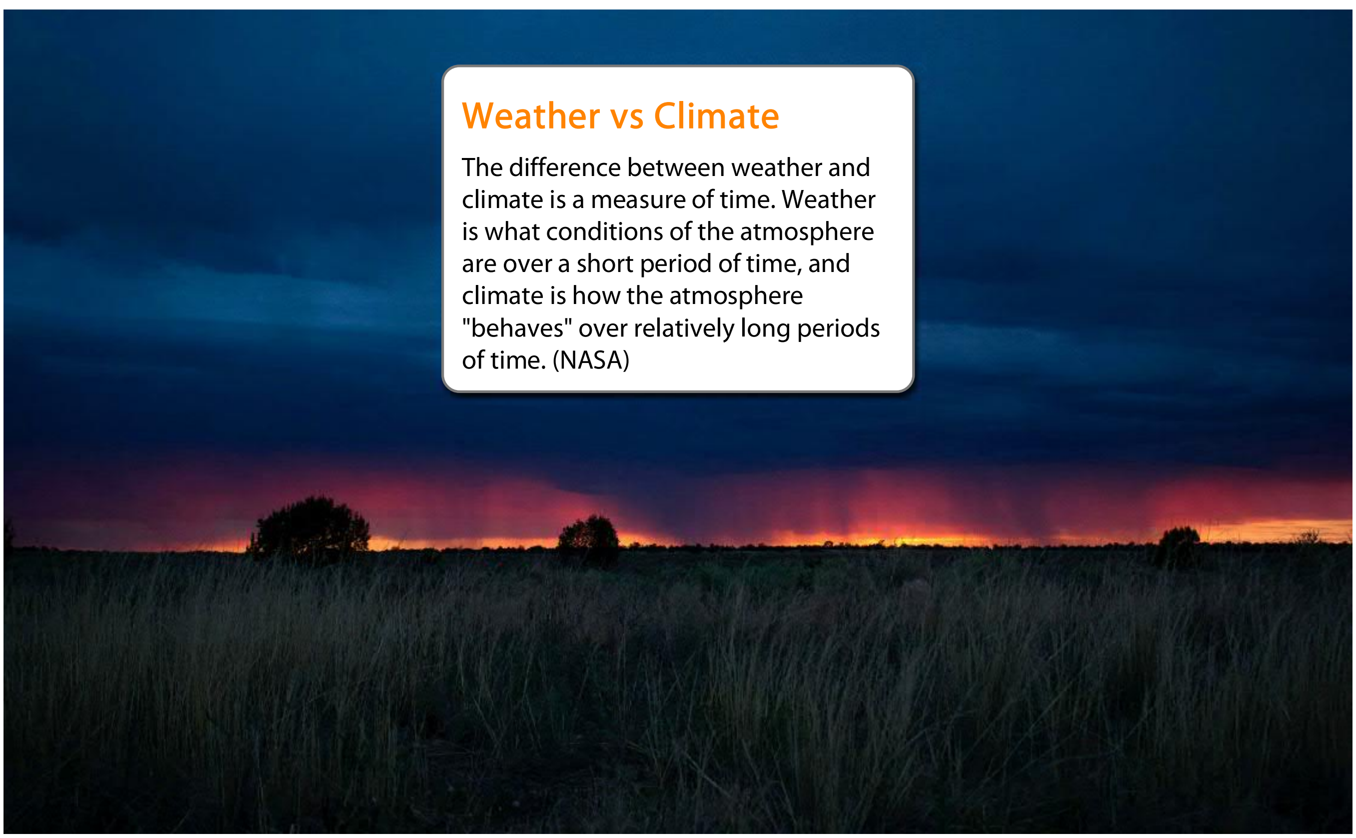
Why Study Climate Change Vulnerability?

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

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

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

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



Weather vs Climate

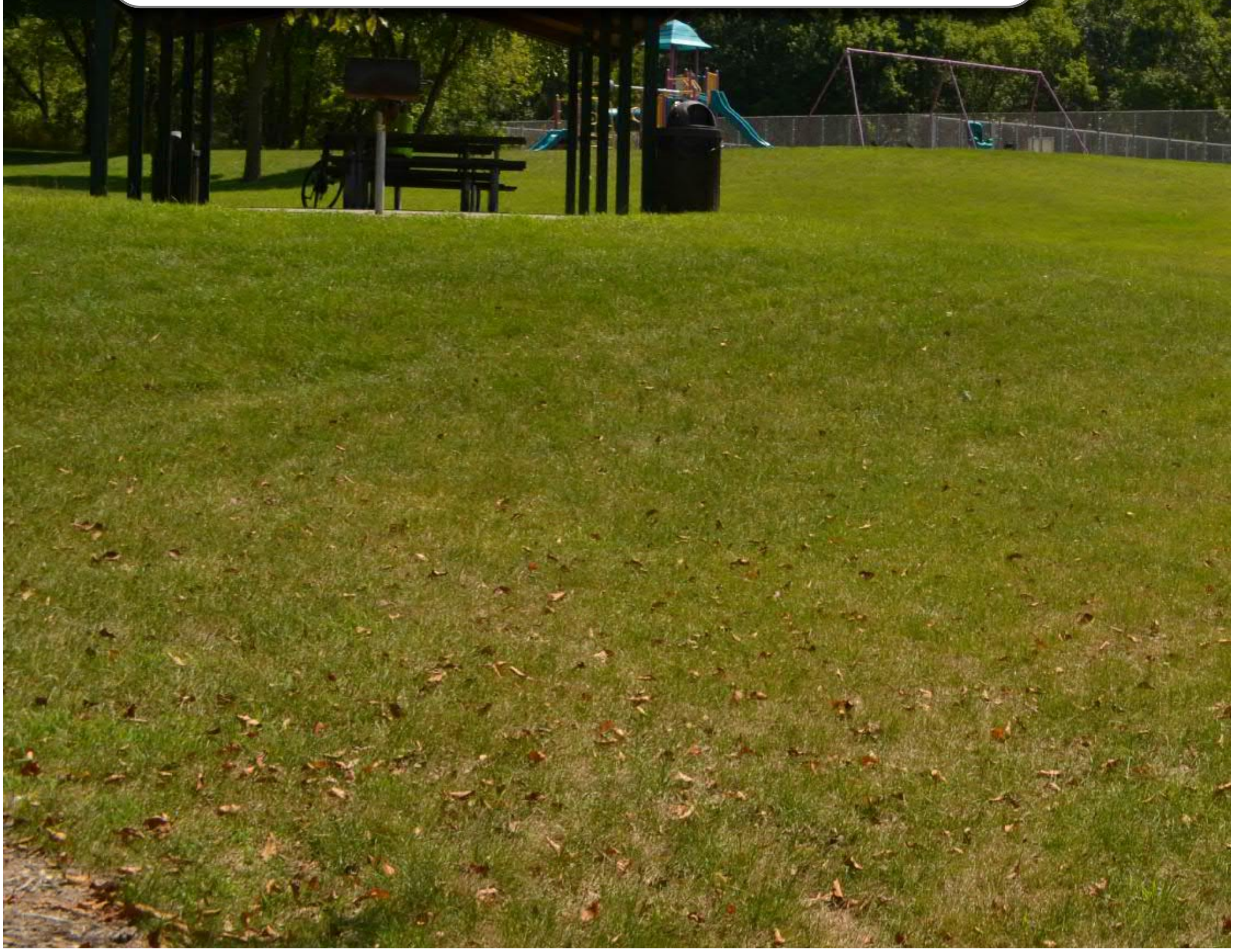
The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time. (NASA)

About This Report

This Climate Vulnerability Assessment has been developed in conjunction with the City of Ames' Citywide Greenhouse Gas Inventory 2018 project effort. This report seeks to:

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

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



Section 02

Climate Change In The Midwest

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Climate Change in The Midwest

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

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

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

Primary Issues for Midwest

1: Impacts to Agriculture

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

2: Forest Composition

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

3: Public Health Risks

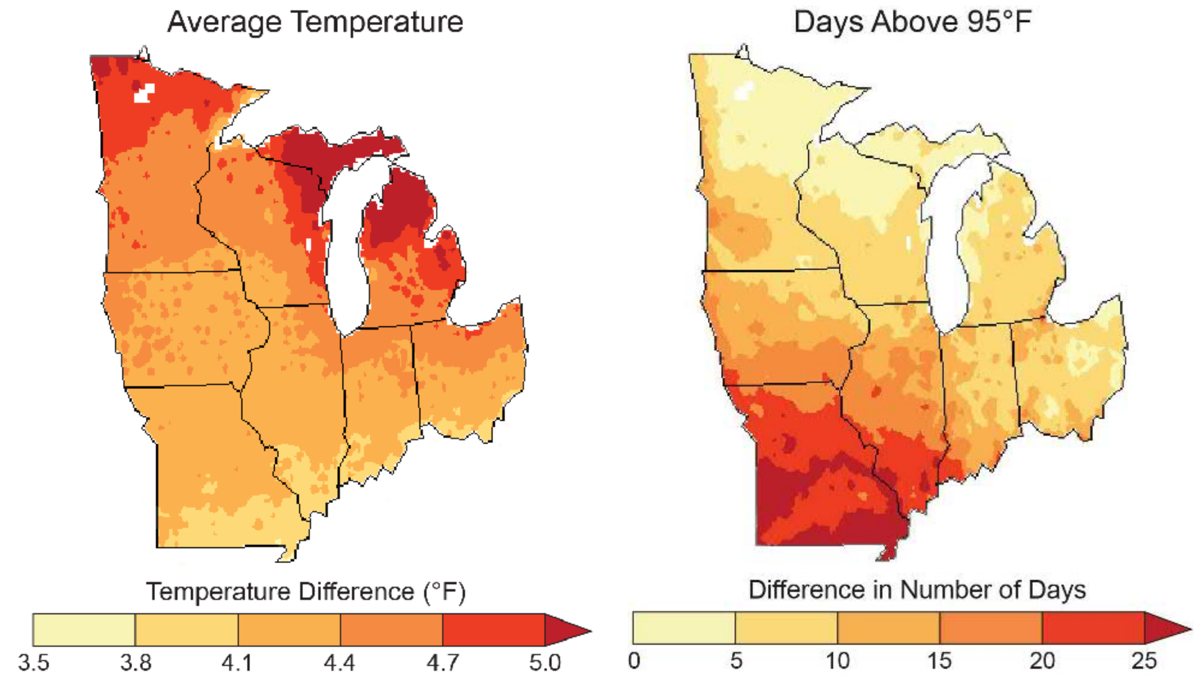
Increases incident rate of days over 95 degrees, and humidity are anticipated to contribute to degradations in air and water quality. Each of these will increase public health risk, especially for at-risk populations.

4: Increased Rainfall and Flooding

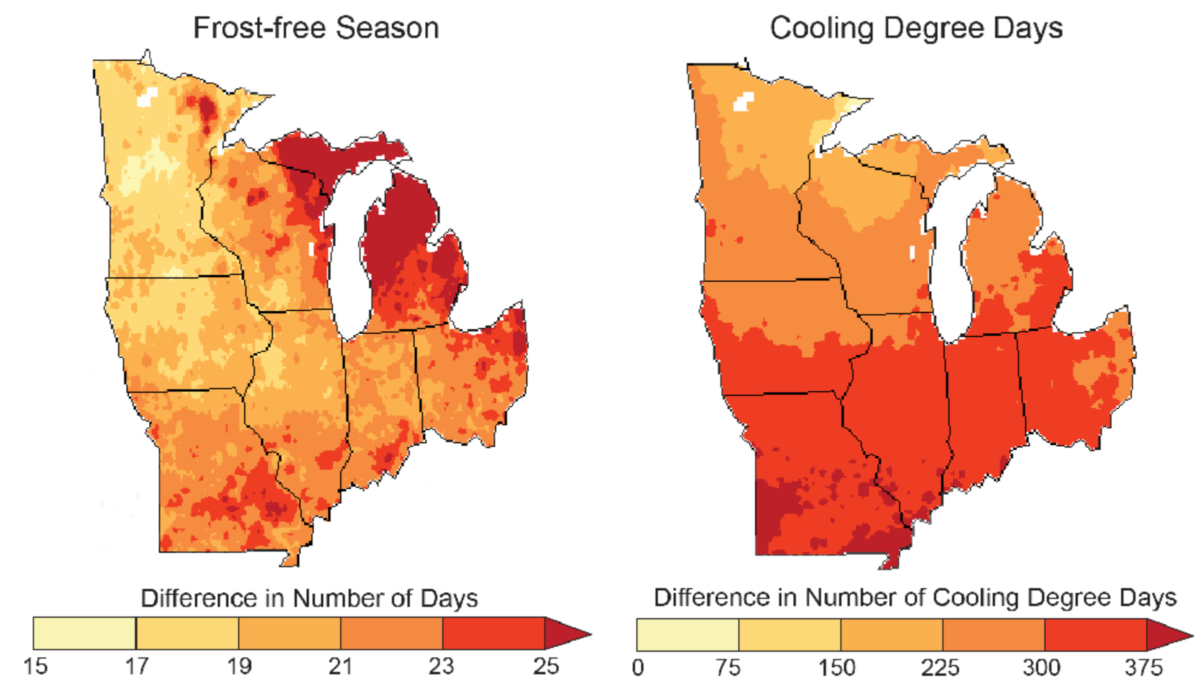
The frequency and size of extreme rainfall events and flooding has increased over the last century. In addition, the number of days without precipitation have increased. These trends are expected to continue, causing erosion, declining water quality, and impacts on human health, and infrastructure.

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

Hotter…



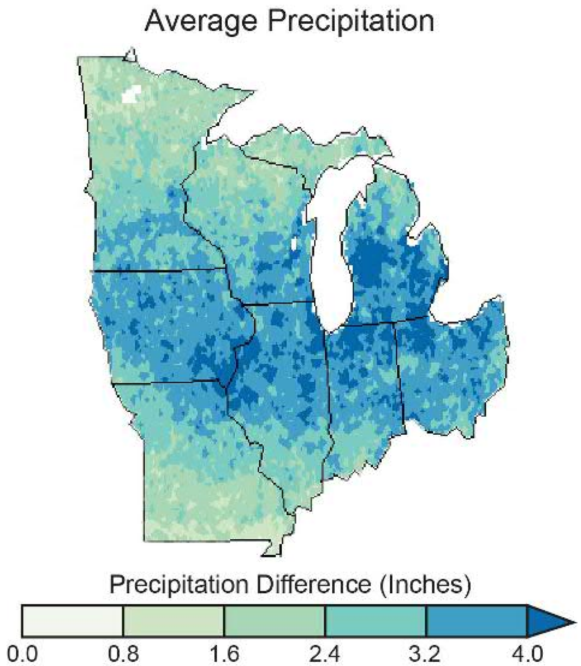
(Source: United States National Climate Assessment, based on SRES A2 Scenario)

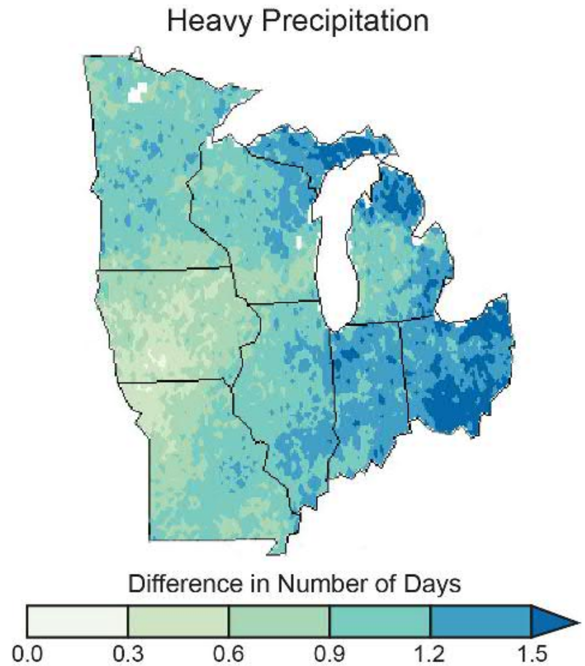


(Source: United States National Climate Assessment, based on SRES A2 Scenario)

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

Hotter…with more rain

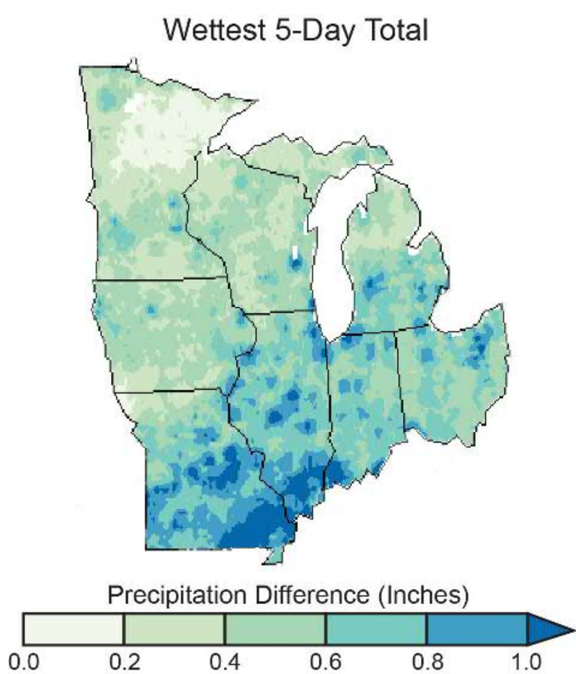


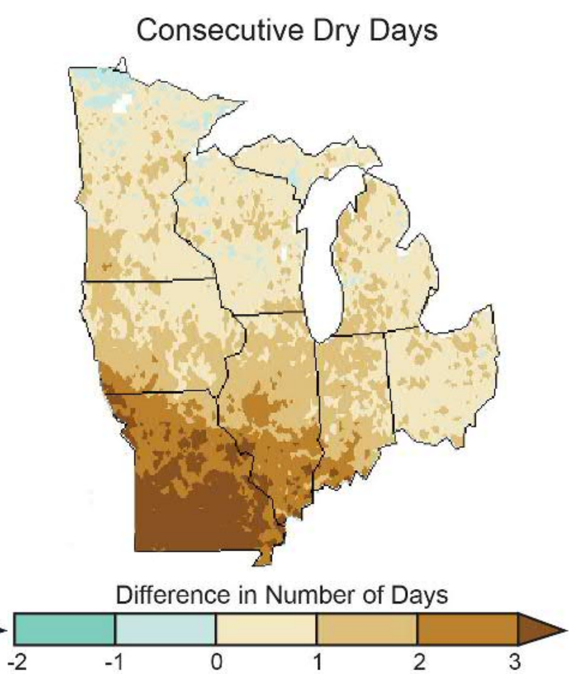


The Midwest can expect continued increases in annual average precipitation, the number of days with heavy precipitation, making the wettest days of the year even wetter.

(Source: United States National Climate Assessment, based on SRES A2 Scenario)

…and drought





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

(Source: United States National Climate Assessment, based on SRES A2 Scenario)

Section 03

Climate Change In Iowa

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Climate Change in Iowa

Annual Rainfall

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

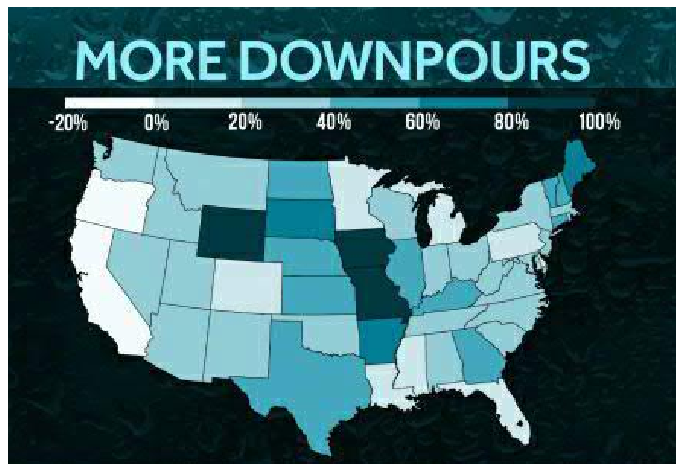
Iowa, home to a number of recent significant flooding events, has strong trends in heavy precipitation events. The State has seen an increase in the magnitude of heavy rain events - the top 1% annual rain events have increased over 20% in the volume of water deposited since 1950.

Statewide Annual Climate Trends (1895-2016)

Temperature in degrees F, Precipitation in percent

State	Average Temperature	Maximum Temperature	Minimum Temperature	Precipitation
Iowa	**1.2**	**0.2**	**2.1**	**15%**
Kansas	1.5	1.2	1.8	10%
Missouri	0.8	0.1	1.4	7%
Nebraska	1.8	1.2	2.5	6%
Four-state Average	1.3	0.7	2.0	10%

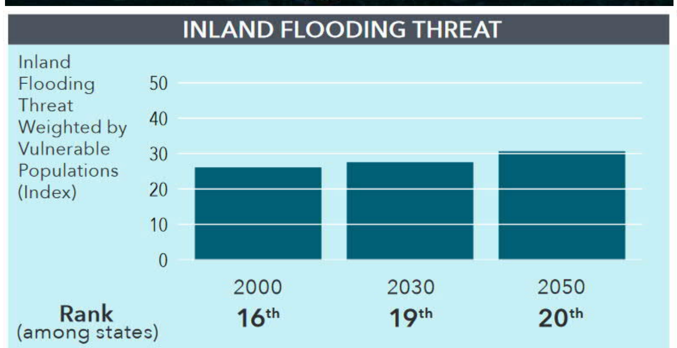
According to the High Plains Regional Climate Center: "Over the 122-year time period, average annual precipitation has increased by about 15% in Iowa, which is the largest increase in the four-state region. There is variability in the precipitation record, with drought periods of the 1930s and 1950s evident in the record, as well as the extremely dry years of 1910 and 1988. The past few decades have been part of a wetter period for the state, with two of Iowa's worst flooding years in modern history occurring in 1993 and 2008 (Zogg 2014). Although 1993 stands out as the wettest year on record for Iowa, it is worth noting that four of the top ten wettest years have occurred in the past ten years, including 2007, 2008, 2010, and 2015. "



Inland Flooding Threat in Iowa

By 2050, Iowa is projected to see an increase of inland flooding threat of 20 percent. With this increase, by 2050, Iowa is projected to be ranked 20th for inland flooding threat within the United States.

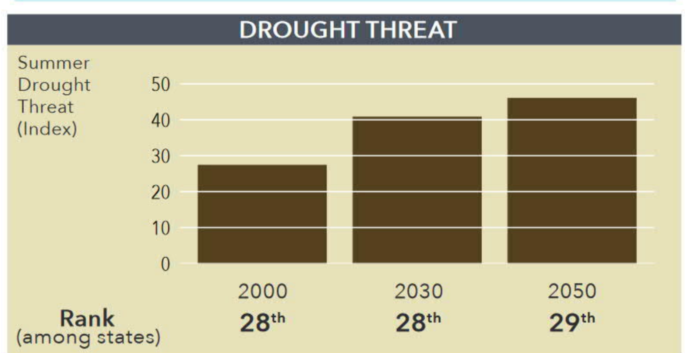
(Threat is calculated by severity of flooding weighted by the State's estimated flood vulnerable population)



Summer Drought in Iowa

By 2050, the severity of widespread summer drought is projected to see an increase of 70 percent. With this increase, by 2050, Iowa is projected to be ranked 29th for drought severity threat within the United States.

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



(Source: High Plains Regional Climate Center, Climate Central)

Observed Climate Change in Iowa

Annual Temperatures

Annual temperatures have increased throughout Iowa over the last few decades. Typically, all seasons are warming across the US, with winter temperatures increasing the fastest. Iowa is no exception to this trend. Since 1970, Iowa temperatures have risen an average of 2.1 degrees in the winter.

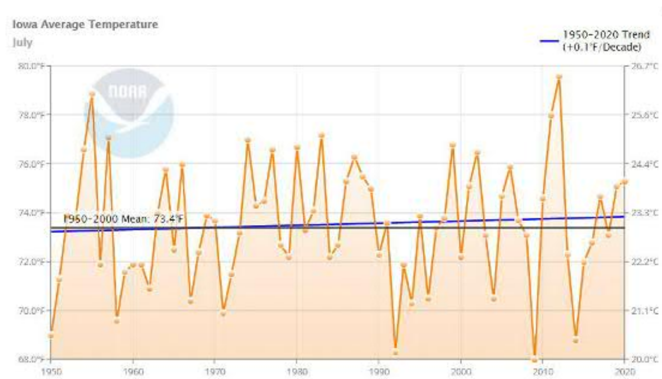
There have been marked changes in temperature extremes across the contiguous United States. The frequency of cold waves has decreased since the early 1900s, and the frequency of heat waves has increased since the mid-1960s. The number of high temperature records set in the past two decades far exceeds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

Extreme Heat Threat in Iowa

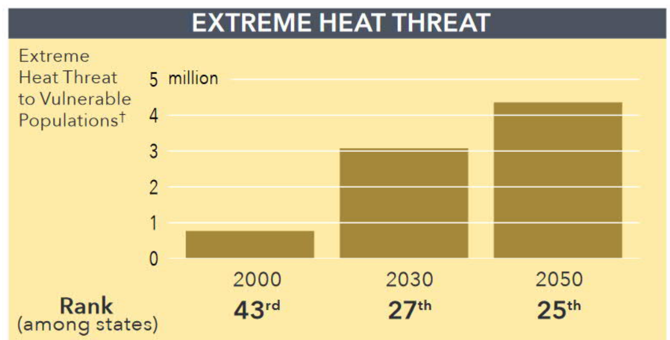
By 2050, Iowa is projected to see an increase in the Extreme Heat Threat of six fold. With this increase, by 2050, Iowa is projected to be ranked 25th for extreme heat threat within the United States.
(Threat is calculated by number of heat wave days multiplied by the State's estimated extreme heat vulnerable population)

Dangerous Heat Days in Iowa

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



(Graphic: NOAA)

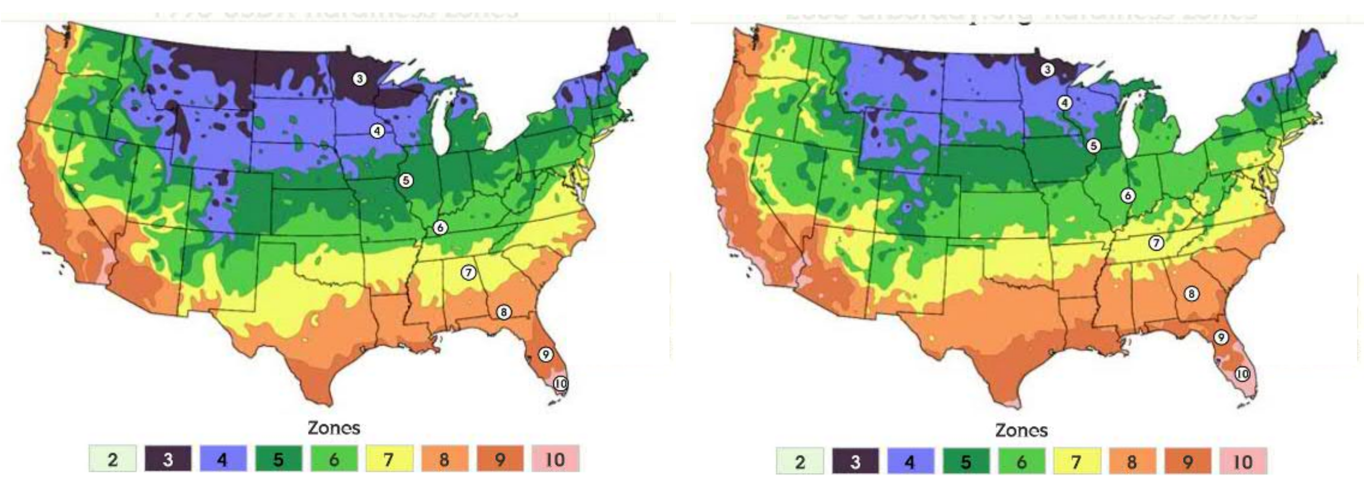


(Graphic: Climate Central)

Changing USDA Zones

In addition to warmer weather, Iowa is experiencing less spring snow cover and earlier thaw dates resulting in more rapidly warming soil. The cumulative effects is a shift of USDA Hardiness zones to the North. In 1990 North Central Iowa was a Zone 4, today portions of it are Zone 5.
(Graphic: Arbor Day Foundation)

Hardiness Zone Changes in Iowa



1990

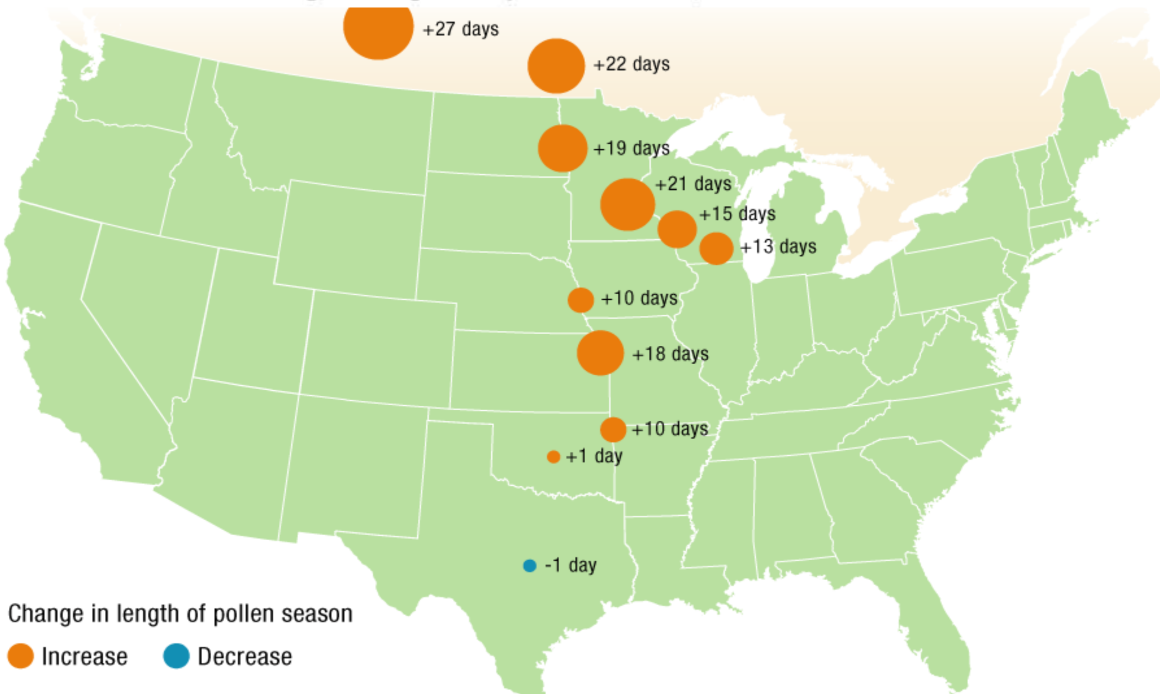
2015

Observed Climate Change in Iowa

Human Allergies

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

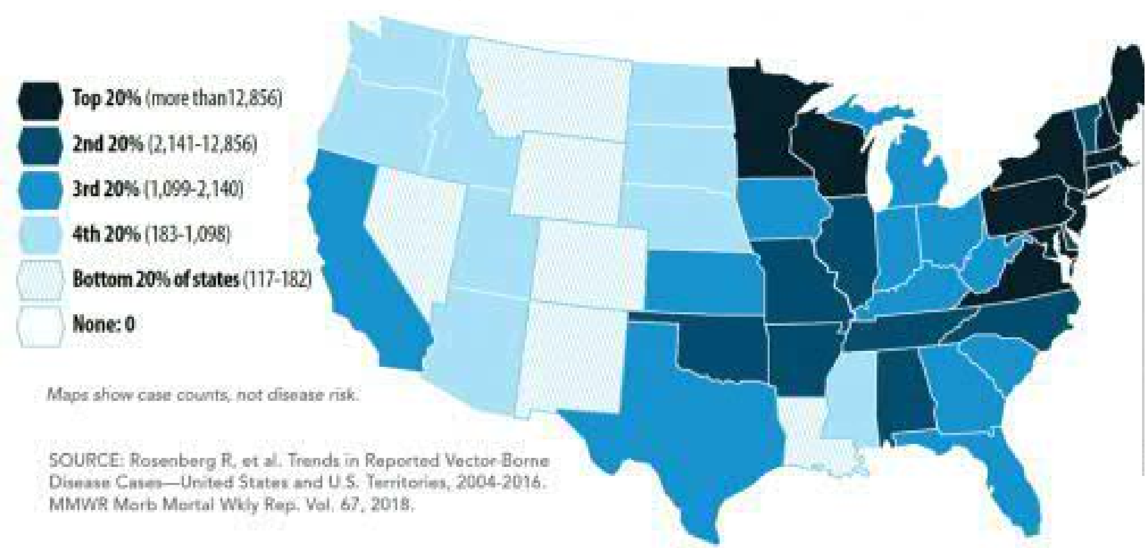
Change in ragweed pollen season, 1995-2013



Vector Borne Disease

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

Disease Cases From Ticks (2004-2006 reported)



Section 04

Local Climate Change

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Climate Change in Ames

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

Some of the most significant changes in the climate relate to variability. Climate variability can be seen in the changes in annual precipitation for Ames. Overall annual precipitation has increased, however, this increase is not evenly distributed throughout the year. Spring and Summer precipitation have increased up to 25%, while Fall and Winter precipitation have decreased 3-5%.

(Sources: US Climate Resilience Toolkit, Climate Science Special Report, High Plains Regional Climate Center, US NOAA, Union of Concerned Scientists)

Looking Back

From 1980 through 2018, Ames has experienced:

Increase in annual average temperature:	1.7°
Increase in annual precipitation:	15%
Increase in heavy precipitation	42%
Increase in Days above 95:	2 days
Decrease in Days below 32:	-9 days
Increase in growing season:	10 days

Storm Weather Events

Number of Events Reported In Story County:

From March 1999 to March 2009: 370 events

From March 2009 to March 2019: 502 events - an increase of 36%

Average Annual Storm Weather Economic Damage 1999-2019: $4,908,700

(source: NOAA National Centers for Environmental Information)

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

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

To serve the same size population, the projected increase in air conditioning demand would require an increase in city-wide electricity consumption of : 61%

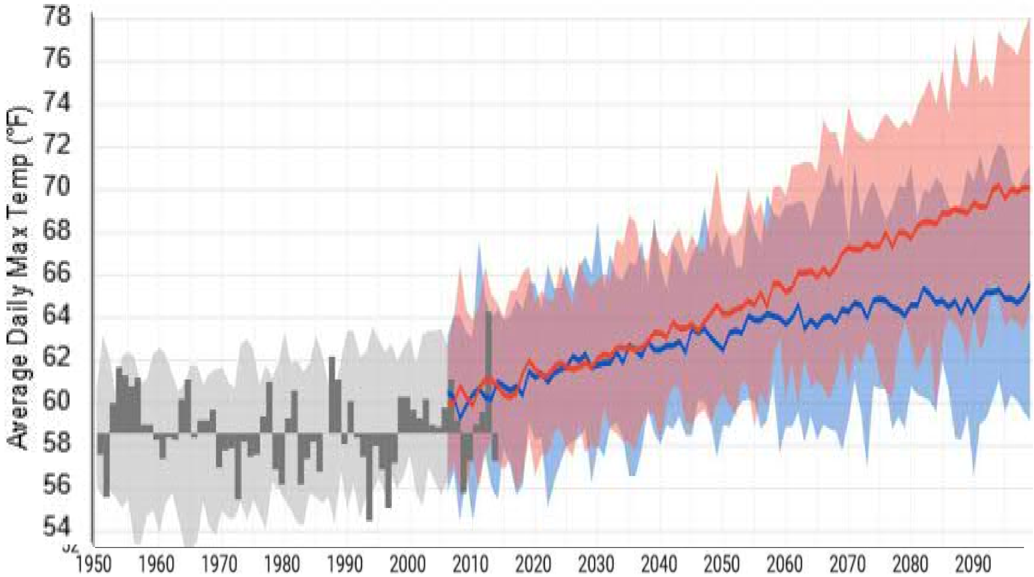
Looking Forward

By 2100, Ames Can Expect:

Increase in annual average temperature:	6-11°F
Increase in annual precipitation:	-9 to 15% With Significant Seasonal Variation
Increase in heavy precipitation events:	30%
Increase in Days above 95:	+55 days
Decrease in Days below 32:	-45 days
Increase in growing season:	48 days
Increase in Air Conditioning Demand:	245%

Mean Daily Maximum Temperature

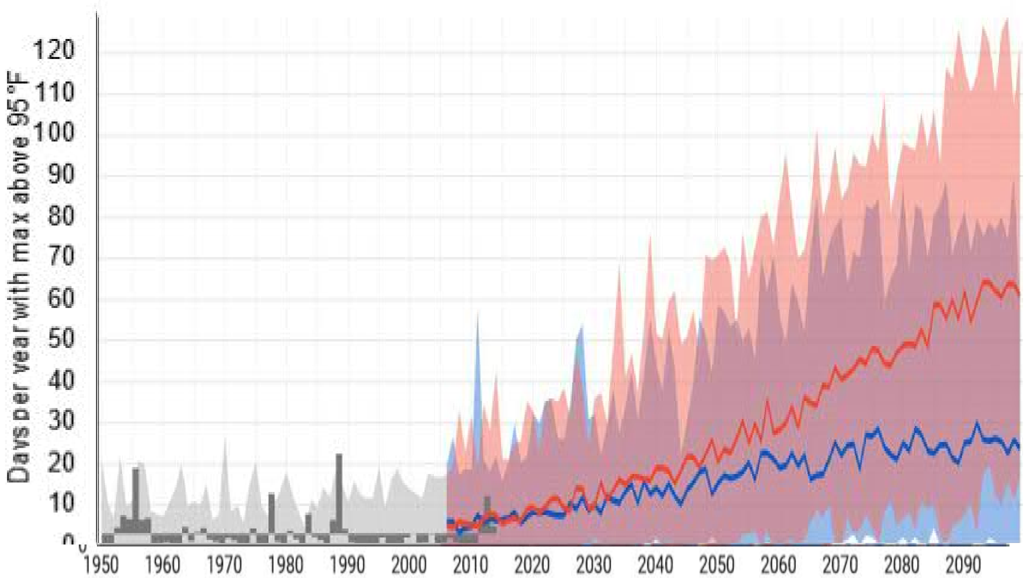
This chart shows observed average daily maximum temperatures for Story County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. Maximum temperature serves as one measure of comfort and safety for people and for the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



(Source: US Climate Resilience Toolkit)

Days with Maximum Temperature Above 95°F

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



(Source: US Climate Resilience Toolkit)

How To Read These Charts

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

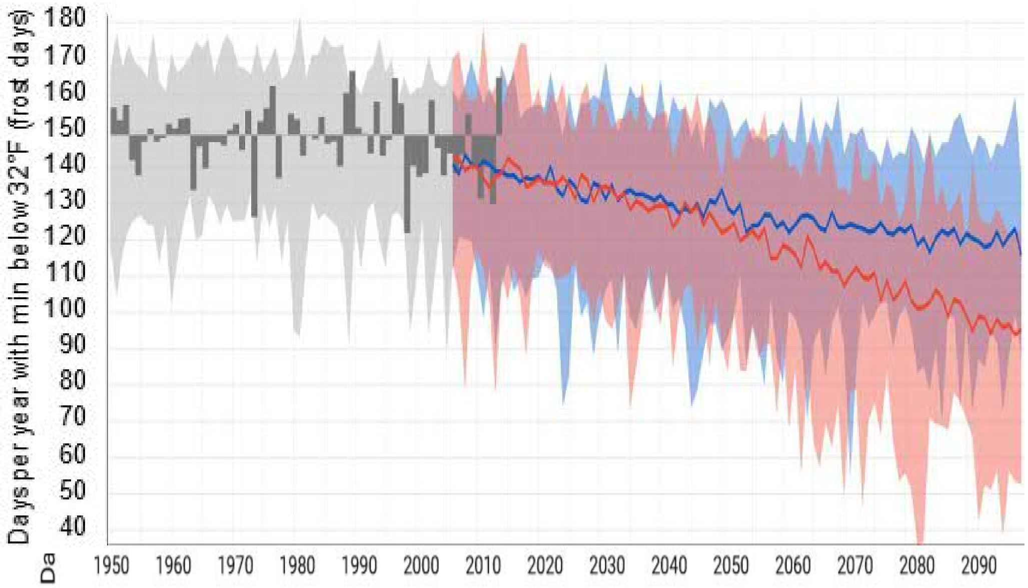
Starting from the left and moving right, the red toned band, or area, shows the range of future projections assuming global greenhouse gas emissions continue increasing at current rates. The darker red line shows the median of these projections. For planning purposes, people who have a low tolerance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

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

Days with Minimum Temperature Below 32°F

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

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

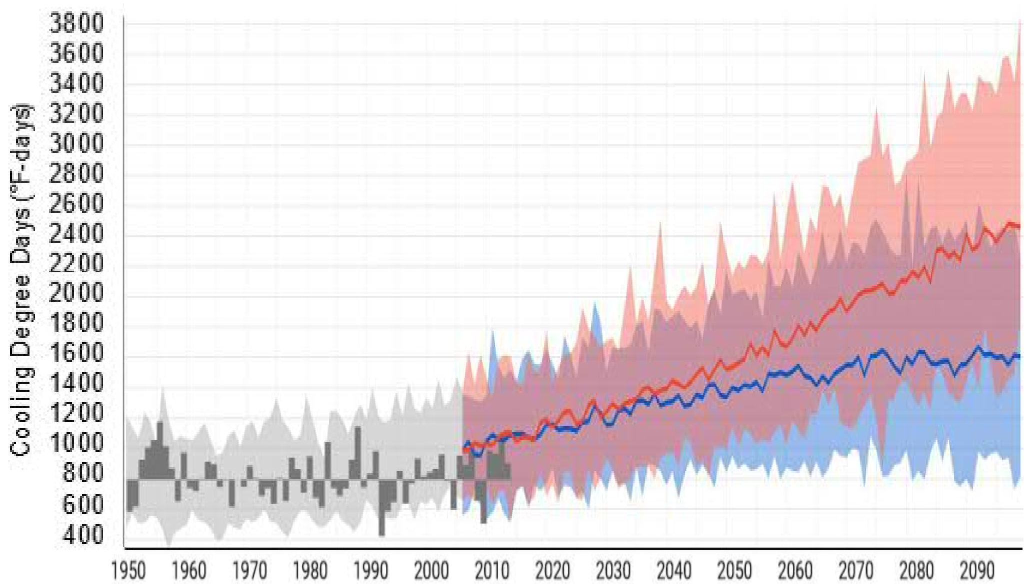


(Source: US Climate Resilience Toolkit)

Cooling Degree Days

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

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



(Source: US Climate Resilience Toolkit)

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Section 05

City on The Move

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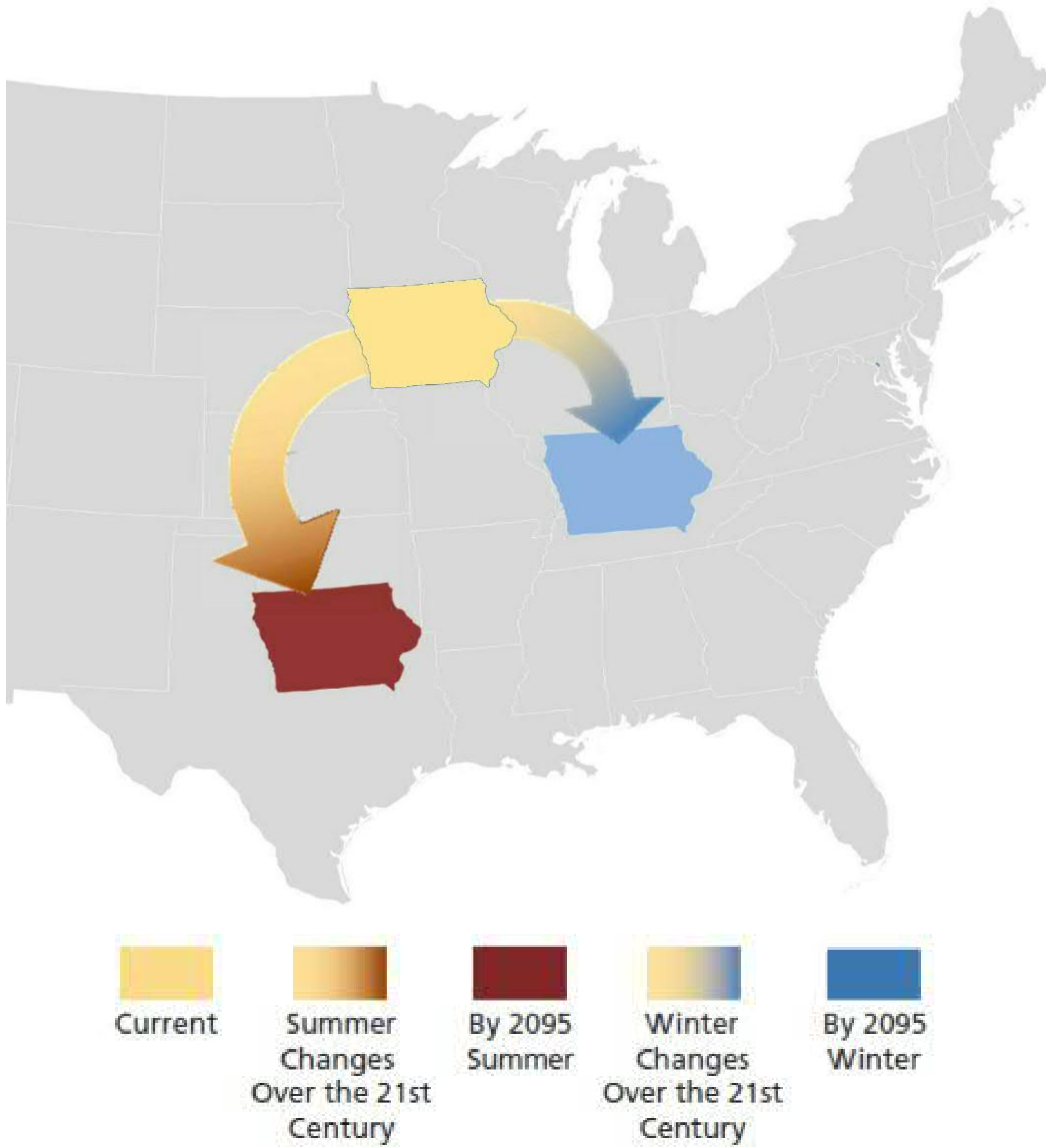
City on The Move

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

According to the University of Nebraska at Lincoln High Plains Climate Center, by 2040-70 summertime conditions in Ames are anticipated to be similar to those today in Springfield Missouri
(Source: University of Nebraska Lincoln High Plains Climate Center)

11 miles Distance southward the City of Ames' climate experience moves every year.

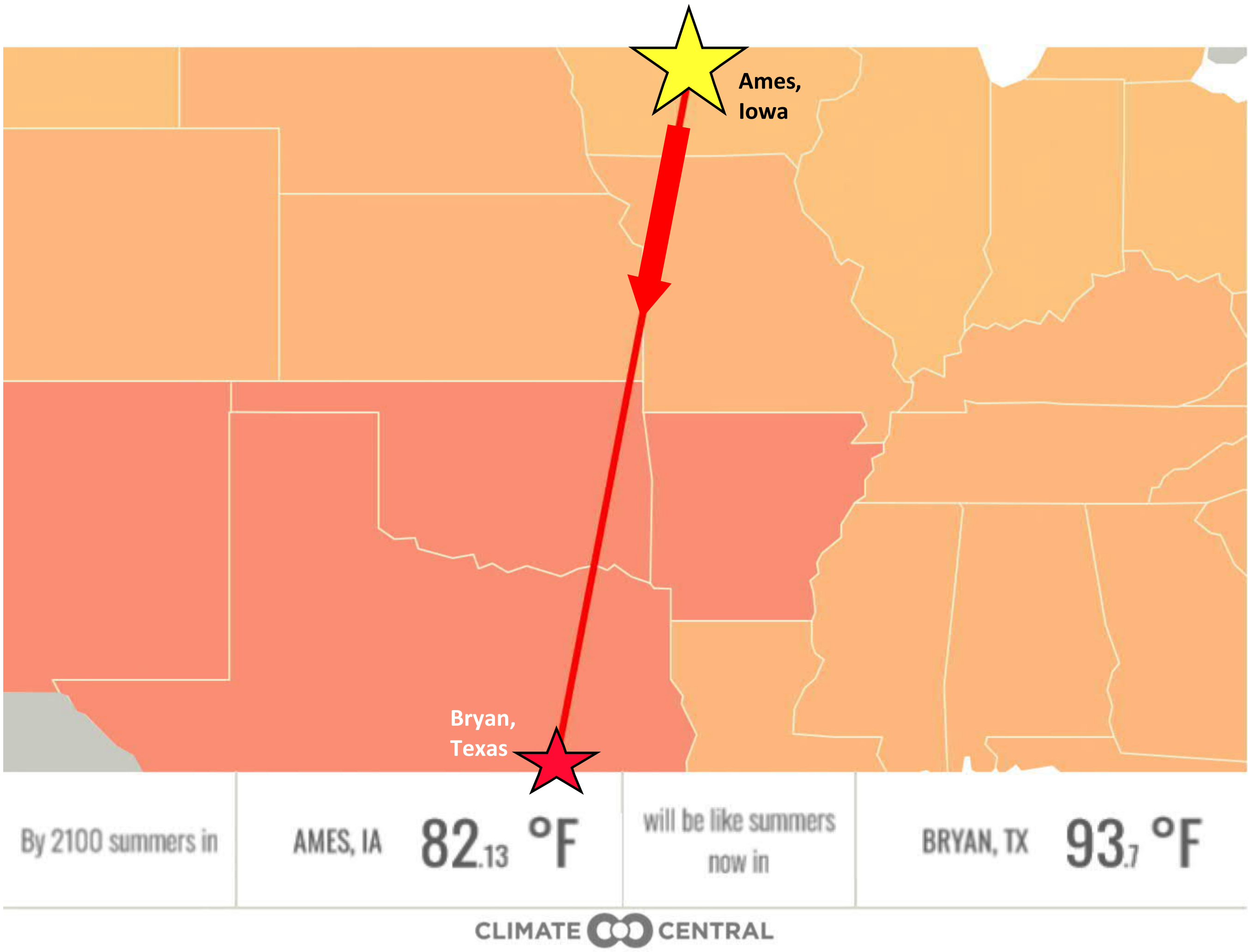
Which is equal to moving **159 feet** every day.



Climate Peers - State of Iowa 2095

State Climate Peers experience current conditions which match the projected conditions for the State of Iowa by 2095. As temperatures continue to rise for Iowa into the future, the State's climate will resemble that of States to the South more and more. Climate models predict that by 2095 summers in Iowa will be more like the current summers of Texas, Louisiana, and Mississippi, while winters will be more like current winters in Missouri and Kentucky.

(Source: US Climate Assessment, University of Nebraska Lincoln High Plains Climate Center, Climate Central).



Ames Climate Peers - 2100

City Climate Peers experience current conditions which match the projected conditions for the Ames by the year 2100. Summertime conditions in Ames Iowa in this period can be anticipated to be similar to those currently experienced by Bryan Texas, over 900 miles to the South.

(Source US Climate Assessment, University of Nebraska Lincoln High Plains Climate Center, Climate Central)

Section 06

Climate Risks to The Population

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Climate Risks to Ames

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

Extreme Weather / Temperature:

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

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

According to the US National Climate and Health Assessment:

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

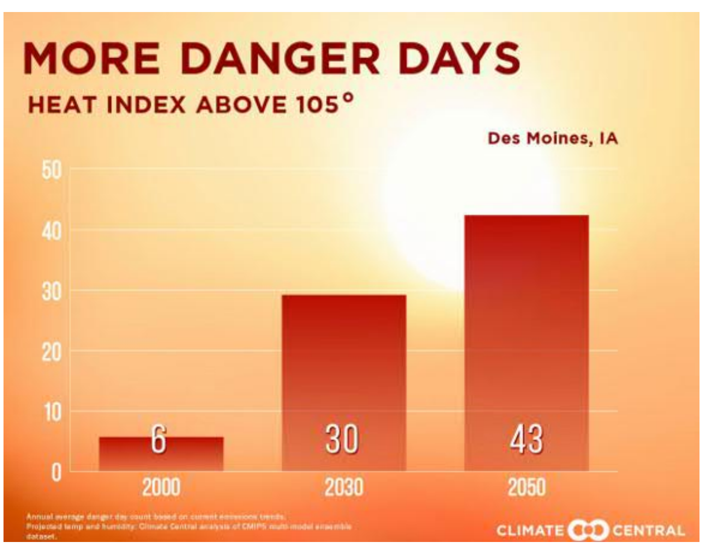
In addition, extreme weather can cause economic stress. Property damage, business closure, crop loss, job loss, and employment "down time" can all be caused by extreme storms, weather, and temperatures. These economic impacts can affect individuals, families, businesses, and communities at large.

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

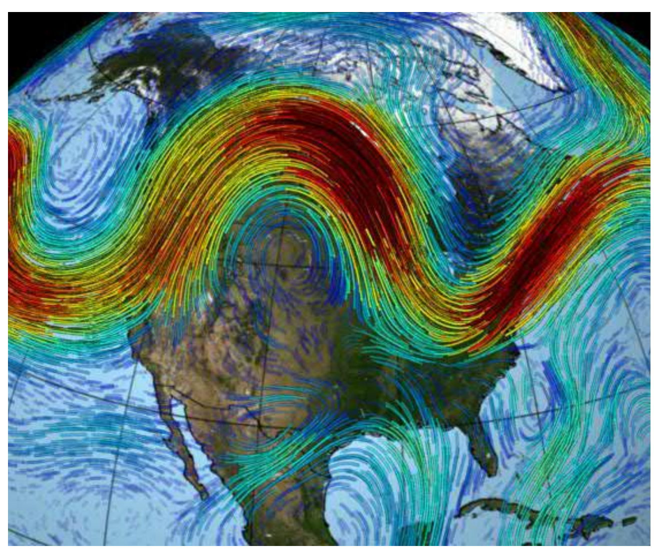
More than 70,000 people in Iowa are especially vulnerable to extreme temperatures.

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

Increased Risk of Extreme Heat



Increased Risk of Extreme Cold



Climate Risks to Ames

Extreme Weather / Temperature (continued)

Increased Risk of Extreme Cold

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

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

Flood and Drought Vulnerability

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

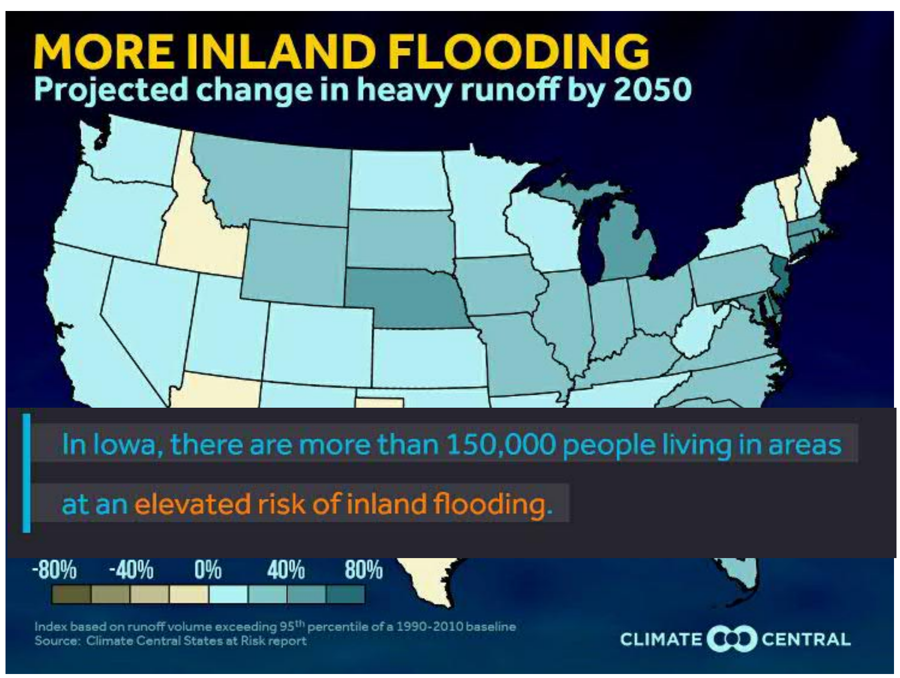
In addition to the immediate health hazards associated with extreme precipitation events when flooding occurs, other hazards can often appear once a storm has passed. Elevated waterborne disease outbreaks have been reported in the weeks following heavy rainfall, although other variables may affect these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

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

By 2050, Iowa is projected to see:

An increase of flood risk by more than 30%

As well as a 155% increase in its index of the severity of widespread drought.



(Source: US Climate Resilience Toolkit, Climate Central)

Climate Risks to Ames

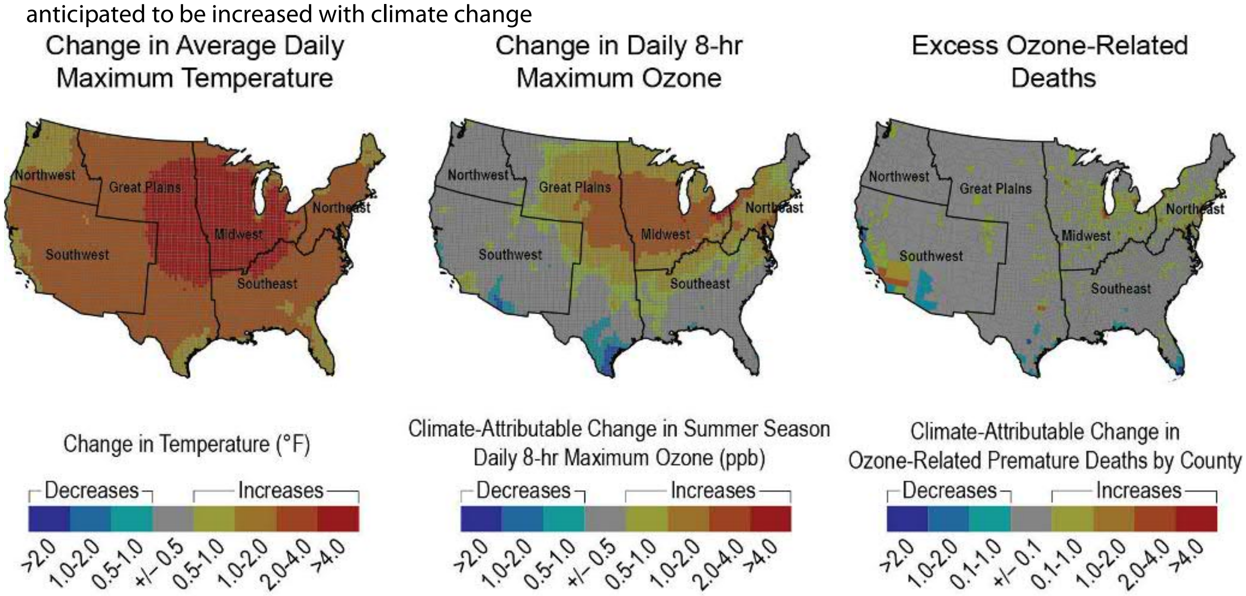
Air Quality Impacts

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

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

The US EPA designates counties with unhealthy levels of air pollution as "Non attainment" areas and areas which are on the edge of unhealthy levels "maintenance" areas. The State of Iowa has had multiple jurisdictions designated as "non attainment" areas. However as of 2002 all of these areas have re-met federal air quality requirements and are now maintenance areas. Air quality issues currently being addressed in State of Iowa implementation plans include Carbon Monoxide, Sulfur Dioxide, and Particulate Matter. For current and forecasted air quality throughout the state visit the Iowa State DNR: https://dnr.wi.gov/topic/AirQuality/ You can also download Plume Lab's free mobile phone air quality monitoring app: https://plumelabs.com/en/air/

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



Projected Change in Temperature, Ozone, and Ozone-Related Premature Deaths in 2030

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

(Source: US Climate Resilience Toolkit)

Climate Risks to Ames

Vector-Borne Diseases

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

Food Insecurity and Food-borne Diseases

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

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

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

Climate Risks to Ames

Water Quality/Quantity

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

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

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

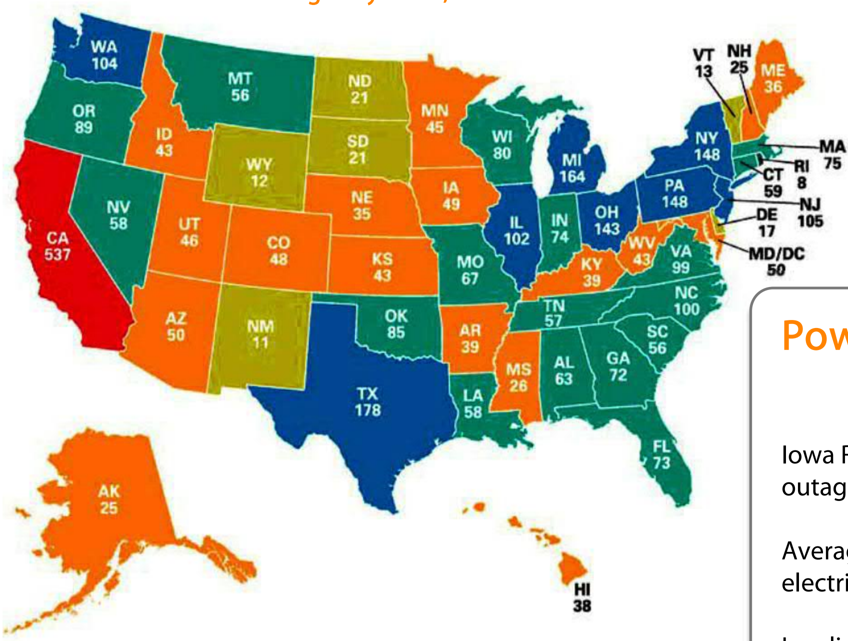
Waterborne Illness

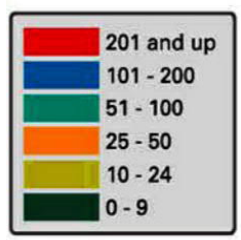
Waterborne diseases are caused by a variety of microorganisms, biotoxins, and toxic contaminants, which lead to devastating illnesses such as cholera, schistosomiasis and other gastrointestinal problems. Outbreaks of waterborne diseases often occur after a severe precipitation event (rainfall, snowfall). Because climate change increases the severity and frequency of some major precipitation events, communities could be faced with elevated disease burden from waterborne diseases. Increased frequency of intense extreme weather events can cause flooding of water and sewage treatment facilities, increasing the risk of waterborne diseases.

Infrastructure Failure

Extreme weather events, flooding and flash flooding, as well as increasing daily stresses caused by increasing climate variability all represent potential causes of failure of our aging infrastructure. Power outages, road damage, bridge collapse, water infrastructure failure - each of these represent significant physical climate risks to the community, especially individuals who are climate vulnerable.

Number of Power Outages by State, 2014





(Source: US Department of Energy)

Power Outages

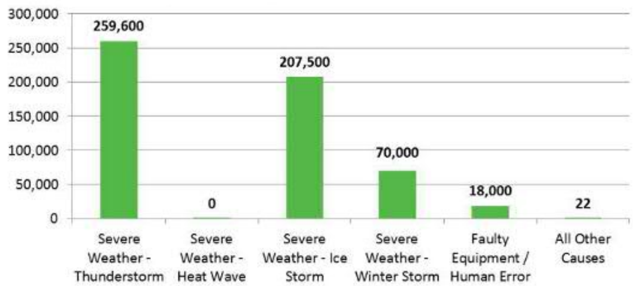
Iowa Residents effected by electric outages annually: **116,995**

Average Annual duration of electric outages in Iowa: **45.4 hrs/yr**

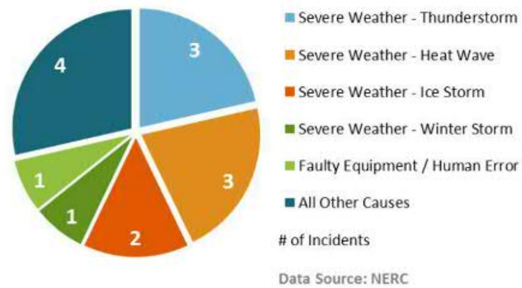
Leading cause of electric outages in Iowa (in terms of number of customers effected): **Weather/ falling trees**

Infrastructure Failure (continued)

Electric Customers Disrupted by NERC-Reported Electric Transmission Outages by Cause (1992–2009)



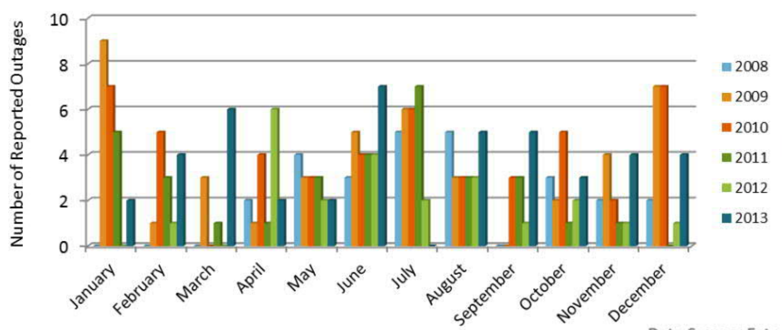
Number of NERC-Reported Electric Transmission Outages by Cause (1992–2009)



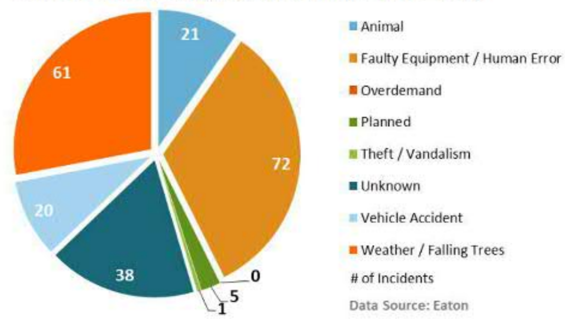
Data Source: NERC

(Source: US Department of Energy)

Electric Utility Reported Power Outages by Month (2008–2013)



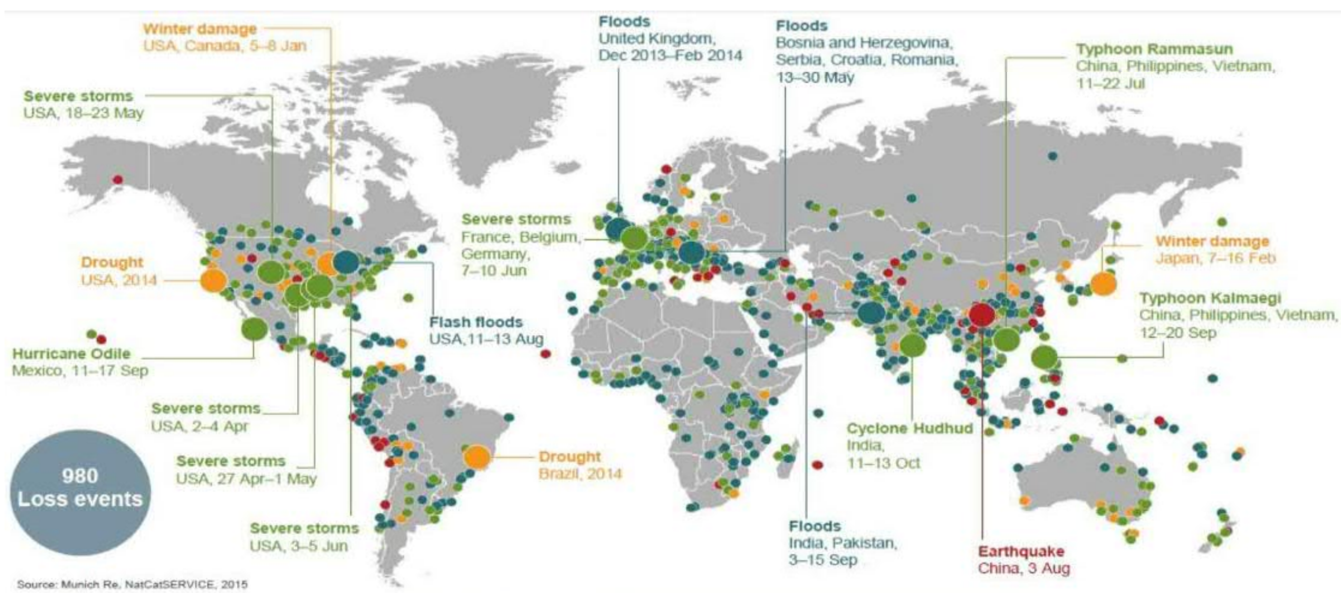
Causes of Electric-Utility Reported Outages (2008–2013)



Data Source: Eaton

(Source: US Department of Energy)

Global Loss Events, 2014



Section 07

Climate Impact Multipliers

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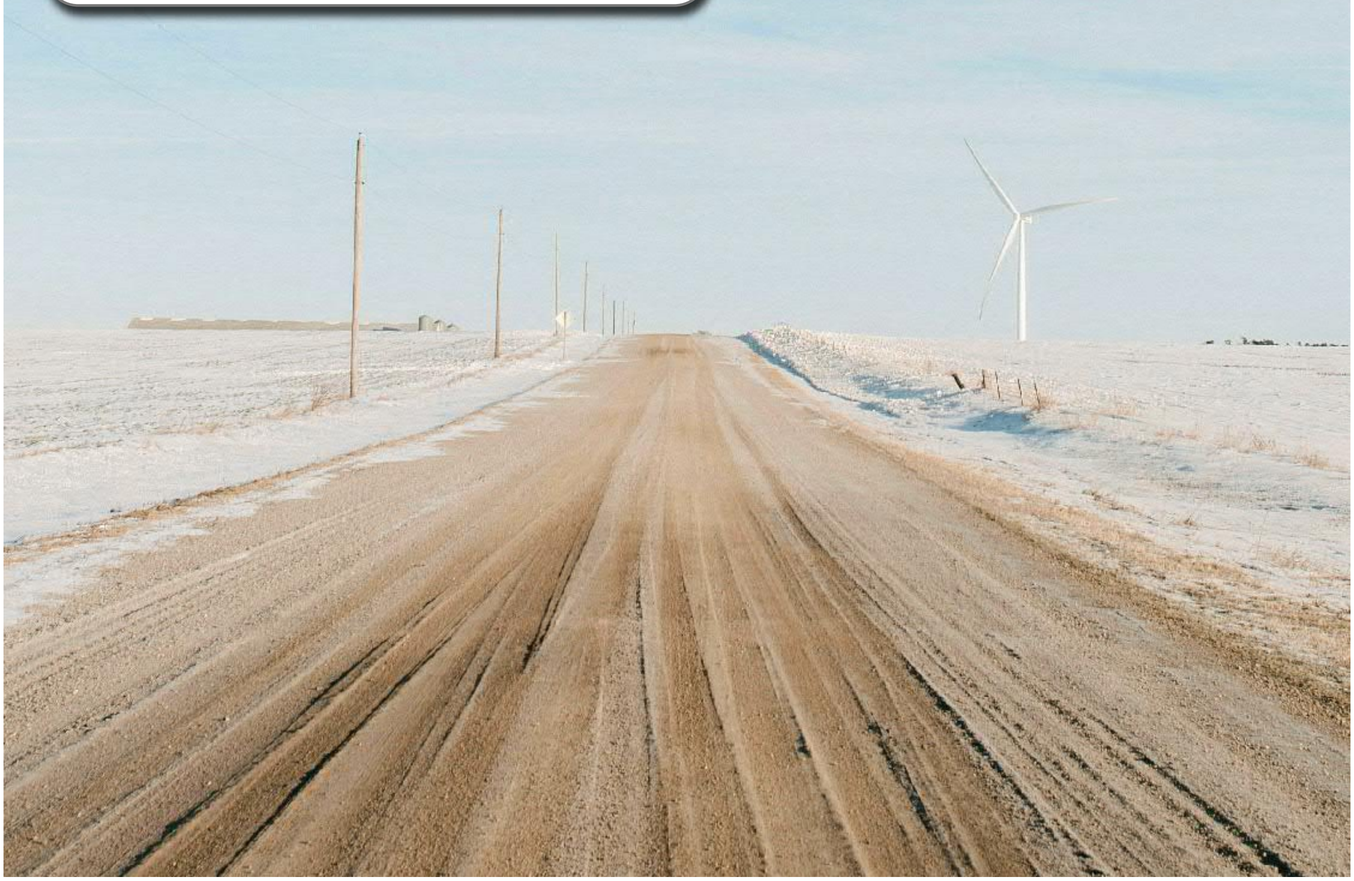
Climate Impact Multipliers

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

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

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



Climate Impact Multiplier - Tree Canopy

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

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

City of Ames Tree Canopy

The Iowa Department of Natural Resources, in partnership with the United States Department of Agriculture Forest Service and the Iowa Urban Tree Council has estimated the total urban tree canopy coverage of communities throughout Iowa. The data from that study below was developed using high resolution land cover dataset, target year 2009, in conjunction with the incorporated boundaries from the 2010 census data. Zonal statistics were acquired using ArcGIS 10.1.

Tree Canopy	Existing Tree Canopy (acres)	Tree Canopy Coverage
City of Ames:	3,514.48	23%
Des Moines:	15,029.3	29%
Dubuque:	5,946.97	30%
National Average:		27.1%

Planting Climate Adaptive Trees

Tree canopies in Iowa also have some vulnerabilities associated with the current and projected impacts of climate change. Trees have a degree of vulnerability to changes in temperature ranges, precipitation patterns, soil temperature and moisture levels, and changes to winter processes and growing season length. Climate change also introduces the potential for introducing new or expanding the life cycle or range of existing tree pests - such as Emerald Ash Borer (EAB) which can cause vast damage to existing tree stock.

According to the US Forest service, urban forests are very susceptible to a number of climate change factors including species invasion, and insect and pathogen attack. These stressors will make it more difficult to preserve or increase canopy cover in Iowa communities. Conducting tree canopy studies and creating climate adaptive tree canopy policies will help Iowa communities in adapting to these stressors.

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

Climate Impact Multiplier - Impervious Land Cover

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

Increases in impervious cover can also dramatically increase the impact of so-called 100-year flood events. Typically, floods in areas of high impervious surfaces are short-lived, but extended flooding can stress trees, leading to leaf yellowing, defoliation, and crown dieback. If damage is severe, mortality can occur. In addition, flooding can lead to secondary attacks by insect pests and diseases. Some species are more tolerant of flooding than others.

Climate Impact Multiplier - Heat Island and Micro Heat Island

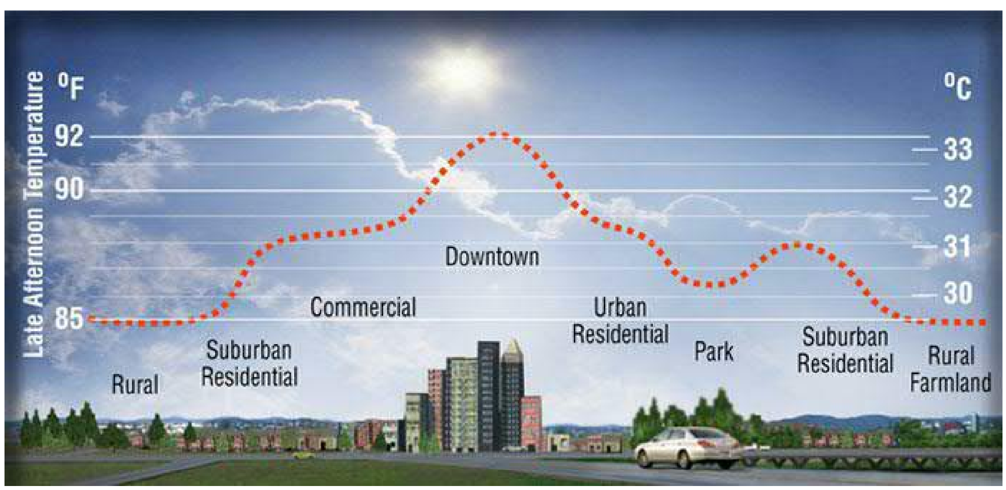
Residents of cities and town centers are more at risk for heat-related illnesses than rural dwellers. The radiant heat trapped by impervious surfaces and buildings as well as heat generated by building mechanical systems, motorized equipment, and vehicles is known as the “Heat Island Effect” . In larger cities, heat island effects create a micro-climate throughout the metro area while occupants of smaller cities and towns can still experience higher temperatures and decreased air movement due to the effects of surrounding buildings and impervious surfaces in what is sometimes referred to as “Micro Heat Islands” which refers to urban hot spots such as poorly vegetated parking lots, non-reflective roofs and asphalt roads.

Both the heat island effect of larger cities and the micro heat islands of smaller cities (or portions of communities) serve to increase the impact of climate change effects in developed areas of all size populations, especially those with low or intermittent tree canopy coverage. A developed area’s impervious surface characteristics, and tree canopy conditions combine to exacerbate or mitigate the community’s heat island or micro heat island impacts.

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

Agricultural Heat Island

Research indicates that in rural areas or regions with significant agriculture, crops can impact heat island effect. Unlike many plants, corn transpires, or sweats, both day and night. Keeping humidity and heat high at night means there is little chance for relief. A University of Minnesota study released in 2016 shows farm crops can increase dew points and heat indices by as much as 5 degrees, while a Northern Illinois University climatologist David Changnon released a study in 2002 showing that modern-day heat waves probably are worse than a century ago because of crops.



Source: Lawrence Berkeley National Laboratory

Climate Impact Multiplier - Water Stress

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

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

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

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

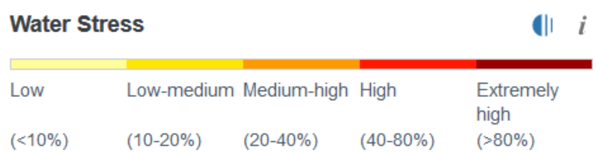
Overall water risk identifies areas with higher exposure to water-related risks and is an aggregated measure of physical risks related to quantity (flooding, drought, etc), physical risks related to water quality that may impact water availability (such as the percentage of available water that has been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

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

Ames Water Stress (current)

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

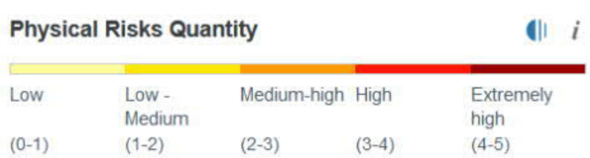
The current water stress in Ames is “Low”
(Source: World Resources Institute)

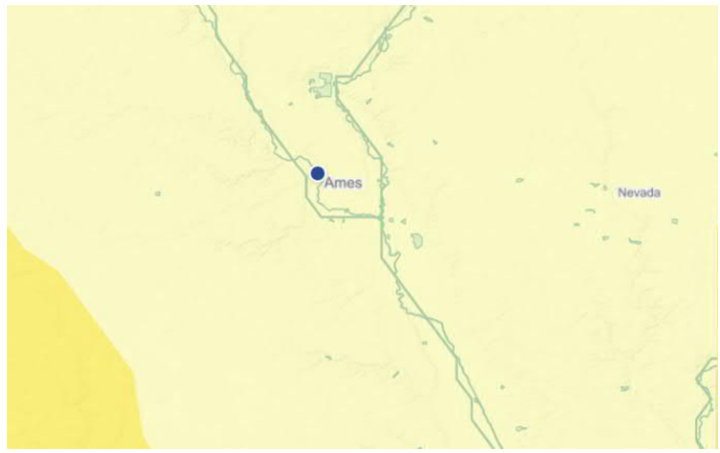


Ames Overall Water Risk Quantity (current)

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

The current water risk in Ames is “Low”
(Source: World Resources Institute)

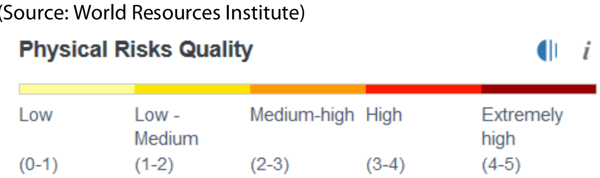


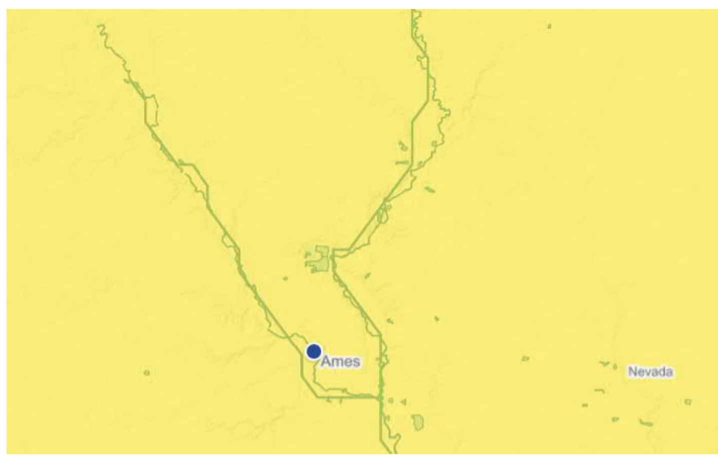


Ames Overall Water Risk Quality (current)

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

The current water risk in Ames is “Low-Medium”
(Source: World Resources Institute)

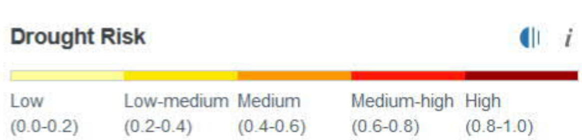


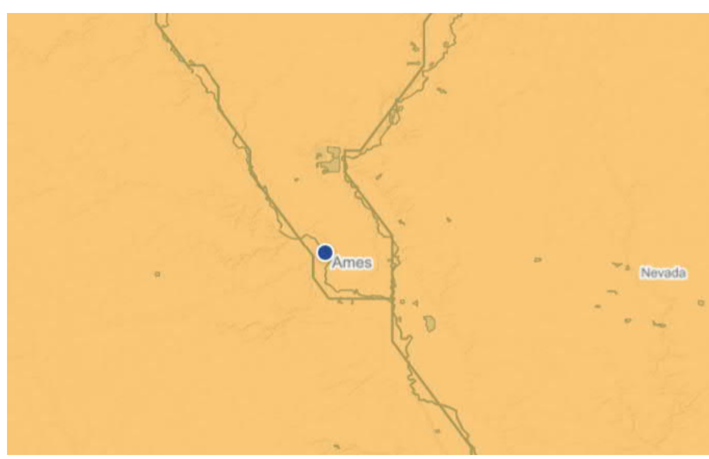


Ames Drought Risk (current)

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

The current water risk in Ames is “Medium”
(Source: World Resources Institute)

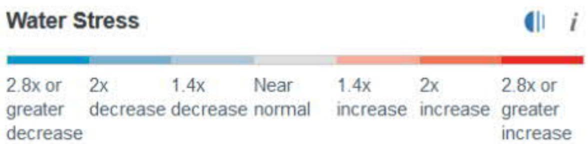




Ames Projected Water Stress (through 2040)

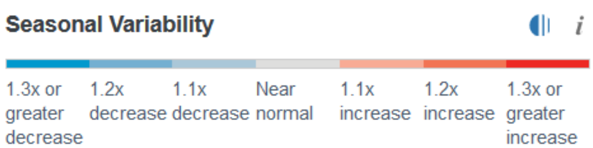
Water stress is an indicator of competition for water resources and is defined informally as the ratio of demand for water by human society divided by available water.

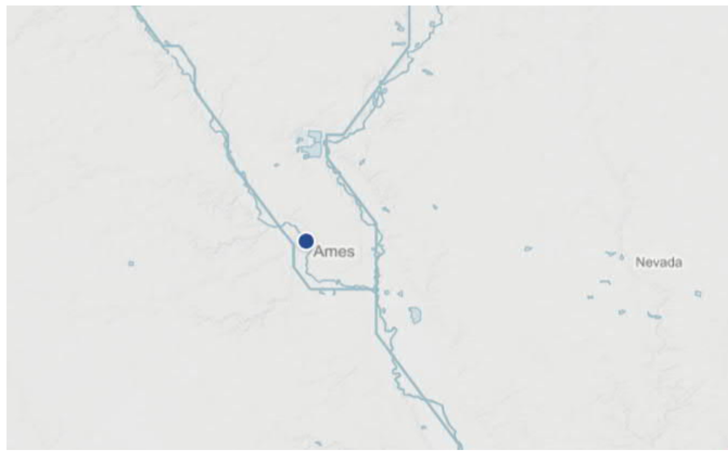
The projected water stress in Ames is "near normal"
(Source: World Resources Institute)



Ames Projected Seasonal Variability (Through 2040)

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

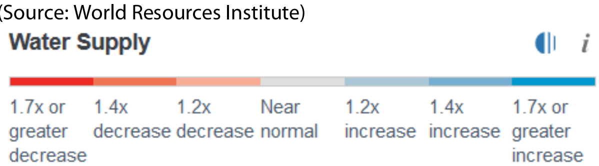


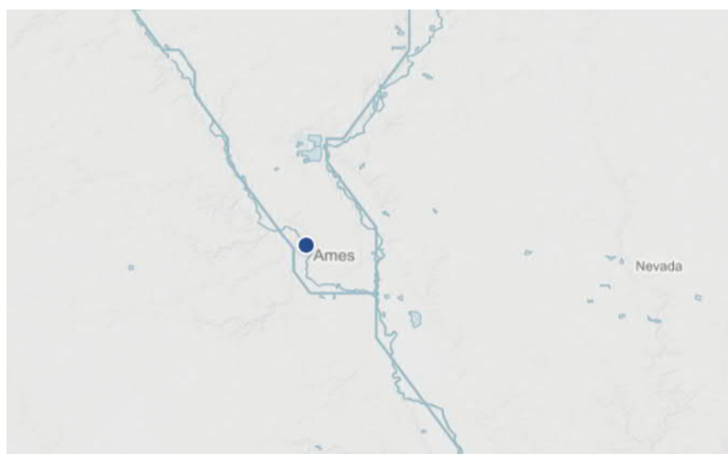


Ames Projected Water Supply (Through 2040)

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

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

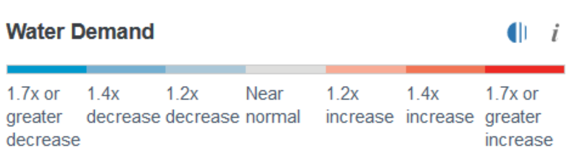




Ames Projected Water Demand (Through 2040)

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

The current water risk in Ames is "1.2 to 1.4x Increase"
(Source: World Resources Institute)

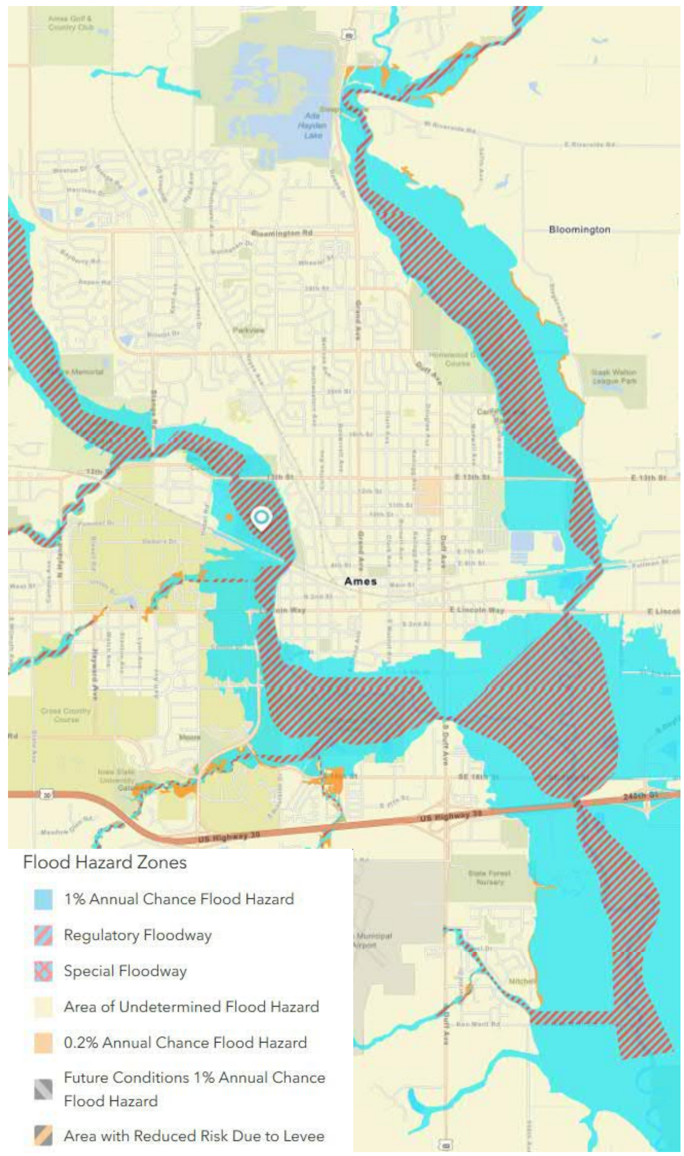


Ames Flood Vulnerability

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

The maps below illustrate flood inundation risks for the City of Ames area. The map to the left below shows the flood inundation risk areas as defined by the Iowa Flood Center (IFC). IFC inundation maps are generated with physics-based computer models to predict how a flood wave travels through communities. The map shown illustrates the extent of flooding under a storm of 1% annual chance (also known as a "100-year" event). The map to the right below shows the flood inundation risk areas as defined by FEMA and illustrated by National Flood Services and includes sections beyond the City boundary to the North and South for broader regional context.

(Sources: Iowa Flood Center, FEMA, FM Global, National Flood Services)



$ 12.15 M	168	$ 62,621
Total Flood Losses In The Community	Total Current Policies In The Community	Total Average Claim Amount In The Community

Section 08

Climate Resilience Indicators

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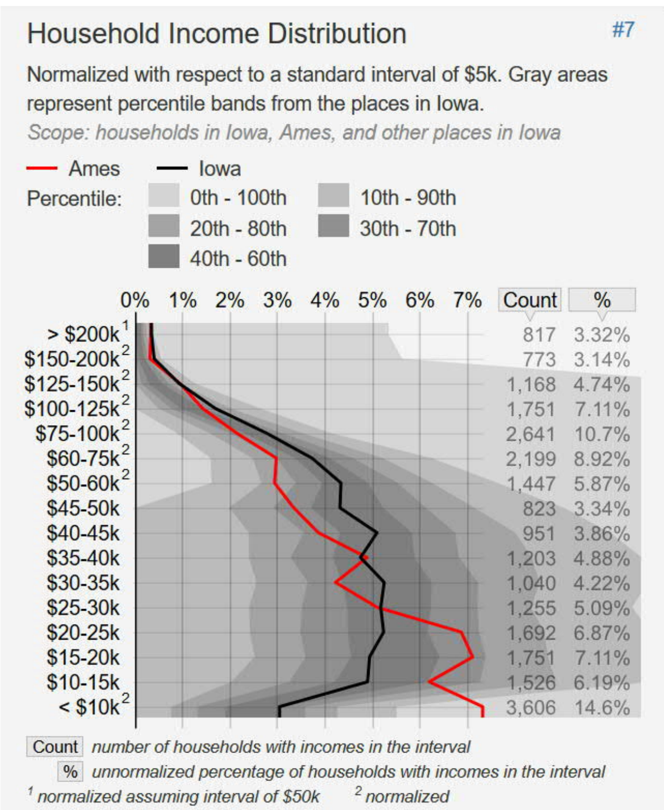
Climate Resilience Indicators

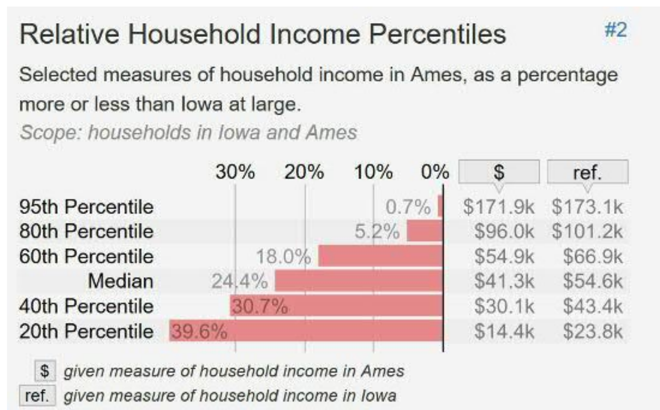
Similar to Climate Impact Multipliers, a community's overall resilience can have a multiplying or a mitigating affect on the population's ability to adapt to climate risks and rapidly recover from extreme weather events. Understanding and tracking the state of these Resilience Indicators will help identify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

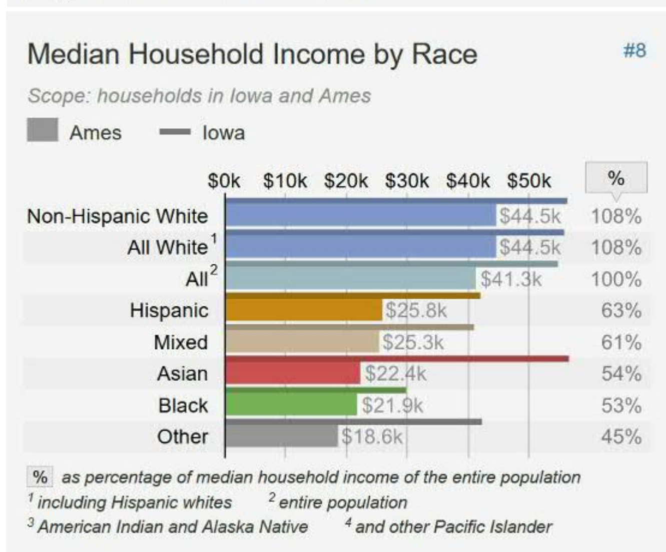
Resilience Indicators include: Economic Stress, Health Indicators, EPA Environmental Justice Screen, EPA Social Vulnerability Index, Housing Burden.

Ames Resilience Indicators - Economic Stress

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







(Source: US Census, Statistical Atlas)

Ames Resilience Indicators - Health

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

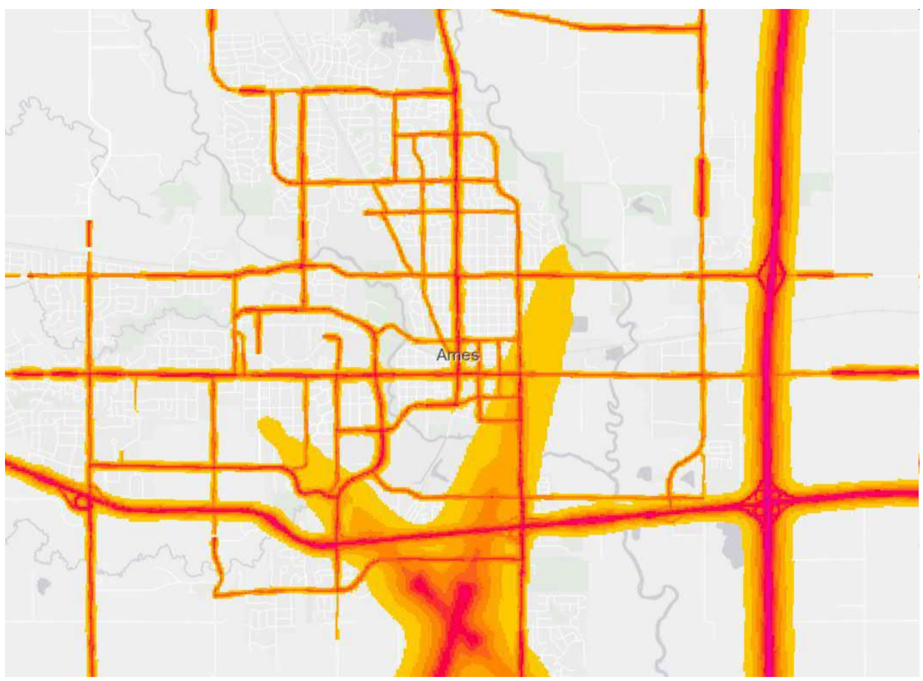
On the other hand, it should be understood that these community resilience indicators are usually only available at the granularity of County level. This means that the City should carefully consider potential implications for any community resilience indicator even if the local demographic appears "stronger"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

	State	County
Poor/Fair Health	12%	**13%**
Uninsured	5%	**5%**
Asthma emergency department visits (per 10,000)	31.3	**13.65**
Pulmonary Disease Hospitalizations (COPD per 100,000)	21.64	**15.14**
Heart attack hospitalizations (per 100,000)	27,87	**24.48**
Frequent Physical Distress	9%	**10%**
Frequent Mental Distress	10%	**11%**

(Source: County Health Rankings & Roadmaps program, Iowa Public Health Tracking Portal)

Health and Heavy Traffic

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



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

Ames Resilience Indicators - EPA Environmental Justice Screen

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

Selected Variables	Value	State		EPA Region		USA	
		Avg.	%tile	Avg.	%tile	Avg.	%tile
Environmental Indicators							
Particulate Matter (PM 2.5 in µg/m³)	7.58	7.71	42	7.77	38	8.3	29
Ozone (ppb)	40.2	40.3	53	42.5	15	43	29
NATA* Diesel PM (µg/m³)	0.351	0.266	78	0.367	50-60th	0.479	<50th
NATA* Air Toxics Cancer Risk (risk per MM)	21	22	46	27	<50th	32	<50th
NATA* Respiratory Hazard Index	0.3	0.28	66	0.36	<50th	0.44	<50th
Traffic Proximity and Volume (daily traffic count/distance to road)	850	260	93	330	90	750	78
Lead Paint Indicator (% pre-1960s housing)	0.54	0.42	64	0.34	74	0.28	78
Superfund Proximity (site count/km distance)	0.02	0.11	24	0.1	23	0.13	17
RMP Proximity (facility count/km distance)	0.29	1.2	23	0.94	38	0.74	48
Hazardous Waste Proximity (facility count/km distance)	1.4	0.49	90	0.8	83	4	71
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	0.00022	0.54	56	0.97	49	14	58

* The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

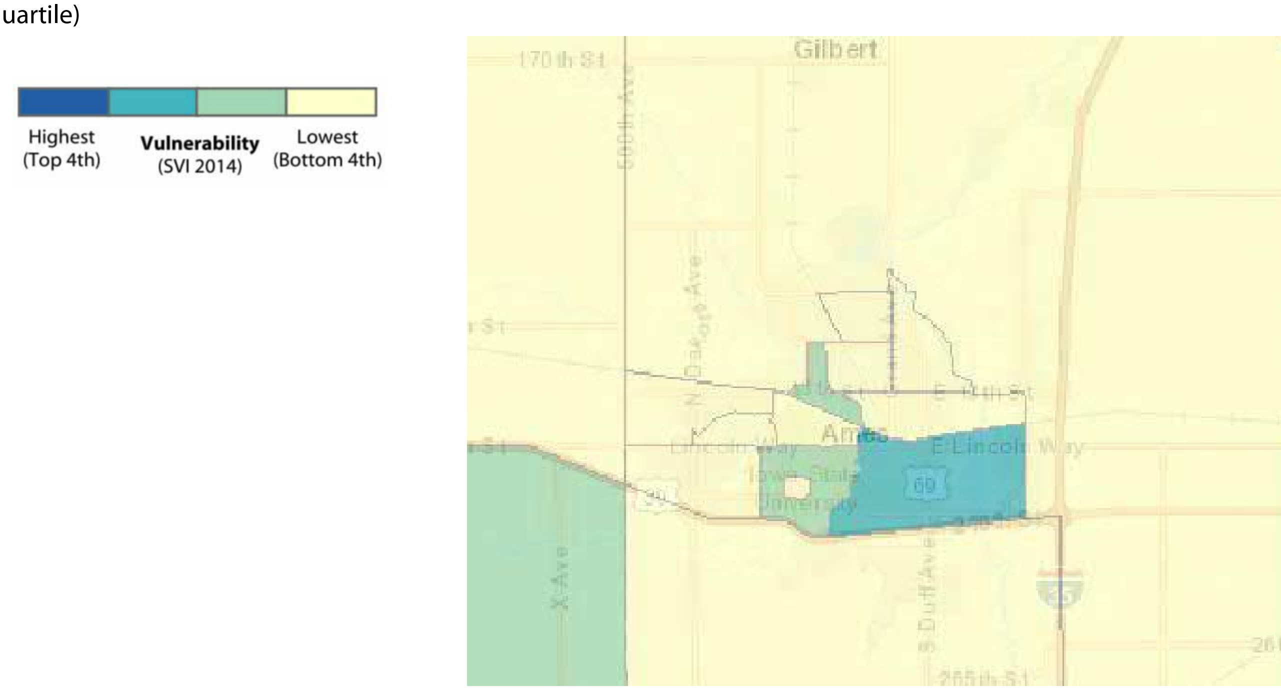
+ The hazardous waste environmental indicator and the corresponding EJ index will appear as N/A if there are no hazardous waste facilities within 50 km of a selected location.

RMP Proximity represents the potential for chemical accident based on the number of Risk Management Plan sites in area.

Ames Resilience Indicators - EPA Social Vulnerability Index

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

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



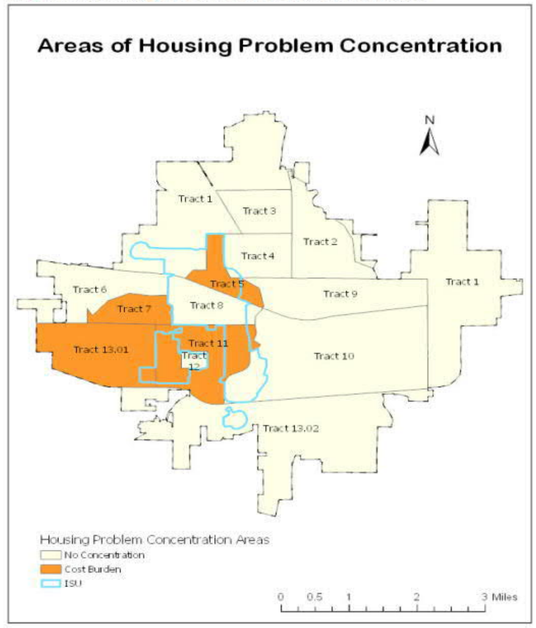
Ames Resilience Indicators - Housing Burden

Housing burden can be understood as a household living with any of four housing problems: overcrowding, high housing cost, no kitchen, no plumbing. Households with housing burden can occur at any income level, though they may be more common in middle to lower income brackets. Housing burden factors, like other economic stress indicators, can challenge a household's capacity to respond to emergencies increasing that household's climate vulnerability.

According to City of Ames 2019 Analysis To Impediments To Fair Housing Choice, a total of 11.4% of owner-occupied households and 84% of renter-occupied households are are living with housing affordability burden in the City of Ames. Families living under housing cost burden are required to spend higher portions of their income on their rent or mortgage, frequently leaving too little to cover other family expenses such as utility costs, housing and equipment maintenance, appropriate medical care, etc.

These economic stressors impact a family's resilience under favorable circumstances, while the projected climate impacts can be anticipated to exacerbate the burden felt by these families. Extreme heat events will result in even higher utility costs, potential health impacts related to water and air quality issues and heat exposure require the ability to access appropriate healthcare. Additionally, the best preventative measures to make homes climate ready - such as improved insulation, air conditioning, improved energy efficiency, and well placed shade trees - require investment. Home owners living under housing cost burden are typically incapable of making these investments. Families with housing cost burden who rent, meanwhile, typically have little leverage to see to it that landlords make the investments needed to make buildings climate ready.

Figure 9. Housing cost burden by census tract, 2015



Data Source: 2011-2015 CHAS

Source: City of Ames 2019 Analysis To Impediments To Fair Housing Choice

Housing Type Impacts on Housing Burden

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

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

Ames Housing by Type and Occupancy

Housing Type	Housing Units			Owner-Occupied			Renter-Occupied		
	Number	% of Total	State Ave	Number	% of Total	State Ave	Number	% of Total	State Ave
1, detached	9,873	39.30%	74.60%	8,237	83.40%	90.50%	1,631	10.70%	35.60%
1, attached	1,934	7.70%	4.10%	790	8.00%	3.70%	1,128	7.40%	5.00%
2 apartments	1,206	4.80%	2.10%	109	1.10%	0.40%	1,098	7.20%	6.50%
3 or 4 apartments	1,055	4.20%	3.20%	30	0.30%	0.40%	1,021	6.70%	10.00%
5 to 9 apartments	2,161	8.60%	3.40%	30	0.30%	0.30%	2,134	14.00%	11.10%
10 or more apartments	8,215	32.70%	9.20%	237	2.40%	1.00%	7,974	52.30%	29.20%
Mobile home	703	2.80%	3.40%	444	4.50%	3.70%	259	1.70%	2.50%
Total Occupied Units	25,123			9,877	39.3%	71.1%	15,246	60.7%	28.9%

(Source: US Census Bureau)

Section 09

Vulnerable Populations

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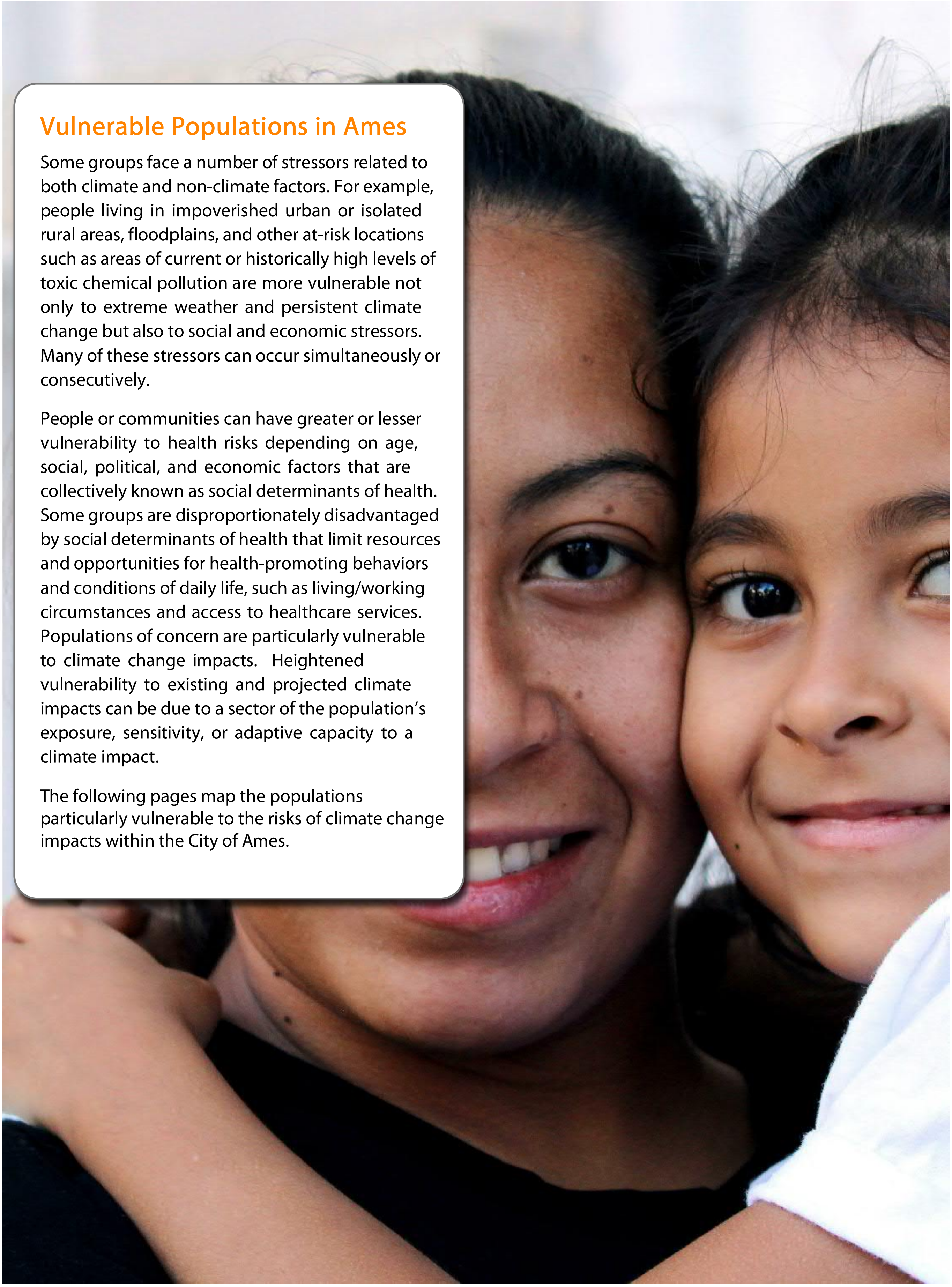


Vulnerable Populations in Ames

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

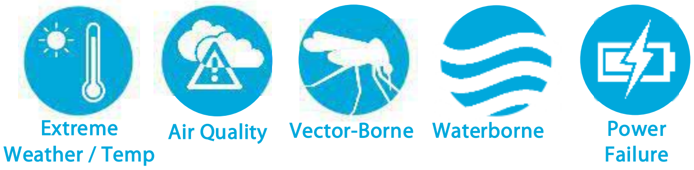
People or communities can have greater or lesser vulnerability to health risks depending on age, social, political, and economic factors that are collectively known as social determinants of health. Some groups are disproportionately disadvantaged by social determinants of health that limit resources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

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

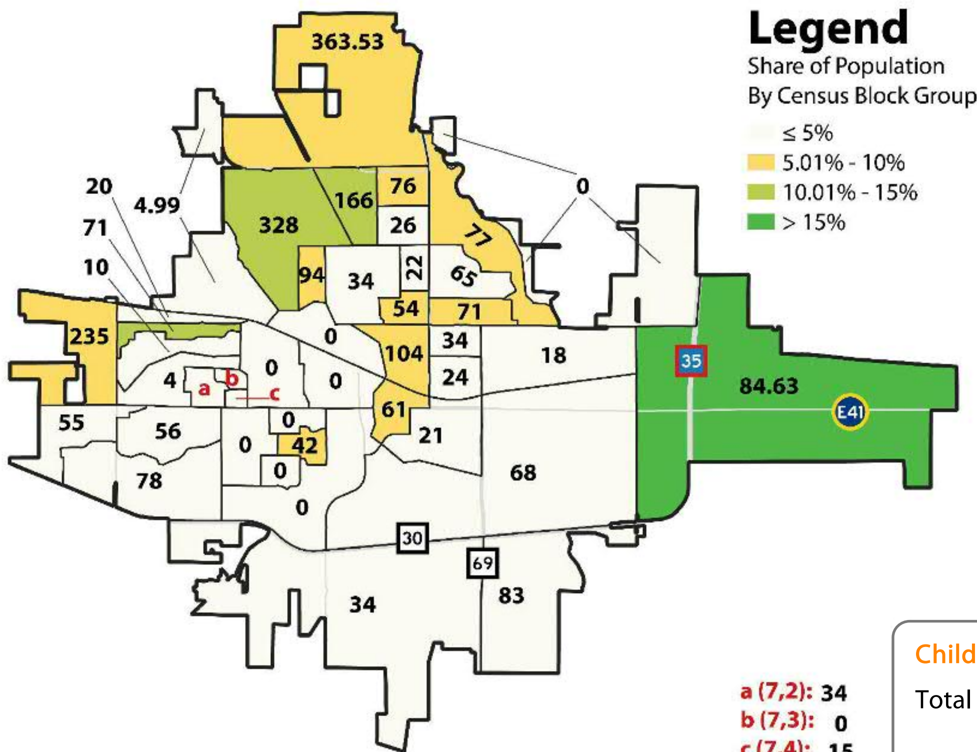
Children

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

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



Map of Vulnerable Population Distribution Within Community



Children Under 5

Estimated Population Count

Source: Census 2013-2017 American Community Survey 5-Year Estimates

Children Under 5 Summary	
Total Estimated Population:	2,777
Estimated Share of Total Vulnerable Population:	6-9%
Estimated Share of Total City Population:	3.96%

Observations for Ames

The estimated total child population under five for Ames is 2,777. This vulnerable population makes up 3.96% of the City's total population. Children under five are most concentrated in the Eastern and North Central sections of the City. These sections represent both the highest estimated population as well as the highest share of the total population of these tracts - ranging from 5% to over 15% of the total population of those neighborhoods.

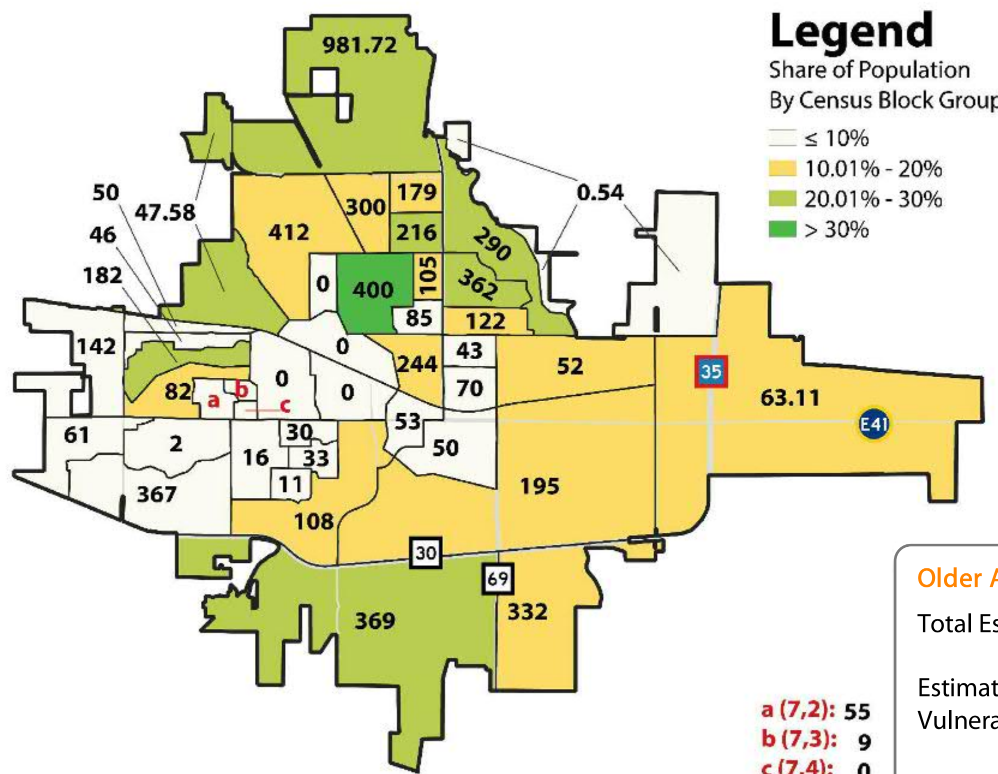
Older Adults (65 and over)

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

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

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

Map of Vulnerable Population Distribution Within Community



Adults 65 And Over

Estimated Population Count

Source: Census 2013-2017 American Community Survey 5-Year Estimates

Older Adults Summary

Total Estimated Population: **6,664**

Estimated Share of Total Vulnerable Population: **16-22%**

Estimated Share of Total City Population: **9.5%**

Observations for Ames

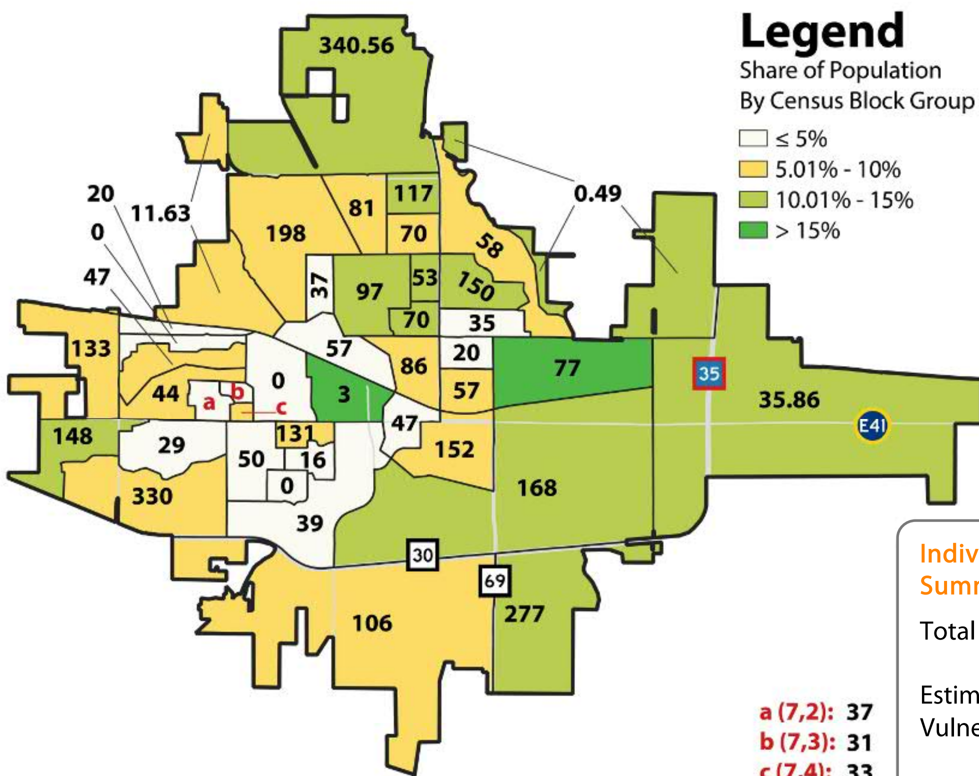
The estimated total older adult population for Ames is 6,664. This vulnerable population makes up 9.5% of the City's total population. Older adults make up at least 16% of the climate vulnerable individuals in Ames . Older adults are most concentrated in the North Central and South Central sections of the City. These sections represent the highest share of the total population of these tracts - making up 20% or more of the total population of those neighborhoods.

Individuals with Disabilities

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

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

Map of Vulnerable Population Distribution Within Community



People With Disabilities

Estimated Population Count

Source: Census 2013-2017 American Community Survey 5-Year Estimates

Individuals with Disabilities Summary

Total Estimated Population: **4,318**

Estimated Share of Total Vulnerable Population: **11-17%**

Estimated Share of Total City Population: **6.5%**

Observations for Ames

The estimated total population of individuals with disabilities for Ames is 4,318. This vulnerable population makes up 6.5% of the City’s total population. Individuals with disabilities make up at least 1 in every 8 climate vulnerable individuals in Ames . Individuals with disabilities are fairly evenly distributed throughout the City, however, the Eastern, Central, and North Central sections have the highest concentration based on share of population. These sections range from 10% to over 15% of the total population of those neighborhoods.

Individuals Under Economic Stress

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

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

Those in economic stress are also frequently food insecure. In Iowa, food insecurity affects 1 in 9 people. Many of the projected climate change impacts are likely to effect agricultural production and distribution, which in turn, may cause spikes in food costs and increase food and nutrition insecurity among those in economic stress.

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

Map of Vulnerable Population Distribution Within Community

See maps on next page.

Observations for Ames

The estimated total population in economic stress for Ames is 18,799 with 44% being individuals and 56% being families. Those living in economic stress make up over 44% climate vulnerable individuals in Ames.

Families living in economic stress are most concentrated in the East Central and West Central sections of the City while individuals living in economic stress are most concentrated in the Central sections of the City. These sections represent both the highest estimated economically stressed population as well as the highest share of the total population of these tracts - ranging from 25% to >50% of the total population of those neighborhoods.

It should be noted that the 1-person household US Census demographic numbers this assessment is based on include full-time City of Ames residents as well as Iowa State University (ISU) students. Any program development or plan implementation which may focus on low income 1-person households should take the potential impact of ISU student populations into account.

Economic Stress Summary

Total Estimated Population: **18,799**

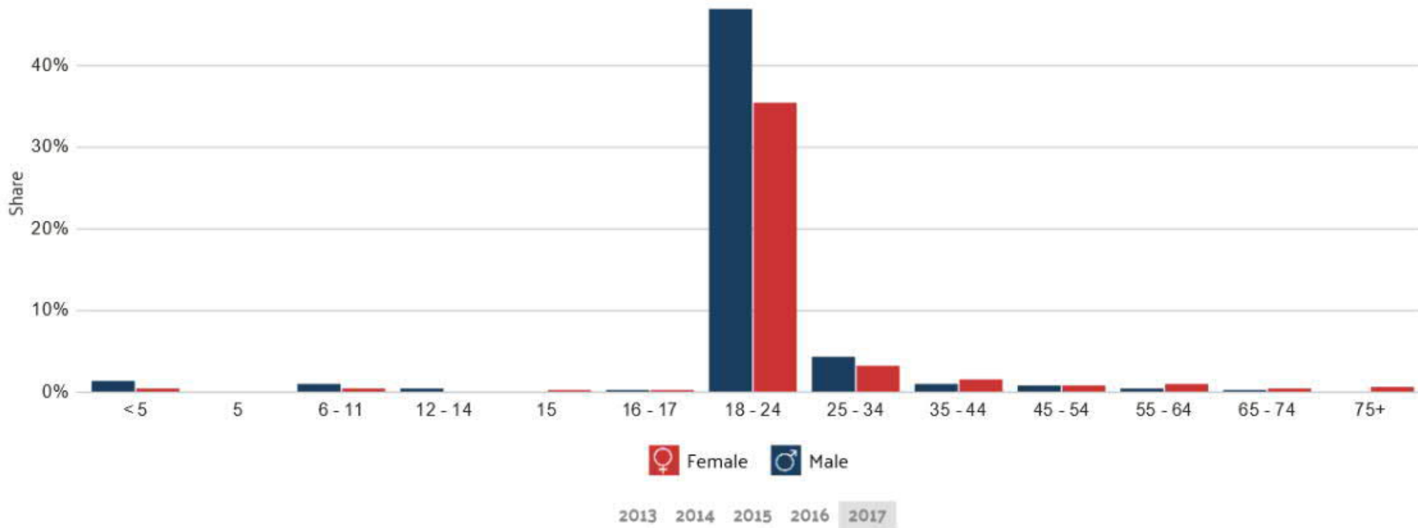
Estimated Share of Total Vulnerable Population: **44-48%**

Estimated Share of Total City Population: **26.8%**

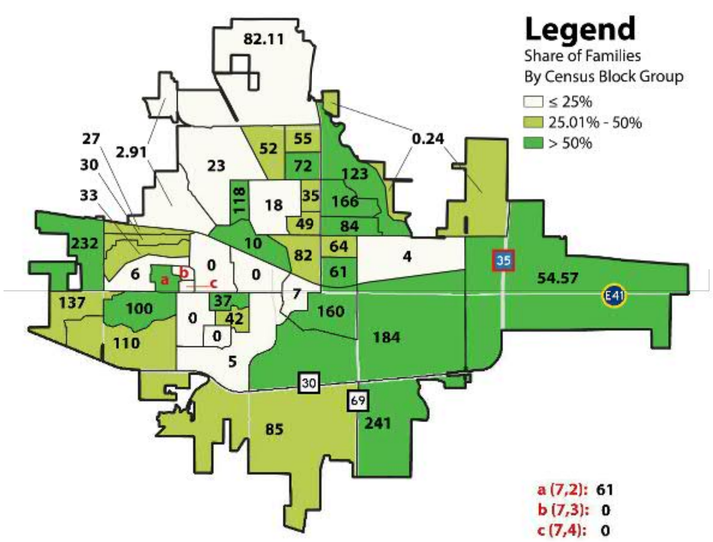
Poverty by Age and Gender

29.3% of the population in Ames live below the poverty line. The largest demographic living in poverty is male 18-24, followed by Female 18-24 and then Male 25-34. Likely, these numbers are impacted significantly by the City's total university population.

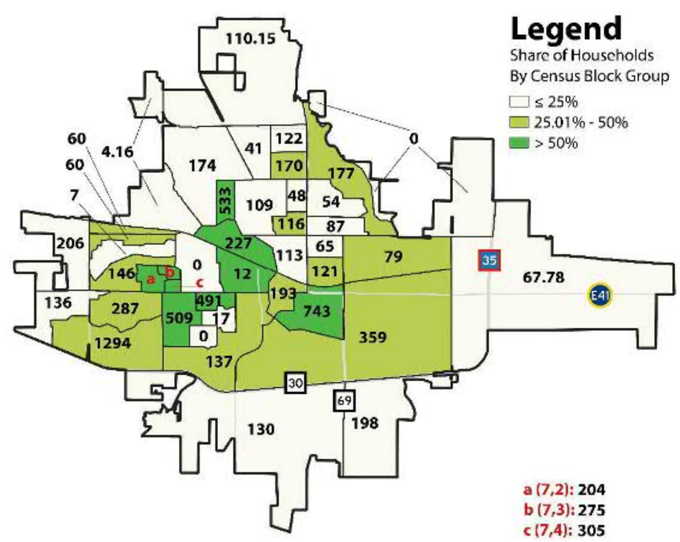
The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who classifies is impoverished. If a family's total income is less than the family's threshold than that family and every individual in it is considered to be living in poverty.



Map of Vulnerable Population Distribution Within Community



Household Income at 200% Poverty Level (Family of Four)
Estimated Count of Families
Source: Census 2013-2017 American Community Survey 5-Year Estimates



Household Income at 200% Poverty Level (1-Person Household)
Estimated Count of Households
Source: Census 2013-2017 American Community Survey 5-Year Estimates

People of Color and Limited English Populations

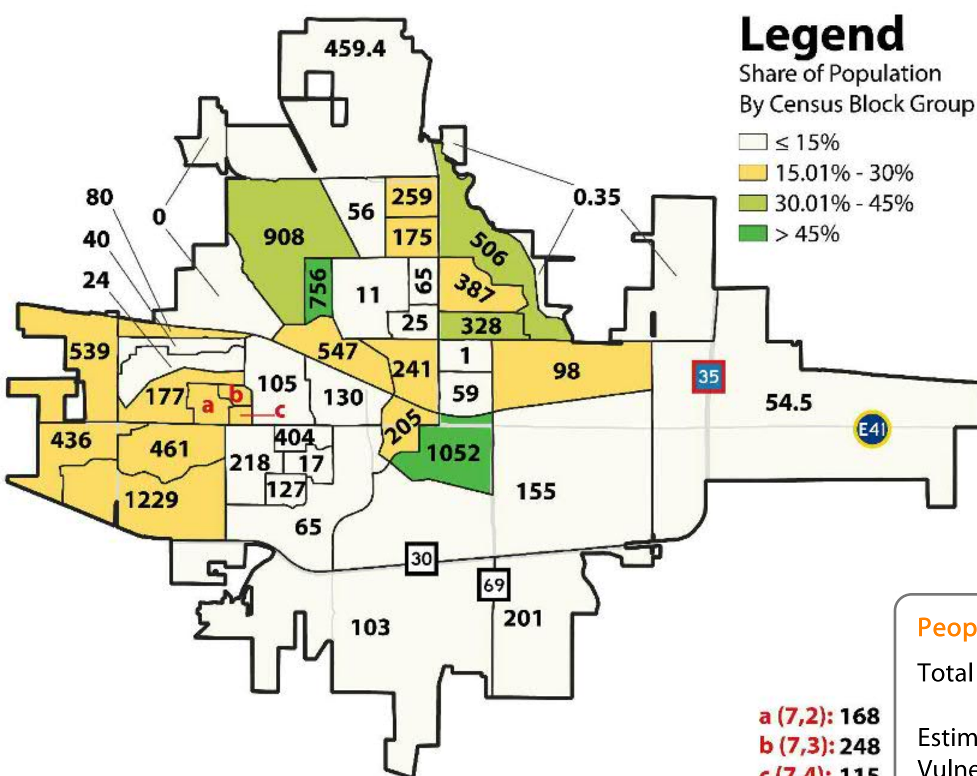
These populations are at increased risk of exposure given their higher likelihood of living in risk-prone areas, areas with older or poorly maintained infrastructure, or areas with an increased burden of air pollution. In addition, according to the Center for Disease Control and the National Health Interview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

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

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

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

Map of Vulnerable Population Distribution Within Community



People of Color and Native Americans

Estimated Population Count

Source: Census 2013-2017 American Community Survey 5-Year Estimates

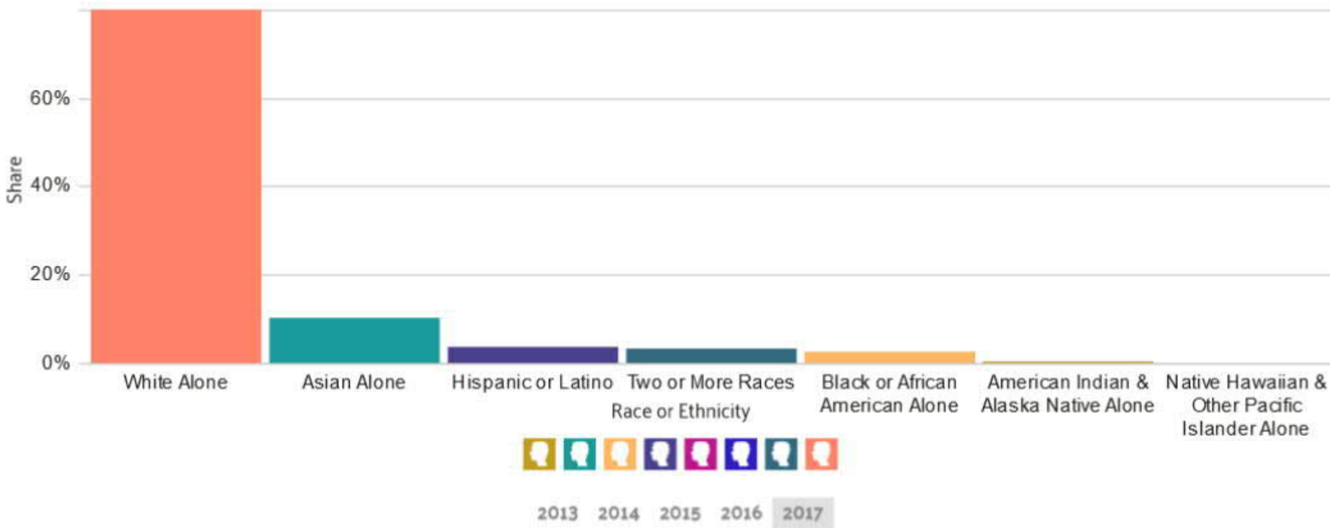
People of Color Summary

Total Estimated Population: 11,494

Estimated Share of Total Vulnerable Population: 27-32%

Estimated Share of Total City Population: 16.4%

Breakdown of Race and Ethnicity

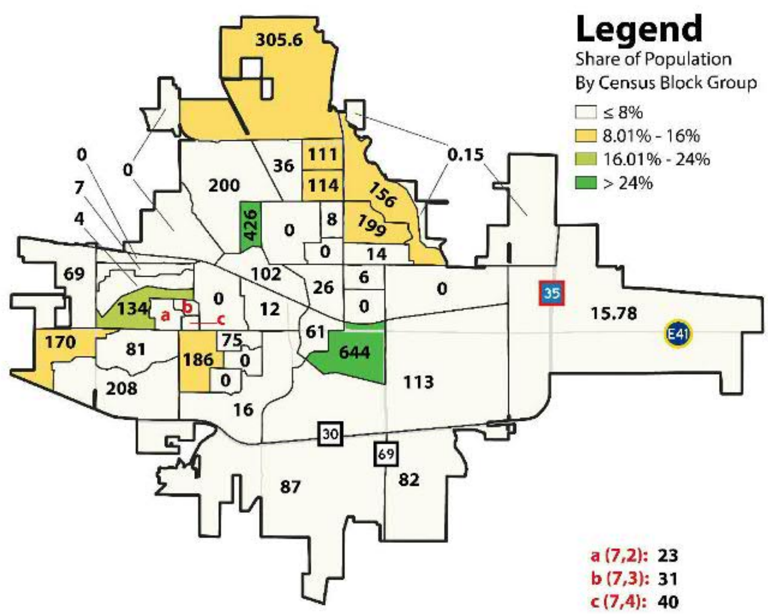


Observations for Ames

The estimated total population of people of color in Ames is 11,494 with approximately 60% being Asian, 24% Hispanic or Latino, 14% African-American, and the balance Native American, Pacific Islander, or two or more races. This vulnerable population makes up 16.4% of the City's total population and approximately 1 in 3 of all climate vulnerable individuals in Ames.

Populations of color are most concentrated in the Central and West Central sections of the City. These sections represent both the highest estimated population of color as well as the highest share of the total population of these tracts - ranging from 15% to over 45% of the total population of those neighborhoods

There are an estimated 3,754 limited English speakers in the Ames. Assuring key communications related to community resources, safety, emergency, and extreme weather preparedness is equally accessible to community residents with limited English is important for overall community resilience. The City should review its current and future communications for translation opportunities targeting the city's non-English primary languages to the greatest extent feasible.



Limited English Speakers
Estimated Population Count
Source: Census 2013-2017 American Community Survey 5-Year Estimates

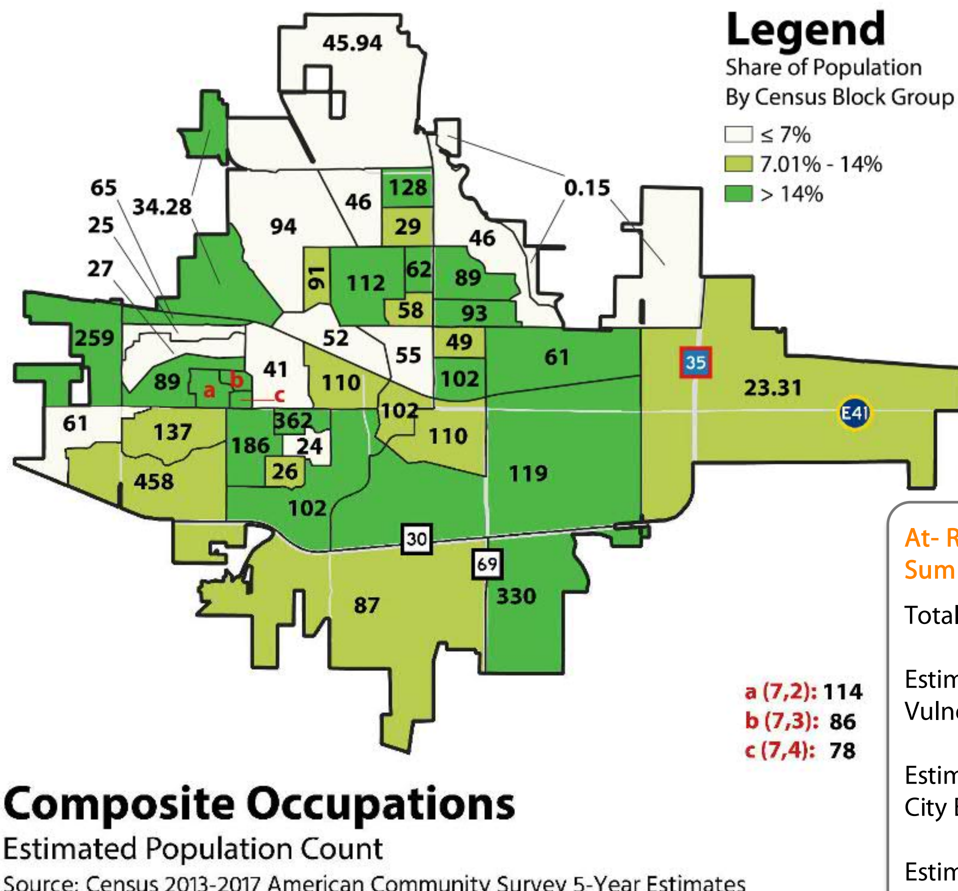
At-Risk Workers

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

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

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

Map of Vulnerable Population Distribution Within Community

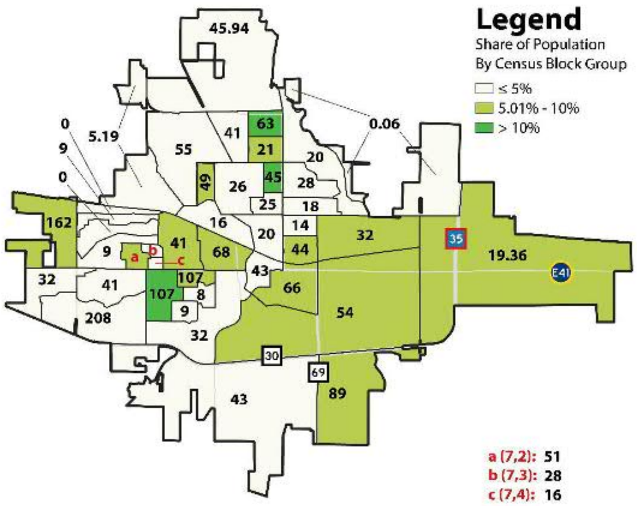


At- Risk Employment Summary

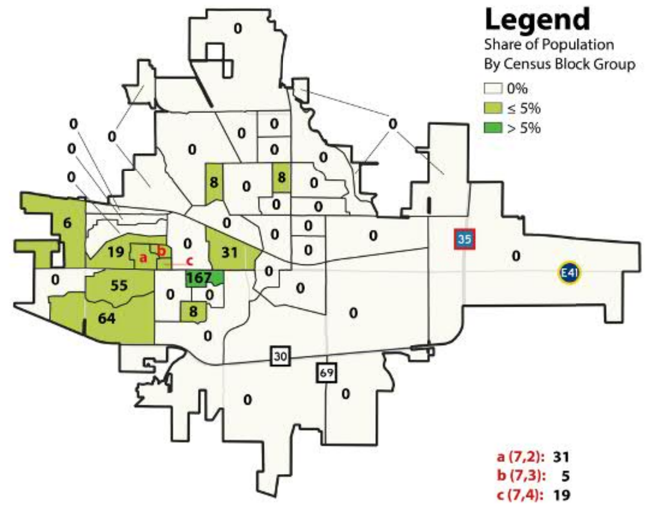
Total Estimated Population:	4,686
Estimated Share of Total Vulnerable Population:	12-18%
Estimated Share of Total City Employment:	12.9%
Estimated Share of Total City Population:	6.7%

Observations for Ames

The estimated total Ames residents employed in at-risk occupations is 4,686, nearly 13% of all Ames residents who are employed, and over 6.7% of the City's total population. At-risk workers make up at least 1 in every 7 climate vulnerable individuals in the City . At-risk workers are most concentrated in the Eastern, Southern, and Western sections of the City, making up to 7% to over 14% of the total population of those neighborhoods. The largest at-risk worker categories are employed in First Responder, Transportation, Material Mover, Construction, Extraction, and Production jobs.



First Responders, Transportation Workers, and Material Movers
Estimated Population Count
Source: Census 2013-2017 American Community Survey 5-Year Estimates



Farming, Fishing, and Forestry Workers
Estimated Population Count
Source: Census 2013-2017 American Community Survey 5-Year Estimates

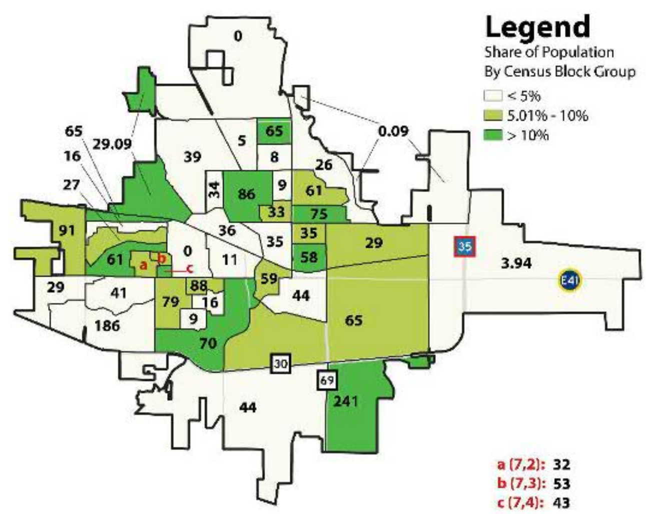
At-Risk Occupations Breakdown

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

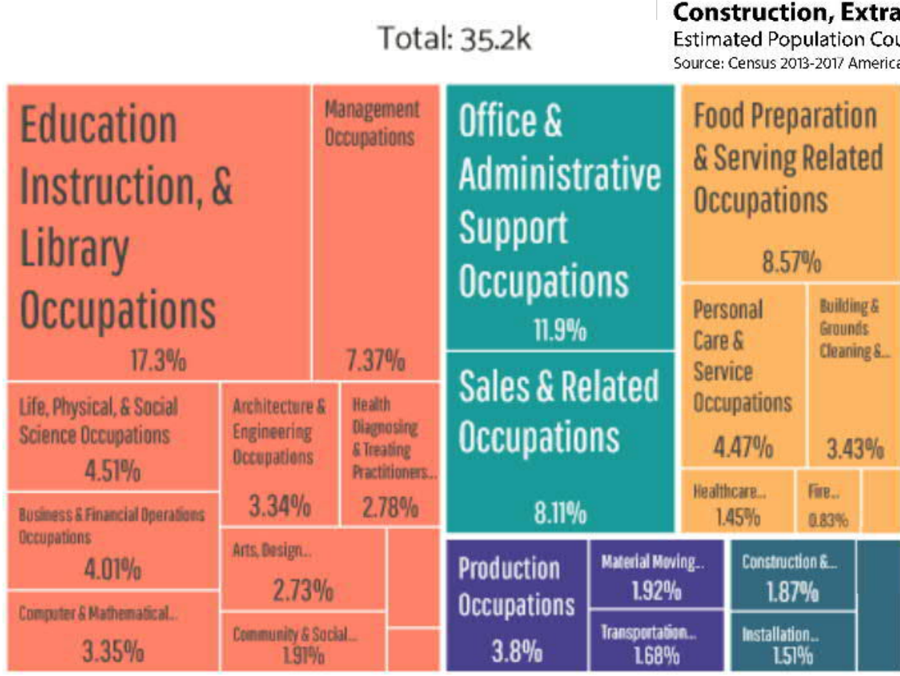
Total Employment by Occupation

Employment in Ames, IA grew at a rate of 0.635%, from 2016 to 2017. The chart below shows the share breakdown of the primary jobs held by residents of Ames.

(Source: USAData, US Census Bureau)



Construction, Extraction, and Production Workers
Estimated Population Count
Source: Census 2013-2017 American Community Survey 5-Year Estimates



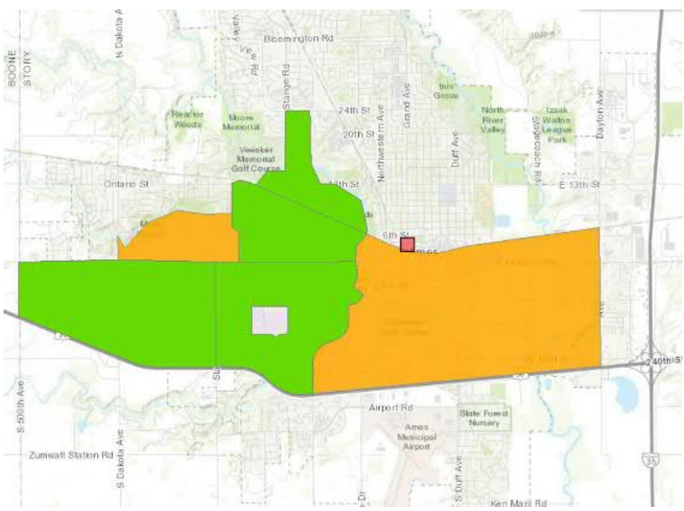
(Source: Feed America)

Individuals with Possible Food Insecurity

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

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

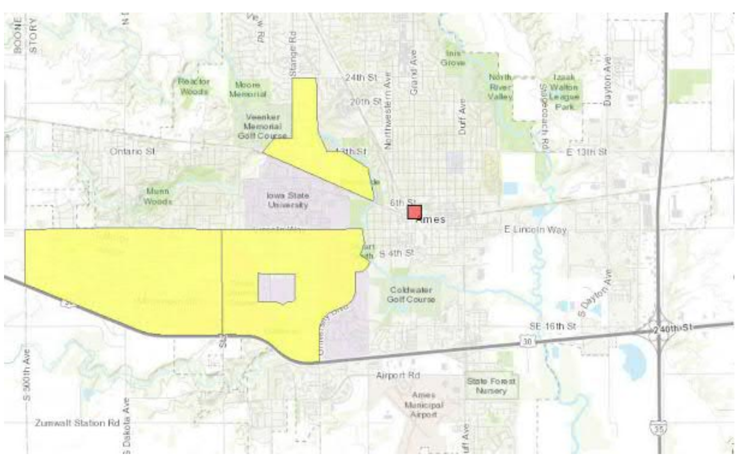
Individuals experiencing food insecurity may be particularly sensitive to the following Climate Risks:



Food Access

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

(Source: USDA Economic Research Service Food Atlas)



Vehicle Access

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

(Source: USDA Economic Research Service Food Atlas)

Climate Migrant Populations

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

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

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

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

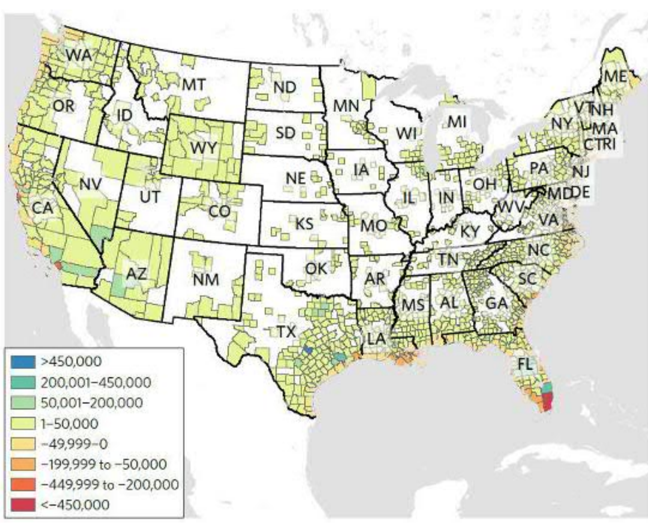
The impacts of climate migration will cause accelerated changes for inland areas, particularly urban areas, that will observe much higher levels of incoming migrants than they would have without climate impacts. It is projected that 86% of all communities with populations of over 10,000 will be impacted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

Projected Potential Climate Migrant Population by 2100

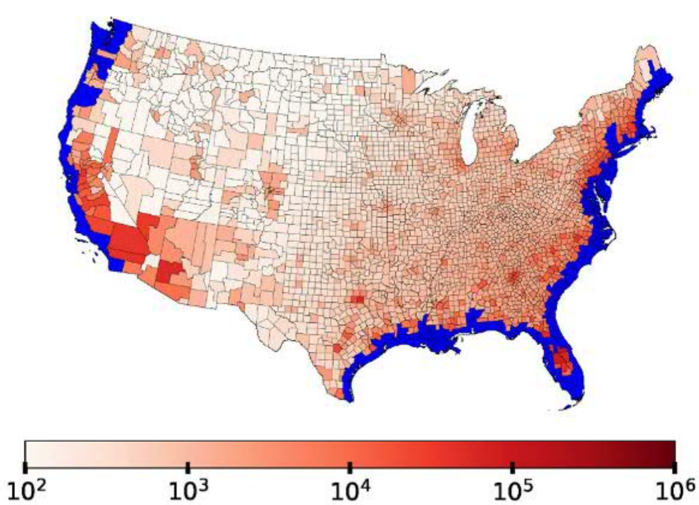
Story County:	10-50,000
City of Ames: (Pro rata share)	7-35,000

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

Hauer Projection - Migration induced by sea-level rise in US



Robinson Projection - Migration induced by sea-level rise in US



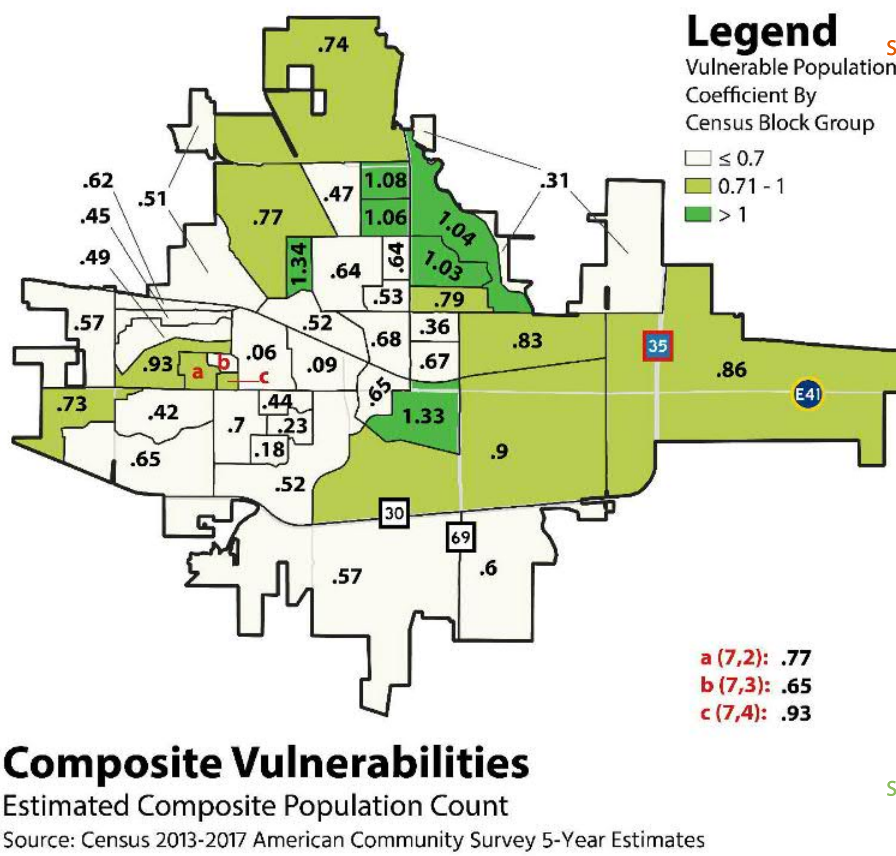
(Sources: United Nations International Organization on Migration
Hauer, M. Migration induced by sea-level rise could reshape the US population landscape. Nature Clim Change 7, 321–325 (2017). https://doi.org/10.1038/nclimate3271
Robinson C, Dilkina B, Moreno-Cruz J (2020) Modeling migration patterns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

Composite Vulnerabilities

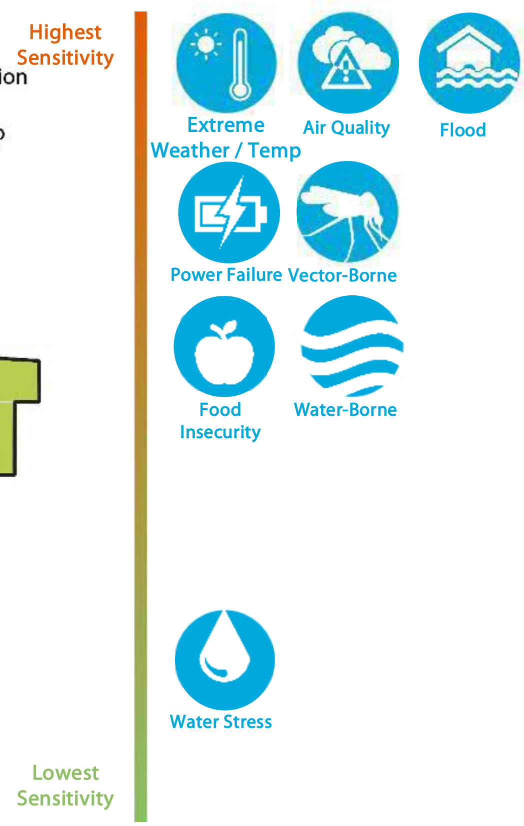
The map below provides a composite mapping of all vulnerable populations illustrated in this section. It should be noted that it is possible for individuals to be members of more than one vulnerable population. For example, an individual may be both an adult over age 65 as well as an individual living below 200% of poverty level. Consequently, the "Estimated Population" counts provided on this composite vulnerabilities map may not be accurate, but the numbers represented here provide a reasonable estimate of the magnitude of total vulnerable populations in each census tract. This composite view of vulnerable populations is also useful in identifying those climate risks which may be most impactful to the most vulnerable individuals.

As indicated in the map below, the census tracts can be ordered from fewest instances of population vulnerability to most instances of population vulnerability (Total Population Vulnerability). The Vulnerability Coefficient represents the ratio of total instances of population vulnerabilities to the total population within the census tract where higher numbers represent a higher prevalence of vulnerabilities within the census tract population.

Map of Total Vulnerable Population Distribution Within Community



Ames Risk Sensitivity



Vulnerability Risk Sensitivity

Based on the total estimated population count for each vulnerable population and considering the risks each demographic is most sensitive to, the population vulnerabilities can be considered from highest sensitivity (more vulnerable individuals) to lowest (fewer vulnerable individuals) sensitivity.

It should be noted that risks which appear to have lower sensitivity levels should not be considered irrelevant for the community. To the right, above, is a possible ordering of risk sensitivity for the City of Ames.

Section 10

Findings

Click to
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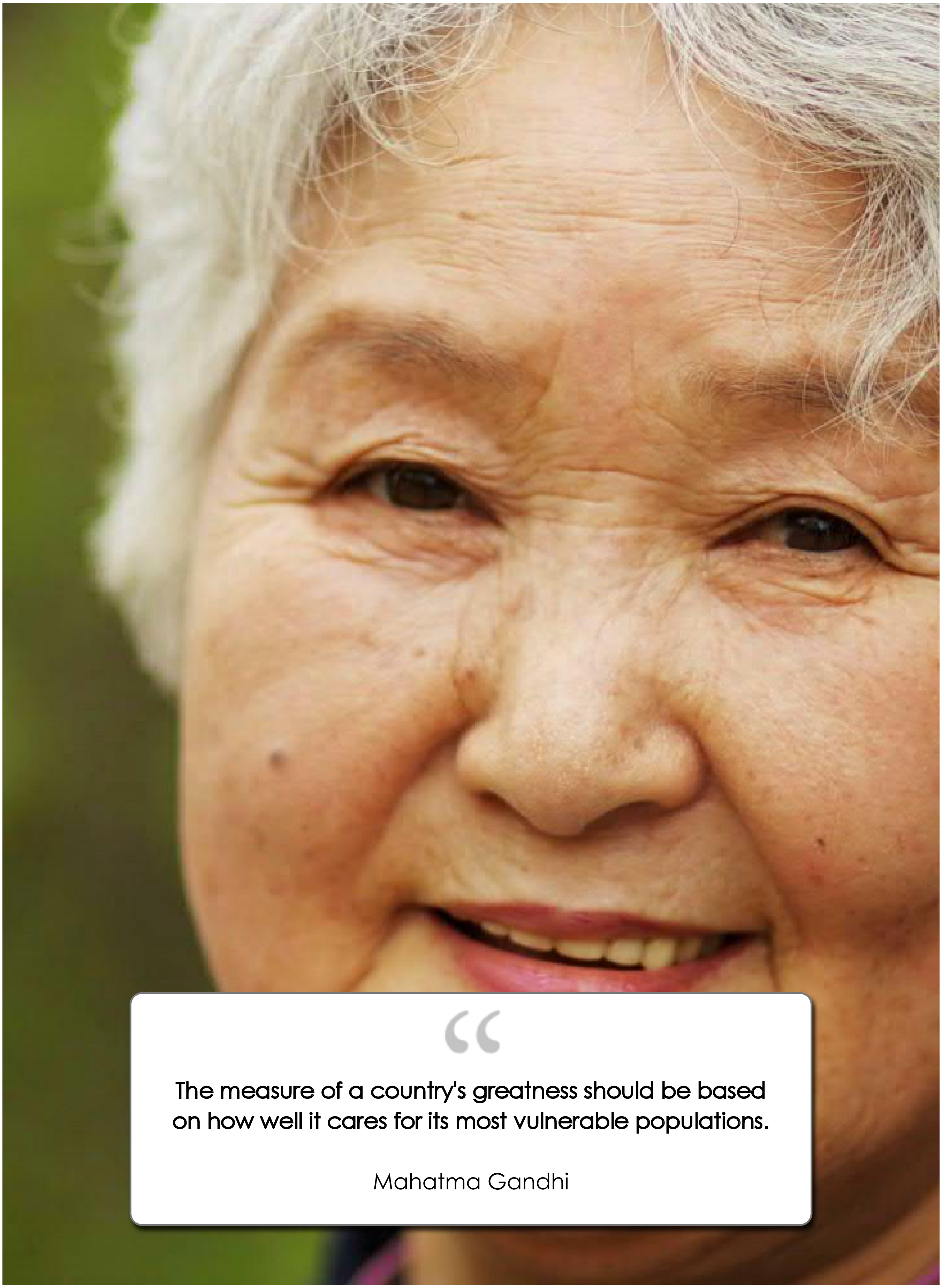

"
The measure of a country's greatness should be based on how well it cares for its most vulnerable populations.
Mahatma Gandhi

Findings

Findings - Vulnerable Populations

Climate change impacts will affect everyone and City policies and actions should consider climate adaptive needs of the entire community. As with all planning efforts climate adaptation benefits from analysis in order to assist in establishing priorities for initial efforts. An effort to structure a prioritization should not be seen as an attempt to discard the need to address climate impacts for any population within the City - whether or not it is defined as one of the "vulnerable" populations . Prioritization, however, is necessary to ensure the greatest impact and effectiveness of limited City resources. To assist in prioritization, this report reviews the community Vulnerable Populations data through the following "filters":

Highest Sensitivity

Comparing Vulnerable Populations Within The City of Ames

Population	Estimated Total	Share
Children	2,777	6-9%
Older Adults	6,664	16-22%
Disabled	4,318	11-17%
Economic Stress	18,799	44-48%
People of Color	11,494	27-32%
At Risk Workers	4,686	12-18%

Based on this view of Ames population vulnerabilities, those living in Economic Stress, People of Color, Older Adults, and At Risk Workers represent those with the most significant vulnerabilities.

Comparing Vulnerability by Census Tract
(highest 6 Census Tracts)

Tract	Vuln Pop	% of Vuln	Vulnerability Coefficient	
13.01	6,431	15.2%	0.61	
1	5,533	13.1%	0.63	
10	5,022	11.9%	1.04	*
2	3,739	8.84%	0.97	*
11	3,358	7.94%	0.50	
5	3,050	7.21%	0.89	*
6	2,750	6.5%	0.56	
13.02	2,745	6.49%	0.60	
3	2,697	6.38%	0.79	*
7	2,644	6.25%	0.80	*
9	2,116	5.0%	0.62	
4	1,636	3.87%	0.62	
8	413	0.98%	0.11	
12	164	0.39%	0.2	

Lowest Sensitivity

Comparing Risk Sensitivities Across Ames

This comparison is based on the total estimated count for each vulnerable population and considers the particular risks each demographic is most sensitive to. The result is an accounting of the risks with the greatest number of sensitive individuals (see Section 9 for more info)

The risks with the highest sensitivities are:

Extreme Temp / Weather

Air Quality Impacts

Flood

Infrastructure Failure

Based on a review of the Vulnerability Coefficient, that is, the total instances of vulnerability represented against total census tract population, Census Tracts 10, 2, 5, 3, and 7 have the highest levels of impact sensitivities.

Findings - City’s Climate Impact Multipliers

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

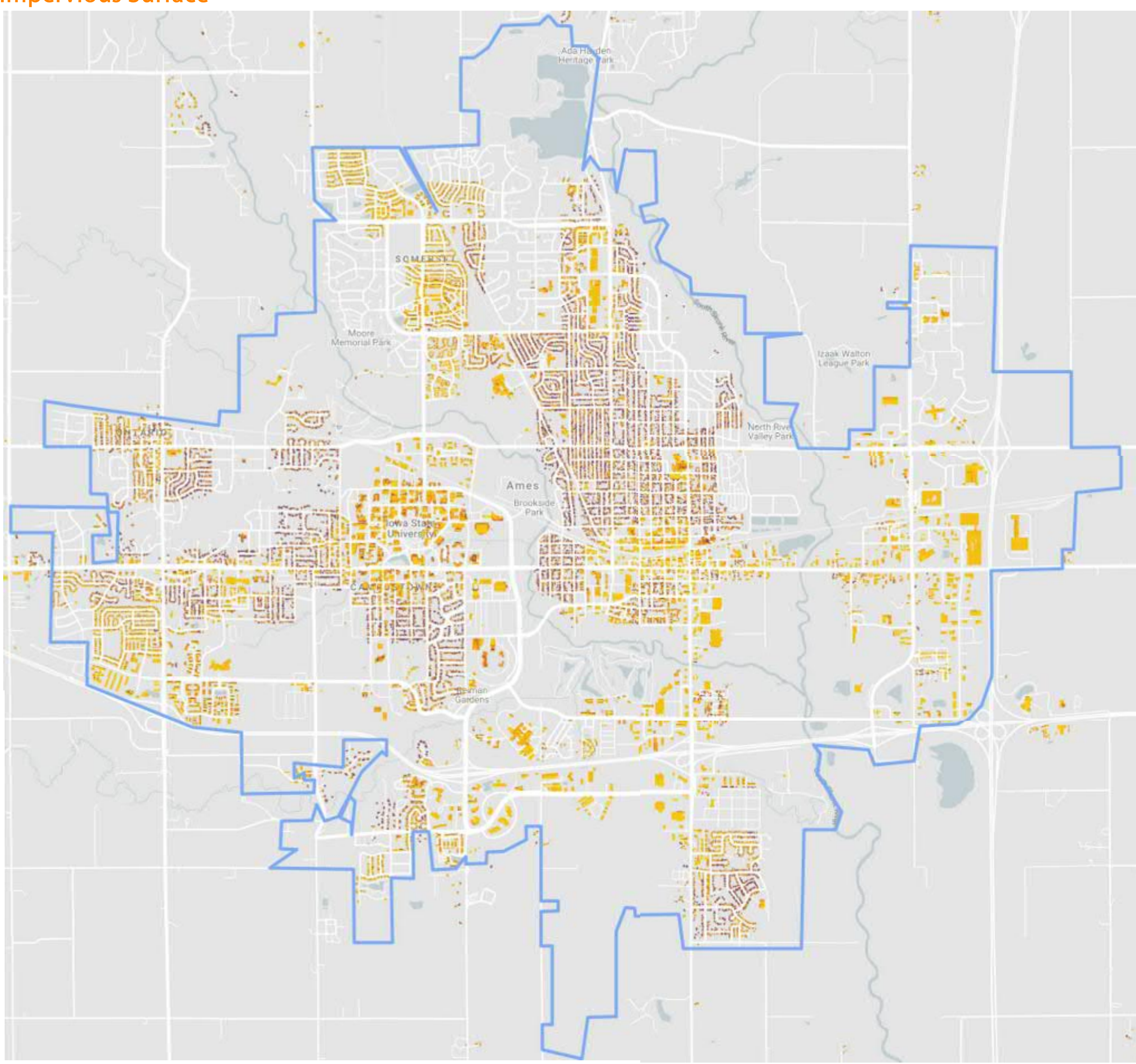
Based on the City’s vulnerable population findings, a review of the City’s Climate Impact Multiplier characteristics provides:

Findings - Impervious Surface, Tree Canopy, and Heat Island

The City’s average existing Tree Canopy coverage of 23% is below the national average indicating there are likely portions of the City which could benefit from increased tree canopy. Identifying opportunities for increased greenspace and decreasing impervious surfaces - particularly dark pavement areas - in these portions of the community would also be beneficial in mitigating heat island effects.

The graphic below illustrates building density and exposure within the City. Darker colors represent increased shading on buildings while lighter colors represent increased sun exposure. Areas which have both higher density and higher solar exposure (lighter color) are areas likely to experience micro climate heat island effects and would benefit from anti-heat island strategies particularly those in the tracts with the highest impact sensitivities.

Impervious Surface



Findings - Climate Resilience Indicators

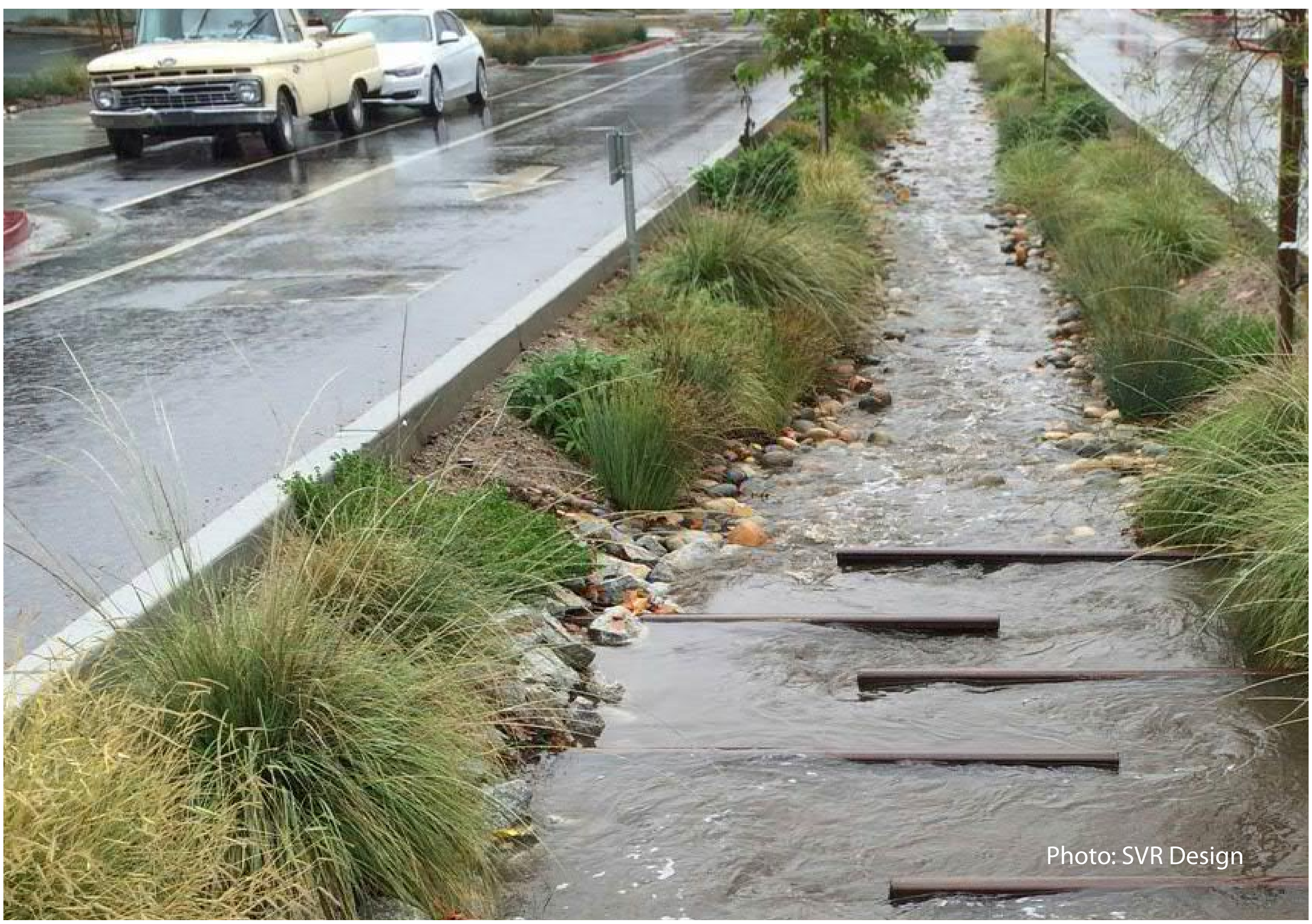
Based on the City's increased risk sensitivity of Air Quality the EPA Environmental Indicators of particular concern are Diesel Particulate Matter in which Ames ranks in the 78th percentile in the State, Respiratory Hazard Index in which Ames ranks in the 66th percentile in the State, Traffic Proximity and Volume in which Ames ranks in the 93rd percentile in the State, and Hazardous Waste Proximity in which Ames ranks in the 90th percentile in the State. Breathing in particles causes inflammation in our respiratory and circulatory system. These pollutants can make it harder to breathe; it can cause asthma-like symptoms - of concern even with Story County's lower than average instance of asthma emergency department visits. High rates of particulate matter pollution have been linked to higher rates of cancer, heart disease, stroke, and early on-set dementia.

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

The primary source for particulate matter pollution is vehicle emissions and incomplete fossil fuel combustion for heating, cooling, and energy generation. The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). Ames' proximity to high traffic volumes is in the 93rd percentile for the State and the 78th percentile nationally.

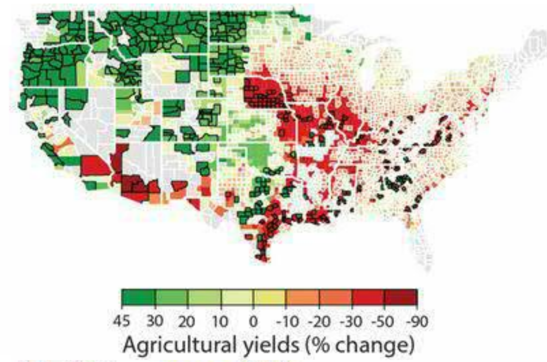
Summary of Climate Impact Multiplier and Climate Resilience Findings

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



Projected Economic Impacts of Climate Change

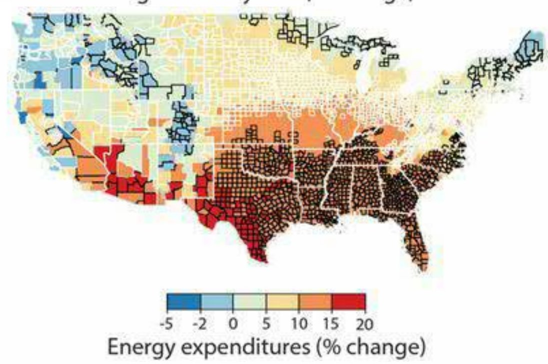
“Estimating economic damage from climate change in the United States”, a 2017 study completed by Solomon Hsiang and others from the University of California at Berkeley assessed the economic impact of current climate projections throughout the United States. The sectors assessed, and the findings for Story County Iowa and the City of Ames are below:



Agricultural Yields Through 2100

Agricultural yields are projected to decline with the increase of Global Mean Surface Temperature in addition to impacts related to precipitation changes. Although increased CO2 levels are anticipated to offset a portion of these yield loses, the impact for much of the United States will be a net negative. Local projections:

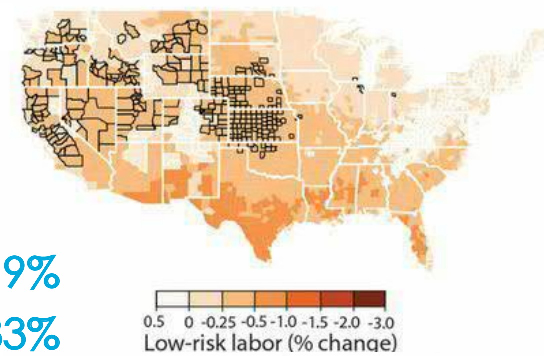
Story County and City of Ames: **-24.2%**



Energy Expenditures Through 2100

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

Story County and City of Ames: **+8.76%**

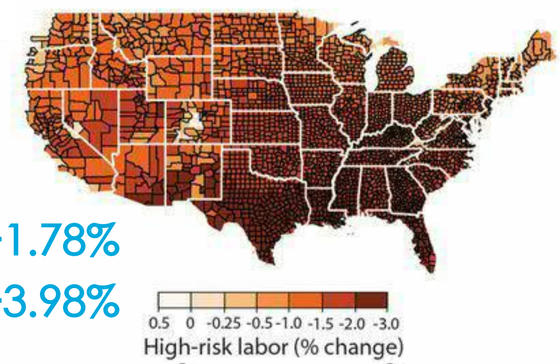


Reduced Labor Productivity Through 2100

Labor productivity declines with the instance of increased temperature. Rates vary for “low-risk” workers who are predominantly not exposed to exterior conditions and for “high-risk” workers (those identified as “At Risk Workers” in Section 9). Local projections:

Low-Risk Labor Loss for Story County and City of Ames: **-0.19%**

High-Risk Labor Loss for Story County and City of Ames: **-1.33%**

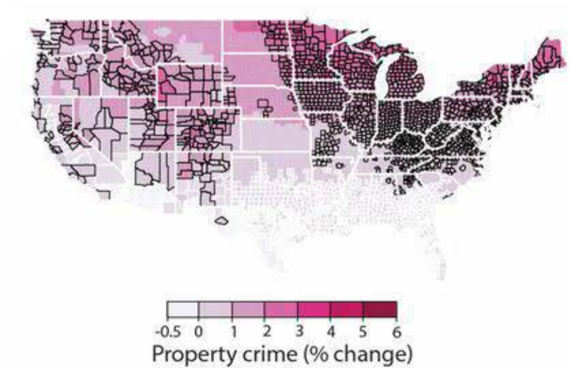


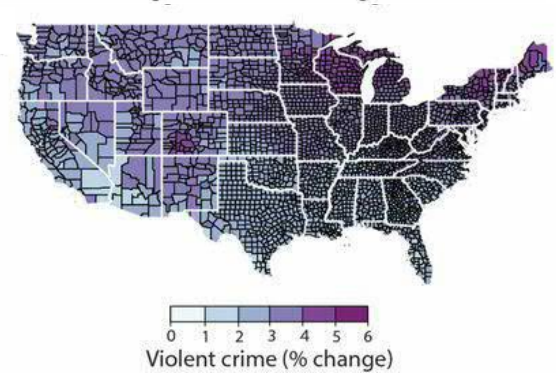
Increases in Crime Rates Through 2100

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

Property Crime Increase for Story County and City of Ames: **+1.78%**

Violent Crime Increase for Story County and City of Ames: **+3.98%**

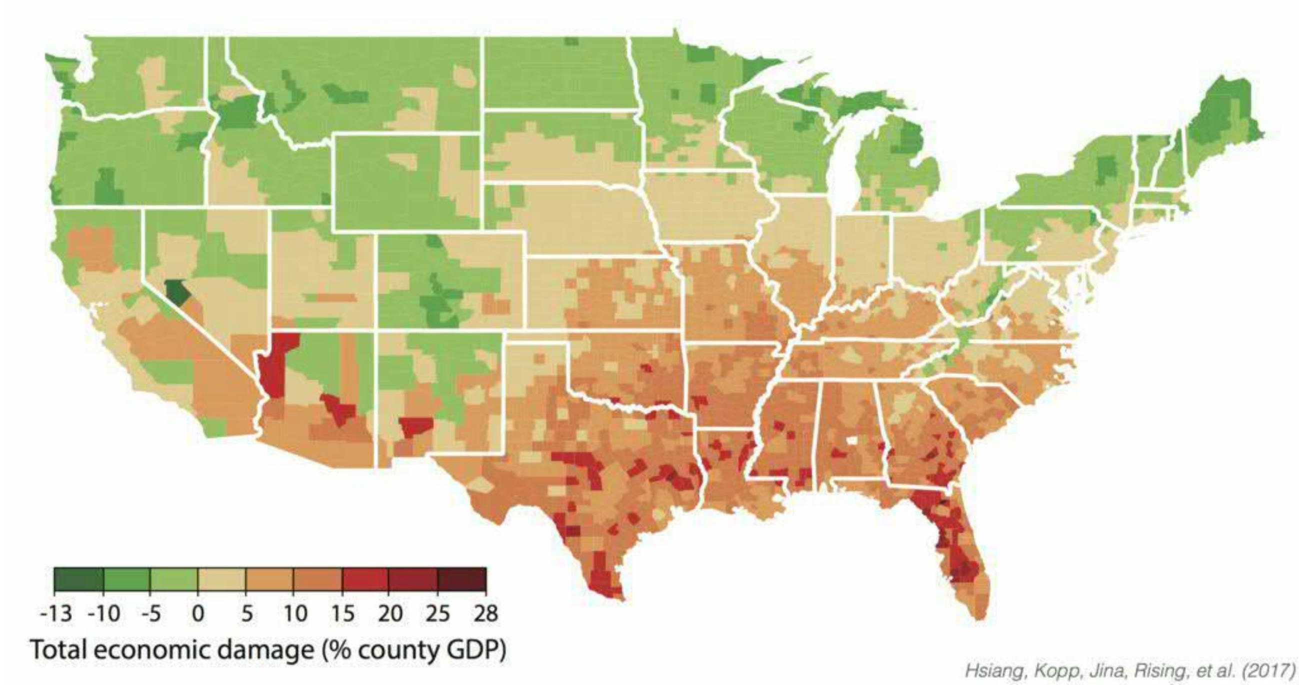


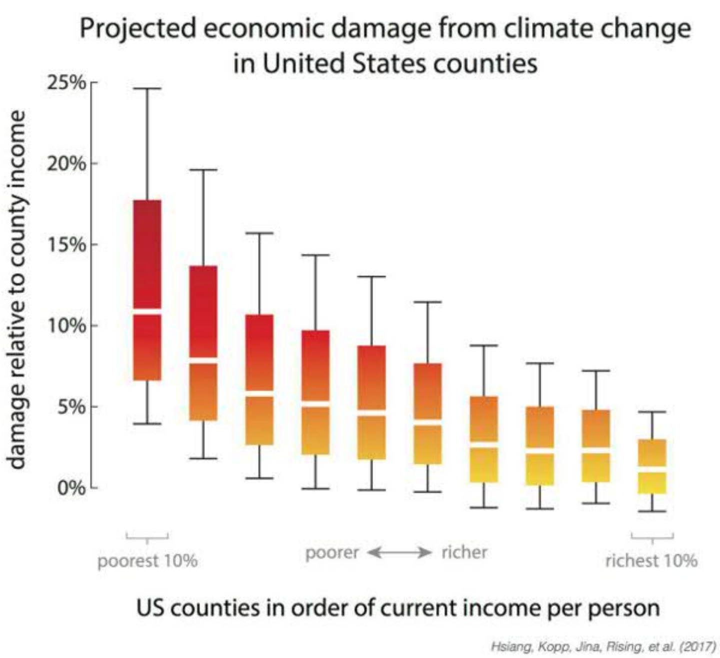


Total Projected Economic Impacts Through 2100

According to research completed for "Estimating economic damage from climate change in the United States", a 2017 study completed by Solomon Hsiang and others from the University of California at Berkeley the total annual economic impact for Story County Iowa by 2100 will be: **$88,174,200 annually (2018 dollars)**

Estimating the total annual economic impact for the City of Ames on a Pro Rata share results in:
$60,136,284 annually (2018 dollars)





Inequity of Economic Impacts Through 2100

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

Source: "Estimating economic damage from climate change in the United States" Muir-Wood, Paul Wilson, Michael Oppenheimer, Kate Larsen and Trevor Houser Solomon Hsiang, Robert Kopp, Amir Jina, James Rising, Michael Delgado, Shashank Mohan, D. J. Rasmussen, Robert
DOI: 10.1126/science.aal4369
Science 356 (6345), 1362-1369.

Review of Climate Hazards for the City of Ames

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

The chart below reviews the current, future, and timeline of change for each of the primary Climate Hazards for the city. In addition, the columns on the right illustrate the reported number of events, % change, and annualized economic impact of each of these hazards over the last 20 years.

Climate Hazards

Climate Hazard Type	Current hazard risk level	Expected change in intensity	Expected change in frequency	Timeframe	Number of Events 1999-2009 vs 2009-2019 (NOAA)	% Change	Statewide Annualized Property Loss Value (NOAA)
Extreme Heat	Low	Increase	Increase	Medium-term	0 events to 3 events	N/A	$300K
Extreme Cold	Moderate	Increase	Decrease	Medium-term	0 events to 8 events	N/A	$23,100K
Extreme Precipitation	Not Known	Increase	Increase	Short-term	20 events to 152 events	760%	See Flood
Floods	High	Increase	Increase	Short-term	43 events to 76 events	176%	$125,300K
Droughts	Low	Increase	Increase	Medium-term	4 events to 5 events	125%	$302,900K
Storms	High	Increase	Increase	Short-term	210 events to 303 events	144%	$55,700K
Forest/Wild Fires	Low	Not known	Not known	Not known	0 events to 0 events	N/A	N/A
Air Quality Impacts	Low	Increase	Increase	Long-term	N/A	N/A	N/A

Review of Climate Risks for the City of Ames

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

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

Climate Risks to Population

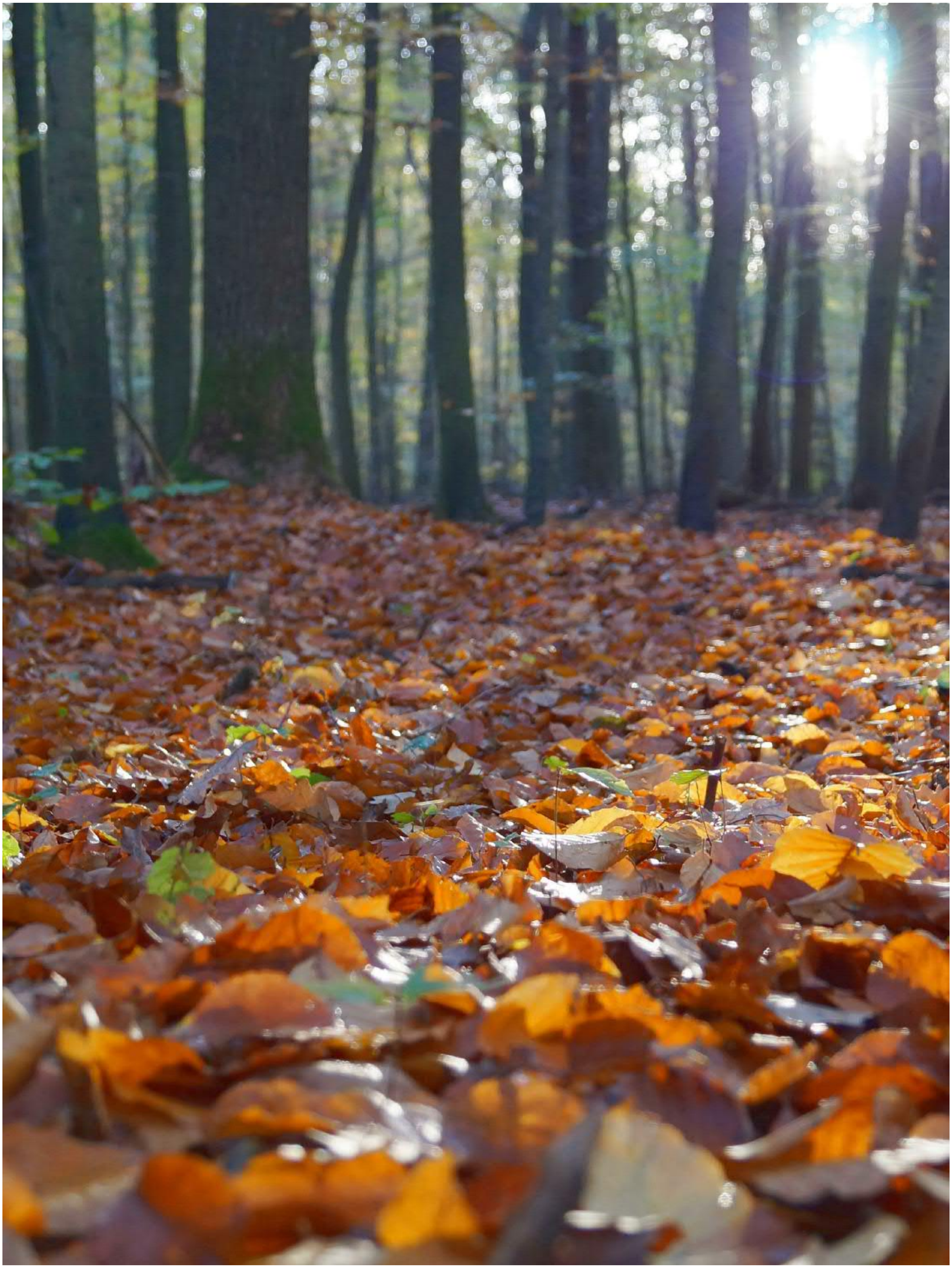
Health Impacts	Expected Impact(s)	Likelihood of Occurrence	Impact Level (Population Vulnerability)	Timeframe	Risk (Likelihood x Impact)	Impact-related Indicators
Extreme Heat	Increased demand for cooling; heat stress and emergency visits, heat related health	Possible	High	Medium-term	High	Cooling Degree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

Climate Risks to Infrastructure and Institutions

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

Priority Climate Risks for the City of Ames

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



Section 11

Recommendations

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Recommendations

Recommended Adaptation and Resilience Goals

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

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

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

Climate Adaptation and Resilience Goals

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

Goals To Build Capacity For Preparing For And Responding To Population Risks Of Climate Change Impacts

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

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

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

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

Goal C5 - Enhance resilience of critical city operations.

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

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

Goals Responding to Heat Stress And Extreme Weather

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

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

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

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

Goal H5 - Enhance resilience of community tree canopy and park/forest land (strategies may include planting climate adaptive trees and native prairie grasses, wild flowers, and landscaping).

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

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

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

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

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

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

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

A Goals Responding to Air Quality Impacts

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

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

F Goals Responding To Flood Vulnerability

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

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

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

V Goals Responding To Vector-Borne Disease Risks

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

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

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

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

W Goals Responding To Water Quality and Quantity Risks

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

WB Goals Responding To Waterborne Illness Risks

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

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

E Goals Enhancing Economic Resilience In Support of Climate Resilience

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

Goal E2 - Enhance community resilience through economic resilience

Goal E3 - Including Economic Resilience in Emergency Response Planning

Section 12

Possible Funding

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Possible Funding

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

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

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

Partnership for Sustainable Communities

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

FEMA (Federal Emergency Management Agency) Preparedness (Non-Disaster) Grants

FEMA provides state and local governments with preparedness program funding to enhance the capacity of their emergency responders to prevent, respond to, and recover from a range of hazards.
https://www.fema.gov/preparedness-non-disaster-grants

FEMA Hazard Mitigation Assistance

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

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

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

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

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

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

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

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

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

Quadratec Cares 'Energize The Environment' Grant Program

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

Wildlife Conservation Society's Climate Adaptation Fund

This fund supports projects that demonstrate effective interventions for wildlife adaptation to climate change. http://wcsclimateadaptationfund.org/

Climate Solutions University

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

Open Space Institute Resilient Landscape Initiative

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

Section A1

Appendix 1
Local Climate Risks to the Environment

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

Climate Risks to the Environment

Warmer summers

Pollution control risks:
Wildfires may lead to soil erosion

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

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

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

Warmer winters

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

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

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

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

Warmer water

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

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

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

Climate Risks to the Environment

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

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

Increased drought

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

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

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

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

Increased storminess

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

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

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

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

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

Section A2

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

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

DRIFTLESS AREA (ECOLOGICAL SECTION 222L)

Midwestern forests will be affected by climate change during this century. Several reports describe the climate change risks to the region's forests and natural communities (WICCI 2017, Handler 2012). Foresters and researchers can use experience and information from past events to develop expectations about how future change might affect forests, but there are limits to what we can learn from the past. For example, future climate change may be beyond what has been experienced in recent centuries. Tools like computer models can help provide answers by testing scenarios that haven't been experienced before.

TREE SPECIES INFORMATION:

The "Tree Atlas" tool uses climate scenarios and current distribution information to project future habitat suitability for individual tree species (Landscape Change Research Group 2014). This page shows the most common tree species in this local area, organized into general categories of future expectations. Full results for all species for two climate scenarios can be compared side-by-side on page 2 to get a sense for the range of possible outcomes.

SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
Bigtooth aspen	Early-sucessional colonizer, but susceptible to drought
Eastern white pine	Good disperser, but susceptible to drought and insects
Northern pin oak	Tolerates drought and fire
Northern red oak	Susceptible to some insect pests and oak wilt
Paper birch	Early-sucessional colonizer, but susceptible to insects and drought
Quaking aspen	Early-sucessional colonizer, but susceptible to heat and drought
Red maple	Competitive colonizer tolerant of disturbance and diverse sites
Red pine	Susceptible to insect pests and diseases, and limited dispersal.
MAY DECREASE	
American basswood	Tolerates shade but susceptible to fire
Sugar maple	Grows across a variety of sites and tolerates shade
White oak	Fire-adapted and grows on a variety of sites
MIXED MODEL RESULTS	
Black cherry	Susceptible to insects and fire, tolerates some drought
Ironwood	Grows across a variety of sites and tolerates shade

NIACS
Northern Institute of Applied Climate Science

www.forestadaptation.org

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

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

SPECIES	ADDITIONAL CONSIDERATIONS
NO CHANGE	
Black oak	Tolerates drought, but susceptible to pests and diseases
Bur oak	Tolerates drought and fire
Slippery elm	Affected by Dutch elm disease, but tolerates shade
MAY INCREASE	
American elm	Affected by Dutch elm disease, grows across a variety of sites
Bitternut hickory	Tolerates some drought, but not shade
Black walnut	Doesn't tolerate drought or shade
Black willow	Susceptible to drought and fire
Boxelder	Tolerates drought, also disperses and establishes well
Eastern redcedar	Tolerates drought, but susceptible to fire and insect pests
Green ash	Emerald ash borer causes mortality
Hackberry	Tolerates drought, but susceptible to fire
Shagbark hickory	Susceptible to insects and fire
Silver maple	Good disperser and tolerates wet soils, but vulnerable to drought
White ash	Emerald ash borer causes mortality

Get this handout online at: **www.forestadaptation.org/Northwoods_treehandouts**

FUTURE PROJECTIONS

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

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

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

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

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

ADAPTABILITY

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

\+ high
Species may perform better than modeled

· medium

– low
Species may perform worse than modeled

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
American basswood	●	▼	·
American beech	▲	●	·
American elm	▲	●	·
American hornbeam	▼	●	·
Balsam poplar	★	★	·
Bigtooth aspen	▼	▼	·
Bitternut hickory	▲	●	+
Black ash	▼	▼	–
Black cherry	▲	▼	–
Black hickory		★	·
Black locust	▲	▲	·
Black maple	▼	▼	·
Black oak	●	●	·
Black walnut	▲	▲	·
Black willow	▲	▲	–
Blackjack oak		★	+
Boxelder	▲	▲	+
Bur oak	●	●	+
Butternut	▼	▼	–
Cedar elm		★	·
Chestnut oak	★	★	+
Chinkapin oak	★	★	·
Chokecherry	▲	●	·
Common persimmon	★	★	+
Eastern cottonwood	▲	▲	·
Eastern redbud	★	★	·
Eastern redcedar	▲	▲	·
Eastern white pine	▼	▼	·
Flowering dogwood	★	★	·
Green ash	●	▲	·
Hackberry	▲	▲	+
Honeylocust	▲	▲	+
Ironwood	▲	▼	+
Jack pine	▼	▼	·
Kentucky coffeetree		★	·

SPECIES	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (HAD A1FI)	ADAPT
Mockernut hickory	★	★	+
Northern catalpa		★	·
Northern pin oak	▼	▼	+
Northern red oak	▼	▼	+
Ohio buckeye	★	★	·
Osage-orange	▲	▲	+
Paper birch	▼	▼	·
Pawpaw	★	★	·
Peachleaf willow		★	·
Pecan		★	–
Pignut hickory	★	★	·
Pin oak	★	★	–
Post oak	★	★	+
Quaking aspen	▼	▼	·
Red maple	▼	▼	+
Red mulberry	▲	▲	·
Red pine	▼	▼	·
River birch	▲	▲	·
Sassafras	★	★	·
Shagbark hickory	▲	●	·
Shellbark hickory	★	★	·
Shingle oak	★	★	·
Silver maple	▲	▲	+
Slippery elm	●	●	·
Sugar maple	●	▼	+
Sugarberry		★	·
Swamp white oak	▲	▲	·
Sycamore	★	★	·
Tamarack	▼	▼	–
Water oak		★	
Waterlocust		★	
White ash	▲	▲	–
White oak	●	▼	+
Wild plum	▲	▲	·
Winged elm		★	·
Yellow-poplar	★	★	+

RESOURCES: Handler, S.D., et al., 2012. Climate change vulnerabilities within the forestry sector for the Midwestern United States. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. **www.glisa.umich.edu/media/files/NCA/MTIT_Forestry.pdf**

Landscape Change Research Group. 2014. Climate Change Atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. **www.fs.fed.us/nrs/atlas/**

Wisconsin Initiative on Change Impacts [WICCI]. 2017. Climate Vulnerability Assessments for Plant Communities of Wisconsin. Wisconsin Initiative on Climate Change Impacts, Madison, WI. **www.wicci.wisc.edu/plants-and-natural-communities-working-group.php**

Section A3

Appendix 3
Data References and Resources

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The following are data references and resources used for this report:

Section 1 Introduction

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

Section 2 Climate Change in the Midwest

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

Section 3 Climate Change in Iowa

US Climate Resilience Toolkit
https://toolkit.climate.gov/
US National Climate Assessment
https://nca2014.globalchange.gov/
Minnesota Public Radio:
https://www.mprnews.org/story/2015/02/02/climate-change-primer
US EPA (January 2017 Snapshot)
https://19january2017snapshot.epa.gov/climatechange_.html
https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-mn.pdf

Section 4 Local Climate Change

NOAA National Centers for Environmental Information
https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=27%2CMINNESOTA
University of Michigan, Climate Center
http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml
US Climate Resilience Toolkit, Climate Explorer
https://toolkit.climate.gov/climate-explorer2/
Minnesota Public Radio:
https://www.mprnews.org/story/2015/02/02/climate-change-primer
US Climate Resilience Toolkit
https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing#tab2-images
US National Climate Assessment
https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing#statement-16556
Union of Concerned Scientists
http://www.climatehotmap.org/global-warming-locations/minneapolis-st-paul-mn-usa.html
DOE Databook
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Section 5 City on The Move

University of Michigan, Climate Center
http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml
State of Minnesota Pollution Control Agency

Section 6 Climate Risk to The Population

National Climate Assessment
https://nca2014.globalchange.gov/highlights/report-findings/human-health
US Global Change Research Program
https://health2016.globalchange.gov/populations-concern
Centers for Disease Control and Prevention
https://www.cdc.gov/climateandhealth/brace.htm
American Public Health Association
http://thenationshealth.aphapublications.org/content/46/9/1.1

Section 7 Climate Impact Multipliers

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

Section 8 Climate Resilience Indicators

United States Census Bureau
https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Data USA
https://datausa.io/
County Health Rankings & Roadmaps Program
http://www.countyhealthrankings.org/app/minnesota/2017/overview

Section 9 Vulnerable Populations

United States Census Bureau
Census 2011-2015 American Community Survey 5-Year Estimates
https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
United States Census Bureau, Quick Facts Table
https://www.census.gov/quickfacts/fact/table/US/PST045217
Data USA
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USDA Economic Research Service, Food Atlas
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See also references and resources for Section 6 Climate Risk to The Population

Section 10 Findings

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http://www.deeproot.com/blog/blog-entries/tree-cover-how-does-your-city-measure-up
Project Sunroof
https://www.google.com/get/sunroof/data-explorer/
NOAA National Centers for Environmental Information
https://www.ncdc.noaa.gov/stormevents/

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

Section A4

Appendix 4

Glossary of Climate Adaptation and Vulnerability Terms

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Glossary of Climate Adaptation and Vulnerability Terms

Term	Definition	Example
Adaptation	The process of adjusting to new (climate) conditions in order to reduce risks to valued assets.	Relocating buildings out of flood plains or further inland from rising seas are examples of physical *adaptations*. Using smaller amounts of water during times of drought is an example of behavioral adaptation.
Adaptive capacity	The ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change.	Increasing the diameter of culverts that channel stormwater away from assets enhances the *adaptive capacity* of places that face flooding from increasingly heavy rainfalls.
Assets	People, resources, ecosystems, infrastructure, and the services they provide. Assets are the tangible and intangible things people or communities value.	The infrastructure of roads, airports, and seaports are *assets*. The service of supply chain stability (supported by transportation infrastructure) is an asset. A community's local "charm" is an example of an intangible asset.
Climate stressor	A condition, event, or trend related to climate variability and change that can exacerbate hazards.	Increasing frequency and intensity of drought conditions can be a *climate stressor* for forests and crops. Rising sea level is another climate stressor.
Consequence	A subsequent result (usually negative) that follows from damage to or loss of an asset. Quantifying potential consequences is an important part of determining risk.	The destruction of commercial buildings in a flood event could result in the *consequence* of reduced tax revenues for a community.
Ecosystem services	Benefits that humans receive from natural systems.	Humans draw food and fiber from ecosystems. Ecosystems also filter water and air, sequester carbon, and provide recreation and inspiration for people.
Exposure	The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.	Homes and businesses along low-lying coasts are *exposed* to coastal flooding from storms.
Hazard	An event or condition that may cause injury, illness, or death to people or damage to assets.	Extended periods of excessive heat are likely to be an increasingly common *hazard* in the coming decades.
Impacts	Effects on natural and human systems that result from hazards. Evaluating potential impacts is a critical step in assessing vulnerability.	In the West, the destruction of homes by wildfires is among the *impacts* of hotter and drier conditions and earlier snowmelt.

Mitigation	Processes that can reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing them from the atmosphere.	Carbon-neutral energy sources such as solar and wind represent *mitigation* efforts.
Non-climate stressor	A change or trend unrelated to climate that can exacerbate hazards.	Altering drainage patterns and replacing open land with roads and buildings are *non-climate stressors* for flooding hazards. Population growth along exposed coasts is another non-climate stressor.
Probability	The likelihood of hazard events occurring. Probabilities have traditionally been determined from the historic frequency of events. With changing climate and the introduction of non-climate stressors, the probability of hazard events also changes.	Locations within a 100-year flood zone have a greater *probability* for a flood hazard than locations in the same region's 500-year flood zone.
Projections	Potential future climate conditions calculated by computer-based models of the Earth system. Projections are based on sets of assumptions about the future (scenarios) that may or may not be realized.	Climate *projections* indicate that if human emissions of heat-trapping gases continue increasing through 2100 (a scenario, or possible future), most locations will see substantial increases in average annual temperature (potential future conditions).
Resilience	The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.	Installation of backflow preventers in the stormwater systems of a coastal city increased their *resilience* to flooding from extreme high tides.
Risk	The potential total cost if something of value is damaged or lost, considered together with the likelihood of that loss occurring. Risk is often evaluated as the probability of a hazard occurring multiplied by the consequence that would result if it did happen.	Warehouses sited on a floodplain represent a higher *risk* for flooding when they are filled with products than when they are empty.
Sensitivity	The degree to which a system, population, or resource is or might be affected by hazards.	The yield of crops with a high *sensitivity* may be reduced in response to a change in daily minimum temperature during the pollination season.
Uncertainty	A state of incomplete knowledge. Uncertainty about future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make.	Though climate model projections are *uncertain* about how much precipitation will change in the future, they generally agree that wet places are likely to get wetter, and dry places are likely to get drier.
Vulnerability	The propensity or predisposition of assets to be adversely affected by hazards. Vulnerability encompasses exposure, sensitivity, potential impacts, and adaptive capacity.	Despite the thick walls of the aging lighthouse, its location on a barrier island and lack of resources to tie its foundations to bedrock made it *vulnerable* to shoreline erosion.

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